Dataquest
A Gartner Group Company

251 River Oaks Parkway, San Jose, CA 95134-1913
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February 1996

Dear Dataquest Client,

By now, you should have received the 1996 Dataquest research program binders for filing the newsletters and reports that will be sent to you throughout the year.

To let you know what documents you can expect to receive as part of your subscription, enclosed please find the 1996 datasheet for the research program to which you subscribe. The back side of the datasheet lists the Dataquest Perspectives, Market Trends reports, Market Statistics books, reports, and electronic newsletters that are included in this year's research portfolio.

If you have any questions about the research schedule, please contact your Dataquest research analyst or client services representative.

Sincerely,

Jeffrey A. Byrne
Vice President
Worldwide Marketing

December 1995

Dear Dataquest Client:

In 1996, Dataquest will celebrate its 25th year as the leading global supplier of market intelligence to the IT vendor and financial communities. I would like to thank you, on behalf of all Dataquest associates worldwide, for your support. We are proud to be your information partner by providing the IT market insight and analysis you need to make crucial business and planning decisions.

The enclosed binder is for filing and storing the printed market research newsletters and reports that you will receive on an ongoing basis throughout 1996 as part of your subscription to Dataquest. You may notice that we've streamlined the binder tab and document filing structure this year. We hope that this 5-tab scheme increases your efficiency in filing and locating documents.

You probably know that in addition to paper-based delivery, Dataquest is also committed to delivering our market statistics and analysis electronically. We expect that our electronic products, known collectively as *Dataquest on the Desktop*, will play an increasing role in our ability to deliver information to you in a timely, efficient way. For your information, our electronic tools include:

- ***Dataquest on Demand*** — Our monthly CD-ROM containing a rolling 13 months of Dataquest's printed documents
- ***MarketView*** — A data analysis tool containing many of Dataquest's market statistics databases
- ***Electronic NewsTakes and Dataquest Alerts*** — Weekly/event-driven summary and analysis of top IT news, published via e-mail or fax by most Dataquest research groups
- ***Dataquest Interactive*** – Our Internet-based electronic delivery system that you are invited to preview at this URL: http://www.dataquest.com

One last note: an optional binder called *Electronic News* is available on request for clients who wish to file their electronic newsletters and Dataquest Alerts. To order your copy, please fill out the FaxBack form found in the binder pocket and fax it back to us.

We look forward to working with you in our continuing process to improve the content, quality, and timeliness of our products and services. I encourage you to share with us your comments about our publications and electronic delivery tools.

Sincerely,

Jeffrey A. Byrne
Vice President, Worldwide Marketing

1996 RESEARCH PROGRAMS

From semiconductors to systems, software to services, telecommunications to document management, Dataquest's scope of expertise provides clients with a clear view of the relationships among information technology segments – relationships that can have a profound impact on making strategic business decisions.

Computer Systems and Peripherals

Computer Systems
- Client/Server Computing *Worldwide*
- Computer and Client/Server Systems *Europe*
- Servers *Europe*
- UNIX and Open Systems *Europe*

Workstations
- Advanced Desktop and Workstation Computing *Worldwide*
- Workstations *Europe*

Computer Storage
- Removable Storage *Worldwide*
- Optical Disk Drives *Worldwide*
- Optical Disk Drives *Europe*
- Rigid Disk Drives *Worldwide*
  - RAID Storage Systems *Worldwide*
- Rigid Disk Drives *Europe*
- Tape Drives *Worldwide*
- Tape Drives *Europe*

Graphics
- Graphics and Displays *Worldwide*

Personal Computing
- Personal Computers *Worldwide*
- Personal Computers Strategic Service *Europe*
- Personal Computers *Asia/Pacific*
- Mobile Computing *Worldwide*
- PC Distribution Channels *Worldwide*
- PC Distribution Channels *Europe*
- Desktop PC Technology Directions *Worldwide*
- Mobile PC Technology Directions *Worldwide*
- Personal Computers *Central and Eastern Europe*

Quarterly Statistics
- Advanced Desktop and Workstation Quarterly Statistics *Worldwide*
- Workstation Quarterly Statistics *Europe*
- Server Quarterly Statistics *North America*
- Server Quarterly Statistics *Europe*
- PC Quarterly Statistics *United States*
- PC Quarterly Statistics *Europe*
- PC Quarterly Statistics *Japan*
- PC Quarterly Statistics *Asia/Pacific*
- PC Quarterly Statistics *Worldwide by Region*

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- Multimedia *Europe* (Module)
- Online Strategies *Worldwide*
- Online Strategies *Europe* (Module)

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- Client/Server Software *Worldwide*
- Workgroup Computing *Worldwide*
- Workgroup Computing *Europe* (Module)
- Personal Computing Software *Worldwide*
- Personal Computing Software *Europe* (Module)

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- AEC and GIS Applications *Worldwide*
- Electronic Design Automation (EDA) *Worldwide*
- Mechanical CAD/CAM/CAE *Worldwide*
- CAD/CAM/CAE/GIS *Europe* (Module)
- CAD/CAM/CAE *Asia/Pacific* (Module)

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- Customer Services and Management Trends *Europe*

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- Professional Service Trends *North America*
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  - Consulting and Education
  - Systems Management
- Vertical Market Opportunities *North America*
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  - Systems Integration
  - Consulting and Education
  - Systems Management
- Professional Services Vertical Market Opportunities *Europe*
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- System Services *North America*
  - Desktop Services
  - Notebook Services
  - Server Services
- User Computing Services *Europe*
- Network Integration and Support Services *North America*
- Network Integration and Support Services *Europe*
- Software Services *North America*
- Strategic Service Partnering *North America*

Dataquest

1996 RESEARCH PROGRAMS

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- Copiers *Europe*

Facsimile
- Facsimile *North America*

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- Printers *North America*
- Printers *Europe*
- Colour Products *Europe* (Module)
- Printer Quarterly Statistics *Europe*
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- Printer Quarterly Statistics *Asia/Pacific*

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- Memory Applications *Europe*
- Memory IC Quarterly Statistics *Worldwide*
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- Semiconductor Supply and Pricing Worldwide

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- Semiconductor Application Markets *Asia/Pacific*
- Communications Semiconductors & Applications *WW*
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- Semiconductor Directions in PCs & PC Multimedia *WW*
- PC Teardown Analysis
- PC Watch *Europe*
- Electronic Equipment Production Monitor *Europe*
- Electronic Application Markets *Europe* —Automotive
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- Electronic Application Markets *Europe* —Consumer
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  - Wide Area Networks *North America*
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  - ISDN *Europe*
  - Modems *Europe*
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  - Computer-Integrated Telephony & Automatic Call Distributors *North America*
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- Voice Communications *Europe*
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- Personal Communications *North America*
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- Personal Communications Distribution Europe

Cross-Technology Programs

Technology Insights for:
- Financial Services
- Government Agencies
- Publishing, Media, and Consulting Firms
- IT Business Development for Financial Organizations
- IS and Purchasing Organizations
- IT Supporting Industries

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- Telecommunications

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- Personal Computers *Asia/Pacific* & Quarterly Statistics
- Printers *Asia/Pacific* & Quarterly Statistics
- Professional Service Trends *Asia/Pacific*
  - Country-level reports on Asia/Pacific IT markets

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Program Code: NONE-WW
MKTG 1/96 (PSB)

DATAQUEST 1996 CONFERENCES

Dataquest sponsors an on-going series of conferences and invitational events focusing on trends and issues in information technology and IT services. These conferences are the preeminent source of insight and analysis of global IT market dynamics.

North America	January 24	Capitalizing on the Wireless Phenomenon	San Jose, California
	January 30	Dataquest Predicts	Boston, Massachusetts
	February 20	Dataquest Predicts	San Jose, California
	March 7	Channel Trends Conference	San Jose, California
	April 1-2	ServiceTrends Conference	Orlando, Florida
	April 1 *	Mining the Internet	Boston, Massachusetts
	May 6-7	Personal Computer Conference	San Jose, California
	May 13-14	Copier Conference	Boston, Massachusetts
	June 26-27	Storage Track Conference	Monterey, California
	July 1 *	SEMICON/West	San Francisco, California
	September 25-26 *	Multimedia	San Jose, California
	October 24-25	Semiconductors '96	Palm Desert, California
	December 1 *	Mining the Internet	San Jose, California
Europe	January 24	Computer Storage	Munich, Germany
	May 22-23	Semiconductors '96	Frankfurt, Germany
	September 10	Computer Storage	London, England
Japan	May 13-14	Semiconductors '96	Tokyo, Japan
	September 10-12	Computers and Peripherals	Tokyo, Japan
	December 6	Telecommunications	Tokyo, Japan
Dataquest Invitational Computer Conferences	December 1 *	Asia/Pacific Series	Tokyo, Japan
	December 1 *	Asia/Pacific Series	Seoul, Korea
	December 1 *	Asia/Pacific Series	Beijing, PRC
	December 1 *	Asia/Pacific Series	Shanghai, PRC
	December 1 *	Asia/Pacific Series	Xi'an, PRC
	December 1 *	Asia/Pacific Series	Guangzhou, PRC
	March 5	Dataquest Storage Solutions Series - USA	San Jose, California
	April 10	Dataquest Storage Solutions Series - USA	Irvine, California
	April 24	Dataquest Storage Solutions Series - USA	Nashua, New Hampshire
	September 24	Dataquest Storage Solutions Series - USA	Newton, Massachusetts
	April 1	Mediterranean Series	Dubai, UAE
	May 21	Mediterranean Series	Athens, Greece
	October 30	Mediterranean Series	Tel Aviv, Israel
	November 6	Mediterranean Series	Istanbul, Turkey

Date tentative/may change

Dataquest Invitational Computer Conferences *(continued)*

January 17	Dataquest Storage Solutions Series-Europe	Paris, France
January 23	Dataquest Storage Solutions Series-Europe	Munich, Germany
January 30	Dataquest Storage Solutions Series-Europe	Milan, Italy
February 1	Dataquest Storage Solutions Series-Europe	Rome, Italy
June 10	Dataquest Storage Solutions Series-Europe	Budapest, Hungary
June 12	Dataquest Storage Solutions Series-Europe	Prague, Czech Republic
June 21	Dataquest Storage Solutions Series-Europe	St. Petersburg, Russia
June 25	Dataquest Storage Solutions Series-Europe	Moscow, Russia
July 1	Dataquest Storage Solutions Series-Europe	Warsaw, Poland
September 1	Dataquest Storage Solutions Series-Europe	Amsterdam, Holland
September 5	Dataquest Storage Solutions Series-Europe	Stockholm, Sweden
September 11	Dataquest Storage Solutions Series-Europe	London, England
September 19	Dataquest Storage Solutions Series-Europe	Frankfurt, Germany
October 1 *	Latin America Series	Caracas, Venezuela
October 1 *	Latin America Series	Mexico City, Mexico
October 1 *	Latin America Series	São Paulo, Brazil
October 1 *	Latin America Series	Buenos Aires, Argentina
October 1 *	Latin America Series	Santiago, Chile
October 1 *	Latin America Series	Bogotà, Columbia
October 1 *	Latin America Series	Lima, Peru
February 19	South Africa Series	Capetown, South Africa
February 22	South Africa Series	Johannesburg, South Africa
April 11	LINK Series - North America	Orlando, Florida
April 30	LINK Series - North America	Austin, Texas
May 1	LINK Series - North America	Philadelphia, Pennsylvania
May 9	LINK Series - North America	Charlotte, North Carolina
May 14	LINK Series - North America	Denver, Colorado
May 21	LINK Series - North America	Portland, Oregon
November 1 *	LINK Series - North America	Montréal, Québec
November 1 *	LINK Series - North America	Ottawa, Ontario
November 1 *	LINK Series - North America	Calgary, Alberta
November 1 *	LINK Series - North America	Vancouver, BC
November 1 *	LINK Series - North America	Toronto, Ontario

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Place your request by calling our Fax-on-Demand system at
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Program Code: DQGE-WW MKTG 1/96 (PSB)

SEMICONDUCTOR EQUIPMENT, MANUFACTURING & MATERIALS WORLDWIDE

Dataquest's Semiconductor Equipment, Manufacturing & Materials Worldwide program is a comprehensive market research service emphasizing an integrated perspective of the interdependence of wafer fabrication equipment technology, semiconductor materials applications, and IC process technology as they relate to the broader issues of semiconductor manufacturing.

Market Coverage

Semiconductor Manufacturing Issues

Dataquest provides executives with strategic insight into issues relating to the global nature of the semiconductor manufacturing environment. Topics include:

- Global fab facilities
- Semiconductor production
- Capital spending
- Capacity trends
- Factory productivity
- Factory automation
- R&D trends
- IC process technology

Wafer Fabrication Equipment

Detailed market estimates and forecasts are provided for products in the following broad categories:

- Lithography
- Etch and clean
- Deposition
- Diffusion/RTP
- Implantation
- Wafer inspection
- Chemical mechanical polishing

Semiconductor Materials

The following represents some of the areas covered in our materials research:

- Silicon and epitaxial wafers
- Gases
- Photoresist
- Other materials

Partnering to Provide Solutions

As a client, you have direct access to experienced analysts who can provide insights and advice on market dynamics, industry events, and competitive issues.

Through an interactive approach, Dataquest analysts work with you to tailor the program to meet the unique needs of your organization.

Inquiry Support

Personalized inquiry support is a primary component of your Dataquest annual subscription program.

Electronic Delivery

Dataquest offers a variety of tools, known collectively as *Dataquest On The Desktop*, that have the power to deliver Dataquest insights directly to you, whether you are on the road or in the office.

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Should your needs exceed the scope of this program, Dataquest offers extensive primary research and consulting services.

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WHAT YOU WILL RECEIVE AS A CLIENT

SEMICONDUCTOR EQUIPMENT, MANUFACTURING & MATERIALS WORLDWIDE

Perspectives

Dataquest Perspectives present analysis and commentary on key technologies, companies, market opportunities, trends, and issues in the market. A minimum of six Perspectives will be published on an event-driven basis throughout the year, as well as two Dataquest Predicts.

Dataquest Predicts: In these hard-hitting documents, Dataquest takes a bold, opinionated, often controversial look at key issues, products, and trends shaping the semiconductor equipment and materials markets. The reports make predictions about why, when, and how events will happen.

Market Trends

Semiconductor Equipment, Manufacturing, and Materials Forecast: This report, updated twice a year, contains forecasts for semiconductor consumption and production by region, semiconductor capital spending by region, silicon wafer consumption by region, and wafer fabrication equipment consumption by region and by major equipment category.

Available in July and December 1996

Semiconductor Consumption and Shipment Forecast: Five-year revenue forecasts for the global semiconductor market by region.

Available in the Second and Fourth Quarters 1996

Market Statistics

Wafer Fabrication Facilities—North America, Japan, Europe, and Asia/Pacific: Pilot and production fab lines by company, location, fab name, products produced, process technology, minimum linewidth, wafer diameter, estimated wafer capacity, square feet of cleanroom, and cleanroom class. *(Four separate publications)*

Available in November 1996

Silicon Market Share: Market share by company and by region for merchant suppliers, as well as trends in the merchant silicon and epitaxial wafer market, captive silicon production, wafer prices, and silicon square-inch consumption.

Available in June 1996

Wafer Fabrication Equipment Market Share: Market share by company by region for 150 companies that participate in 40 different segments of front-end wafer fab equipment.

Available in May 1996

Reports

Focus Report - Planned Fabs: This report will deliver a forward-looking assessment of planned fabs and related market issues.

Available in the First Quarter 1996

Electronic News

Dataquest Alerts : Event-driven news and analysis, delivered by fax, giving a concise overview of significant announcements in the semiconductor industry.

Event-driven

The DQ Monday Report - OPTIONAL: Weekly news and commentary on semiconductor industry events and issues with a monthly snapshot of semiconductor pricing for 25 key semiconductors in 6 regions. Clients may wish to subscribe to this valuable newsletter for a broad view of this dynamic industry.

Available Weekly via Electronic Mail

Conferences

Dataquest hosts the industry's preeminent semiconductor conferences in the United States, Europe, Japan, Taiwan, and Korea. Clients receive a discount on conference fees.

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Here's How to Order Your *Electronic News* Binder

Dataquest provides a separate binder called *Electronic News* to help you organize your printouts of the electronic newsletters and Dataquest Alerts that will be sent to you by your Dataquest North America research programs throughout the year.

Although not all clients will print out electronic news bulletins or file faxes, the *Electronic News* binder is available by request for those who do.

To order your *Electronic News* binder, just fill out the form below and fax it back to us. We will mail your binder to you immediately.

Note: If you subscribe to more than one Dataquest North America research program, then indicate how many binders you need in the space provided below (plan on one binder per research program), and we'll send them to you in one shipment.

Thank you for helping us serve you better.

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SEMICONDUCTOR EQUIPMENT, MANUFACTURING AND MATERIALS WORLDWIDE 1996
VOLUME 1
TABLE OF CONTENTS

PERSPECTIVES

MARKET TRENDS

GUIDES

Dataquest ALERT

251 River Oaks Parkway • San Jose • CA • 95134-1913 • Phone 408-468-8000 • Fax 408-954-1780

With Applied's Acquisition of Opal and Orbot, Has the Merger and Acquisition Era Begun in the Semiconductor Capital Equipment Market?

With the acquisition of Opal Inc. and Orbot Instruments Ltd., Applied Materials Inc. enters the process control market. Applied purchased Opal for $175 million and Orbot for $110 million. Based on the financial community's estimates of the revenue of Opal and Orbot, the acquisition took place for under 3 times and 2.5 times each company's revenue, respectively.

Implications

We believe there are two aspects to this event:

- The impact of Applied's entry in the process control arena
- The capital equipment industry's continuing trend of market concentration

Applied's Entry into Process Control

Applied has acquired two very strong companies. We estimated 15 percent market share for Opal in the 1995 CD-SEM market. It follows only the market leader Hitachi, with its estimated 75 percent share of the $313 market in 1995. In the U.S. market, Opal's market share is almost equal to that of Hitachi. Its weakness is in Japan and Asia/Pacific, where the market is, on average, 1.5 times that of the United States, and Hitachi dominates both regions with over 90 percent market share.

Orbot participates in the mask and wafer inspection market, the latter generating half of the revenue of the first. Orbot has recently entered the wafer inspection market, and in 1995, it did not hold significant market share compared with the top three players—KLA Instruments (66 percent) , Tencor (14 percent), and Hitachi (10 percent). In mask inspection, with about one-quarter market share, Orbot is a strong second to the industry leader, KLA Instruments. This is basically a two-player market. Maskmaking equipment is a significant market, and it should experience strong growth in the next several years as semiconductor manufacturing faces capacity shortage and mask shops (captive and merchant) build capacity fast.

It is important to note that Orbot and Opal's product offering is directly related to lithography exposure systems, or better steppers. The stepper market is a highly cyclical market that follows closely the DRAM technology and price-per-bit transitions and trends. Process control as a whole has gained more prominence in the past several years, with well over 50 percent average growth, compared with the overall front-end equipment market growth of under 35 percent. However, we believe, given the overall market conditions and the DRAM cycles, that process control will grow at slightly below the overall equipment market's growth (estimated at 16 percent) over the next five to six years.

Therefore, Applied's acquisitions may not be for the sole reason of increasing revenue but also to enable Applied to incorporate process control into its vast and dominating product portfolio and perhaps offer its clientele a turnkey fab in the future. Does this imply that Applied will be looking at the only two major equipment segments that are not included in its products—lithography and clean process? Well, we will have to wait and see, but this brings us to the second issue concerning the overall trend of market concentration in the equipment market.

Market Concentration

We have focused and quantified this rather overwhelming trend for some time now. Dataquest has in publication a report that analyzes the implications of this trend for the participants in the capital equipment market and the overall semiconductor manufacturing arena. Of the 10 major equipment categories, we cover seven that are segments in which the top two players have at least two-thirds of their market. We do not see any reason for this trend to turn around or not to continue to grow.

It is speculative to look at the market and anticipate mergers and acquisitions. However, the season is pregnant with expectation, with good reason. The cash reserves of the equipment companies have grown tremendously in the past several years. Applied, for instance, has led and grown its market share from the overall market in every one of these years of hypergrowth. But Applied is not alone. The market is currently characterized as one that is experiencing a downturn, but with a silver lining, relatively soon, of recovery because of growing applications across the semiconductor product spectrum.

We are seeing an upsurge in advanced equipment orders as semiconductor manufacturers are gearing for the next generation of devices at below 0.3 micron. Our forecast calls for technology-oriented spending throughout 1997, with an eventual recovery in 1998. In this environment, market positioning becomes important, and technical portfolio plays an important role.

Many companies are "catching their breath" in these slower times. After three years of strong growth where the focus has been reactive in trying to meet customer demand and manage backlog, we see the focus shifting to building the infrastructure to handle the next upturn and trying to differentiate products and capabilities from competitors.

There are two major ways of acquiring technology and gaining advantage over competition. First is obviously internal R&D. But with adequate cash reserves, a more direct alternative is external—or merging with or acquiring companies that fit a marketing strategy. In Applied's case, we see an expanding product portfolio—whereas we may also see mergers in the same equipment segments between players, even the top ones.

We also see a trend in acquiring companies that are OEMs to larger end users. This is very strong among the software companies that support the equipment companies; however, it does not have be limited to software. These acquisitions also allow companies to block key technology that may be available to their competitors otherwise.

In conclusion, we see the Applied Materials acquisition as a continuing trend, for Applied and also for the overall industry. Applied is on a path to grow beyond the segments it now dominates while expanding its technology base. The industry, loaded with cash reserves, now needs to build for the next upsurge and to be able to compete and gain market share. Mergers and acquisitions are a very "efficient" way of doing so.

By Näder Pakdaman

Dataquest ALERT

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Applied's Entry into Process Control

Applied has acquired two very strong companies. We estimated 15 percent market share for Opal in the 1995 CD-SEM market. It follows only the market leader Hitachi, with its estimated 75 percent share of the $313 market in 1995. In the U.S. market, Opal's market share is almost equal to that of Hitachi. Its weakness is in Japan and Asia/Pacific, where the market is, on average, 1.5 times that of the United States, and Hitachi dominates both regions with over 90 percent market share.

Orbot participates in the mask and wafer inspection market, the latter generating half of the revenue of the first. Orbot has recently entered the wafer inspection market, and in 1995, it did not hold significant market share compared with the top three players—KLA Instruments (66 percent) , Tencor (14 percent), and Hitachi (10 percent). In mask inspection, with about one-quarter market share, Orbot is a strong second to the industry leader, KLA Instruments. This is basically a two-player market. Maskmaking equipment is a significant market, and it should experience strong growth in the next several years as semiconductor manufacturing faces capacity shortage and mask shops (captive and merchant) build capacity fast.

It is important to note that Orbot and Opal's product offering is directly related to lithography exposure systems, or better steppers. The stepper market is a highly cyclical market that follows closely the DRAM technology and price-per-bit transitions and trends. Process control as a whole has gained more prominence in the past several years, with well over 50 percent average growth, compared with the overall front-end equipment market growth of under 35 percent. However, we believe, given the overall market conditions and the DRAM cycles, that process control will grow at slightly below the overall equipment market's growth (estimated at 16 percent) over the next five to six years.

Therefore, Applied's acquisitions may not be for the sole reason of increasing revenue but also to enable Applied to incorporate process control into its vast and dominating product portfolio and perhaps offer its clientele a turnkey fab in the future. Does this imply that Applied will be looking at the only two major equipment segments that are not included in its products—lithography and clean process? Well, we will have to wait and see, but this brings us to the second issue concerning the overall trend of market concentration in the equipment market.

Market Concentration

We have focused and quantified this rather overwhelming trend for some time now. Dataquest has in publication a report that analyzes the implications of this trend for the participants in the capital equipment market and the overall semiconductor manufacturing arena. Of the 10 major equipment categories, we cover seven that are segments in which the top two players have at least two-thirds of their market. We do not see any reason for this trend to turn around or not to continue to grow.

It is speculative to look at the market and anticipate mergers and acquisitions. However, the season is pregnant with expectation, with good reason. The cash reserves of the equipment companies have grown tremendously in the past several years. Applied, for instance, has led and grown its market share from the overall market in every one of these years of hypergrowth. But Applied is not alone. The market is currently characterized as one that is experiencing a downturn, but with a silver lining, relatively soon, of recovery because of growing applications across the semiconductor product spectrum.

We are seeing an upsurge in advanced equipment orders as semiconductor manufacturers are gearing for the next generation of devices at below 0.3 micron. Our forecast calls for technology-oriented spending throughout 1997, with an eventual recovery in 1998. In this environment, market positioning becomes important, and technical portfolio plays an important role.

Many companies are "catching their breath" in these slower times. After three years of strong growth where the focus has been reactive in trying to meet customer demand and manage backlog, we see the focus shifting to building the infrastructure to handle the next upturn and trying to differentiate products and capabilities from competitors.

There are two major ways of acquiring technology and gaining advantage over competition. First is obviously internal R&D. But with adequate cash reserves, a more direct alternative is external—or merging with or acquiring companies that fit a marketing strategy. In Applied's case, we see an expanding product portfolio—whereas we may also see mergers in the same equipment segments between players, even the top ones.

We also see a trend in acquiring companies that are OEMs to larger end users. This is very strong among the software companies that support the equipment companies; however, it does not have be limited to software. These acquisitions also allow companies to block key technology that may be available to their competitors otherwise.

In conclusion, we see the Applied Materials acquisition as a continuing trend, for Applied and also for the overall industry. Applied is on a path to grow beyond the segments it now dominates while expanding its technology base. The industry, loaded with cash reserves, now needs to build for the next upsurge and to be able to compete and gain market share. Mergers and acquisitions are a very "efficient" way of doing so.

By Näder Pakdaman

Dataquest ALERT

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Wafer Fab Equipment Forecast—Putting Recent Events into Perspective: A "Square U" or a "V"?

Dataquest is in the process of updating the wafer fab equipment forecast, to be released in the first week of January. Recent positive events in the market include the semiconductor book-to-bill's exceeding 1.0, Intel's current stronger business outlook, Applied Materials' optimistic earnings conference call, and its news release of a $117 million order from Hyundai. Also released this past week was the equipment book-to-bill ratio at 0.75, with monthly bookings continuing a downward trend.

The popular question is—have we hit bottom in the equipment market, or when will we? But we believe the most pertinent question is—what is the nature and speed of the recovery? We feel it is important to share with our clients our current thinking in this uncertain market.

One thing is true: Current sentiment is polarized. Depending on whom you talk with, either we have bottomed and a recovery is in progress in equipment, or the bottom is ahead of us and the sluggish market conditions could extend into 1998. So now we will analyze what the "shape" of the recovery will look like.

Summary of Event Details

First, the recent semiconductor book-to-bill exceeded unity in October for the first time this year as the market for PCs remains strong and as suppliers gear up for the holiday season. Spot prices of DRAM ticked up slightly but have since settled back down as suppliers quickly responded with inventory releases of packaged products and die inventory in wafer form.

Second, Intel recently made positive comments about fourth quarter demand for MPUs and has recently increased spending plans for 1997. In mid-year, we were estimating Intel would spend $3.9 billion for production capacity in 1996. This figure has since been reduced to $3.4 billion, and we now estimate that the company will spend over $4 billion in 1997.

Third, Applied Materials released results for the fiscal quarter ending October 1996 that were in line with expectations. Orders were $683 million, down significantly from the $1.3 billion level experienced in the first part of the year. Sales were $861 million in the fourth quarter, down from $1.1 billion in the prior quarter. However, this was not the significant news. Comments made in the conference call after market close on November 21 were much more positive than negative. Although members of Applied Materials management did indicate that they expected the slowdown in the equipment market to continue into 1997, they did give guidance that orders in the next quarter would be in the range of $725 to $750 million and sales would be about $800 million. The primary focus being placed on the call by the investment community is the fact that orders are up sequentially from the previous quarter: a rally cry has ensued. Fourth, Applied announced a $117 million dollar order from Hyundai for its DRAM fab in Oregon. This represents the first order over $100 million Applied has received in over six months, and it has been interpreted by some that the rebound is under way.

Fifth, Semiconductor Equipment and Materials International (SEMI) released the equipment book-to-bill for October at 0.75. While this ratio is up modestly from the 0.70 reported for September, the bookings continued to decline in October.

Initial Thoughts and Some Background Facts on the Events

We are viewing the semiconductor book-to-bill improvement as one primarily driven by the Christmas seasonal buying of components for the PC market. It remains to be seen what the end-use demand will actually be and the effect on the channel flow of orders for components, come January. Our PC group believes that there is less "overbuying" occurring this year than last, yet we remain cautious, thinking that order rates will soften again early next year as DRAM prices continue to decline.

The positive comments and recent investment increase made by Intel reflect its unique position in the market and the strong unit growth of PCs in the fourth quarter. While its increase in spending will stabilize the market in the United States in 1997, capital spending in MPU represents only perhaps 10 percent to 12 percent of the market, on average. There is no fundamental reason why this short-term trend would transfer to other areas of spending in present conditions.

Applied Materials is a very well-run company, with seasoned management that has seen many downturns. Management took quick action to position the company to weather the storm. For this reason, Applied should be considered to perform slightly better than the market. It should also be noted that its backlog level at the beginning of the year was about six months and is currently five months and declining. We would expect the company to consume and manage its backlog to about the four-month level, at the minimum. Not all equipment companies will be so well positioned.

However, an order rate increase from $683 million to $725 or $750 million is *noise-level* movement in this industry, and caution should be exercised about reading too much into this increase. Further, the $117 million order from Hyundai does *not* reflect a return to capacity buys, in our opinion. In a recent set of visits to companies, the consensus was that any orders received today are "strategic" buys. In the case of Hyundai, Samsung, and TSMC, orders for equipment for U.S. production are seen as strategic for the company's long-term success in the market. This kind of sustained investment is normal in the earlier stages of a downturn, and likely represents only a portion of the planned investment to position. There was a recent announcement by Samsung that capital spending will decline 17 percent in 1997 overall, meaning that spending in Korea is being cut deeper than that.

The SEMI equipment book-to-bill reflects continued order weakness. Although the ratio will likely strengthen in the coming months, being very heavily influenced by Applied Materials, we would expect order rates to remain somewhat flat, with some fluctuations throughout most of 1997. This is a very volatile indicator, as the equipment business is much more "lumpy" than the chip market. Consensus from most companies we speak with sees *order* rates bottoming in the second quarter of next year.

Some Fundamental Analysis—Numbers Do Not Sum to Recover Now

The capital spending market for 1996 splits about: 30 percent foundry/logic, 50 percent memory, 10 percent MPU, and 10 percent others (mixed signal, analog, and discrete, among others). Let us look at each capacity area separately.

Foundry/Logic

Foundry factory utilization rates are falling, and wafer prices have collapsed, according to a recent pricing survey completed. Investment will continue in the foundry area because many projects have joint-venture and partnership commitments, but initial ramp rates are likely to be cut back. Current projections are that excess capacity may last through all of 1998 in this area, as a result. With cheap foundry capacity available, this will likely subdue large capacity outlays for nonfoundry logic. While there is a stability in the investment picture here, there is also not a big driver for growth until 1999.

Memory/DRAM

DRAM capacity is in oversupply today. As we have noted several times, because the industry is in a transition from the 4Mb to the 16Mb DRAM and since die sizes continue to shrink and yields to ramp up, high bit demand does not necessarily translate to a similar higher requirement for silicon capacity. Table 1 shows the result of fundamental capacity analysis.

Table 1
Fundamental Silicon Capacity Analysis for DRAMs in 1996 and 1997

	1996	1997	Comments
Bit Demand Growth (%)	73	70 to 75	1997 growth is industry consensus, Dataquest forecast is about 60 percent
Growth Silicon Area Required to Meet Bit Demand (%)	12	12 to 15	Average die size, yields, and product mix for 4Mb and 16Mb DRAM included
Growth in DRAM Silicon Area Capacity (%)	23	21	1997 growth factors in capital spending decline, as currently forecast, and slow ramp in new DRAM fabs
Oversupply Percentage in Capacity	9	14 to 17	Assumes baseline is a balanced market at the end of 1995

Source: Dataquest (November 1996)

This fundamental analysis indicates that the "strategic investments" being made by DRAM suppliers will actually delay the timing of when demand catches supply. Current factory utilization rates for DRAM fabs are running around 70 percent, and we would expect utilization to continue falling in 1997, perhaps a percentage in the low 60s. According to this fundamental analysis, capacity spending in DRAM is not expected to return until late in 1998. An obvious question from this analysis is: What does bit demand have to be in 1997 to create a balanced market at the end of 1997? The answer is about 100 to 110 percent, meaning the average PC would have to ship with more than 32MB of memory in the next year. While higher bit demand than that shown is possible, creating a balanced market in 1997 is highly unlikely, so we would expect DRAM prices to remain under pressure through all of 1997.

MPU and Other Areas

We do expect these areas to be the first to recover and to be tightly coupled with unit demand from the various product areas. But because this represents a smaller percentage of spending, the result will only create some stability in the market short term and not be a fuel for growth.

Where Are We Likely to Take Our Forecast?

We would not expect large changes in our thesis and forecast outlook. Here is a short summary of any adjustments being considered:

- Our July forecast placed growth in wafer fab equipment for 1996 at about 17 percent. The third quarter results were significantly weaker than anticipated and, when carried forward, should lower the actual growth for 1996 in the range of 11 to 14 percent.
- Our outlook for 1997 should not change appreciably. We are getting indications that the absolute levels will be adjusted down slightly but, with a weaker 1996, the market should be close to our 16 percent decline forecast of July, or down in the range of 15 to 20 percent.
- Our biggest challenge is to forecast the 1998 market. In July we were cautious on growth prospects, as we believed the fundamentals for supply/demand dynamics would continue to be weak at the beginning of the year. Given the analysis in this Alert, we would continue to be cautious on 1998 and will likely be in the range of 3 to 7 percent growth.
- At this point, we would maintain the stronger growth forecasts for 1999 and beyond, as our outlook for semiconductor growth in the longer term remains good, but this will come under review as we progress through our forecast process currently under way.

There are some who would like to believe that this recovery will be shaped like a "V" and that we are at the bottom now. Although we are likely close to a bottom, we believe that the recovery in equipment spending growth will depend on fundamentals of supply and demand dynamics. Large capacity spending growth will likely not return until well into 1998, and the industry is likely to experience several quarters of "skirting along the bottom," making the likely shape of the recovery a "square U."

By Clark Fuhs, Calvin Chang, Ronald Dornseif, Takashi Ogawa, and Näder Pakdaman

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MEMC Releases Weaker Second-Half Outlook—What Does It Mean Compared with Our Forecast?

MEMC announced late on Tuesday, September 10, that the third quarter, ending September 30, would be below analysts' expectations and that the fourth quarter would be significantly below their earlier estimates and likely below the third quarter. Specific figures provided were limited to the third quarter and were limited in scope.

Comments made in a conference call on the morning of September 11 indicate a volume-driven slowdown, most notably in Asia, as the company's Korean joint venture, Posco-Hüls, is experiencing lower sales. It was mentioned that the lower volumes result from semiconductor manufacturers conserving cash by lowering wafer inventories on hand, as well as from the weakness in the memory market. MEMC noted that semiconductor manufacturers are likely to take advantage of the current situation in the soon-to-begin contract negotiations for 1997 in terms of pricing. No specifics were given.

Summary of Details—Calibrating MEMC to the Market

MEMC specifically released the information that it expected third quarter sales to be in the neighborhood of $290 million, down from second quarter revenue of $324 million. Expectations for the fourth quarter are down from the third but were not specified. Gross margin and profit will be under pressure not only from reduced sales but also from start-up costs associated with the company's joint venture, Taisil, in Taiwan. Although not specifically mentioned, we expect that the start-up of MEMC Southwest in Texas and pricing issues in 1997 will subdue reported profits through early 1997.

Given the updated third quarter sales expectations, the first nine months of 1996 would see MEMC sales at about $900 million, up 44 percent from the comparable period in 1995. Making a reasonable guess at the range for the fourth quarter, Dataquest estimates a revenue growth in the range of 31 percent to 33 percent for the year 1996 over 1995. This is slightly higher growth than our general market revenue forecast growth of 25 percent (see Table 1). This is also consistent with our belief that, through more aggressive joint-venture expansion recently, MEMC is likely to gain market share slightly in 1996.

Before reviewing additional issues, we think it important to put MEMC in context with the general market in order to understand some specific issues that were addressed in its press release and subsequent conference call.

Table 1
Silicon Worldwide MSI and Revenue Forecast, 1995-2001 (Published in July 1996)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Millions of Square Inches of Silicon	3,524	4,102	4,545	4,944	5,450	6,221	6,924	11.9
Percentage Growth	21.2	16.4	10.8	8.8	10.2	14.2	11.3	
Silicon Wafer Revenue ($M)	6,298	7,867	8,729	9,544	11,137	13,359	15,120	15.7
Percentage Growth	37.4	24.9	11.0	9.3	16.7	20.0	13.2	

Source: Dataquest (July 1996)

MEMC has focused its business on supplying advanced logic and DRAM fabs, primarily outside of Japan, with silicon wafers. A significant percentage of the general market is in the power and discrete market, a market on which MEMC has chosen not to focus. The power/discrete wafer market primarily involves wafer sizes less than 150mm, and, as a result, MEMC's business is generally less concentrated in smaller wafer sizes.

Samsung is a joint-venture partner to Posco-Hüls, and a large part of the production from Posco-Hüls is shipped to Samsung. Further, MEMC is known to be a major supplier of IBM, whose DRAM capacity is run on epitaxial silicon. Because of the IBM connection, Dataquest suspects that the company also supplies Siemens with some epitaxial wafers for DRAM. These are the two companies that currently use epitaxial silicon for DRAM; the rest of the manufacturers use polished wafers. Thus, the inventory correction that MEMC is likely to see would be more balanced between polished and epitaxial wafers than the general market, which would tend to see less weakness in epitaxial than polished.

Does This Announcement Change Our Outlook? ... A Little

For 1996, we expected a marked slowdown in the second half, and that is already factored into our millions of square inches (MSI) growth of 16.4 percent and revenue growth of 25 percent. MEMC's torrid pace of growth being moderated is essentially in line with our near-term expectations, and our 1996 forecast remains unchanged.

What worries us a little are the assumptions in our forecast for 1997 and 1998. The forecast in Table 1 assumes that there would be a moderate transition to the 16Mb DRAM, extending into 1998. However, the sooner-than-expected wafer weakness in South Korea, coupled with the fact that both Samsung and Hyundai are no longer producing 4Mb DRAMs appreciably, makes us believe that the transition is happening more quickly than we expected. Instead of forecasting the majority of the transition to occur by mid-1998, we now expect it to be substantially complete by the end of 1997. As a result, we would guide our clients to the following changes in our forecast:

- MSI growth in 1997 is likely to be weaker than our 10.8 percent forecast. It is more likely to be in the range of 4 percent to 7 percent growth, and most of the reduction in growth would come in Asia/Pacific and Japan.

- MSI growth in 1998 will likely be higher than the 8.8 percent growth but likely below the gross value of 4,944 MSI. We would guide an MSI growth range of 11 percent to 12 percent.

- Our current silicon wafer revenue per square inch forecast is flat for 1997 and 1998, with the belief that pricing pressures would be generally offset by the change in mix to 200mm wafers, which sell at a higher price per square inch. This outlook remains unchanged, and, as a result, we would maintain a revenue forecast in line with MSI growth for 1997 and 1998.

- At this point, we would maintain the MSI and revenue forecasts for 1999 through 2001, as our outlook for semiconductor unit growth in the longer term remains good, but this will come under review following our updated semiconductor forecast due out in October.

Why Can Wafer Demand Decline When DRAM Bit Demand Is Up?

An obvious question in today's environment is, "With bit and unit demand up strongly and weakness in the DRAM market almost purely revenue driven, how can wafer demand decline?" The answer lies in the fact that the DRAM industry migrates product densities, in today's case moving from 4Mb to 16Mb units. The industry's average die size (not the smallest) for the 4Mb DRAM is about 45 to 50 square millimeters, and the 16Mb DRAM is about 80 to 85 square millimeters today. When shipping the equivalent number of bits, there is much less silicon used if the demand is met by 16Mb chips. The industry dynamic in a product transition includes fabs that convert from the older generation to the new, and, in the short term, the actual number of wafer starts can decline. This is the key driving force in our demand forecast model presented in Table 1.

The short-term situation is also driven by the inventories currently held at the DRAM suppliers, which we understand are in the range of two to three months. The inventory correction has not ended, just shifted.

How Do the Shortages Look Now?

Raw Polysilicon Material

In a recent Dataquest Perspective (SEMM-WW-DP-9603, July 22, 1996), we detailed our outlook that polysilicon will still be short later this year into 1997. Recent input on industry inventories have verified continued depletion, and a recent visit to Hemlock Semiconductor verified an intermediate-term very tight market. Silicon manufacturers have efficiency programs, in some cases recycling material, and there has been a supply restarted from Ukraine this year. This pushed back the "depletion to zero" point into the fourth quarter of this year. Will this softening demand improve the situation? Perhaps, so the industry can barely squeak by, but true capacity relief will not occur until later in 1997, in our opinion. MEMC shared this view in the conference call. Further, if there are any production hiccups in the polysilicon supply, the food chain is wired so tight that spot shortages in wafers could reemerge. With luck, that will not happen.

200mm Wafers

In a recent Dataquest Perspective (SEMM-WW-DP-9603, July 22, 1996), we concluded that the 200mm market was entering a short-term (two-year) period of easier supply. This manifested itself in a calculation that the highest 200mm wafer production plant utilization rates are behind us, and the trend in utilization would be down for the next 12 to 18 months. In the longer term, we expect tightness to reemerge in late 1998 and into 1999. In the shorter term, we would expect pricing for 200mm wafers to ease by 6 percent to 8 percent in 1997, essentially coming back to 1995 pricing. Also, we would expect that while the basic programs for capacity expansion continue, the timing of equipment installation for wafer production would be pushed out from 1997 into 1998 or 1999, bringing the market into supply/demand balance more quickly. MEMC verified that plant utilization rates were declining but also stated that although no major programs would be delayed, and no immediate capital spending plans would be curtailed, they would likely review the timing of some equipment installation after 1996.

Our 1997 Outlook for Wafer Fab Equipment May Be Optimistic

In July, we released a forecast for a decline in the wafer fab equipment market of 16 percent. Given the increased speed at which the wafer manufacturers are feeling the downturn, our 1997 forecast could be optimistic. We would not be surprised to see a decline well in excess of 20 percent, when all is said and done, as the significance of capital spending cuts from Korean companies is factored.
By Clark Fuhs

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Silicon Market Forecast and Supply/Demand Update—Growth Picture Intact, Industry Responses Bringing Balance

The silicon market demand picture is only a little changed from our outlook six months ago. Dataquest has predicted a slower growth picture for square-inch consumption over the next few years as the industry migrates to the 16Mb DRAM, which uses silicon area more efficiently per bit than the 4Mb. The dynamics of our forecast have been modified slightly to account for the quicker than expected price decline and migration timing. Responses from the silicon suppliers and semiconductor companies to supply/demand issues have brought most aspects of the silicon shortage closer to a balanced picture for later in the decade.

This document will be followed by publication of the Semiconductor Equipment, Manufacturing, and Materials Worldwide 1996 Midyear Forecast, as well as two documents providing more detail of the silicon market outlook. Semiconductor Equipment, Manufacturing, and Materials Worldwide clients should receive these within the next few weeks.

The Silicon Forecast

Table 1 shows the millions of square inches (MSI) and revenue forecasts for the silicon wafer industry. The forecast for 1996 has been raised slightly because lower DRAM prices are resulting in more memory installed per PC. Because the industry has only started to migrate to the 16Mb DRAM, the short-term dynamic will be an increase in silicon area consumption.

Table 1
Silicon Worldwide MSI and Revenue Forecast, 1995-2001

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Millions of Square Inches of Silicon	3,524	4,102	4,545	4,944	5,450	6,221	6,924	11.9
Percentage Growth	21.2	16.4	10.8	8.8	10.2	14.2	11.3	
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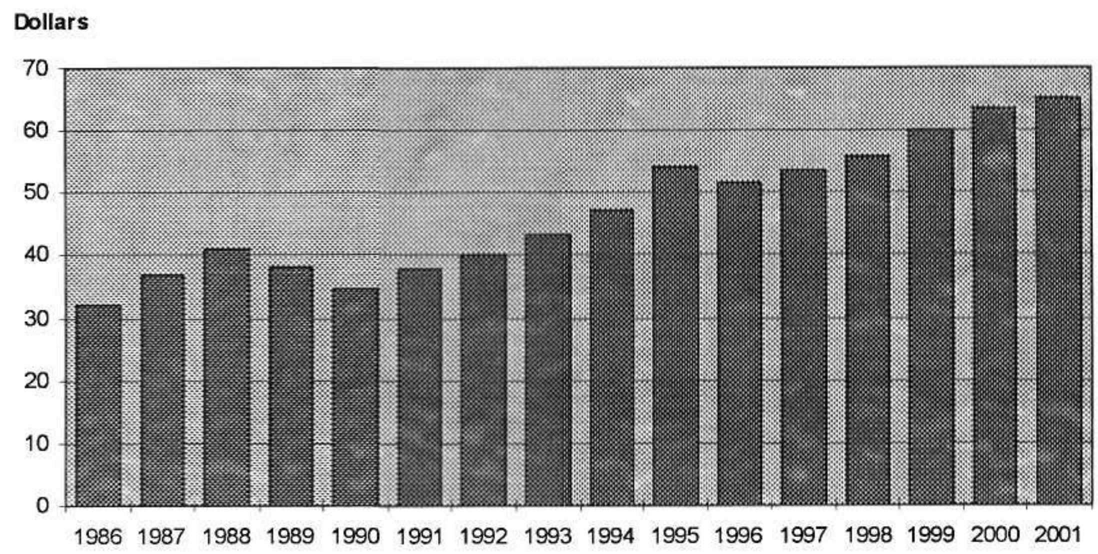
Percentage Growth	37.4	24.9	11.0	9.3	16.7	20.0	13.2	

Source: Dataquest (July 1996)

The accelerated schedule of the product migration has caused our growth outlook to be slightly more cautious for 1997 and 1998, but stronger into 1999. Still, the slowest growth year of 1998 is expected to be about 9 percent, primarily because PC unit demand is expected to remain robust through the decade. Silicon consumption tends to depend more on unit demand than on revenue of the semiconductor industry.

How can the silicon industry grow in the face of a slowing semiconductor market? The answer lies in the cyclical dynamic of the semiconductor industry revenue per square inch. Figure 1 shows the historical and forecast semiconductor industry revenue per square inch. What is evident is that it is a cyclical pattern, and Dataquest has concluded that the cycles are driven primarily by the price fluctuations of the DRAM market.

Figure 1
Semiconductor Revenue per Square Inch of Silicon, Test Excluded



Source: Dataquest (July 1996)

How Do The Shortages Look?

The silicon shortage has many dimensions, as outlined in Dataquest's November 1995 Focus Report. Each of them will be briefly reviewed here as an update. The various dimensions include:

- Raw polysilicon material
- 200mm supply and demand
- Smaller wafers, 125mm and below
- Potential for a 150mm shortage later in the decade

Raw Polysilicon Material

The industry has been consuming more polysilicon than it has produced since 1994, and we expect that to continue through 1997, depleting industry reserves later this year. However, several new plant commitments have been made, and polysilicon production will again exceed supply starting in 1998. The polysilicon market is expected to remain tight through 1998, but the threat of shortage after 1997 seems to have disappeared through our forecast horizon. More details will follow in a Dataquest Perspective to follow in a few weeks.

200mm Wafers

Future demand for 200mm wafers has been affected positively by the semiconductor industry's excess capacity. Why? Semiconductor companies now have some time to convert 150mm fabs to the more cost-effective 200mm wafers. This has added incremental product wafer demand to the industry at 200mm wafers. However, IC manufacturers are being more aggressive in the reduction of test wafer consumption, which has the impact of reducing demand. Suppliers have increased 200mm wafer production commitments because their good cash flow has given them the ability to make plant investments. The net of all this response activity is that 200mm wafers will be essentially closely in balance through the decade. Although the supply base has increased commitment, we do not see evidence of overspending in capacity as yet. More details will follow in a Dataquest Perspective to follow in a few weeks.

Small Wafer Sizes

The silicon industry began "squeezing" the semiconductor industry supply at 125mm and 100mm wafers in order to address 150mm wafer demand. Semiconductor companies generally did not accept this, and silicon manufacturers have responded by incrementally increasing capacity at 150mm wafers. This segment of the industry has now reinitiated a natural decline in demand, driven by programs of conversion to larger wafers. Although we expect the demand decline to be slow and long, it appears that the shortage at the smaller wafers is starting to dissipate.

Possible 150mm Shortage?

Demand for 150mm wafers is dependent on several factors: how many new 150mm fabs are being built (there are still several), how fast fabs are converting from smaller wafer sizes to 150mm (slowly occurring), and how fast supply and fab conversions ramp to 200mm wafers (accelerating rapidly). In our November 1995 report, Dataquest outlined a demand point in the year 2000 at which, based on various scenarios, the demand could be in the range of 85 million to 120 million wafers, with our last forecast at 91 million wafers. The current capacity of the industry was estimated at 68 million per year. As a result primarily of the 200mm ramp acceleration, the demand picture has eased for 150mm wafers slightly, and suppliers have also increased capacity incrementally. We no longer see the need to increase 150mm capacity beyond 1996 for this cycle, and it is unlikely that any new capacity is required for the next.

By Clark Fuhs and Takashi Ogawa

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Wafer Fab Equipment Market Today—Setting Up for Resumption of Growth in 1998

Overcapacity in the DRAM market, created by the massive spending from 1994 through the first part of this year and the normal DRAM product migration, is finally taking its toll, resulting in a faster than expected contraction in the wafer fab equipment market. We expect this contraction to be sharp and relatively deep but slightly shorter than historical norms, around 18 to 24 months. The key reason for the belief that the slowdown will be shorter than normal is the continued robust forecast for PC unit shipment growth through this decade.

This document will be followed by publication of the Semiconductor Equipment, Manufacturing, and Materials Worldwide 1996 Midyear Forecast, which Semiconductor Equipment, Manufacturing, and Materials Worldwide clients should receive within the next few weeks.

What Happened?

Although Dataquest has been forecasting a DRAM oversupply-driven capital spending slowdown over the last year to occur in 1997, the swift nature of its arrival still has shock value. We should point out why we were looking for a slowdown in capital spending.

The industry migration from 4Mb to 16 Mb DRAMs would cause overcapacity even in the face a high bit demand growth. Why? Die size relationships mean that the average 16Mb DRAM has two to three times more bits per square inch than the 4Mb generation. Because capacity in the industry is built in wafers, this event causes a step-function increase in bit capacity of the industry. This usually happens in a hurry and is triggered by the new generation hitting a critical yield level of about 65 percent, estimated to have been hit by the end of 1995.

The complicating factor, and the reason for the severity of the downturn today, was the artificial demand created in 1995 by the anticipation of Windows 95, which, taken with the tight supply of memory last year, caused inventories to inflate to enormous levels. This corrected in the final quarter of last year, slightly in advance but essentially on top of the conversion timing.

How Are Semiconductor Companies Responding?

It is very normal in this type of a downturn to get a pocket of companies that will stay and continue to invest in the infrastructure. These companies today are IBM, Texas Instruments, and, on a moderate level, the Korean companies. Japanese companies, which were the companies that held on in the last cycle for a year or more, have already shut off spending, and these companies as a group will spend slightly less in dollar terms in 1996 than in 1995. Except for Taiwan Semiconductor Manufacturing Co., Chartered Semiconductor, and Macronix, Asian companies are cutting back dramatically, starting in the last couple of months. As a group, the DRAM manufacturers are responding more rapidly to the situation, cutting spending faster than in previous cycles.

Table 1shows the latest Dataquest forecast for wafer fab equipment by region.

Table 1
Wafer Fab Equipment Forecast, 1995-2001 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Total Wafer Fab Equipment	19,054	22,309	18,760	19,900	25,380	36,219	46,889	16.2
Percentage Growth	76.6	17.1	-15.9	6.1	27.5	42.7	29.5	
Americas	5,179	6,217	5,453	6,163	7,797	10,530	13,105	16.7
Percentage Growth	62.3	20.1	-12.3	13.0	26.5	35.1	24.5	
Japan	6,352	6,423	5,272	5,635	7,011	9,679	11,694	10.7
Percentage Growth	73.5	1.1	-17.9	6.9	24.4	38.1	20.8	
Europe	2,316	2,642	2,428	2,486	3,124	4,253	5,520	15.6
Percentage Growth	69.1	14.1	-8.1	2.4	25.7	36.1	29.8	
Asia/Pacific	5,208	7,026	5,607	5,616	7,448	11,757	16,570	21.3
Percentage Growth	102.9	34.9	-20.2	0.2	32.6	57.8	29.5	

Source: Dataquest (July 1996)

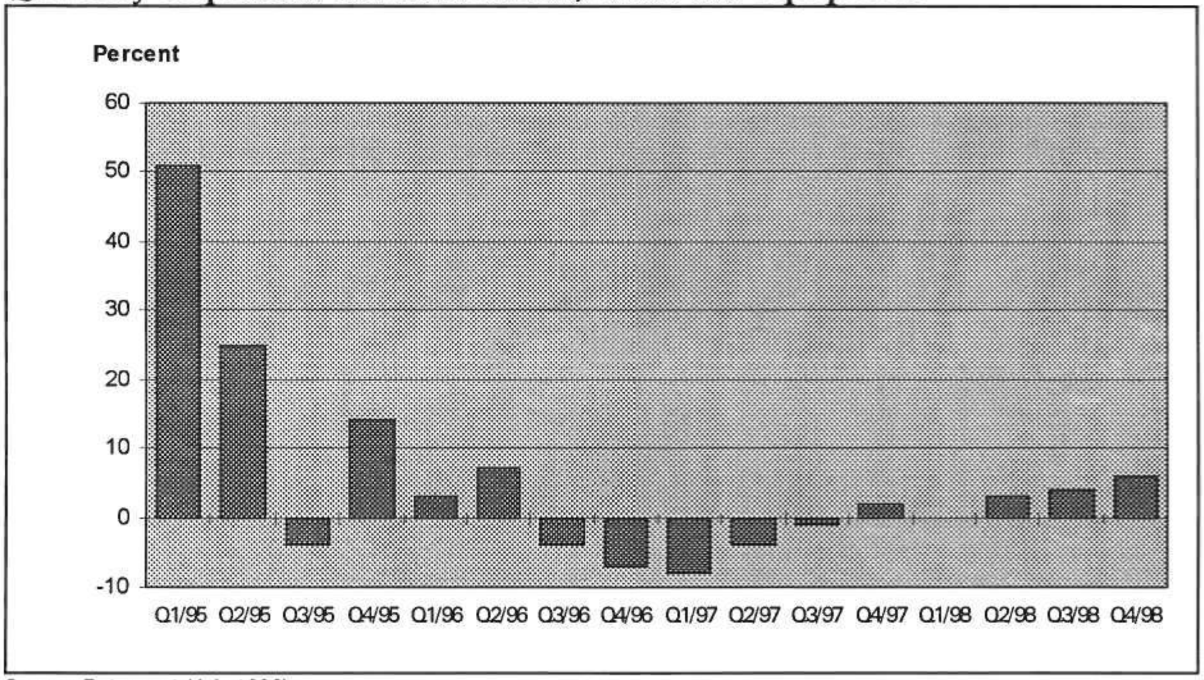
The Concept of "Capacity Trickle" and the Dynamics for Recovery

The industry is experiencing primarily a DRAM oversupply coupled with a product transition. In order to determine how capital spending may recover, it is important to understand how this excess capacity may migrate or "trickle" to other areas in semiconductor capacity.

There are two general blocks of capacity now available. The first comprises old 4Mb DRAM fabs that cannot run 16Mb chips. These are limited to two-level metal and are 0.6-micron to 0.8-micron technology fabs. Microcontrollers, telecommunications chips, mixed signal, and analog ICs are quite happy being processed in these fabs. It is likely that most of these fabs in Japan and some in Korea will migrate into this area. The power and discrete chips require specialized processes not found in old DRAM fabs, so these segments are relatively isolated from extraneous supply impacts. The second block of capacity comprises idle or underused advanced 16Mb capacity, which is limited today to two-level metal but at 0.4 micron to 0.5 micron. Because these fabs generally lack the process sequences of self-aligned silicide and three-level metal or more, they cannot be redirected effectively to advanced logic or fast SRAM. Therefore, they are limited to commodity SRAM, flash, other nonvolatile memory, or a limited span of logic products.

Therefore, Dataquest believes that the first areas of spending recovery will be in the advanced logic area, and equipment companies positioned for these markets will have more moderate slowdowns, starting to recover as early as mid-1997. The microcontroller, analog, mixed signal, and telecom chip capacity will be next to recover, but probably not until the end of 1997 or early 1998. The DRAM segment, the root cause of the problem, is not expected to resume robust spending until mid-to-late 1998. A quarterly revenue forecast, seasonally adjusted (see Figure 1) shows that the first sequential quarter of growth will by the fourth quarter of 1997. This scenario again assumes continued growth in the PC unit and other core semiconductor businesses.

Figure 1
Quarterly Sequential Growth Forecast, Wafer Fab Equipment



Source: Dataquest (July 1996)

By Clark Fuhs, Näder Pakdaman, Calvin Chang, Takashi Ogawa, and Yoshihiro Shimada

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Do We Still Expect a Silicon Shortage in the Face of the Lower Semiconductor Forecast? In a Word ... Yes.

Dataquest's outlook for silicon consumption remains basically unchanged from the forecast released in January 1996, even in the face of our lower semiconductor forecast of 7.6 percent growth for 1996. This Alert will review the reasons why our outlook remains firm. The next formal update to the silicon forecast is planned for release in mid-July, but we do not expect adjustment beyond a "fine tuning." Further, the basic analysis contained in the November 1995 report on the silicon shortage remains valid, and fine tuning updates will be made over the next couple of months through the publication of *Dataquest Perspectives.*

Lower Semiconductor Forecast Driven by Revenue Events, Not Units

The new semiconductor forecast made primarily revenue revisions, as opposed to unit revisions. Table 1 may illustrate this more clearly.

Table 1
Review of Changes Made to Semiconductor Revenue Growth in 1996 (Billions of Dollars)

Event or Characteristic	1996 Growth Rate (%)	Growth Impact (%)	Year 2000 Forecast
October 1995 Forecast	+ 22.1		331
DRAM Pricing		- 8.5	
Yen-to-Dollar Exchange Rate		- 3.0	
Other Demand Factors		- 3.0	
April 1996 Forecast	+ 7.6		310

Source: Dataquest (May 1996)

Two points must be made regarding Table 1. First, DRAM prices and exchange rate issues are *revenue* effects only and account for nearly 80 percent of the 1996 revision. Unit demand, which is the primary driver for silicon demand, will be relatively unchanged. (Slightly lower unit growth in general is expected to be offset by higher DRAM units in 1996 because of demand elasticity.) Second, the longer-term view can be almost entirely explained by the yen/dollar exchange rate change (again, no significant unit forecast decrease).

DRAM Pricing Assumptions Are in Silicon Forecast Methodology

Dataquest's silicon forecast has two things factored into the methodology that have anticipated and modulated the effects of the revision in the semiconductor forecast. The changes were largely anticipated, and therefore we do not expect the silicon forecast to change appreciably.

The DRAM price assumption is part of the silicon forecast methodology. Dataquest actually attempts to forecast semiconductor industry revenue per square inch of silicon. The price of DRAM is the single most important factor in projecting this industry number, and exchange rates are also taken into account. The new semiconductor forecast will simply adjust these assumptions, effectively canceling the effect of the lower revenue inputs. Our silicon square-inch growth forecast for 1996 is 15.6 percent, and we do not expect this to change appreciably.

Further, the silicon forecast was compiled in December, a couple of months after the previous semiconductor forecast and in the middle of the memory price slide. Therefore, we attempted to incorporated additional information in the January silicon forecast that had not been available in the October semiconductor forecast. So, in essence, we anticipated the adjustments and built the silicon forecast model on an assumption of a $310 billion to $315 billion model for semiconductors in the year 2000, with weakness near-term loaded, factoring in a more aggressive price decline in memory.

Polysilicon Demand Will Still Cause Shortage

With unit demand and forecast models intact, the inevitable shortage in polysilicon will happen. The fact remains that industry inventories of polysilicon raw material have decreased in 1994 and 1995 because consumption exceeded production. Industry inventories in polysilicon will be exhausted during 1996. PC unit growth would have to decline to about 5 percent in 1996 to avoid this situation (which, by the way, would tend to drive the semiconductor market to an actual *decline* of 4 percent to 7 percent or more in 1996). Dataquest just does not see this happening.

Since the report on the supply/demand situation in November, there have been several announcements for increased polysilicon capacity. This will drive production to exceed consumption starting in late 1997 through 2000. However, the industry operates efficiently with some inventory in the channel, and it will take until 1999 for the industry to get back to the two-month inventory level considered to be the minimum for comfortable operation. So we would expect tight (although not short) conditions to exist in the market through 1999. The details of this demand update will be in a forthcoming document.

200mm Wafer Demand Continues to Ramp Faster Than Supply

Regardless of unit demand for semiconductors, the 200mm wafer market is expected to continue to be supply constrained for the rest of the decade. Suppliers are simply behind the power curve in ramping up production. In the worst case of a PC unit slowdown, more semiconductor companies will migrate their 150mm fabs to 200mm fabs, resulting in a continued tight 200mm market. In the worst case (which we are not forecasting), a PC unit slowdown would mean that the 150mm wafer supply situation only would be eased.

Bottom Line: PC Unit Demand Drives the Silicon Shortage

The bottom line to the silicon shortage resides with PC unit demand. PCs drive the need for about one-third of all semiconductor revenue and about one-quarter of silicon in the world, and they continue to be one of the fastest growth segments for semiconductors. As long as this growth trend is intact at the level of a 17 percent compound annual growth rate (and Dataquest's 1996 PC unit growth was recently confirmed at 19 percent), silicon demand will remain high and continue to drive a tight market for wafers.

By Clark J. Fuhs

Dataquest ALERT

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Industry Backlogs Make 1996 Wafer Fab Equipment Growth of 36 Percent a "Slam Dunk"—What About 1997?

The industry almost hopes that 1995 will not be repeated for a while because the infrastructure of supply is being strained. Backlogs in the equipment industry exploded in 1995, with reports that stepper lead times are over one year. Companies are having trouble filling all their open positions, and silicon supplies are extremely tight. Yet the engines of demand for semiconductors—PCs and communications/networking equipment—continue.

This document will be followed by publication of the Semiconductor Equipment, Manufacturing, and Materials Worldwide 1995 Year-End Forecast, which SEMM clients should receive within the next few weeks.

What Are the Trends?

On top of booming growth 1994, global semiconductor capital spending grew another 72 percent during 1995 to $38 billion, with the wafer fab equipment market growing 67 percent to $17.9 billion. Anticipated tight capacity and a strong semiconductor market in 1995 mean continued growth into 1996.

North America is showing consistent strength in 1995. North American capital spending is expected to remain strong in 1996 and moderate in 1997 as investment is absorbed, but we expect the North America region to grow at faster-than-market rates as foreign multinationals and foundry companies invest in capacity in the United States.

Japanese companies are continuing to invest in semiconductor capacity to preserve their market share position in memories, although the strength of the yen in the middle of the year temporarily put a lid on spending enthusiasm. Japan as a region kept pace with the world in investment in 1994, but lagged the market in 1995 as Japanese companies invested more outside Japan. Lagging investment within Japan is expected to continue throughout the decade. Japanese companies, however, increased spending during 1995 about 61 percent worldwide to a total of $12.2 billion, second only to North American companies, with spending of $13.6 billion, and well ahead of Asian companies, at $9.1 billion.

Dataquest has been bullish on the prospects in Europe, and remained so in 1995, although the region came in slightly under expected spending. European companies are a large part of this expansion, aided by strong domestic economies, and major projects by the multinational manufacturers are also contributing. We still see Europe as a significant growth region for spending through the decade.

Following very strong capital investment growth in 1994, spending in the Asia/Pacific region doubled in 1995 as Korean DRAM expansion accelerated (further), foundry expansion in Taiwan, Singapore, and others continued to grow, and new DRAM players entered the scene in Taiwan. The new projects started in 1995 will continue to consume capital funds in 1996. Asia/Pacific and the rest of world region (ROW) will continue to be one of the fastest-growing regions through this decade.

Performance of Equipment Segments

Segment growth in 1994 and 1995 was led by DRAM or capital spending-sensitive equipment (those segments that tend to be bottlenecks or directly influence incremental yield), with steppers, implant, wafer inspection, and factory automation exhibiting significantly stronger-than-market growth. New technology segments such as chemical mechanical polishing (CMP), high-voltage implant, and rapid thermal processing (RTP) were the fastest-growing segments. We expect no major segment declines in 1996, as capacity additions are broad-based and worldwide, and we expect those segments that lagged in 1995 to be among the leaders in 1996 (etch, tube chemical vapor deposition, and sputtering). Companies will continue to invest in advanced technology in 1996, with the CMP and RTP segments remaining strong.

Is This Cycle Different?

Dataquest believes that the relatively large capacity expansion of 1993 to 1995 (three-year growth of 265 percent) has now exceeded the three-year growth recorded in the 1987-to-1989 expansion. It should be noted, however, that the two periods are different in two key respects. First, the current period is experiencing accelerated long-term growth for the underlying semiconductor industry, driven by a productivity related PC boom. The PC boom is expected to continue, so we are not overly alarmed about the magnitude of this cycle.

Second, the manufacturing infrastructure is more efficient today, and there is a diminishing return in productivity and yield improvements. This has led to a higher natural capital investment ratio required today than in the 1987-to-1989 period, closer to 22 percent of revenue, on average, being a standard (versus 18 percent in the late 1980s).

However, we also believe that, in 1996, spending will decelerate, starting in the second half of the year, causing a relatively flat spending pattern through 1997 and 1998. Although we continue to believe that the cyclical nature of investment in semiconductor capacity will diminish, the PC boom must continue to drive the underlying semiconductor growth strongly enough to dampen the memory component of the cycle. After a flat two-year period, investments should pick up again in 1999.

What about 1997? Some Fundamental Capacity Analysis

Point 1: Fab Announcements

Over 130 fabs planned fabs have been announced for the forecast horizon (1995 and after). The density of new fabs, about 35 per year, has not changed significantly, but the announcement horizon has lengthened. A year ago, new fabs were being announced 18 months to 21 months before they were to come on line. Today, with huge backlogs in equipment companies, announcement are made for fabs 24 months to 30 months in the future. Are these fabs real? We believe so, because to achieve a $330 billion semiconductor market by 2000, the industry needs to maintain a run rate of 30 to 35 fabs per year. Our concern is that the 1996 and 1997 run rates are slightly ahead of this figure, and some of the late-1997 and 1998 fabs may be delayed by six to 12 months, softening the quality of backlogs for 1997.

Point 2: DRAM Capacity

Although we think the recent talk on DRAM pricing has been overblown (we see continued shortages through 1996), we do believe we are past the "pinch point" in the supply/demand imbalance, and availability of DRAM is beginning improve. We are now viewing 1997 as a year for a slight oversupply of DRAM (based on silicon area capacity), so capital investment in 1997 is likely to cool in this area.

Point 3: Foundry

Does this spell doom for 1997? No, the foundry industry supply will get tighter in 1996, leading to increased spending for logic-oriented capacity over DRAM starting late in 1996 and continuing into 1997. The foundry market will not see relief in capacity until the middle of 1998, by our silicon area-based capacity analysis.

Point 4: Discrete and Analog Capacity Shortages

It may come as a surprise to many people that significant capacity is being added at the 1-micron level and above. The boom in electronic equipment and semiconductors has created a demand for power/discrete and analog devices. Normally, companies would rely on migration of older capacity toward these areas to meet demand, but the boom in microcontrollers has prevented this. Although the demand for new equipment may be limited to some lithography and older lines of other types of equipment, because semiconductor companies in these segments tend to rely on the used equipment market, it does mean new fabs. Mainland China is expected to benefit specifically.

Result: Crosscurrents for 1997

DRAM capacity investment will be weaker, but very strong logic capacity growth will continue. As DRAM becomes oversupplied, investment is likely to dry up quickly. But the continued tight supply of foundry and logic capacity is expected to produce continued investment in the United States and Asia in 1997. We expect DRAM investment to decline some 10 percent to 20 percent, while logic investment increases 20 percent to 30 percent.

The Forecast

Tables 1 and 2 shows the regional top line capital spending and wafer fab equipment forecast through the year 2000. Further details will be reviewed in the report mentioned previously.

Table 1
Capital Spending Forecast, 1994-2000 (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Total Capital Spending	22,037	37,994	49,281	50,765	49,441	54,778	69,472	21.1
Growth (%)	53.9	72.4	29.7	3.0	-2.6	10.8	26.8	
Percent of Semiconductors	19.6	25.1	26.7	23.9	20.6	19.7	20.9	Average = 22.1
North America	7,182	12,169	16,579	18,021	17,954	20,645	25,722	23.7
Growth (%)	45.3	69.4	36.2	8.7	-0.4	15.0	24.6	
Japan	6,654	9,777	12,102	11,766	11,320	12,542	15,986	15.7
Growth (%)	50.8	46.9	23.8	-2.8	-3.8	10.8	27.5	
Europe	2,481	4,384	5,293	5,521	5,240	5,968	7,402	20.0
Growth (%)	43.5	76.7	20.7	4.3	-5.1	13.9	24.0	
Asia/Pacific	5,720	11,665	15,308	15,458	14,927	15,623	20,361	23.6
Growth (%)	76.7	103.9	31.2	1.0	-3.4	4.7	30.3	

Source: Dataquest (December 1995)

Table 2
Wafer Fab Equipment Forecast, 1994-2000 (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Total Wafer Fab Equipment	10,755	17,911	24,338	24,709	23,293	26,542	34,365	21.4
Growth (%)	56.4	66.5	35.9	1.5	-5.7	14.0	29.5	
North America	3,141	5,262	7,512	7,969	7,855	9,281	11,723	24.5
Growth (%)	47.5	67.5	42.8	6.1	-1.4	18.2	26.3	
Japan	3,668	5,901	7,094	6,445	6,082	7,073	9,055	16.3
Growth (%)	49.1	60.9	20.2	-9.1	-5.6	16.3	28.0	
Europe	1,385	2,130	2,733	2,590	2,503	2,927	3,655	17.6
Growth (%)	41.6	53.8	28.3	-5.3	-3.3	16.9	24.9	
Asia/Pacific	2,562	4,618	6,998	7,705	6,852	7,261	9,931	25.3
Growth (%)	95.7	80.2	51.5	10.1	-11.1	6.0	36.8	

Source: Dataquest (December 1995)

By Clark Fuhs, Näder Pakdaman, Calvin Chang, Yoshihiro Shimizu, and Yoshihiro Shimada

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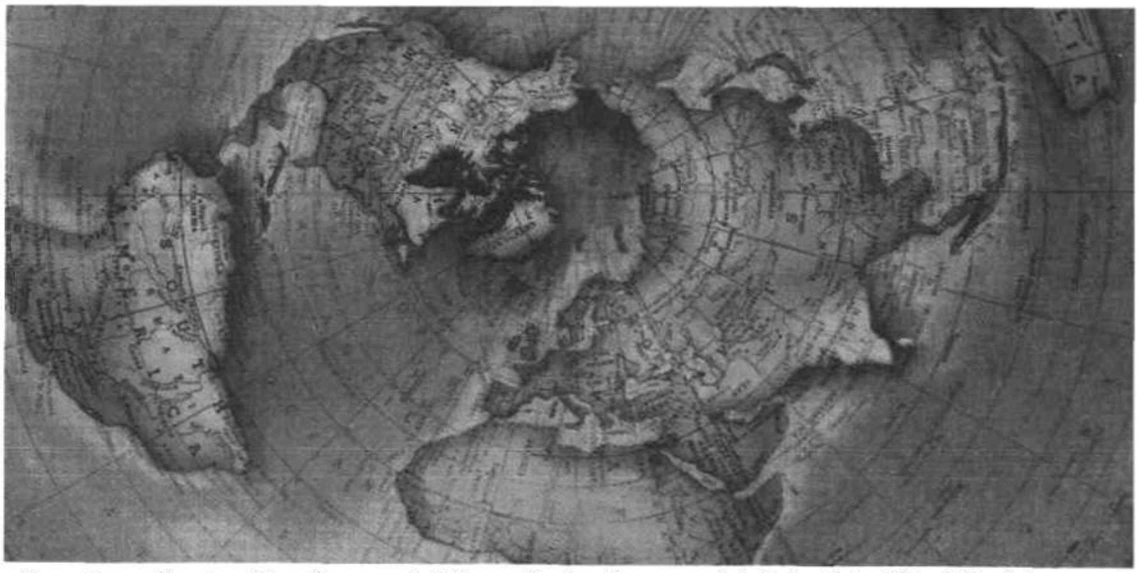

Perspective

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Market Analysis

The 1995 Worldwide Wafer Fab Equipment Market: A Record Year—Competitive Analysis of Regional Dynamics, Industry Segments, and Company Market Shares

Abstract: *The wafer fab equipment experienced a banner year in 1995. How did the industry's regional markets, product segments, and equipment suppliers weather the tidal wave of industry activity? This document offers a market performance index to better analyze the industry's competitive dynamics and trends.*
By George Shiffler and Näder Pakdaman

Introduction

In 1995, estimated front-end equipment manufacturers' total revenue grew a dizzying 77 percent, from $10.8 billion in 1994 to $17.8 billion. Dataquest had anticipated a very strong year in capital spending in 1995, following 57 percent growth in 1994. However, 1995 growth exceeded even the most aggressive predictions we made at the beginning of the year. Our initial forecast was based on healthy growth in ICs driven by continued broadening in semiconductor applications, led by a strong PC market.

The PC market continued to sustain and grow demand for DRAM bits. With low 16Mb yields and availability, prices for 4Mb not only remained strong but actually inched upward. We had estimated that 16Mb shipments would begin to dominate the market by midsummer. This prediction did not materialize until the end of 1995. As a result, the DRAM market not only experienced rising production but climbing prices, as well. This scenario led to a DRAM market in 1995 that grew by 66 percent over 1994,

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from an estimated $23 billion to over $42 billion. Excluding the hypergrowth experienced by the DRAM market in 1995, the market for other semiconductors grew by 24 percent. Including the hypergrowth experienced by DRAMs, the market for all semiconductors grew by 37 percent.

Capital spending and equipment investment are driven by semiconductor profitability. Throughout 1995, margins for DRAM products, dominated by 4Mb devices, were at historical highs. In a soon-to-be published Dataquest Perspective, we will investigate the impact of DRAM pricing and technology transitions on the capital equipment market. In this document, we will focus on a competitive and regional analysis of the 1995 capital equipment market.

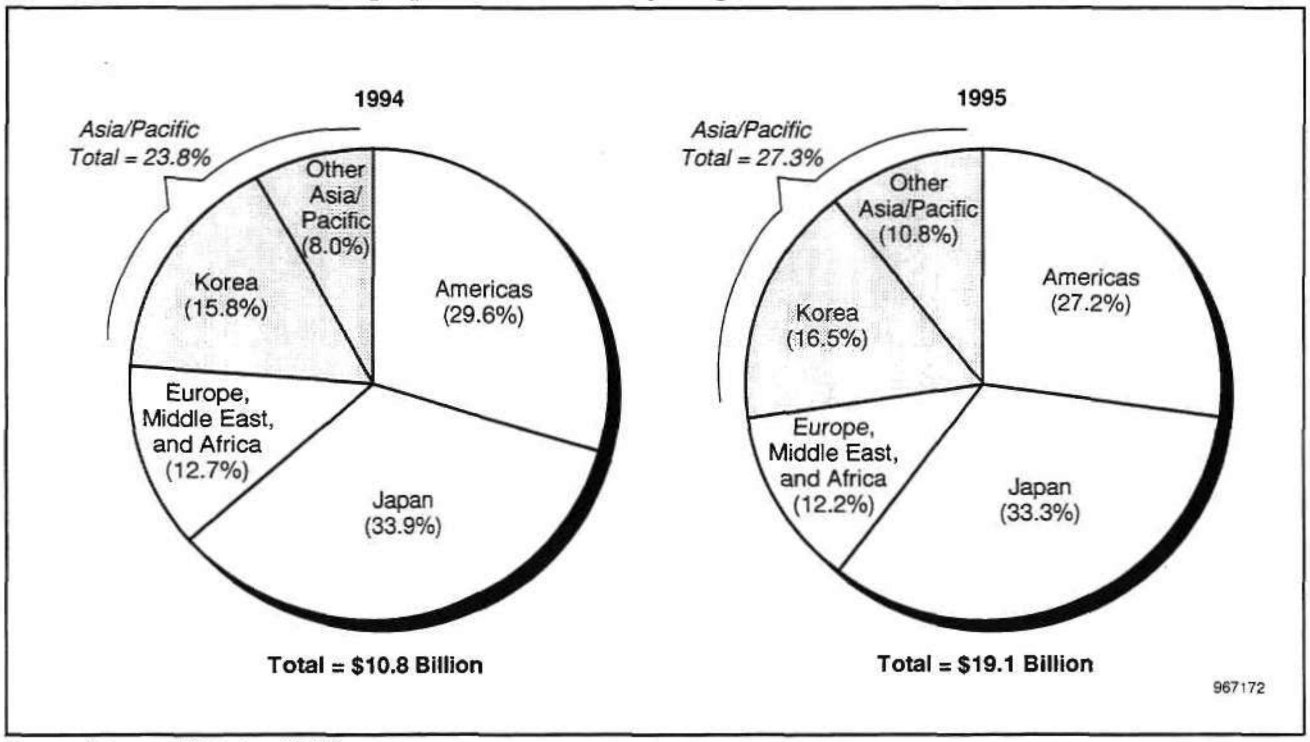
1995 Regional Wafer Fab Equipment Markets

Vigorous equipment spending by DRAM producers spurred strong equipment revenue growth in the world's dominant DRAM-producing regions and countries, Asia/Pacific, Korea, and Japan. The regional distribution of wafer fab equipment revenue in 1994 and 1995 is shown in Figure 1. Beginning this year, Dataquest separated the Korean equipment market from the Rest of Asia/Pacific market. As indicated in the figure, we have developed separate data for Korea and Rest of Asia/Pacific for 1994 and 1995. We are in the process of publishing an extensive Focus Report on the wafer fab equipment market, capital spending, and semiconductor production in Korea. Figure 2 shows the historical regional distribution of equipment revenue from 1985 to 1995. (In the figure, Asia/Pacific includes both Korea and Rest of Asia/Pacific.)

Asia/Pacific's rising share of equipment consumption accelerated in 1995. Equipment consumption in this region grew an astounding 103 percent over 1994, raising the region's contribution to worldwide figures from under 24 percent in 1994 to over 27 percent in 1995. For the first time, this translated into an equipment market equivalent in size to the one in Americas. The surprise is, perhaps, that Korean growth fell below the cumulative average for the region! Whereas Korean equipment sales grew an impressive 84.5 percent, more strongly than those of any region or country outside Asia/Pacific, Rest of Asia/Pacific grew even more strongly, with its 140 percent expansion. The contribution of Rest of Asia/Pacific to world revenue grew from 8 percent in 1994 to nearly 11 percent in 1995. This growth was not only fueled by capital spending on the part of the foundry-related manufacturing companies in Taiwan, Singapore, and Thailand, but also by the aggressive entry of Taiwan into the advanced DRAM market. As Figure 2 shows, 1995 marks the fifth consecutive year in which the Asia/Pacific region's share of worldwide equipment consumption increased. Since 1990, Asia/Pacific's share of the worldwide market has about tripled, rising from under 9 percent in 1990 to over 27 percent in 1995.

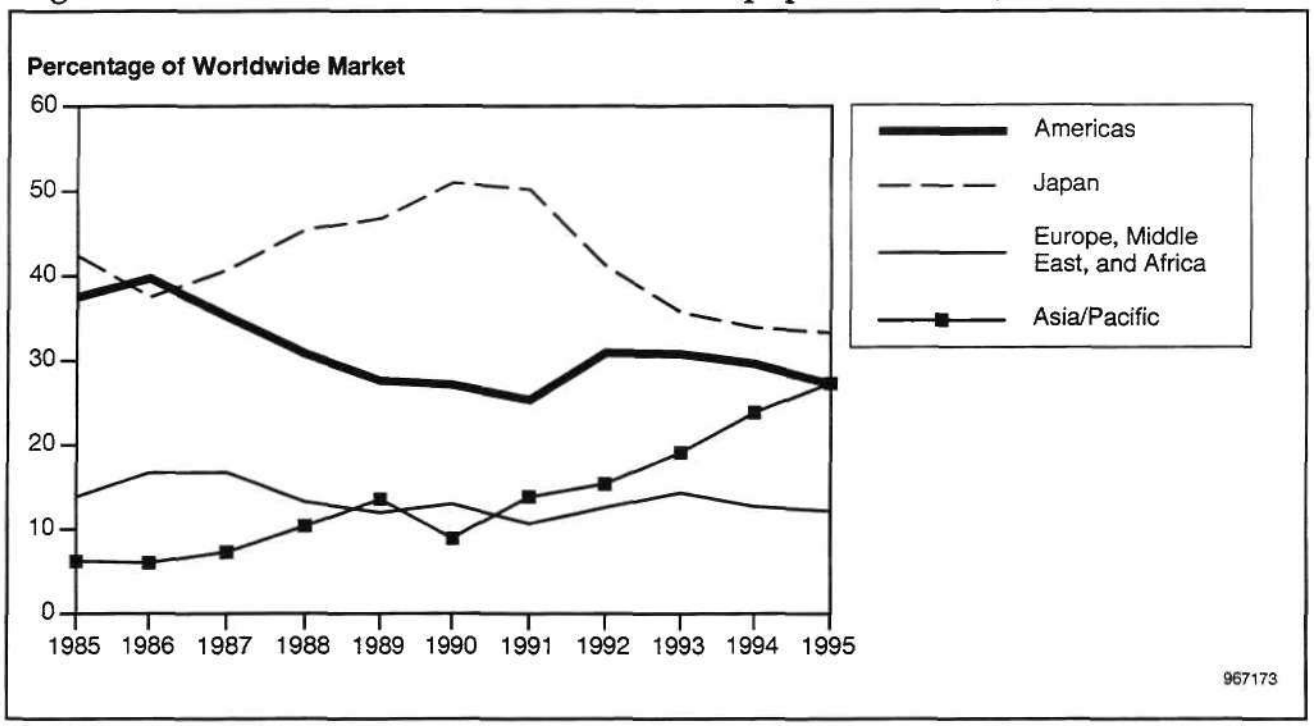
Elsewhere in the world, equipment revenue also realized robust growth. The Japanese market grew 73.5 percent in 1995. However, because this rate of growth was just under the average worldwide rate of 76.6 percent, equipment sales in Japan as a percentage of worldwide revenue declined slightly, sliding from under 34 percent to an estimated 33.3 percent. As shown in Figure 2, Japan's contribution to world revenue has now declined for five consecutive years, falling from a historic high of over 50 percent in 1990 to

Figure 1
Worldwide Wafer Fab Equipment Market by Region, 1994 and 1995



Source: Dataquest (October 1996)

Figure 2
Regional Distribution of Worldwide Wafer Fab Equipment Market, 1985-1995



Source: Dataquest (October 1996)

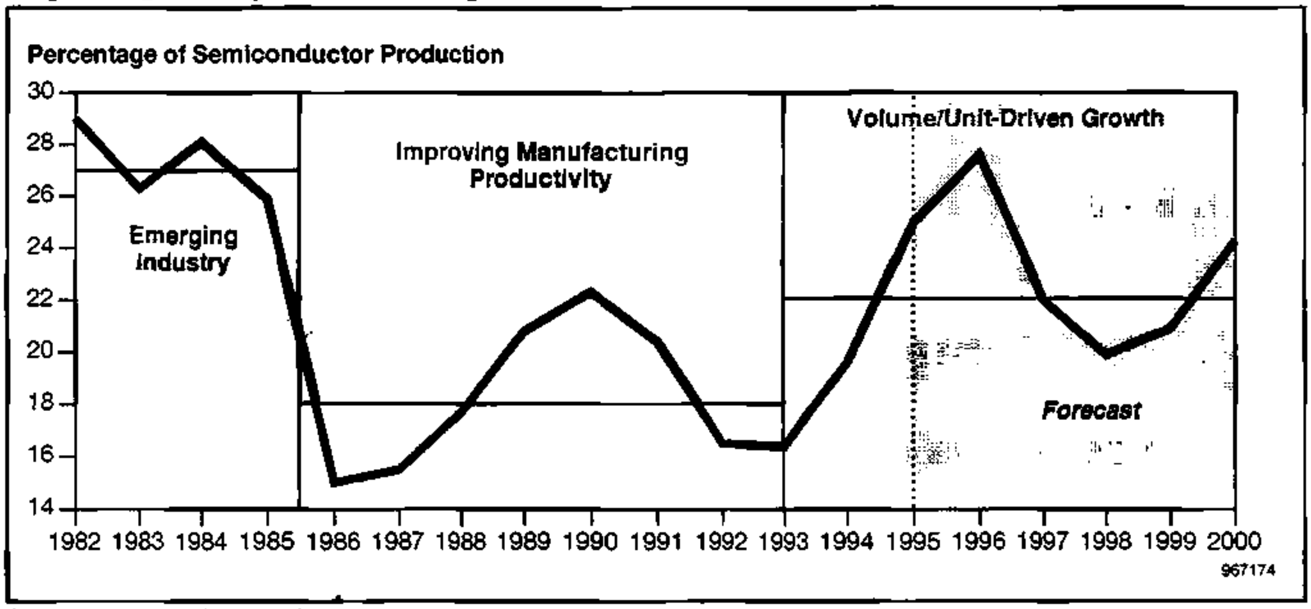
the current 33.3 percent. This decline is not only because of the relative strengthening in spending within Asia/Pacific but also because of Japanese companies' strong investment outside of Japan.

For Europe and the Americas, we estimated similarly strong spending growth. In both cases, however, growth proved to be below the worldwide average. Equipment revenue in Europe (including consumption in Israel) grew nearly 70 percent between 1994 and 1995. Robust growth in the Americas market lagged every other region at just over 62 percent. European and Americas estimated shares of equipment consumption fell from 12.7 percent to 12.2 percent and from under 30 percent to slightly over 27 percent, respectively. In short, then, except for Japanese consumption, which almost kept pace with the explosive growth realized in 1995, European and Americas equipment consumption growth fell below average, while Korean and Asia/Pacific growth outstripped every other region.

In a global market, where prices of ICs are relatively uniform by product type across all regions, why are spending trends so uneven? We need to look at capital spending as a fraction of semiconductor production revenue to better answer this question. The ratio of capital spending to estimated semiconductor production revenue is shown in Figure 3. In this figure, we see three distinct periods in the evolution of this spending-to-production-revenue ratio. In the early to mid-1980s, the semiconductor industry was spending, on average, $0.27 per dollar of revenue. During this time, Japanese manufacturers were spending nearly $0.39 per dollar of revenue. In contrast, U.S. manufacturers were spending $0.22 per dollar of revenue. In the second period, from the mid-1980s to the early 1990s, the worldwide average spending ratio fell to $0.18 per revenue dollar. Although Korean manufacturers spent $1.65 for every dollar of revenue they generated in this interval, semiconductor manufacturers in larger and more mature regions of the world were improving equipment productivity to generate more revenue per dollar spent. In the third period, from the early to the mid-1990s, we see the average at around $0.22 per revenue dollar. In this regime, Japanese and U.S. manufacturers are estimated to have spent around $0.20 per revenue dollar, while manufacturers in Korea and the rest of Asia/Pacific spent over $0.65 for every dollar of revenue. (We should note that in emerging markets government subsidies often play an important role in supporting aggressive manufacturing investment.) In every period, the European spending-to-revenue ratio has fallen below the global average. However, we see European spending ratios rising and approaching the overall average.

We believe that as the IC market and capital spending become more global, every region should more or less approach the approximate spending ratio of the more "mature" regions (that is, Americas and Japan) at about $0.20 per dollar of revenue. Eventually, higher-than-average spending for Asia/Pacific should lend itself to smaller ratios than its current above-average figures as this region's advanced manufacturing base becomes more similar to that of its peers in other regions. However these smaller ratios will be for a much larger share of production revenue and will thereby translate into larger spending figures. Europe's product mix, led by advanced telecommunications ICs, requires higher spending ratios. This translates into higher spending rates in Europe, a trend already realized by local and foreign investors in this region.

Figure 3
Capital Spending as a Percentage of Semiconductor Production Revenue



Source: Dataquest (October 1996)

1995 Wafer Fab Equipment Segment Growth

In 1995, virtually all major equipment segments posted positive revenue growth. Among the 42 front-end equipment segments that Dataquest tracks in semiconductor manufacturing, we estimate that 39 enjoyed positive growth, 23 posted over 50 percent growth, and nine experienced better than 100 percent growth. Figure 4 illustrates the 1995 revenue growth rates of the equipment segments tracked by Dataquest. As the figure shows, the fastest-growing equipment segment in 1995 was high-voltage implanters. Incredibly, revenue for this segment grew nearly 350 percent, rising from under $26 billion to over $119 billion.

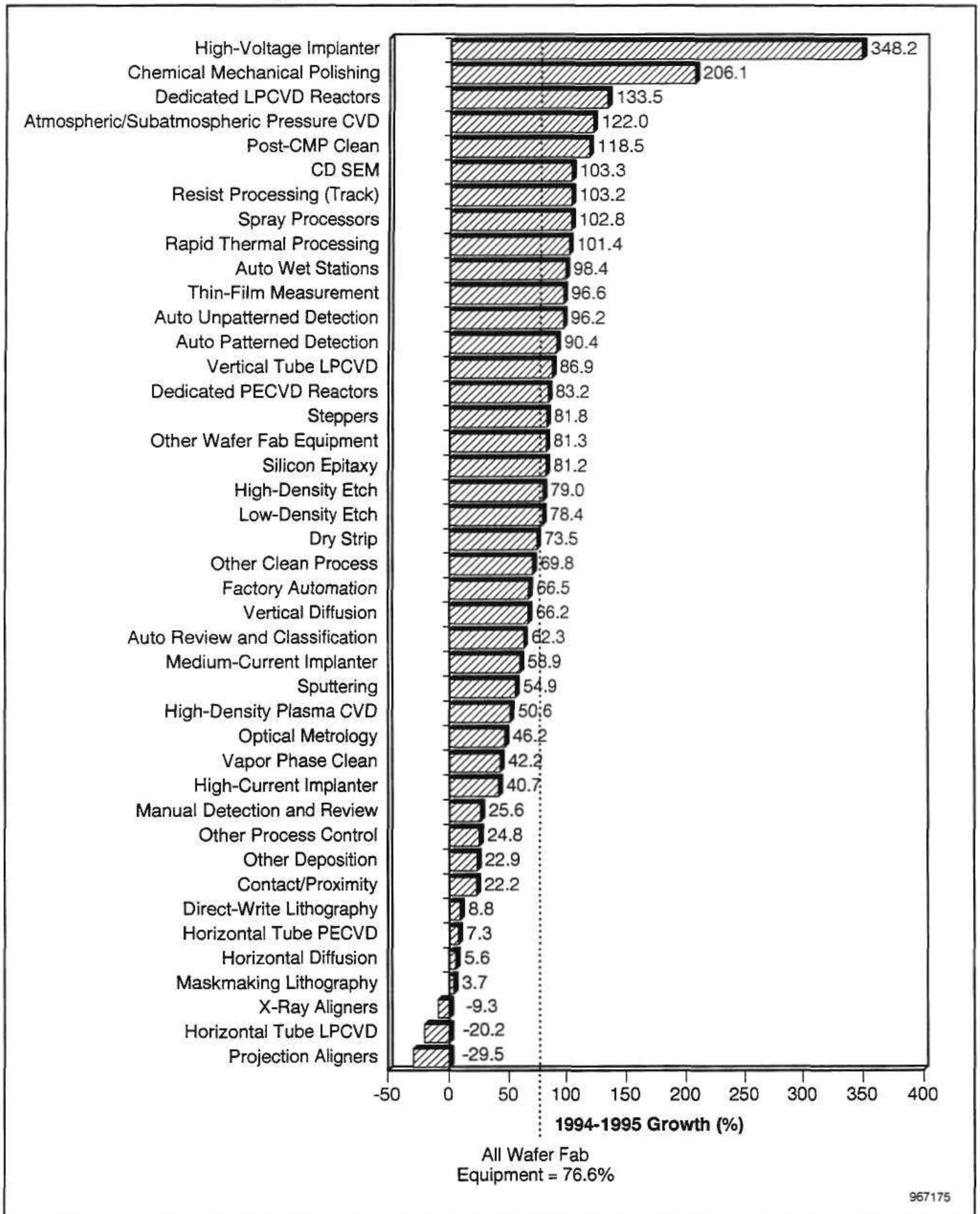
The only laggards in the 1995 market were rather small segments in lithography (X-ray and projection aligners). The X-ray market is more or less concentrated in advanced R&D centers, while projection aligners are being used more and more in nonsemiconductor production applications.

Equipment Segment Performance Index Defined

There are, of course, many ways to gauge the relative performance of different equipment segments within a year. One could rank equipment segments by revenue growth rate, as in Figure 4, by absolute revenue change, by change in market share, or by some combination of these variables. We believe that relative equipment performance should be based on a measure that evaluates a given segment's performance in terms of that segment's relative impact on the overall market. We believe this relative impact is best gauged by looking at how a given segment's growth affects its position in the market vis-à-vis other segments. To this end, we have created a market-share-based performance index defined as follows:

Market performance index = 100 x change in market share x market share weighting

Figure 4
Worldwide Wafer Fab Equipment Segment Growth, 1994-1995



Source: Dataquest (October 1996)

In this formula, market share weighting equals the arithmetic average of an equipment's market shares for the two consecutive years being studied.

Table 1 presents a ranking of equipment segments in 1995 according to our market-share-based performance index. The index values reported are the mathematical product of the year-to-year difference in each segment's market share (with respect to the overall market) and the arithmetic average of each segment's market share from 1994 and 1995. In effect, the first factor is a measure of annual growth, while the second gauges the importance of a segment in the overall equipment market. Thus, our performance index considers both the market share of each equipment segment and changes in that share that result from revenue growth. As indicated above, we have multiplied the product of the change in market share and market share weighting by 100 to add further resolution to the rankings. By way of example, consider the calculation of our index for steppers:

$$\text{Index for steppers} = 100 \times (17.5 - 17.0) \times (17.5 + 17.0)/2 =$$
$$100 \times 0.5 \times 17.25 = 855.0$$

(The end result differs from the calculation because of rounding.)

The index will be positive only if a segment experiences growth greater than the industry average. The index heavily penalizes segments with large market shares that fail to keep pace with the industry and thereby lose significant market share. Conversely, the index spotlights segments with small market shares that substantially outpace the industry and so gain significant market share. We believe this index eliminates the inherent bias in pure growth-rate-based measures. Those measures tend to single out small, emerging segments that, despite their fast-paced growth, continue to remain small in terms of overall impact on the market. At the same time, our measure eliminates the inherent bias in pure absolute-revenue-change measures. Those measures tend to highlight large established segments that, because of their size, continue to experience large absolute revenue growth but that, nonetheless, may be losing market share and hence impact on the market.

Steppers a Top Performer in 1995

According to Dataquest's performance index, steppers proved to be the top-performing equipment segment in 1995. Stepper revenue grew nearly 82 percent between 1994 and 1995, rising from $1.8 billion in 1994 to $3.3 billion in 1995. Stepper revenue increased from 17 percent of total revenue in 1994 to 17.5 percent in 1995. As calculated above, the value of our index for steppers was an impressive 855.0. Table 1 shows that resist processing equipment and auto wet stations finished behind steppers as top-performing segments. Both these segments actually enjoyed better growth than steppers in 1995. However, because of their significantly smaller share of the overall market, their growth had a smaller relative impact on the market.

The worst-performing segment according to this index was sputtering. Although this segment posted growth, its performance index was estimated at negative 1,106.2. Sputtering experienced below-industry-average growth of 55 percent in 1995. As a result, sputtering's share of equipment

Table 1
Top-Performing Equipment Segments in the Worldwide Wafer Fab Equipment Market, 1995 (Millions of Dollars)

	1994 Revenue	1994 Market Share (%)	1995 Revenue	1995 Market Share (%)	Revenue Change	1994-1995 Revenue Growth (%)	1994-1995 Share Change (%)	Performance Index
Steppers	1,832.7	17.0	3,331.6	17.5	1,498.9	81.8	0.5	855.0
Resist Processing (Track)	695.1	6.4	1,412.5	7.4	717.4	103.2	1.0	672.1
Auto Wet Stations	467.6	4.3	927.6	4.9	460.0	98.4	0.5	245.7
Dedicated LPCVD Reactors	218.1	2.0	509.3	2.7	291.2	133.5	0.7	152.8
Low-Density Etch	1,139.6	10.6	2,032.7	10.7	893.1	78.4	0.1	110.9
Atmospheric/Subatmospheric Pressure CVD	191.4	1.8	425.0	2.2	233.6	122.0	0.5	91.3
Vertical Tube LPCVD	392.3	3.6	733.2	3.8	340.9	86.9	0.2	79.2
Dedicated PECVD Reactors	467.2	4.3	855.9	4.5	388.7	83.2	0.2	71.0
Auto Patterned Detection	281.0	2.6	535.1	2.8	254.0	90.4	0.2	55.0
Chemical Mechanical Polishing	64.2	0.6	196.7	1.0	132.4	206.1	0.4	35.5
CD SEM	153.9	1.4	312.9	1.6	159.0	103.3	0.2	33.1
Total Wafer Fab Equipment	10,787.3	100.0	19,053.5	100.0	8,266.1	76.6	-	-

Note: The 1994-to-1995 performance index equals 100 times the change in equipment share times the average of equipment's 1994 and 1995 share.
Source: Dataquest (October 1996)

revenue fell from 9.4 percent in 1994 to 8.2 percent in 1995. Sputtering's significant market size further accentuated its poor performance index. Perhaps sputtering's relatively poor performance should not surprise us in a year where over 65 percent of the investments were focused on DRAM capacity increases. This equipment segment is heavily dependent on the logic portion of the industry, for which metal deposition requirements are significantly higher than for memory chips. Therefore, in a DRAM spending spree, this segment's relative growth was below overall market performance.

1995 Wafer Fab Equipment Company Shares: Riding the Wave

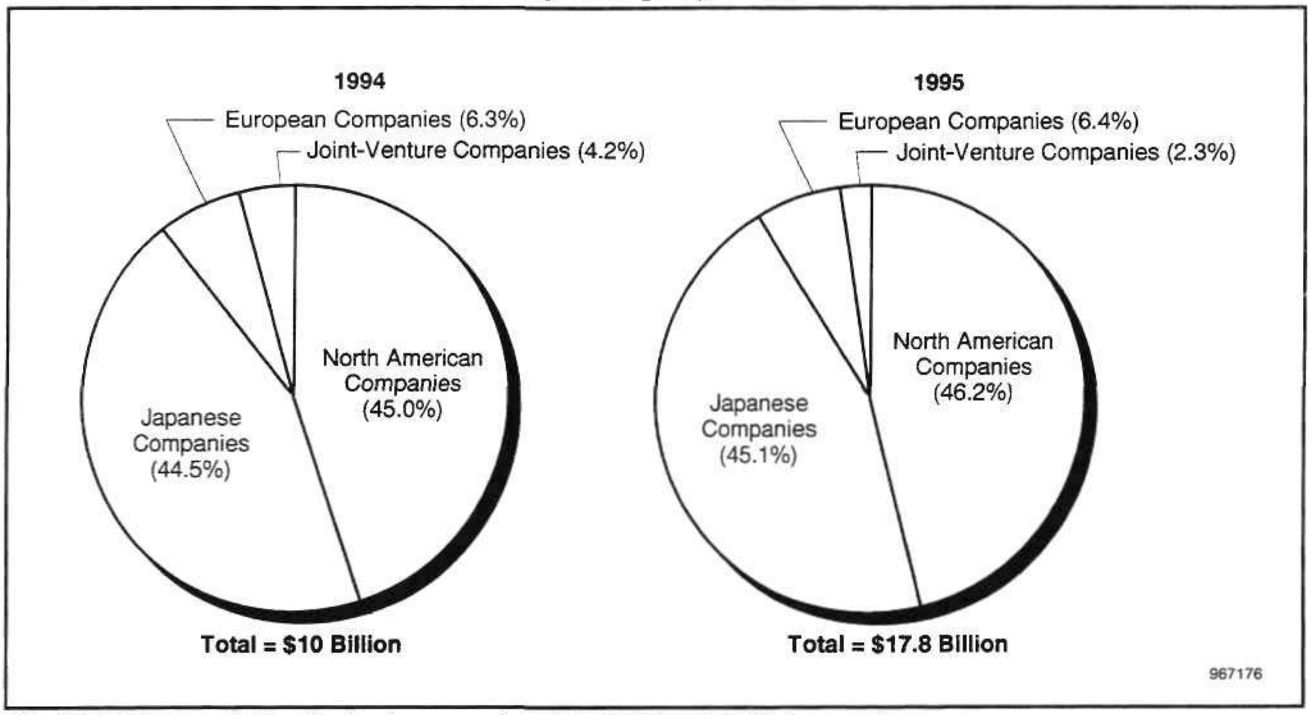
It is said that a rising tide lifts all ships. In 1995, almost all equipment companies rose on the tidal wave of industry activity. Of the 120 companies with estimated revenue in 1994, 109 experienced positive revenue growth. Of these, 66 experienced revenue growth in excess of 50 percent, and 27 experienced revenue growth in excess of 100 percent. Not surprisingly, the changing fortunes of most companies were strongly linked to the performance of the equipment segments in which they compete. Companies that gained market share in strong equipment segments rode the crest of the industry's tidal wave. There were, however, exceptions. Some companies proved unable to ride the wave and floundered, losing hard-won market share. Others with excellent performances gained market share in what might be seen as unpromising and relatively weaker equipment segments.

North American and Japanese Companies Remain Neck and Neck in Race for Market Share

North American and Japanese equipment companies remained neck and neck in the race for global market share in 1995. North American companies increased their lead slightly in 1995, but the increase cannot be considered significant. Figure 5 illustrates the revenue shares by company base for 1994 and 1995. Figure 6 illustrates historical company shares from 1985 to 1995. As shown in Figure 5, North American companies as a group increased their estimated share from 45 percent in 1994 to 46.2 percent in 1995. By our estimates, Japanese companies also increased their share from 44.5 percent in 1994 to 45.1 percent in 1995. As Figure 6 shows, however, the race for dominance remains tight since North American companies returned to challenge the Japanese in 1992. In general, North American companies owe their 1995 edge over Japanese companies to their strong market positions in 1995's lead-performing equipment segments. Among the 10 segments highlighted as top performers in Table 1, North American companies as a group hold dominant market positions in seven segments.

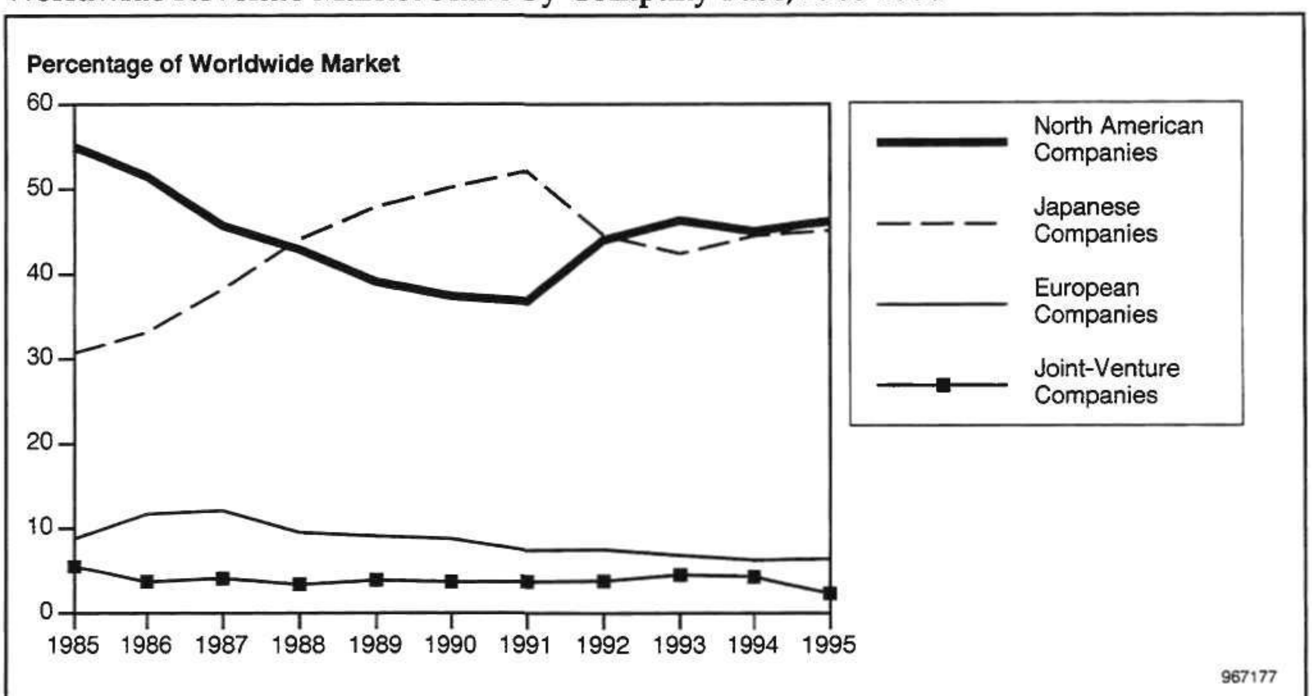
The worldwide 1995 market share of European companies continued to hold more or less steady in the range of 6 to 7 percent. As Figure 5 shows, the market share of European companies as whole has been trending downward since 1987. Nonetheless, European companies as a group still hold sizable market positions in Europe as well as the Americas. The worldwide market share of joint-venture companies suffered a sharp decline in 1995, falling from 4.2 to 2.3 percent. This sharp decline is largely related to the dissolution of the Tokyo Electron Ltd./Varian joint-venture agreement.

Figure 5
Worldwide Revenue Market Share by Company Base, 1994 and 1995



Note: Market shares exclude estimate of unsurveyed market activity by unidentified companies.
Source: Dataquest (October 1996)

Figure 6
Worldwide Revenue Market Share by Company Base, 1985-1995



Source: Dataquest (October 1996)

Even without the TEL/Varian joint venture, the market share of joint ventures active in both 1994 and 1995 declined slightly from 2.4 percent in 1994 to 2.3 percent in 1995.

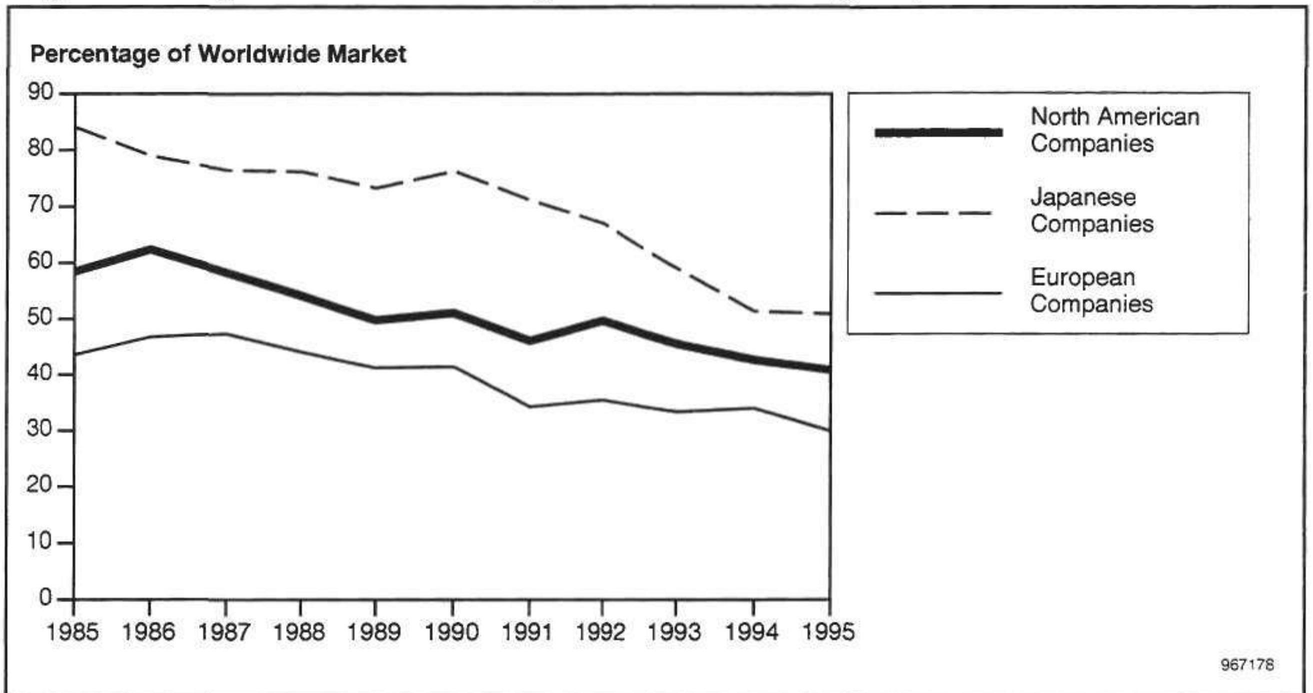
Global Competition between Companies Intensifying

The trend toward increased globalization of the wafer fab equipment market continued in 1995. The term "globalization" refers to the situation where suppliers are less dependent on their indigenous markets. Figure 7 illustrates equipment company dependence on local markets. (Note that equipment companies are classified here according to the region of their base.) As the figure shows, reliance on local markets has fallen dramatically for companies since 1986. Most significant is the dramatic decrease of Japanese companies' reliance on Japan. Japanese companies derived nearly 85 percent of their revenue from Japan in 1985. In 1995, they derived just over 50 percent of their revenue from Japan. Not surprisingly, equipment companies throughout the world have become increasingly dependent on the fast-growing Asia/Pacific region. Asia/Pacific sales now account for over 30 percent of Japanese companies' revenue. North American and European companies now derive about 25 percent and 18 percent of their revenue from Asia/Pacific, respectively. In addition to their sucesses in Asia/Pacific, Japanese companies have also successfully pursued both revenue and market share in Americas and Europe. Combined, these regions now account for about 19 percent of Japanese companies' revenue. The share of North American companies' revenue derived from Japan and Europe has remained fairly constant since 1985. However, North American companies have gained some market share in Japan, especially in recent years, while holding share in Europe. Finally, in addition to relying increasingly on Asia/Pacific, European companies have grown increasingly reliant on the Americas region but with little gain in market share. European companies have become decreasingly dependent on Japan, losing market share in the process.

Dataquest believes that there are several interdependent factors responsible for the globalization of the equipment market. We note several factors responsible for this trend:

- Global semiconductor manufacturing: Capital spending has grown increasingly international as the semiconductor market has globalized. Naturally, wafer fab equipment suppliers have worked to satisfy overseas investment demands. Also, globalization of the semiconductor market has significantly raised technology requirements and the cost of semiconductor manufacturing. As a consequence, there has been an increase in the number of semiconductor joint ventures. These circumstances virtually force equipment suppliers across the board to compete internationally and penetrate new overseas markets in order to survive.
- Technology spending requirements: Each new generation of semiconductor devices requires technological enhancement and innovation in wafer fab equipment. Because enhancement and innovation require concentrated and long-term investment in equipment technology development from the equipment industry, the cost to new entrants of entering the industry is raised with each new generation of devices. This "raising of the bar" has greatly slowed entry into the industry and has translated into more global presence for those with access to the capital required for introducing enabling technology.

Figure 7
Regional Companies' Shares of Respective Domestic Regions, 1985-1995



Source: Dataquest (October 1996)

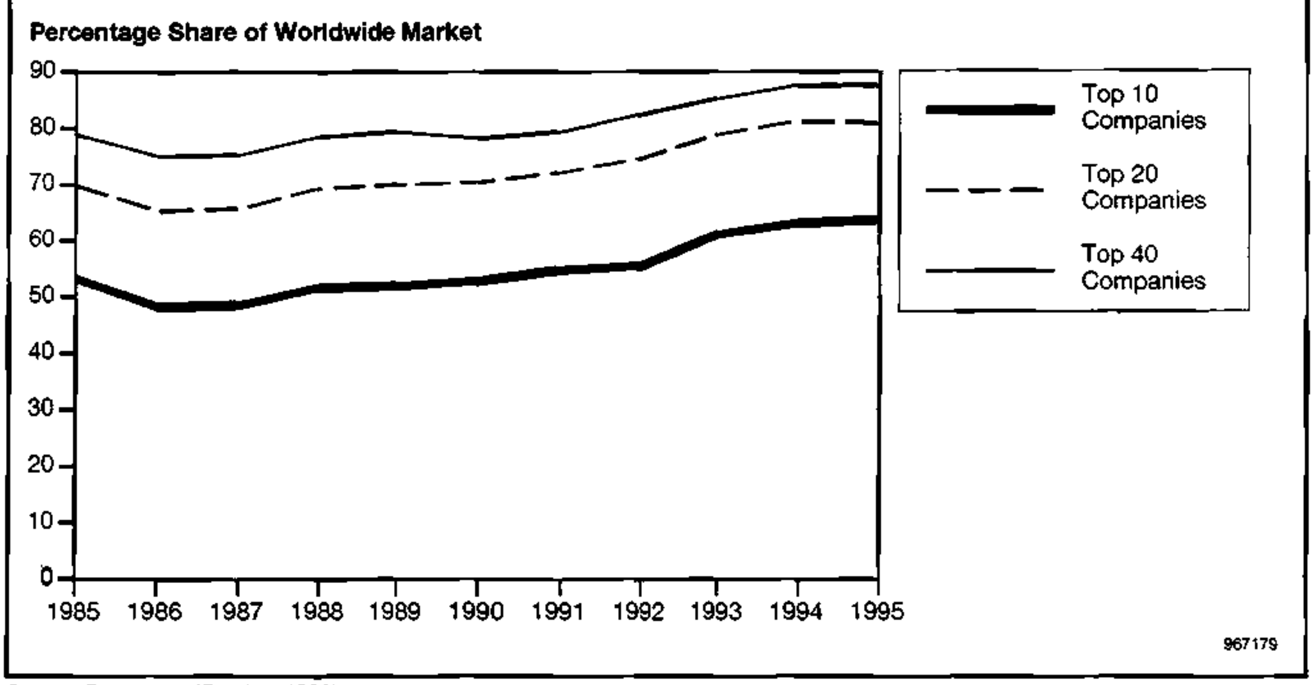
- Equipment market concentration: We have observed a marked trend toward increased market concentration among many equipment segments in the wafer fab industry. We believe this trend can be traced to many factors. Semiconductor manufacturers are increasingly moving toward replicating processes down to the most minute features from fab to fab. Process variations and innovations have become more and more evolutionary and show smaller variances from one device generation to the next. We believe that this "copy-exact" approach on the part of chipmakers is likely to lead to copy-exact equipment suppliers. This, in turn, is likely to create "installed-base momentum," where IC manufacturers enjoy the benefits of shorter training cycles and more intimate familiarity with the next generation of equipment from the same supplier. One other attractive feature of equipment market leaders is their extensive support structure for spare parts and services. In sum, rising manufacturing costs and migration to the next fab or device generation promotes concentration in the equipment market. In turn, concentration among equipment suppliers enhances global presence. There are equipment segments that are exceptions to this trend, such as chemical mechanical polishing (CMP). Primarily "new" enabling technologies would realize a more even distribution of market share among smaller companies.

Increased Concentration: A Historical Market Perspective

In 1995, the trend toward greater market concentration in the wafer fab equipment industry continued. Figure 8 illustrates the market share of the wafer fab equipment industry's top 10, top 20, and top 40 revenue earners from 1985 to 1995. The market share garnered by the industry's 10 largest revenue earners reached an estimated all-time high of just under 64 percent in 1995. There was some decline in the market share of the 20 largest earners, and the share garnered by the 40 largest revenue earners remained about the same. As Figure 8 indicates, market concentration as gauged by the market shares of the wafer fab equipment industry's top 10, 20, and 40 companies has been steadily increasing since the late 1980s. The top 20 companies appear to have gained share largely at the expense of companies outside the top 40. However, the decline in the difference between the shares of the top 20 and top 40 companies suggests that the industry's second-tier 20 have also surrendered market share to their larger counterparts. The number of companies Dataquest identifies as market participants has also been declining. These changes in the structure of the industry are likely to have important implications for the future performance of both the wafer fab equipment and semiconductor industries.

Dataquest will soon focus further on this trend, its implications, and its impact in a separate Perspective.

Figure 8
Worldwide Market Shares of Top 10, Top 20, and Top 40 Wafer Fab Equipment Companies, 1985-1995



Source: Dataquest (October 1996)

Top 20 Companies and Top-Performing Companies: The Big Become Bigger

Applied Materials Inc. topped Dataquest's annual ranking of wafer fab equipment companies by individual company market share for the fourth consecutive year. Also, Applied Materials' growth and market share positioned the company in first place according to the performance index described earlier. Table 2 presents our ranking of the industry's top 20 companies based on 1995 revenue. The table also presents these companies' revenue and rankings for 1994. Table 3 presents a list of the top-performing companies for 1995 based on our performance index. As shown in Table 2, Tokyo Electron Ltd. and Nikon Corporation once again ranked No. 2 and No. 3 behind Applied Materials. This marked the fourth straight year in which these three companies have ranked in this order since Applied Materials took the top spot from Nikon in 1992. Elsewhere within the top 20, there were some minor changes in rankings but little change in this group of companies. Among the minor changes in rank, Canon Inc. and Lam Research Corporation exchanged positions. Alcan Technology rejoined the top 20 after a two-year absence, displacing Materials Research Corporation. In recent years, the industry's top 20 has proven to be a very select club. Since 1990, only 22 companies have been members of the club for at least one year. During that time, battles for positions at the rear of the club have proved much keener than competition for positions at its head.

Applied Materials' market leadership really comes as no surprise, given its industry-leading performance, as shown in Table 3. Although several smaller companies posted higher revenue growth rates than Applied Materials in 1995, the company receives the leading mark for its performance on the basis of our performance index. Applied Materials successfully increased its already substantial market share in 1995. Applied Materials is a good example of a company that rode equipment segments along the industry's breaking growth wave for outstanding performance. The company holds strong market positions in four of the 10 equipment segments highlighted as top-performing equipment segments in Table 1. Applied Materials also did an exceptional job of growing in segments that lagged industry growth. Applied Materials' strong market position in sputtering proved not to be the handicap one might have thought given our conclusion that sputtering was 1995's worst-performing segment. Applied Materials' sputtering revenue grew almost 75 percent, far outpacing revenue growth for the segment as a whole.

Dataquest's list of top performers may appear to contain some surprising members. Actually, few of the members turned out to be real surprises, given the information in Table 1. Virtually all of the companies singled out as top performers in Table 3 hold significant market positions or derive a significant percentage of their revenue from at least one of the segments highlighted in Table 1.

More surprising, perhaps, would be our list of 1995's poorest performers. That list would be headed by several prominent players in the top 20 revenue list. Nikon, Varian Associates Inc., and Dainippon Screen had performance marks of negative 877.1, negative 256.3, and negative 120.8, respectively. Varian's mark is undoubtedly influenced by the dissolution of its joint-venture agreement with Tokyo Electron Ltd. Still, even considering this, Varian's performance would rank fourth worst in the year because of its below-industry-average growth.

Table 2
Top 20 Wafer Fab Equipment Companies, 1994 and 1995 (Millions of Dollars)

	1994 Revenue	1994 Market Share (%)	1994 Ranking	1995 Revenue	1995 Market Share (%)	1995 Ranking
Applied Materials	1,480.7	14.9	1	2,904.9	16.3	1
Tokyo Electron Ltd.	1,066.3	10.7	2	2,098.2	11.8	2
Nikon	1,027.1	10.3	3	1,675.1	9.4	3
Canon	499.9	5.0	5	984.1	5.5	4
Lam Research	520.6	5.2	4	899.2	5.1	5
Hitachi	387.2	3.9	6	643.2	3.6	6
Dainippon Screen	342.5	3.4	8	545.3	3.1	7
Varian	375.3	3.8	7	535.4	3.0	8
Kokusai Electric (Including Bruce Technologies)	306.1	3.1	9	523.1	2.9	9
ASM Lithography	272.7	2.7	10	498.3	2.8	10
Silicon Valley Group	269.9	2.7	11	490.1	2.8	11
KLA Instruments	255.5	2.6	12	459.6	2.6	12
Eaton (Including Sumitomo/ Eaton Nova)	227.2	2.3	13	430.0	2.4	13
Novellus Systems Inc.	197.4	2.0	15	345.2	1.9	14
Tencor Instruments	210.4	2.1	14	309.1	1.7	15
Anelva	170.1	1.7	16	256.3	1.4	16
ASM International	120.1	1.2	19	210.4	1.2	17
Watkins-Johnson	122.4	1.2	18	202.0	1.1	18
Alcan Technology	93.6	0.9	21	188.3	1.1	19
Ulvac	116.0	1.2	20	173.6	1.0	20
All Identified Companies	9,962.2	100.0	-	17,780.9	100.0	-

Note: For 1994, revenue for Tokyo Electron Ltd. and Varian includes revenue from joint ventures Varian/TEL and TEL/Varian.
Source: Dataquest (October 1996)

In contrast to Applied Materials, Nikon and Dainippon Screen represent poignant examples of companies that were unable to ride the industry's growth wave. Nikon's stepper revenue, which constitutes the great majority of its overall equipment revenue, grew only an estimated 63 percent, while stepper revenue overall grew 82 percent. Noteworthy is Nikon's performance in 1994; in that year the company outpaced the average growth in the stepper market (82 percent growth over 1993) with an estimated 106 percent increase in revenue. Dainippon Screen's track and auto wet station estimated revenue grew only 67 and 43 percent, respectively, compared to overall revenue growth of nearly 100 percent by each segment. Below-average growth combined with large market size penalized the performance of both Nikon and Dainippon Screen in our performance index. It is interesting to note that a similar fate befell many top 20 companies when they were evaluated according to our index.

Table 3
Top Performing Companies in the Worldwide Wafer Fab Equipment Market, 1995 (Millions of Dollars)

	1994 Revenue	1994 Share (%)	1995 Revenue	1995 Share (%)	Revenue Change	1994-1995 Revenue Growth (%)	1994-1995 Share Change (%)	Performance Index
Applied Materials	1,480.7	14.9	2,904.9	16.3	1,424.2	96.2	1.5	2,299.9
Tokyo Electron Ltd.	1,066.3	10.7	2,098.2	11.8	1,031.9	96.8	1.1	1,234.5
Canon	499.9	5.0	984.1	5.5	484.2	96.9	0.5	272.7
Eaton (Including Sumitomo/ Eaton Nova)	227.2	2.3	430.0	2.4	202.8	89.3	0.1	32.3
Sugai	34.1	0.3	123.7	0.7	89.6	263.2	0.4	18.4
Steag MicroTech	18.2	0.2	111.6	0.6	93.4	513.2	0.4	18.0
ASM Lithography	272.7	2.7	498.3	2.8	225.5	82.7	0.1	17.9
IPEC/Planar	43.0	0.4	118.9	0.7	75.9	176.5	0.2	13.0
Silicon Valley Group	269.9	2.7	490.1	2.8	220.2	81.6	0.0	12.9
Alcan Technology	93.6	0.9	188.3	1.1	94.7	101.2	0.1	11.9
FSI International	74.1	0.7	152.3	0.9	78.2	105.5	0.1	9.0
Total Identified Companies	9,962.2	100.0	17,780.9	100.0	7,818.6	78.5	-	-

Notes: The 1994-to-1995 performance index equals 100 times the change in equipment share times the average of equipment's 1994 and 1995 share.
Tokyo Electron Ltd.'s 1994 revenue includes revenue for Varian/TEL joint venture.
Source: Dataquest (October 1996)

Dataquest Perspective

The strength of the DRAM market in 1995 translated into strong growth for wafer fab equipment spending in Asia/Pacific and Japan. Among equipment segments, steppers proved to be the industry's top performer in terms of impact on market growth. Several clean process and chemical vapor deposition (CVD) equipment segments were also top performers on this basis. As a consequence, companies with strong positions in these segments performed especially well in 1995.

North American companies as a group held their worldwide market share lead over their Japanese counterparts based on their strong positions in top-performing equipment segments. Among individual companies, Applied Materials stretched its market share lead over No. 2 rival Tokyo Electron Ltd., which closed 1995 with a very strong performance.

Finally, 1995 saw a continuation of the trend toward greater market concentration in the wafer fab equipment industry. The combined market share of the industry's 10 largest companies rose for the third consecutive year. Although the combined shares of the industry's 20 and 40 largest companies declined somewhat, the industry's top 40 companies now account for about seven-eighths of estimated individual manufacturer revenue.

Supporting Tables

Tables 4 through 9 provide the data used to create the figures featured in this Perspective.

Contributing analysts (in alphabetical order): Calvin Chang, Ron Dornseif, Calvin Chang, Akiko Nakayama, Takashi Ogawa, Yoshie Shima, and Yasumoto Shimizu.

Table 4
Worldwide Wafer Fab Equipment Market, Regional Distribution, 1985-1995 (Millions of Dollars)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Americas											
Revenue	1,258.6	1,077.6	1,104.4	1,535.0	1,656.9	1,589.1	1,518.5	1,575.7	2,118.1	3,190.4	5,178.5
Percentage of World Market	37.5	39.7	35.2	30.8	27.6	27.1	25.3	30.9	30.8	29.6	27.2
Japan											
Revenue	1,422.8	1,018.2	1,276.7	2,269.8	2,813.3	2,995.9	3,011.6	2,097.9	2,449.6	3,660.5	6,351.6
Percentage of World Market	42.4	37.5	40.7	45.5	46.8	51.0	50.2	41.1	35.7	33.9	33.3
Europe, Middle East, and Africa											
Revenue	466.9	454.1	526.4	663.2	721.0	764.3	641.1	641.4	988.3	1,369.7	2,315.7
Percentage of World Market	13.9	16.7	16.8	13.3	12.0	13.0	10.7	12.6	14.4	12.7	12.2
Asia/Pacific											
Revenue	208.9	163.5	229.4	518.6	820.1	521.6	831.8	783.3	1,311.7	2,566.7	5,207.7
Percentage of World Market	6.2	6.0	7.3	10.4	13.6	8.9	13.9	15.4	19.1	23.8	27.3
Korea											
Revenue	-	-	-	-	-	-	-	-	-	1,702.9	3,141.4
Percentage of World Market	-	-	-	-	-	-	-	-	-	15.8	16.5
Other Asia/Pacific											
Revenue	-	-	-	-	-	-	-	-	-	863.8	2,066.3
Percentage of World Market	-	-	-	-	-	-	-	-	-	8.0	10.8
Worldwide Market	3,357.2	2,713.4	3,136.9	4,986.6	6,011.3	5,870.9	6,002.9	5,098.3	6,867.7	10,787.3	19,053.5

Note: Asia/Pacific market totals reflect sum of totals for Korea and other Asia/Pacific, when available. No breakout of Korea versus other Asia/Pacific is available before 1994.
Source: Dataquest (October 1996)

Table 5
Worldwide Semiconductor Capital Spending as a Percentage of Worldwide Semiconductor Production Revenue, 1982-2000 (Millions of Dollars)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Capital Spending	4,530	5,666	8,107	7,299	5,129	6,505	9,748	12,331	13,230	13,145	11,599	14,333	22,085	38,308	45,344	40,942	42,915	53,954	75,777
Semiconductor Production	15,621	21,537	28,825	28,132	34,102	41,833	54,987	59,184	59,328	64,453	70,460	87,535	112,464	153,084	164,264	185,840	215,397	257,838	311,468
Percentage of Capital Spending	29.0	26.3	28.1	25.9	15.0	15.5	17.7	20.8	22.3	20.4	16.5	16.4	19.6	25.0	27.6	22.0	19.9	20.9	24.3

Notes: Semiconductor production revenue includes merchant plus captive revenue. Numbers for 1996 to 2000 are based on Dataquest's 1996 midyear forecast.
Source: Dataquest (October 1996)

Table 6
Worldwide Wafer Fab Equipment Market, Companies' Market Shares, 1985-1995 (Millions of Dollars)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
North American Companies											
Revenue	1,507.6	1,154.3	1,221.5	1,878.5	2,094.6	1,977.4	2,010.7	1,985.4	2,898.9	4,480.7	8,219.5
Percentage of Identified Market	55.0	51.5	45.7	42.9	39.1	37.4	36.8	44.0	46.3	45.0	46.2
Japanese Companies											
Revenue	840.2	742.9	1,022.4	1,932.5	2,561.1	2,655.1	2,842.7	2,011.8	2,656.4	4,433.0	8,017.4
Percentage of Identified Market	30.7	33.1	38.2	44.1	47.9	50.2	52.1	44.6	42.4	44.5	45.1
European Companies											
Revenue	240.5	261.2	322.4	417.9	486.9	464.7	405.2	337.5	426.2	623.9	1,136.4
Percentage of Identified Market	8.8	11.7	12.1	9.5	9.1	8.8	7.4	7.5	6.8	6.3	6.4
Joint-Venture Companies											
Revenue	151.9	83.3	108.7	149.2	209.7	195.3	199.7	172.7	282.1	424.7	407.6
Percentage of Identified Market	5.5	3.7	4.1	3.4	3.9	3.7	3.7	3.8	4.5	4.2	2.3
Identified Companies' Revenue	2,740.2	2,241.7	2,675.0	4,378.1	5,352.3	5,292.5	5,458.3	4,507.4	6,263.6	9,962.2	17,780.9
Other Companies' Revenue	617.0	471.7	461.9	608.5	659.0	578.4	544.6	590.9	604.1	825.1	1,272.6
All Companies' Revenue	3,357.2	2,713.4	3,136.9	4,986.6	6,011.3	5,870.9	6,002.9	5,098.3	6,867.7	10,787.3	19,053.5

Note: Totals for identified companies reflect estimates based on individual company survey data; totals for other companies reflect Dataquest estimates of unsurveyed market activity.
Source: Dataquest (October 1996)

Table 7
Regional Companies' Shares of Respective Domestic Regions, 1985-1995

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
North American Companies											
Americas	880.6	719.8	711.2	1,015.4	1,043.1	1,010.1	927.2	987.5	1,323.1	1,912.2	3,363.7
World	1,507.6	1,154.3	1,221.5	1,878.5	2,094.6	1,977.4	2,010.7	1,985.4	2,898.9	4,480.7	8,219.5
Percentage of Domestic Region	58.4	62.4	58.2	54.1	49.8	51.1	46.1	49.7	45.6	42.7	40.9
Japanese Companies											
Japan	706.2	586.8	782.6	1,472.9	1,877.1	2,026.5	2,022.3	1,347.2	1,566.0	2,280.2	4,077.7
World	840.2	742.9	1,022.4	1,932.5	2,561.1	2,655.1	2,842.7	2,011.8	2,656.4	4,433.0	8,017.4
Percentage of Domestic Region	84.1	79.0	76.5	76.2	73.3	76.3	71.1	67.0	59.0	51.4	50.9
European Companies											
Europe, Middle East, and Africa	104.9	122.3	152.8	184.5	201.0	193.0	139.0	119.7	142.5	212.3	340.8
World	240.5	261.2	322.4	417.9	486.9	464.7	405.2	337.5	426.2	623.9	1,136.4
Percentage of Domestic Region	43.6	46.8	47.4	44.1	41.3	41.5	34.3	35.5	33.4	34.0	30.0

Source: Dataquest (October 1996)

Table 8
Worldwide Market Shares of Top 10, Top 20, and Top 40 Wafer Fab Equipment Companies, 1985-1995

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Top 10 Companies											
Revenue	1,464.2	1,079.4	1,298.4	2,260.4	2,780.2	2,795.7	2,987.1	2,498.1	3,820.1	6,278.4	11,306.8
Market Share (%)	53.4	48.2	48.5	51.6	51.9	52.8	54.7	55.4	61.0	63.0	63.6
Top 20 Companies											
Revenue	1,916.4	1,462.9	1,757.2	3,036.1	3,739.9	3,728.4	3,935.7	3,364.3	4,939.0	8,091.9	14,371.3
Market Share (%)	69.9	65.3	65.7	69.3	69.9	70.4	72.1	74.6	78.9	81.2	80.8
Top 40 Companies											
Revenue	2,163.6	1,681.0	2,015.3	3,434.8	4,252.0	4,141.0	4,332.8	3,719.3	5,333.9	8,722.0	15,562.3
Market Share (%)	79.0	75.0	75.3	78.5	79.4	78.2	79.4	82.5	85.2	87.6	87.5
Identified Companies											
Revenue	2,740.2	2,241.7	2,675.0	4,378.1	5,352.3	5,292.5	5,458.3	4,507.4	6,263.6	9,962.2	17,780.9
Number of Companies	125	137	146	156	154	159	164	137	136	121	122

Source: Dataquest (October 1996)

Table 9
1995 Worldwide Wafer Fab Equipment Market Summary Statistics (Millions of Dollars)

	Worldwide Wafer Fab Market				1995 Regional Distribution (%)						1995 Market Shares (%)			
	1994	1995	Change (%)	Performance Index	Americas	Japan	Europe, Middle East, and Africa	Total Asia/ Pacific	Korea	Other Asia/ Pacific	North American Companies	Japanese Companies	European Companies	Joint-Venture Companies
Lithography	2,036.5	3,531.5	73.4	-643.2	25.6	37.6	10.7	26.1	16.3	9.8	8.5	75.8	15.7	0
Contact/Proximity	27.7	33.9	22.2	-1.7	16.2	12.9	40.8	30.1	6.5	23.6	0	5.9	94.1	0
Projection Aligners	50.8	35.8	-29.5	-9.3	31.0	38.8	26.3	3.9	0	3.9	69.3	30.7	0	0
Steppers	1,832.7	3,331.6	81.8	855.0	25.5	37.6	10.1	26.8	16.9	9.9	6.4	78.6	15.0	0
Direct-Write Lithography	34.9	38.0	8.8	-3.3	10.5	67.9	19.7	1.8	0	1.8	0	66.3	33.7	0
Maskmaking Lithography	79.1	82.0	3.7	-17.6	28.9	37.6	12.9	20.6	12.2	8.4	71.2	23.2	5.6	0
X-Ray Aligners	11.2	10.2	-9.3	-0.4	100.0	0	0	0	0	0	27.6	0	72.4	0
Resist Processing (Track)	695.1	1,412.5	103.2	672.1	27.2	30.2	14.5	28.1	14.5	13.6	23.4	73.3	3.3	0
Etch and Clean	2,548.5	4,723.8	85.4	2,826.6	26.9	32.4	12.2	28.6	16.5	12.0	54.9	40.6	2.9	1.6
Auto Wet Stations	467.6	927.6	98.4	245.7	25.6	30.7	9.3	34.4	19.2	15.1	18.3	71.2	10.5	0
Spray Processors	60.6	122.8	102.8	5.0	48.9	21.2	22.7	7.1	0.7	6.4	89.5	10.5	0	0
Vapor Phase Clean	8.8	12.6	42.2	-0.1	28.8	27.4	12.1	31.7	1.5	30.2	76.8	23.2	0	0
Post-CMP Clean	21.7	47.4	118.5	1.1	60.7	15.7	15.0	8.7	4.9	3.8	70.7	29.3	0	0
Other Clean Process	121.4	206.1	69.8	-4.8	36.1	31.7	8.9	23.4	8.2	15.1	33.2	58.3	8.5	0
Chemical Mechanical Polishing	64.2	196.7	206.1	35.5	68.7	17.4	9.4	4.6	2.0	2.5	90.3	8.9	0.8	0
Dry Strip	212.5	368.8	73.5	-6.8	24.4	32.5	9.0	34.1	22.0	12.1	45.8	34.8	0	19.4
Dry Etch	1,591.6	2,841.8	78.6	238.2	22.5	34.8	13.5	29.3	17.5	11.7	65.3	33.9	0.8	0.1
Low-Density Etch	1,139.6	2,032.7	78.4	110.9	22.1	31.5	14.4	32.0	17.5	14.6	69.2	30.4	0.4	0.1
High-Density Etch	452.0	809.1	79.0	23.7	23.5	43.0	11.2	22.3	17.7	4.6	55.5	42.7	1.7	0

(Continued)

Table 9 (Continued)
1995 Worldwide Wafer Fab Equipment Market Summary Statistics (Millions of Dollars)

	Worldwide Wafer Fab Market				1995 Regional Distribution (%)						1995 Market Shares (%)			
	1994	1995	Change (%)	Performance Index	Americas	Japan	Europe, Middle East, and Africa	Total Asia/ Pacific	Korea	Other Asia/ Pacific	North American Companies	Japanese Companies	European Companies	Joint-Venture Companies
Deposition	2,553.2	4,479.9	75.5	-368.8	29.7	31.2	13.1	26.0	16.9	9.1	64.0	26.8	6.2	3.0
CVD	1,327.0	2,582.9	94.6	1,622.5	26.8	30.3	13.1	29.7	21.1	8.6	60.5	28.5	6.0	5.1
Tube CVD	441.5	779.6	76.6	-0.5	19.7	28.9	13.4	38.1	28.3	9.7	13.4	72.7	11.7	2.1
Horizontal Tube LPCVD	23.3	18.6	-20.2	-1.9	44.6	23.1	28.0	4.3	0	4.3	41.4	23.1	0	35.5
Vertical Tube LPCVD	392.3	733.2	86.9	79.2	19.2	28.9	11.7	40.2	30.1	10.1	13.3	76.8	8.6	1.4
Horizontal Tube PECVD	26.0	27.9	7.3	-1.8	17.9	32.3	46.2	3.6	1.1	2.5	0	0	100.0	0
Nontube CVD	885.4	1,803.3	103.7	1,110.1	29.9	31.0	13.0	26.1	18.0	8.1	80.8	9.3	3.5	6.4
APCVD/SACVD	191.4	425.0	122.0	91.3	24.1	31.7	10.2	34.0	21.1	12.9	62.1	10.8	0	27.1
High-Density Plasma CVD	8.7	13.1	50.6	-0.1	84.7	12.2	3.1	0.0	0.0	0.0	93.9	0	6.1	0
Dedicated LPCVD Reactors	218.1	509.3	133.5	152.8	31.6	36.2	6.4	25.7	20.2	5.5	77.8	22.2	0	0
Dedicated PECVD Reactors	467.2	855.9	83.2	71.0	31.0	27.7	18.5	22.7	15.4	7.3	91.6	1.1	7.3	0
Sputtering	1,011.5	1,566.5	54.9	-1,016.2	32.5	32.5	11.6	23.4	12.8	10.6	71.4	25.2	3.4	0
Silicon Epitaxy	114.1	206.7	81.2	3.0	42.8	30.2	21.3	5.7	1.3	4.4	57.8	11.7	30.5	0
Other Deposition	100.7	123.7	22.9	-22.5	32.3	34.1	16.2	17.4	7.7	9.7	NM	NM	NM	NM
Thermal Nondeposition	566.5	926.9	63.6	-195.9	26.4	36.4	11.0	26.2	15.7	10.5	21.1	66.5	6.2	6.2
Rapid Thermal Processing	76.2	153.5	101.4	7.5	45.5	23.9	16.1	14.4	2.7	11.8	58.5	15.0	26.5	0
Diffusion	490.3	773.4	57.7	-209.2	22.6	38.9	10.0	28.5	18.3	10.2	13.7	76.7	2.2	7.4
Vertical Diffusion	421.5	700.8	66.2	-87.2	20.0	39.3	9.5	31.2	20.2	11.1	12.2	81.0	2.4	4.3
Horizontal Diffusion	68.8	72.7	5.6	-13.1	47.3	34.8	15.6	2.3	0.0	2.3	28.1	34.8	0	37.2
Ion Implantation	659.4	1,053.2	59.7	-340.3	27.7	31.4	15.2	25.8	14.7	11.0	78.1	8.1	0	13.8
Medium-Current Implanter	241.6	383.8	58.9	-47.9	27.8	30.3	15.6	26.4	14.1	12.3	78.0	21.4	0	0.6

(Continued)

Table 9 (Continued)
1995 Worldwide Wafer Fab Equipment Market Summary Statistics (Millions of Dollars)

	Worldwide Wafer Fab Market				1995 Regional Distribution (%)						1995 Market Shares (%)			
	1994	1995	Change (%)	Performance Index	Americas	Japan	Europe, Middle East, and Africa	Total Asia/ Pacific	Korea	Other Asia/ Pacific	North American Companies	Japanese Companies	European Companies	Joint-Venture Companies
High-Current Implanter	391.2	550.3	40.7	-240.6	29.2	32.1	15.5	23.2	11.3	11.9	79.7	0.5	0	19.8
High-Voltage Implanter	26.6	119.2	348.2	16.5	20.0	32.1	12.2	35.7	32.5	3.2	71.2	0	0	28.8
Process Control	1,103.3	1,853.5	68.0	-498.2	28.3	35.2	11.5	25.0	14.2	10.8	65.5	30.5	4.0	0
Optical Metrology	66.8	97.6	46.2	-6.0	27.7	37.2	12.3	22.8	20.7	2.1	88.9	10.8	0.3	0
CD SEM	153.9	312.9	103.3	33.1	23.1	34.7	10.4	31.7	15.2	16.5	16.8	83.2	0	0
Thin-Film Measurement	99.7	196.1	96.6	10.2	36.2	26.3	14.5	23.0	14.8	8.2	96.3	3.3	0.4	0
Auto Patterned Detection	281.0	535.1	90.4	55.0	24.9	38.8	8.8	27.5	15.6	12.0	87.9	10.9	1.1	0
Auto Review and Classification	119.6	194.2	62.3	-9.5	27.0	39.3	10.5	23.2	17.6	5.6	22.9	61.8	15.3	0
Manual Detection and Review	54.8	68.9	25.6	-6.4	37.2	22.5	19.7	20.6	9.7	11.0	0	55.6	44.4	0
Auto Unpatterned Detection	56.4	110.6	96.2	3.2	35.2	34.1	11.4	19.3	9.2	10.1	84.1	15.9	0	0
Other Process Control	271.1	338.3	24.8	-158.2	30.9	35.0	13.6	20.6	9.5	11.1	NM	NM	NM	NM
Factory Automation	412.0	686.0	66.5	-81.2	17.8	34.3	6.6	41.4	27.1	14.3	NM	NM	NM	NM
Other Wafer Fab Equipment	212.9	386.1	81.3	10.5	27.3	30.3	13.3	29.1	19.2	10.0	NM	NM	NM	NM
Total Wafer Fab Equipment	10,787.3	19,053.5	76.6	NM	27.2	33.3	12.2	27.3	16.5	10.8	46.2	45.1	6.4	2.3

Note: Total Asia/Pacific equals Korea plus other Asia/Pacific.
NM = Not meaningful
Source: Dataquest (October 1996)

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Dataquest
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Perspective

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Market Analysis

CVD Market Analysis

Abstract: *The worldwide chemical vapor deposition (CVD) equipment market shot up 95 percent in 1995, achieving U.S.$2.58 billion in sales, registering the highest growth recorded since Dataquest began tracking the equipment market in 1982. Japan remained the largest market, and Asia/Pacific rose to prominence. Americas region companies extended their dominance, maintaining more than 60 percent of the worldwide CVD market share.*
By Calvin Chang

The CVD Market in 1995

For the chemical vapor deposition (CVD) equipment market, 1995 was a banner year, with numerous sales records shattered. Explosive sales led to revenue milestones that read like a long string of multiples: worldwide CVD equipment sales almost doubled in 1995, nearly tripled in two years, and close to quadrupled in three years. The CVD equipment segments also outperformed the overall wafer fab equipment market, which grew 75 percent in 1995. Driven by a continued ramp in 16Mb/64Mb DRAM capacity investment, atmospheric pressure CVD/subatmospheric CVD (APCVD/SACVD) and low-pressure CVD (LPCVD) reactors turned in stellar sales growth performance that exceeded more than 120 percent. Also impressive, the plasma-enhanced CVD (PECVD) reactor and LPCVD tube markets turned in 83 percent and 81 percent growth, respectively.

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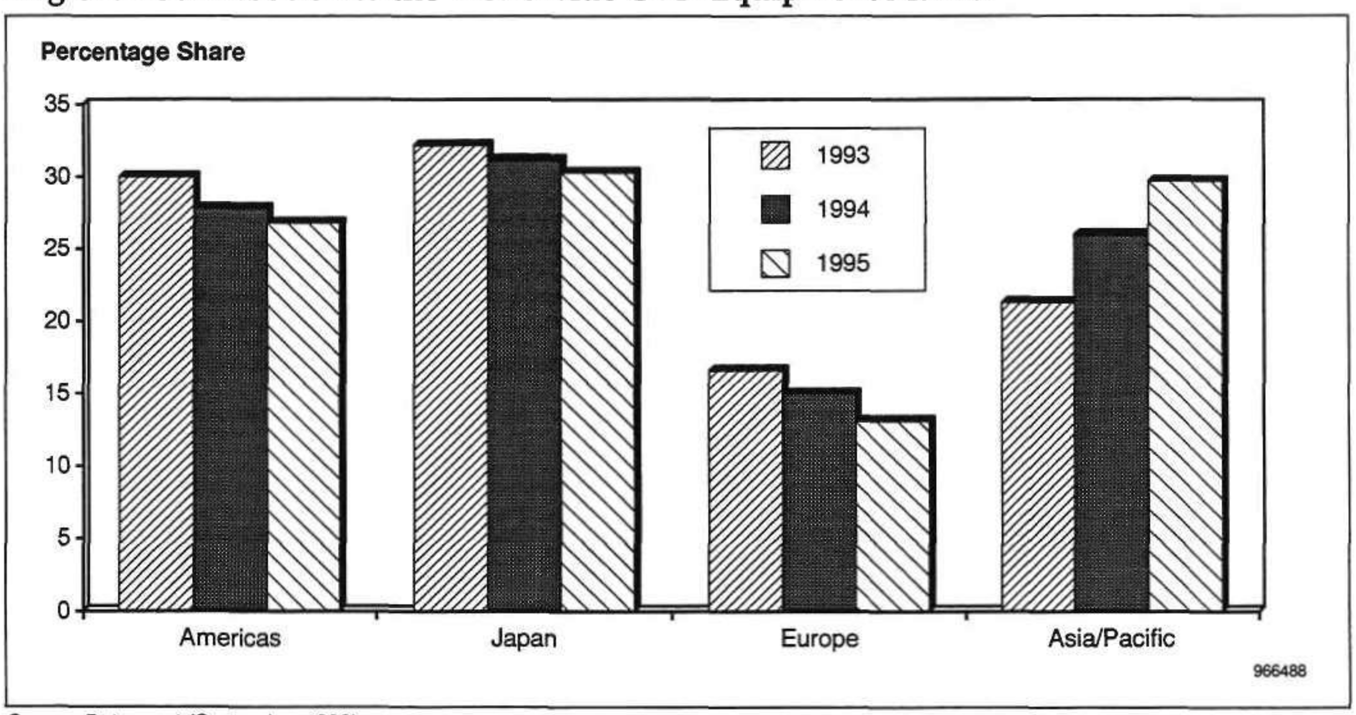
Regional Markets: Japan Remains the Largest, while Asia/Pacific Rises to Prominence

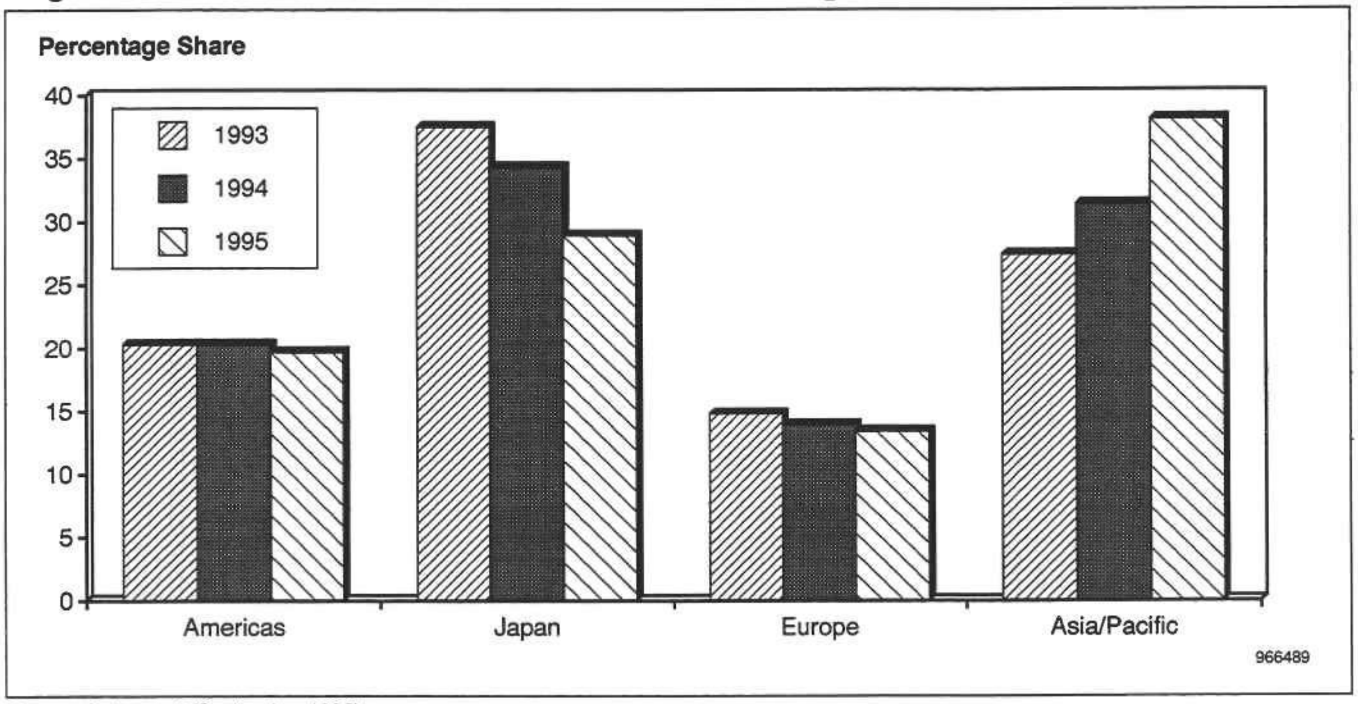
Figure 1 shows the change in the regional markets' percentage contribution to worldwide CVD equipment sales from 1993 to 1995. Asia/Pacific has grown progressively in share, while the other three regions have declined during the three-year period. Consuming nearly 30 percent of world's total CVD shipments, Asia/Pacific is now the second-largest regional market. Japan is still the largest market, with a shade more than 30 percent of the world's CVD total. This compares with the 50 percent share that Japan enjoyed only four years ago. Asia/Pacific's rise in CVD equipment sales resulted from increases in both tube CVD and nontube CVD sales in the region. As Figure 2 illustrates, Asia/Pacific has become the world's largest tube CVD market during 1993 through 1995, principally at the expense of the Japanese market. Large DRAM investments in Korea, Taiwan, and Singapore in recent years have led to Asia/Pacific's garnering the largest share, 38.1 percent of 1995 worldwide tube CVD sales. At the same time, Asia/Pacific sales of nontube CVD equipment, which includes APCVD, PECVD, LPCVD, and high-density plasma (HDP) CVD reactors, also rose as a percentage of the worldwide total. As Figure 3 shows, Asia/Pacific's share of nontube CVD consumption increased to more than 26 percent of the world's total from less than 20 percent in 1993. Japan and Americas are, however, larger markets, each with about 30 percent of the world's total nontube CVD sales.

Figure 1
Regional Contribution to the Worldwide CVD Equipment Market



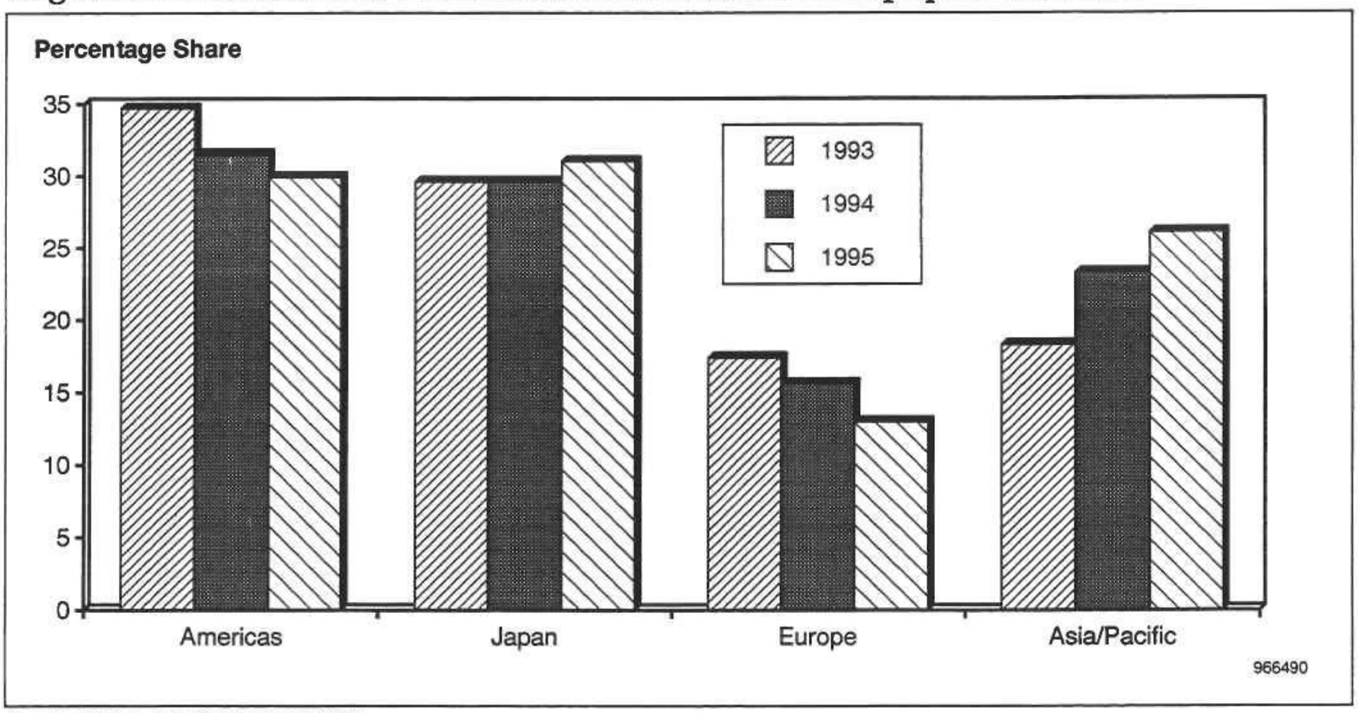
Source: Dataquest (September 1996)

Figure 2
Regional Contribution to the Worldwide Tube CVD Equipment Market



Source: Dataquest (September 1996)

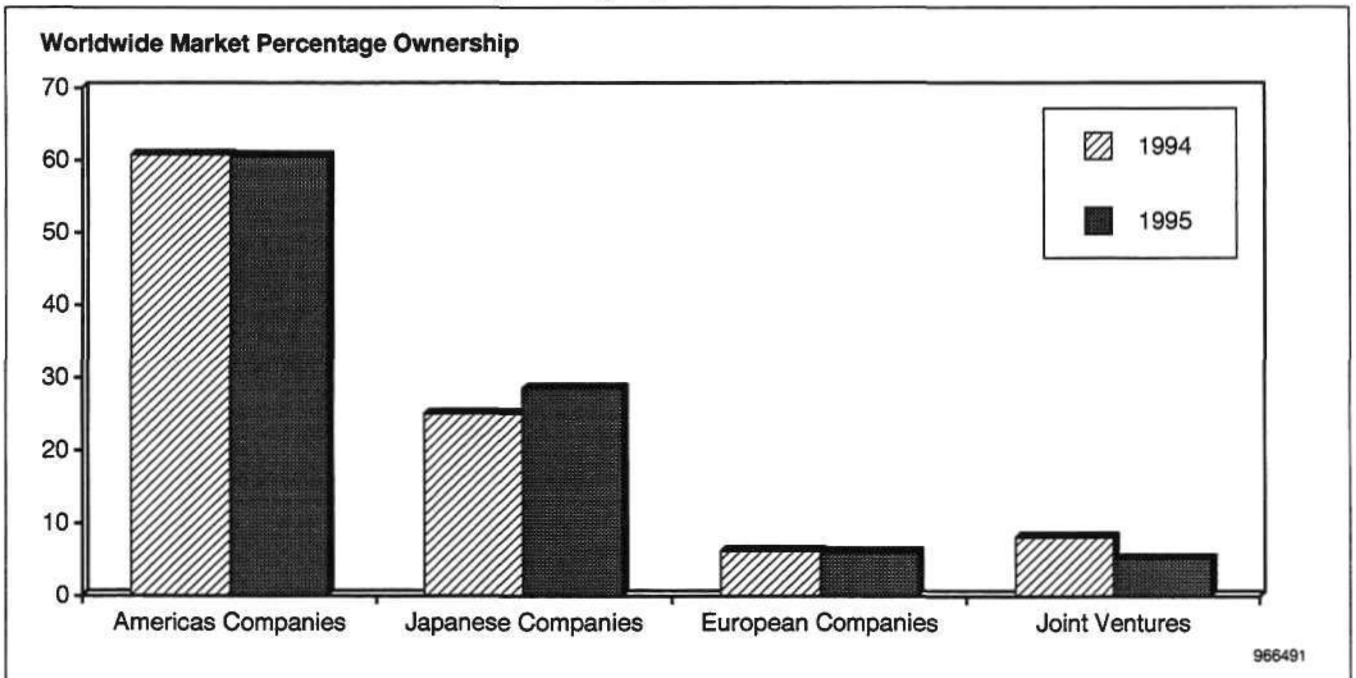
Figure 3
Regional Contribution to the Worldwide Nontube CVD Equipment Market



Source: Dataquest (September 1996)

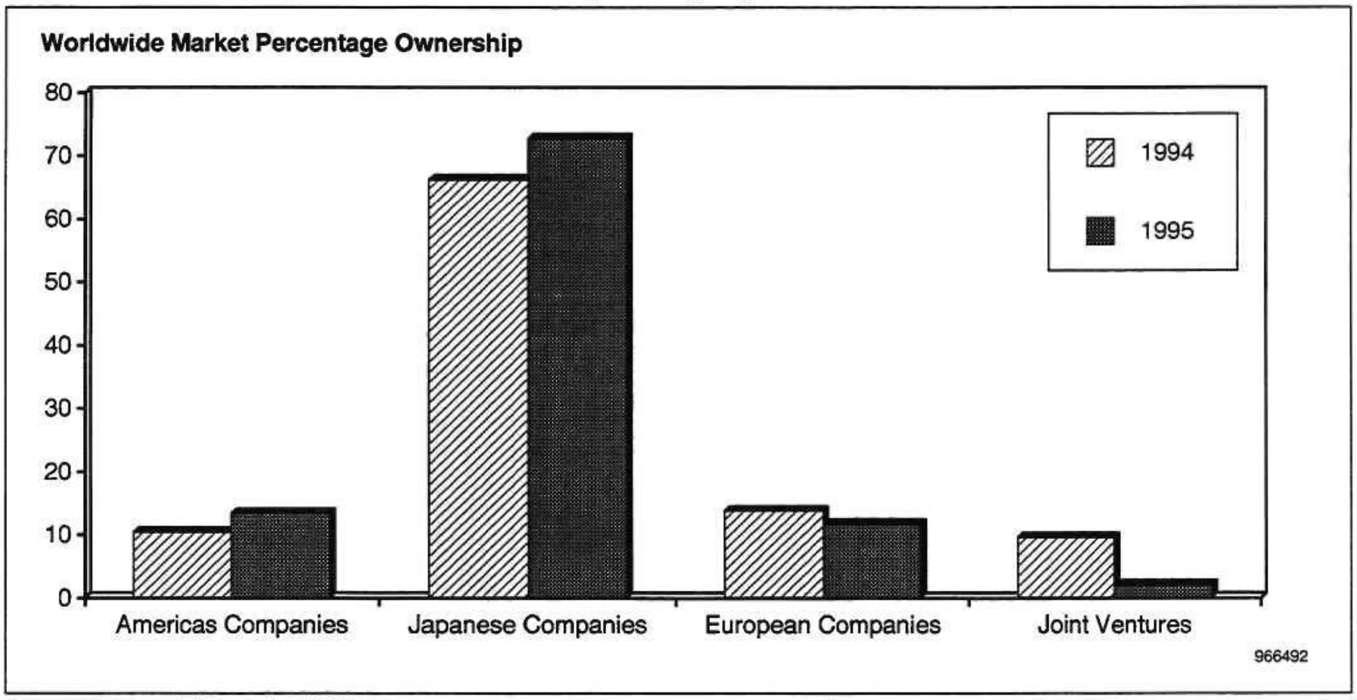
There was little change in 1995 in the ownership of the CVD equipment market by company base. As shown in Figure 4, Americas vendors remained the dominant suppliers of CVD tools, with 60.5 percent of the worldwide market, just a bit less (0.2 percent) than the previous year. Japanese companies' market share rose to 28.5 percent from 25 percent in 1994. This is largely the result of Tokyo Electron Ltd.'s absorbing the Varian/TEL joint venture, which caused the joint ventures' share to drop to 5.1 percent. Joint ventures, considered in the past a favorable business model for sharing costs and complementary resources, are becoming less popular in the equipment industry. Greater support of and access to the customers is requiring suppliers to maintain close control of their product development, marketing, and services. Figures 5 and 6 show the change in market share by company base for tube CVD and nontube CVD, respectively. In tube CVD, which was 30 percent of the total CVD market, Japanese suppliers TEL and Kokusai remained dominant, with a 72.7 percent share of the tube business, compared to 66.2 percent in 1994. The U.S. suppliers' share also rose, to 13.4 percent, an increase of 3 percent, courtesy of Silicon Valley Group Inc. (SVG) and Semitool Inc. In the U.S.$1.8 billion nontube market, U.S. vendors are still the preeminent suppliers but have seen their share slip from 85.8 percent to 80.8 percent. The lost share was won by TEL and Amaya, whose tungsten silicide CVD and APCVD, respectively, contributed to Japanese companies' attaining 9.3 percent of the nontube market. European suppliers are principally represented by ASM International, whose tube and nontube sales contributed to Europe's single-digit share of the market. Asia/Pacific equipment system suppliers, all of them in Korea, have a negligible share of the world market.

Figure 4
Worldwide CVD Market Share by Company Base



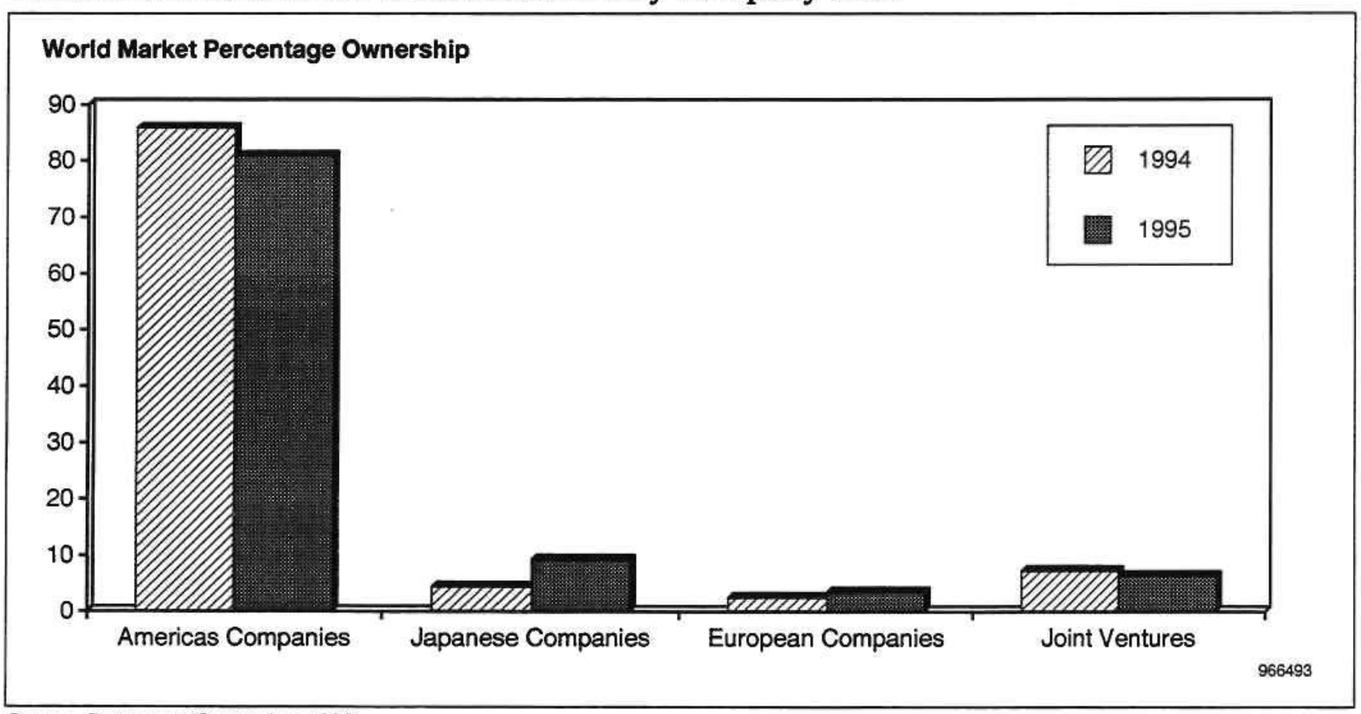
Source: Dataquest (September 1996)

Figure 5
Worldwide Tube CVD Market Share by Company Base



Source: Dataquest (September 1996)

Figure 6
Worldwide Nontube CVD Market Share by Company Base



Source: Dataquest (September 1996)

Company Rankings

Table 1 shows the individual CVD equipment company rankings based on the worldwide 1995 CVD revenue. The table indicates each company's performance in 1995 compared to 1994, as well as individual CVD market segment results.

Table 1
1995 Worldwide Chemical Vapor Deposition Equipment Company Ranking (Millions of U.S. Dollars)

	1995			Tube CVD		Nontube CVD			
	CVD Revenue	Share (%)	Change (%) 1994-1995	Horizontal LPCVD	Vertical LPCVD	APCVD Reactor	LPCVD Reactor	PECVD Reactor	HDP CVD Reactor
Applied Materials	849.9	32.9	1.7	0	0	61.9	240.9	544.3	2.7
Tokyo Electron Ltd.	393.3	15.2	0.6	0	319.1	0	74.1	0	0
Novellus	340.2	13.2	-1.2	0	0	0	100.1	240.1	0
Kokusai Electric	223.2	8.6	-0.9	0	223.2	0	0	0	0
Watkins-Johnson	202.0	7.8	-1.4	0	11.7	202.0	0	0	0
ASM International	136.5	5.3	0.1	0	63.3	0	0	45.3	0
Alcan/Canon/Quester	115.0	4.5	-0.4	0	0	115.0	0	0	0
Silicon Valley Group	76.5	3.0	-0.1	6.8	69.7	0	0	0	0
Genus	46.9	1.8	0.1	0	0	0	46.9	0	0
Amaya	42.3	1.6	1.3	0	0	42.3	0	0	0
Ulvac	36.7	1.4	0.2	2.5	6.0	0	22.6	0	0
Lam Research	17.7	0.7	-0.1	0	0	0	8.1	0	9.6
Bruce Technologies	16.6	0.6	-0.1	6.6	10.0	0	0	0	0
E.T. Electrotech	15.0	0.6	-0.3	0	0	0	0	15.0	0
Materials Research Corp.	14.9	0.6	0.2	0	0	0	14.9	0	0
Others	56.2	2.2	-2.8	2.2	30.1	3.7	1.7	11.2	0.8
Total	2,582.9	100.0	-	18.6	733.2	425.0	509.3	855.9	13.1
1994-1995 Segment Growth (%)				-20	87	122	134	83	51

Source: Dataquest (September 1996)

Applied Materials Inc.

Applied Materials solidified its CVD leadership in 1995, increasing its CVD equipment market share by 1.7 points to 32.9 percent. Applied Materials continued to be the No. 1 supplier in PECVD and LPCVD reactors. PECVD is the largest segment in CVD, with U.S.$856 million sales in 1995, and Applied Materials is the undisputed leader, with nearly two-thirds of the market. The rapid growth of the Asia/Pacific PECVD reactor market and Applied Materials' nearly unchallenged position in the region contributed to the company's dominance in worldwide PECVD shipments. In the U.S.$0.5 billion LPCVD reactor market, Applied is the leader in CVD tungsten and shares the top position in tungsten silicide with TEL.

Another noteworthy Applied Materials achievement has been its quick penetration into new markets. In a few years since its SACVD introduction, Applied Materials has garnered 15 percent of the APCVD/SACVD market. A number of factors contributed to the success of the company's SACVD program. First, its SACVD was developed on the well-established Precision 5000 platform. Precision 5000's position as the most widely installed and proven single-wafer processing platform played well with APCVD's migration into single-wafer multichamber processing. Second, Applied Materials' extensive sales and support infrastructure served as a powerful marketing machine in bringing the company's new SACVD into the global market. This is an important strength because APCVD/SACVD is a DRAM-sensitive market, where a large part of worldwide demand is in the Japanese market and the burgeoning Asia/Pacific market. Applied Materials' global presence played an essential role in the rapid acceptance of its new products into the world market.

HDP CVD is an emerging market that is poised to grow dramatically as a gapfill application for the sub-0.35-micron generations. Applied Materials' Centura is going through a redesign and should remain one of the leading contenders in the HDP CVD market.

Tokyo Electron Ltd. and Kokusai Electric Co.

In the first year since dissolving the Varian/TEL joint venture, TEL expanded its lead over its tube CVD rival, Kokusai Electric, by achieving U.S.$319 million in sales in 1995, or 44 percent of the vertical tube CVD business. It is from the two largest tube CVD markets, Asia/Pacific and Japan, that TEL derived more than 88 percent of its tube revenue, and these two regions will continue to be the battleground where leadership in tube CVD will be fought. TEL also has strong capabilities in nontube CVD with its offering of CVD tungsten silicide and tungsten tools. Currently sharing the top position with Applied Materials in CVD tungsten silicide sales, TEL may have a slight advantage going forward as a result of its entrenched position in Japan and Asia/Pacific, the largest CVD tungsten silicide markets.

Kokusai remains the second-largest tube CVD supplier. It grew its tube revenue 75 percent to U.S.$239.8 million. The bulk of its sales growth came from Asia/Pacific, which now represents 62 percent of Kokusai's revenue base. The other three regions, including home base Japan, turned in lackluster performance. Kokusai may need to do something quickly to prevent losing more market share to TEL in Japan and Silicon Valley Group in North America and Europe. One solution could be to build a stronger global sales and support infrastructure. Kokusai recently became the sole owner of North America-based Bruce Technologies International Inc., which should help forge a global network of marketing and services for the strong suite of vertical and horizontal furnaces offered by the two companies.

Novellus Systems Inc.

After an explosive year in 1994, in which its revenue more than doubled and its nontube CVD market share rose more than six points, Novellus' performance in 1995, although respectable, was overshadowed by the megagrowth of the overall nontube CVD market. Novellus' nontube revenue grew 78 percent, which in the context of a market that doubled in sales translated into a loss of nearly 3 percentage points in nontube CVD market share for Novellus. Despite that, Novellus' position in nontube CVD remains strong. In both PECVD and LPCVD reactors, Novellus' well-secured No. 2 supplier position makes it the most viable, low-cost-of-ownership alternative to Applied Materials.

Also, Novellus' HDP CVD product, SPEED, is making headway and has attained early leadership in the emerging HDP CVD market. HDP CVD could be the market in which Novellus will no longer have to play second fiddle.

Watkins-Johnson Company

Watkins-Johnson grew its CVD revenue by 65 percent in 1995 to U.S.$202 million and maintained its top position in the APCVD/SACVD market. However ,with the APCVD/SACVD market growing much faster, WJ's market share slipped from a dominant 64 percent to 48 percent, a whopping 16 percent loss. Applied Materials' SACVD, Amaya's new ATO-8000, and Alcan/Canon/Quester were all eating into WJ's long-held control of the APCVD BPSG and PSG ILD markets. With DRAM investment waning in the near term and competition in APCVD/SACVD rising, WJ will need to tread carefully and use its resources adequately to prevent its market share from slipping further.

There is a new market opportunity for APCVD/SACVD in the adoption of shallow trench isolation (STI) in the next generation of semiconductor devices. APCVD, with its unmatched step coverage, is the ideal solution for STI. WJ should leverage its leadership position in APCVD and aggressively pursue this new opportunity. Also, WJ has successfully developed its first single-wafer multichamber process platform, the WJ2000, targeting the HDP CVD market. The WJ2000 is getting good reviews and, if marketed successfully, should provide fresh ammunition in WJ's defense of its CVD market position.

ASM International N.V.

ASM International raked in U.S.$136.5 million in sales in CVD in 1995, a 98 percent increase over the previous year. ASMI found dramatic success with its Eagle 10 PECVD system, which grew more than four times in sales to reach U.S.$45.3 million. Although this represents only 5 percent of the U.S.$855 million PECVD market, it does serve notice to Applied Materials and Novellus that there may be cracks developing in their lock of the PECVD market.

Sales of ASMI's tube CVD equipment reached U.S.$91.2 million, equaling growth of 49 percent, a subpar performance in light of the 77 percent jump in total tube CVD revenue. ASMI's tube CVD growth is masked by the company's horizontal PECVD tube shipments, a market with declining sales but which ASMI owns without having to pump in any significant resources. Factoring out horizontal PECVD tube, ASMI's other furnace offerings, the vertical furnace cluster tools, reached U.S.$63.3 million in sales, or 80 percent growth. ASMI's vertical furnaces are gaining rapid acceptance in North America and are the most serious challenge to SVG, the reigning Americas region furnace supplier.

Alcan/Canon/Quester

Alcan/Canon/Quester captured 4.5 percent of the overall CVD market by increasing its sales to U.S.$115 million, a 78 percent rise over 1994. The joint-venture APCVD supplier continued to find success where it has strong, entrenched marketing and support; the company holds the No. 1 and No. 2 APCVD positions in Japan and Asia/Pacific, respectively. But in the Americas region and Europe, the company continues to lag behind Watkins-Johnson and the formidable newcomer, Applied Materials.

Alcan's challenge in the APCVD market, which is becoming increasingly crowded by the recent entry of new players, is to build differentiation based on low cost of ownership and enhanced productivity in its product offerings. Alcan will need to solidify its strong presence in Japan and Asia/Pacific against encroaching APCVD/SACVD upstarts Applied Materials and Amaya. In North America, where Watkins-Johnson is fighting on its home turf against giant Applied Materials, severe competition could translate into a price war. Alcan may be better off focusing on the regional markets where it has an entrenched advantage.

Genus Incorporated

Having exited the CVD tungsten market a few years ago and having begun focusing solely on tungsten silicide, Genus has broken its long stagnation and grown its CVD revenue significantly for the first time in four years. Genus' market share grew for the first time as result of the doubling of its CVD revenue in 1995. Genus is now a viable tungsten silicide equipment vendor and has carved out a 25 percent share of the worldwide CVD tungsten silicide market. Much of Genus' recent success is attributable to its dichlorosilane (DCS) LPCVD tungsten silicide process. The preferred choice for bitline fabrication in 64Mb/256Mb DRAM, DCS tungsten silicide could be the ticket with which Genus regains its past prominence in metal CVD.

Silicon Valley Group Inc.

Silicon Valley Group grew its tube CVD sales by 90 percent in 1995, reaching U.S.$76.5 million in sales. SVG remained the market leader in Americas and Europe for the second straight year. However, SVG is facing a serious challenge in Europe from tube giant TEL, which staged a dramatic entry last year and quickly gained 30 percent of the European market and the second-place spot. Another and bigger challenge for SVG in the furnace market is to forge a strategy for penetrating the lucrative Asia/Pacific and Japan markets, which hitherto have been dominated by TEL and Kokusai.

CVD Market Forecast

Table 2 presents historical data and Dataquest's projection of the worldwide CVD equipment market segmented by film applications. After three years of hypergrowth, the CVD market is expected to take a bit of a breather in 1996—market growth moderates in the face of growing hesitation in chip capacity investment that will likely lead to a significant market contraction in 1997. Bucking the trend, however, could be technologies that are viewed as critical technology enablers. One such technology is HDP CVD oxide, which is expected to provide the most exciting growth in CVD during the next five years. Dubbed the gapfill solution of choice for advanced logic devices at the 0.35- and 0.25-micron generations, HDP oxide is projected to achieve nearly U.S.$0.5 billion in sales by the year 2001. The adoption of growing layers of interconnects in IC devices and the need to fill increasingly small gaps between metal lines with superior films is driving the growth of HDP CVD. PECVD oxides, both silane and tetraethylorthosilicate (TEOS), will also benefit from the continued rise in metal interconnect layers. PECVD silane oxide, in particular, is expected to experience a resurgence because of its superior characteristics as a capping layer for chemical mechanical planarization polishing. APCVD/SACVD will likely be pulled out of the running as a gapfill or IMD solution as the HDP CVD/PECVD oxides combination gains acceptance. The silver lining in APCVD/SACVD, however, will be found in the adoption of shallow trench isolation, for which TEOS/ozone is the prime candidate as the oxide material.

Little growth is projected for LPCVD polysilicon, as DRAM capacity investment is expected to stay in a hiatus for a good part of 1996 through 1998. However, growth is expected to resume beginning in 1999, when investment for the next generations of memory fabs kicks in. In CVD polysilicon, a technology shift will take place from the current batch furnaces to minibatch or single-wafer systems. Consequently, single-wafer CVD polysilicon (and polycide) tool offerings are likely to expand. LPCVD metal comprises both the logic-sensitive (CVD tungsten and CVD titanium/titanium silicide) and DRAM-sensitive (CVD tungsten silicide) segments. This helps mitigate LPCVD metal's exposure to the market cyclicity generally caused by the dramatic swings in DRAM capacity investment. Consequently, LPCVD metal is projected to experience growth that is both healthy and stable.

Table 2
1995 Worldwide CVD Equipment Market History and Forecast by Film Application (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
APCVD + SACVD Oxides	81.9	103.4	191.4	425.0	491.7	397.0	388.3	469.4	666.5	878.1	12.9
LPCVD Oxides	81.2	106.1	181.9	320.4	367.9	320.6	357.9	442.5	612.8	766.0	15.6
PECVD Oxides	176.8	240.0	326.1	615.5	808.4	730.3	756.3	973.1	1,513.7	2,133.9	23.0
HDP Oxide	4.8	12.7	7.9	13.1	78.5	123.7	180.8	225.9	348.4	467.6	81.5
LPCVD Nitride	29.5	36.7	47.2	83.2	87.8	75.9	84.5	99.1	138.3	178.5	13.6
PECVD Nitride	98.4	123.1	167.1	268.3	308.5	266.3	279.8	332.7	389.4	483.8	10.3
LPCVD Polysilicon	87.9	104.6	188.5	356.3	389.1	327.9	322.6	407.2	577.3	726.9	12.6
Single-Wafer CVD Poly/Polycide		1.1	18.8	41.9	47.8	40.5	78.9	126.8	151.6	183.3	27.9
LPCVD Metal	103.0	142.2	207.1	479.2	498.4	438.9	446.0	516.2	727.0	1,002.4	13.1
Total	663.5	869.9	1,326.2	2,583.0	3,054.1	2,700.9	2,855.6	3,529.5	5,049.0	6,728.8	17.3

Source: Dataquest (September 1996)

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Dataquest
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Perspective

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Event Summary

How Long and Deep Will the Slowdown in Wafer Fab Equipment Be? What Will Be the Shape of the Industry Recovery?

Abstract: *Overcapacity in the DRAM market, created by the massive spending from 1994 through the first part of this year and the normal DRAM product migration, is finally taking its toll, resulting in a faster than expected contraction in the wafer fab equipment market. This document is the complete transcript of the telebriefing held by Dataquest on July 11, 1996, with the release of the forecast update on capital spending and wafer fab equipment.*
By Clark J. Fuhs, Näder Pakdaman, and Calvin Chang

Opening Statement by Dataquest

MR. FUHS: Welcome to the Dataquest telebriefing this morning. Our topic is from the Semiconductor Equipment, Manufacturing, and Materials group (SEMM). Our group tracks most aspects of the actual manufacturing of semiconductors worldwide. Today we will be discussing the outlook and forecast for wafer fab equipment and capital spending. We will also present our forecast on silicon wafers supported by a recent supply-and-demand analysis in the silicon market.

My name is Clark Fuhs, Director and Principal Analyst in the group, and your host for the next hour. With me today are Näder Pakdaman and Calvin Chang, who are also senior analysts from the group. After a brief 15- to 20-minute review of our forecast, we will open up the session to your questions.

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You should have received a set of two tables and five figures that visually describe some specific topics we will be reviewing.

Our group has just released its midyear semiconductor capital spending and wafer fab equipment forecast. These are summarized in Tables 1 and 2 of your handout. Our forecast process has several cornerstones, including semiconductor production by region, a worldwide database of existing and planned fabs, and independent comprehensive surveys of the equipment and semiconductor companies. We have just completed an internal audit of the fab database in which we have scrutinized the planned fab activity worldwide.

One comment we should make here regarding our capital spending survey. Our survey was initially done in early May. By mid-June things had changed dramatically, particularly in Taiwan and Korea. We have made an attempt to update these figures before the forecast release, not only for announced cutbacks, but for anticipated cutbacks later in 1996 and in the following year. In many cases, we have reverified the survey responses with companies. However, since we are in a dynamic market where companies are still evaluating their investment levels, some of our judgment is in the numbers.

Forecast Overview

The survey results are just one input into several forecasting models we have, which include analysis of trends and semiconductor production, raw silicon consumption, spending ratios, investment cycle over and under investment, stepper unit growth to DRAM price-per-bit analysis and semiconductor revenue-per-square-inch growth patterns. Our forecast shows the following highlights.

- The year 1996 is a year that turns from growth to decline, but will net out with about a 17 percent growth in wafer fab equipment year over year.
- The only reasons 1996 remains a double-digit-growth year are that there were such strong backlogs coming out of 1995 that the first half remains strong, and a few companies such as IBM, Texas Instruments, TSMC, Siemens, and Chartered Semiconductor have continued to grow investments in the first half of the year.
- Push outs, cancellations, and lack of new orders in wafer fab equipment are commonplace today, virtually guaranteeing 1997 to be a down year.
- In order to quantify and characterize some of the dynamics of the market, we have established for the first time a top line quarterly shipment forecast for wafer fab equipment. This is shown in your handouts and Figures 1 and 2. We expect a decline to accelerate into 1997 and should perhaps bottom in the first half of the year. We believe the first sequential growth quarter after the decline will be in the fourth quarter of next year, but the growth will be constrained until late in 1998.
- This quarterly outlook has produced the annual forecast shown in Table 2 where we show 1997 declining by nearly 16 percent and 1998 as a single-digit-growth year.

Table 1
Capital Spending Forecast, 1995-2001 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Total Capital Spending	38,308	45,344	40,942	42,915	53,954	75,777	96,715	16.7
Percentage Growth	73.5	18.4	-9.7	4.8	25.7	40.4	27.6	-
Americas	12,147	14,828	13,461	14,599	18,453	24,571	29,721	16.1
Percentage Growth	68.8	22.1	-9.2	8.5	26.4	33.2	21.0	-
Japan	9,910	9,692	9,566	10,331	12,730	16,829	20,495	12.9
Percentage Growth	48.6	-2.2	-1.3	8.0	23.2	32.2	21.8	-
Europe	4,137	5,058	4,444	4,317	5,637	7,725	9,718	15.3
Percentage Growth	65.2	22.3	-12.1	-2.9	30.6	37.0	25.8	-
Asia/Pacific	12,115	15,766	13,470	13,668	17,134	26,653	36,781	23.6
Percentage Growth	111.8	30.1	-14.6	1.5	25.4	55.6	38.0	-

Source: Dataquest (July 1996)

Table 2
Wafer Fab Equipment Forecast, 1995-2001 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Total Wafer Fab Equipment	19,054	22,309	18,760	19,900	25,380	36,219	46,889	16.2
Percentage Growth	76.6	17.1	-15.9	6.1	27.5	42.7	29.5	-
Americas	5,179	6,217	5,453	6,163	7,797	10,530	13,105	16.7
Percentage Growth	62.3	20.1	-12.3	13.0	26.5	35.1	24.5	-
Japan	6,352	6,423	5,272	5,635	7,011	9,679	11,694	10.7
Percentage Growth	73.5	1.1	-17.9	6.9	24.4	38.1	20.8	-
Europe	2,316	2,642	2,428	2,486	3,124	4,253	5,520	15.6
Percentage Growth	69.1	14.1	-8.1	2.4	25.7	36.1	29.8	-
Asia/Pacific	5,208	7,026	5,607	5,616	7,448	11,757	16,570	21.3
Percentage Growth	102.9	34.9	-20.2	0.2	32.6	57.8	29.5	-

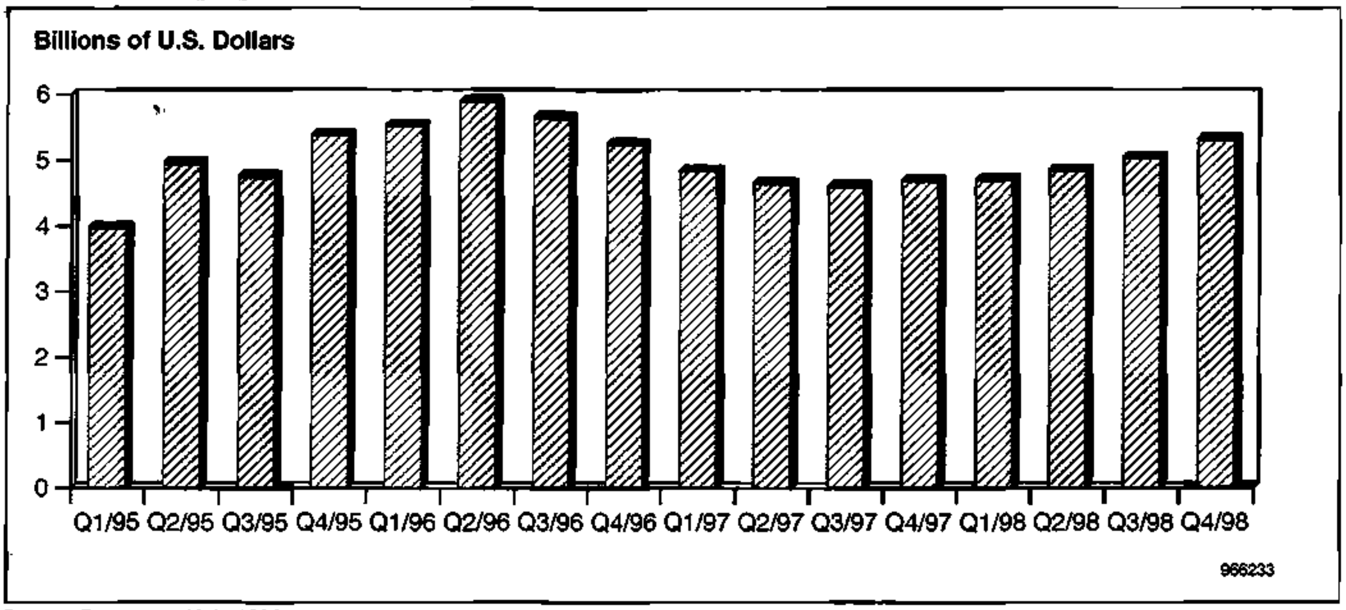
Source: Dataquest (July 1996)

- As the absorption of capacity happens during this two-year pause, we would expect a robust resumption of growth in 1999 with the wafer fab equipment market growing to about the $36 billion level by the year 2000.

What Happened to Trigger the Slowdown?

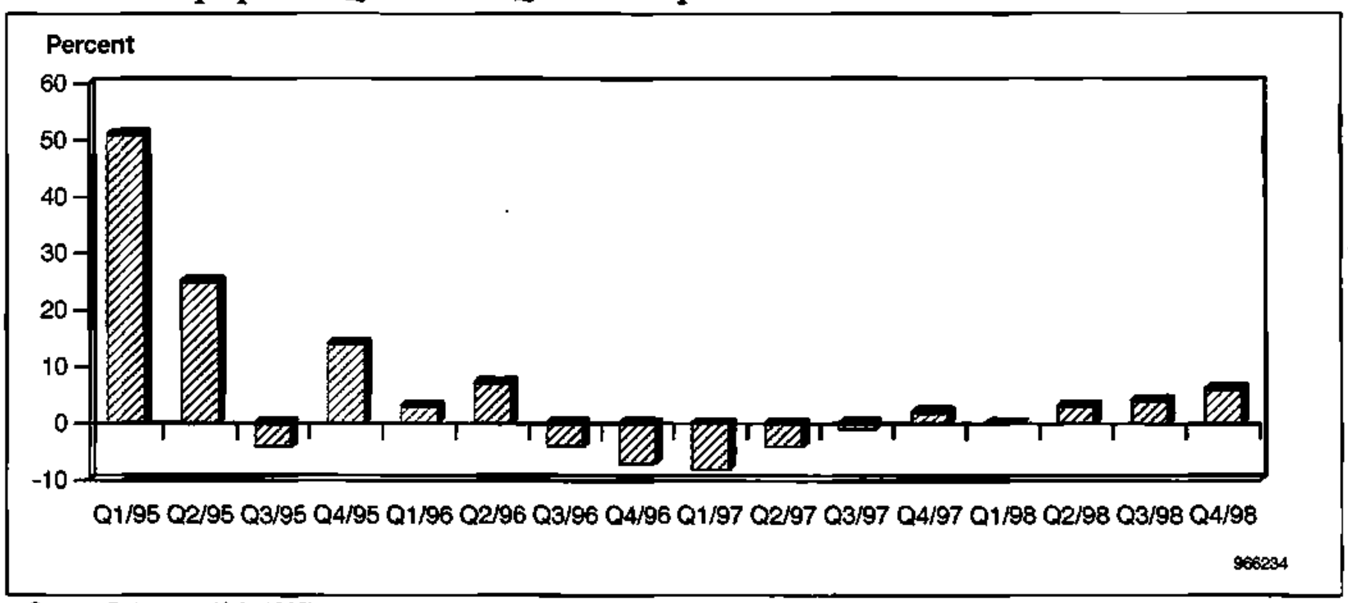
One year ago at this time, we were asking questions like, "Are we ready to call the silicon cycle dead? Are we in a different world today than we were in 1984 and 1989?" At that time, we pointed out that the cycle today is similar to the historical cycles from the perspective of the DRAM business and how DRAM product cycles and silicon area are related. An equipment "pause" was predicted, as we classified it then, and it was expected to be triggered by price softness in the DRAM market, which would depend on when the 16Mb

Figure 1
Wafer Fab Equipment Quarterly Revenue Forecast



Source: Dataquest (July 1996)

Figure 2
Wafer Fab Equipment Quarter-to-Quarter Sequential Growth Rates



Source: Dataquest (July 1996)

DRAM was being produced at economic yields. We thought that ramping to a yield of 65 percent would be a key level, on the road to historical full yields of above 80 percent. This was extremely important for us to understand because the memory spending accounted for nearly 50 percent of capital spending in 1995, up from 40 percent in 1994, and 33 percent in 1993.

In the second half of last year, a complicating factor entered the picture. The overanticipated demand for memory created by the introduction of

Windows 95, which, taken with the short supply of memory last year, caused inventory to inflate to enormous levels. This situation started correcting in the final quarter of last year, slightly in advance, but essentially on top of the yield trigger for the 16Mb DRAM conversion. Today we have a double-barrel driver, both demand and supply, to push the DRAM price slide and capital spending downturn. These events together have increased the anticipated severity of the downturn.

The Shape and Length of the Downturn

We expect this contraction to be sharp, relatively deep, but slightly shorter than historical norms—in the 18- to 24-month time frame. The key reason for the belief of a shorter than normal slowdown is the continued robust forecast for PC shipment unit growth worldwide through this decade, driving the need for silicon.

We also do not see a stoppage in advanced technology investments indicating a belief in the customer base of a strong end-user market for semiconductors. Let's review some specifics.

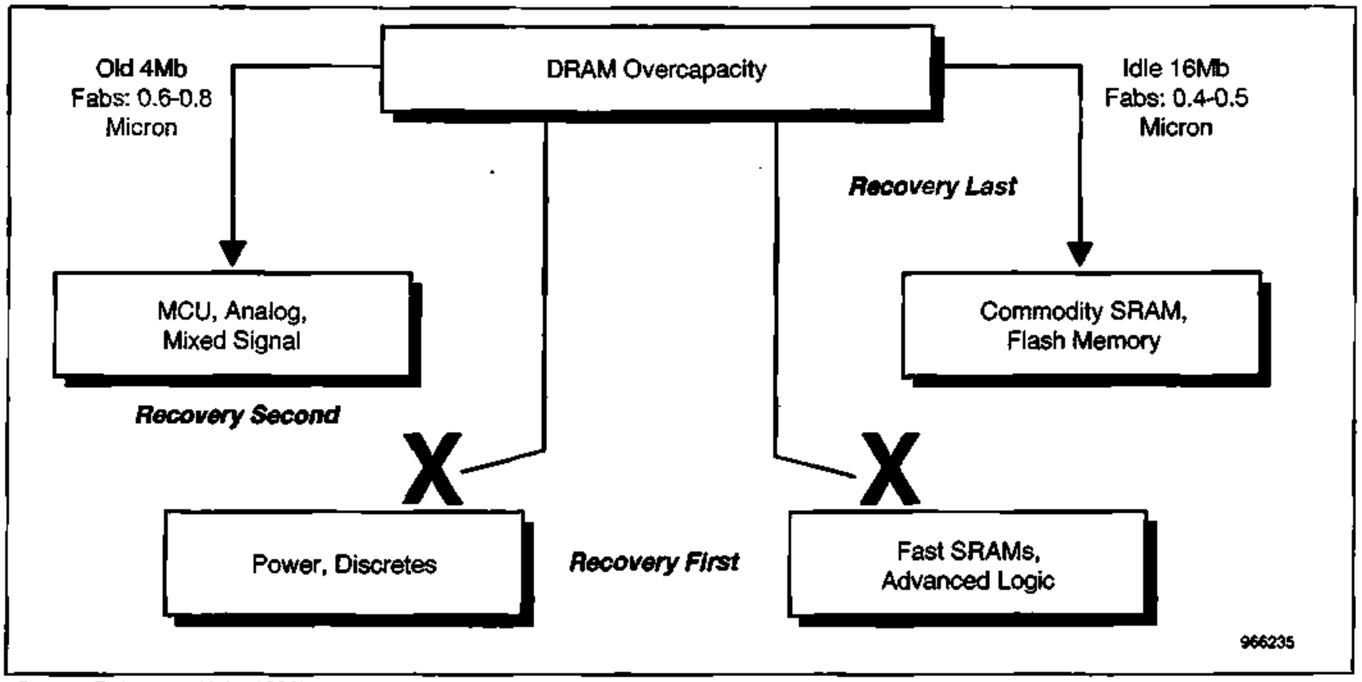
- It is very normal in this type of downturn to get a pocket of companies who will stay and continue to invest in the infrastructure. We mentioned a few names earlier, and Korean companies should continue to grow spending in moderation this year.
- Japanese companies who held spending up in the last cycle for a year or more have already shut off spending. These companies as a group will spend slightly less in dollar terms in 1996 than they did in 1995. However, they are still concentrating what they are spending to build the shells for the next upturn, along with pilot investments for advanced products.
- Outside of TSMC and Chartered, most all other Asian companies are cutting back dramatically, starting in the last couple of months.
- Our most severe reasons for the downturn for 1997, therefore, are Japan and Asia, as these are the DRAM production centers. As a group, the DRAM manufacturers are responding to the situation by cutting spending faster this time than in previous cycles.

An important facet of the semiconductor revenue downturn is that it is driven more by lower margins than the end-user market and lower unit demand. The equipment industry now must rely on a fundamental demand in PCs and telecommunications to catch up to supply. Any hiccups in the end-user markets for semiconductors and we must batten down the hatches for a much longer downturn.

The Shape and Timing of the Recovery in Spending

How will the equipment industry recover? What are the anticipated dynamics? The industry today is primarily experiencing a DRAM oversupply coupled with a product transition. In order to determine how capital spending may recover, it is important to understand how this excess capacity may migrate or trickle into other areas in semiconductor capacity. Please refer to Figure 3 in your handout.

Figure 3
Semiconductor Market in "Capacity Trickle" Mode



Source: Dataquest (July, 1996)

There are two general blocks of capacity now available from today's conditions. The first comprises old 4Mb DRAM fabs that cannot run 16Mb chips. These are limited to two-level metal processing and are generally in the 0.6- to 0.8-micron linewidth technology. Microcontrollers, telecommunications chips, mixed signal, and analog ICs are quite happy being processed in this type of fab. It is likely that most of these fabs in Japan and some in Korea will and have already started to migrate into this area.

The power and discrete chips, which we might think also might have some capacity come their way from this first block, have very specialized processes not found in the older DRAM fabs. So these segments are relatively isolated from extraneous supply impact, since significant time and money is required to convert, and specialized technology and knowledge within the company is required.

The second block of capacity comprises idle or underutilized advanced 16Mb capacity, which is again limited today to two-level metal, running about the 0.4- to 0.5-micron linewidth technology. Because these fabs generally lack the process sequences needed to support self-aligned silicide and three-or-more-level metal, they cannot effectively be redirected to advanced logic or fast SRAM. Therefore, they are limited to commodity SRAM, flash, other nonvolatile memory, or a limited span of logic products that do not require those processing techniques. We expect most of these plants, quite frankly, to remain somewhat idle.

Therefore, we believe the first areas of spending recovery will be in the advanced logic area. An equipment company positioned in these markets should have a more moderate slowdown and will start to recover perhaps as early as the mid-1997. The microcontroller, analog, mixed signal, and telecom chip capacity will be next to recover, but probably not until the end of 1997 or early 1998. Motorola will be a key company to watch here. The DRAM segment, the root cause of the problem, is not expected to resume robust spending until the middle or late 1998.

Outlook on Silicon Consumption

Now I would like to shift gears and talk about our silicon outlook, since it offers a somewhat different view of the market. Figure 4 shows our silicon forecast in terms of square inches. A detailed alert will be sent to our clients shortly. The silicon market demand picture is only slightly changed from our outlook six months ago.

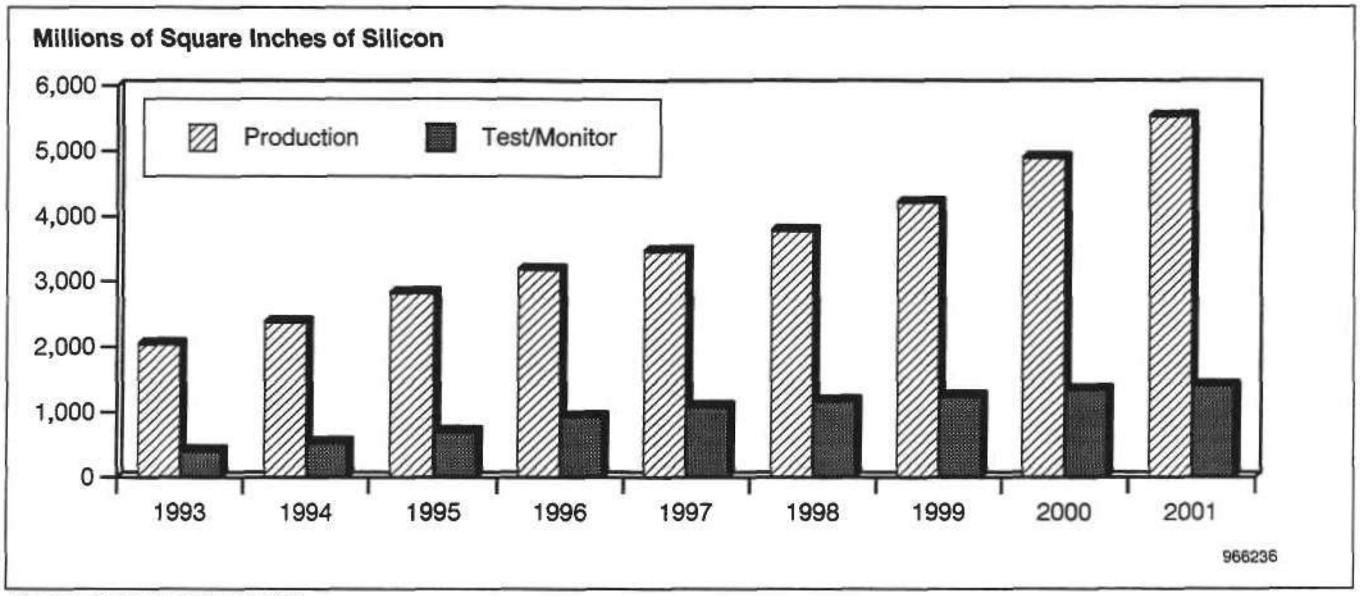
Dataquest has predicted a slower growth picture for square inch consumption over the next few years as the industry migrates to the 16Mb DRAM, which uses silicon area more efficiently per bit than the 4Mb DRAM. The dynamics of our forecast have been modified slightly to account for the quicker than expected price decline in migration timing, which does lag capital spending growth by about 6 to 12 months. The forecast growth for 1996 in silicon has actually been raised slightly, since lower DRAM prices are resulting in more memory installed per PC. Since the industry has only started to migrate to the 16Mb DRAM, the short-term dynamic will be an increase in silicon area consumption.

The accelerated schedule of the product migration has caused our growth outlook to be slightly more cautious for 1997 and 1998, but stronger into 1999. Still, in the slowest-growth year of 1998 it is expected to be about 9 percent growth, as shown in Figure 5, primarily because PC unit demand worldwide is expected to remain robust through the decade. Generally, silicon area is much more stable than capital spending.

How can the silicon industry grow in the face of a slowing semiconductor and equipment market? The answer lies in the cyclical dynamic of the semiconductor industry revenue per square inch. Revenue per square inch is cyclical, and fluctuates with DRAM prices and semiconductor margins. Because of cyclical pricing behavior, silicon consumption tends to meet more closely following unit demand rather than the revenue of the semiconductor industry.

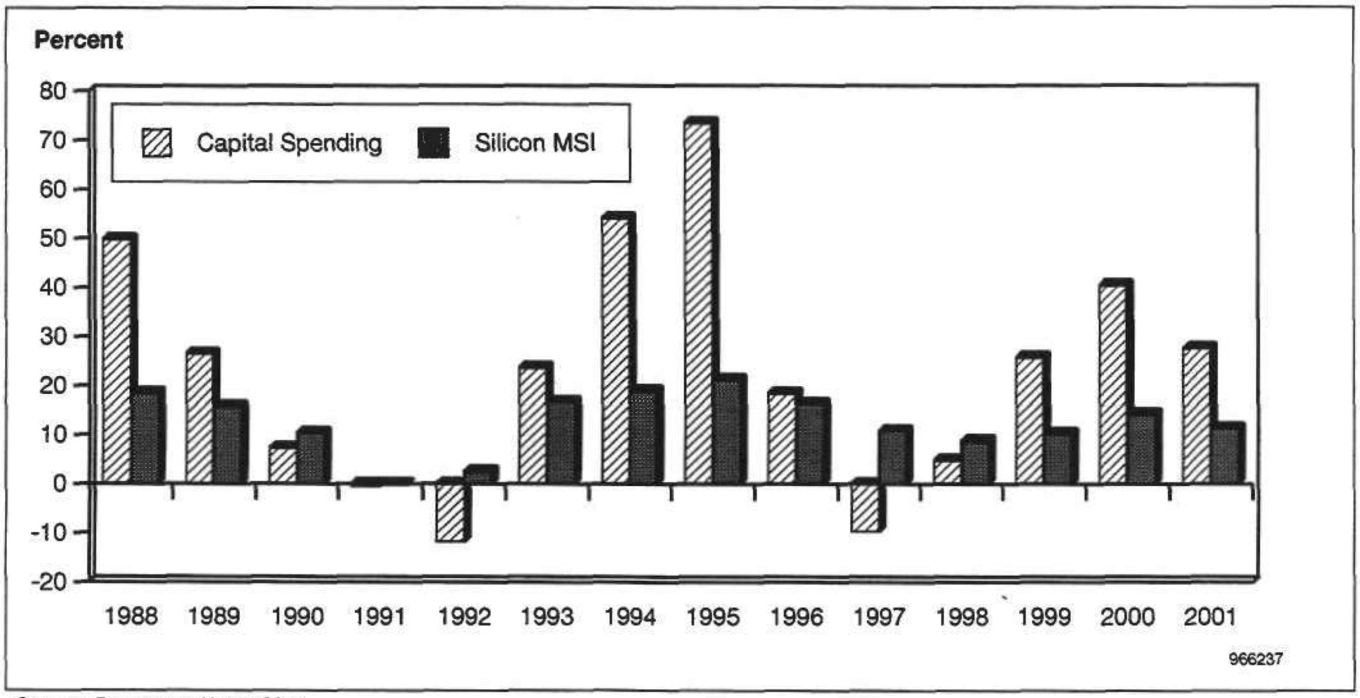
The capital spending and equipment markets are more directly affected by factory utilization than demand. For example, we believe the semiconductor industry runs at maximum at about 92 percent factory utilization. As utilization in an upturn coming from low levels goes above the 85 percent level, spending accelerates and does not typically slow down until it falls back below this 85 percent level. There are constant overshoots, meaning capacity in the industry is added in spurts, whereas silicon is consumed in a more steady fashion. It is the tie between the two that we believe is important to watch during turning points in the industry.

Figure 4
Silicon Area Consumption Forecast



Source: Dataquest (July 1996)

Figure 5
Silicon Consumption Growth Is Less Volatile and Lags Capital Spending Slightly



Source: Dataquest (July 1996)

That concludes our prepared comments. We would now like to open this briefing to your questions.

Question and Answer Period

OPERATOR: Thank you. If you would like to ask a question, please press one on your touch-tone phone. I'll take your questions in the order that they are received. #30, you may ask your question.

CALLER #30: Good morning. I would like to go back to your Figure 2, and if you can explain. I have a little problem understanding what this says, and also if you can walk through again Figure 3, which is very important to me. Thanks.

MR. FUHS: To explain clearly, please refer to Table 2 which is our annual forecast for wafer fab equipment, presenting our revenue by region in an annual fashion. Figure 1 shows the sales represented in quarterly numbers, so the quarterly numbers for the four quarters of 1996 would add up to the annual number in Table 2. What we have done in Figure 2 is prepared what the growth rate is from quarter to quarter. In other words, if I go and look at the third quarter of 1996, it is the first negative quarter. Basically, what we are saying is that on a seasonally adjusted basis, the third quarter of 1996 will be below the second quarter of 1996.

CALLER #30: I understand. Thanks.

OPERATOR: Thank you. #18, you may ask your question.

CALLER #18: Yes, I was just curious. You were saying earlier that obviously, for Dataquest, continued strong growth in the PCs is an important factor in how long the downturn is going to be, and I'm just wondering, if you are starting to rethink that in terms of the news starting to come out of people like Hewlett-Packard about a slowdown.

MR. FUHS: That is really a call for our PC group to make. They're standing by their growth rate of about 18 percent or 19 percent this year in unit growth, and I believe their compound annual growth rate through the year 2000 is roughly 16 percent or so. In past semiconductor slowdowns, the PC unit growth has gone down into the low single digit-growth, and that is basically what happened in the extended downturn in the early 1990s. We are not viewing that to repeat right now.

CALLER #18: Thank you.

OPERATOR: Thank you. #25, you may ask your question.

CALLER #25: Hello, Clark. I noticed that you stated that you believed there's still going to be investment in advanced technology, and I also noted that you didn't really talk about the details on equipment, but do you see any particular areas where you believe there will be strong investment, for example, batch tools to single wafer tools or cluster type tools? Any comments?

MR. PAKDAMAN: This is Näder Pakdaman. Perhaps maybe we can't take it at this time to the level of granularity in terms of any particular equipment. We are seeing in our survey of fabs and information on capital spending that people are not just canceling, but are delaying capacity investments into the latter part of 1997 and 1998 across the board, even for DRAM manufacturers. But they are continuing capital investments for equipment with capability of 0.3 micron and below, obviously not in the same volumes. These include higher ASP equipment and more advanced equipment to set up for later production, and as Clark mentioned in the initial discussion the industry is building a lot of shells. So a lot of the fab announcements, yes, actually fabs are likely to be started in the year of production currently planned for the most part, but capacity will probably be pushed out and the ramp rate is going to be slower. The technology that will be introduced will be more advanced than what was initially anticipated.

MR. FUHS: One additional comment. The 16Mb DRAM is likely in the later stages of the cycle to be processed at 0.3 or 0.25 micron, and what the DRAM companies are doing, particularly the Japanese, is to take this time to investigate advanced technologies. I just saw a release a couple of days ago on Gasonics announcing an order for advanced remote plasma strip systems to go into Japanese companies. We believe that the Japanese companies in particular are going to take this opportunity to look at advanced systems to determine their capability in order to design into their later stages of their 16Mb DRAM process flows.

OPERATOR: Thank you, and #13A, you may ask your question.

CALLER #13A: Two questions for you. I noticed that in Table 1, it looks like in 1997 the wafer fab equipment negative growth was larger than the capital spending. Can you go through some of the assumptions behind those two different growth rates? Are you suggesting the semiconductor manufacturers are building more shells?

MR. FUHS: The wafer fab equipment is a subset of the capital spending. That's correct.

CALLER #13A: That is the main assumption behind that. And my second question. You mentioned that DRAM and oversupply were probably recovering in mid to late 1998. Now, can you make some comments on the supply and demand situations for 1997 and 1998, you know, maybe first half and second half, kind of time frame?

MR. FUHS: The comments that we made are based on the supply demand analysis in DRAM. The current outlook is that DRAM will remain in oversupply at least into the first half of 1998.

CALLER #13A: Thanks.

OPERATOR: Thank you. #5, you may ask your question.

CALLER #5: I've got a two part question. If you look at Figure 2, you show going from a negative to a positive sequential growth rate. Would you review again the reasons you see it going positive starting the end of 1997, that is, what causes the inflection point between the negative to positive cycle and if you could, what portion of that change in growth rate is attributed to technology kinds of buys versus the portion that's attributable to capacity buys?

MR. FUHS: Well, we generally see that the cuts will be fully reflected, with shipments at their lowest levels in the middle of 1997 driven primarily perhaps by the DRAM segment. What we're looking at is a recovery in the advanced logic area in the last half of 1997. The business of wafer fab equipment is driven primarily by capacity needs. The R&D budgets are much smaller than the capital spending budgets for many of these companies when it comes to equipment issues and, in general, the average is roughly probably three or four times as much equipment bought for capacity than it is for R&D. During slow capacity times, that average will probably come down in the closer to two to one to three to one ratio. The driving force behind this stability in R&D spending is growth in the end-use markets for semiconductors. R&D spending will probably continue to have stable growth through this period.

So what we expect at the end of 1997 for capacity buys is a stabilization in the DRAM area, a return to growth in the advanced logic area, with a continued increased investment in R&D systems for 0.3-micron technology. Through the first half of 1998, you start to see the capacity increases at the microcontroller, analog, mixed signal areas and then the end of 1998 into 1999, we expect we will start to see a sequential acceleration in the overall market again as DRAM expansion returns.

CALLER #5: Thank you.

OPERATOR: #13, you may ask your question.

CALLER #13: Yes, Clark, can you comment on the equipment lead time, how lead times are changing? For example, six months ago or so they were saying that lead times were like 12 to 18 months. How is it now?

MR. PAKDAMAN: I will discuss the stepper situation. I think it is a prevalent indicator for the rest of the equipment market. On the advanced systems, we do not see the backlog or the lead times really shrinking perceptively. For advanced deep-UV systems, the lead time is still rather long. However for mainstream products, primarily above 0.3 micron and i-line, we are seeing definitely seeing the pressure alleviated and the lead time coming down to historical levels. We are thinking that by next year around this time, it will come down to about nine months. Right now, it is definitely above a year.

MR. FUHS: One other comment. Implanters and steppers tend to have the longer lead times. Processing equipment, the CVD and etching equipment and so on generally have much shorter lead times. I would classify that an average lead time in this industry is between four and five months. I think at the end of 1995, we were looking at an average six month lead time and I think we'll go out of 1996 with a four to three-and-a-half-month lead time.

OPERATOR: #26, you may ask your question.

CALLER #26: I have three questions and I'll make them brief. First, is your original growth by headquarters location or the actual region of spending? Second question is, I'm wondering if, and I want to get your feel for the risk of the DRAM downturn being longer. What I see going on is that the DRAM guys are converting to 64Mb rather quickly, and they could create a major price war in 64Mb. If they're profitability totally goes away, I would think that they may want to hold back longer before they start spending again, which could make this downturn in DRAM a long one rather than a short one. And the third question is, what impact on 300mm development do you think this downturn will have?

MR. FUHS: First question. The capital spending is by region of spending, so the Americas region would include anything that Samsung spends here in the United States, and thus would be considered American spending.

The second question had to do with DRAM and the impact of the industry trying to convert to 64Mb. Every time that there is a downturn like this, the immediate cry is, "Let's leapfrog and go to the next generation." I am very suspicious of that argument, primarily because there is not a 64Mb design that a PC manufacturer will buy and put in their systems. A 64Mb DRAM is fully 8MB, and the PC industry wants to ship PCs in with megabyte increments which are marketable in the business and particularly the consumer markets. I believe we are projecting that the average PC will have 48-56MB per box, and the shipment mix is expected to be 32, 48, and 64MB systems. In order to get this 16MB "nugget" between systems, and use 64Mb DRAMs, manufacturers will need to make a x32 configuration for the 64Mb in order to penetrate the market. This granularity issue is one of the key reasons behind the long length of the 4Mb DRAM cycle. And just to put this in perspective, nobody makes a x32 today! So to presume that you can drive the end-use industry by the supply side is unrealistic and I'm suspicious of that outcome. I think that by the time we get to the 1999 or 2000 time frame, the 16Mb DRAM will still be the dominant chip being shipped.

MR. PAKDAMAN: I want to also add a comment to that. The fact is that perhaps maybe we should not concentrate on device density of 16 or 64Mb, but look the issue per square inch of silicon. There will be continued investments to put more bytes per square inch, whether it's in a 16Mb or a 64Mb configuration. We are definitely seeing this in the patterns of spending and the price of equipment. But there is one way or another today a byte glut, first because of increased yields, second because of the conversion that has happened from 4Mb to 16Mb. So for that glut to be absorbed we expect to have another at least three or four quarters if not more ahead. In the interim, companies will be making advanced shrink designs to put more bytes per square inch. We will see the "64Mb technology" being applied to 16Mb DRAM as 16Mb technology was very much utilized for the 4Mb product. The fact that the margin has really decreased and the prices have fallen so far recently for DRAM obviously brings the prospect of going to the next device generation closer into focus, but we expect with the robust end-user market that the prices will stabilize eventually, and 16 Mbit will have a similar life cycle as previous generations.

MR. FUHS: Just one more comment and then we'll answer your third one really quickly here. There is a risk that this DRAM slowdown could last longer, and that depends on how many of the 6-inch fabs out there convert to 8-inch wafers, delaying equipment purchases. We have actually increased our product demand for 200mm wafers in the 1997-1998 time frame because we were starting to see a lot more 6-inch to 8-inch conversions happening in that time frame. What this does is add square inch capacity to the industry without the benefit of additional equipment, so that may push the equipment purchase cycle out by six months or so into 1999.

Regarding 300mm wafers, there has been some acceleration in the wafer industry to put in 300m capacity. Four or five companies have announced pilot lines to produce 300mm wafers, and from the semiconductor side NEC is becoming a little bit more aggressive. I do not believe that the industry's slowdown will change the pace appreciably. I think we will continue to move toward the first 300mm R&D pilot line for semiconductor production online by 1999 or 2000, placing the major production ramp of 300mm in the 2003-2004 time frame. This picture is consistent with what we have been saying for the last 18 months and we still see that path continuing.

OPERATOR: #30, you may ask your question.

CALLER #30: Figure 3, could you walk me through the timing of these recoveries?

MR. FUHS: At this point, we expect the advanced logic and fast SRAM part of the market to begin recovery by mid-1997. The analog, mixed signal, and microcontroller area by the end of 1997 and early 1998, and then the DRAM recovering last in the latter half of 1998, perhaps with the risk to go into 1999.

CALLER #30: Okay.

OPERATOR: #15, you may ask your question.

CALLER #15: Looking again at Figure 3 with the early recovery of fast SRAMs and advanced logic, I'm assuming that's why you're showing in Table 2 the Americas kind of leading the recovery in 1998. Can you go into a little more detail on the companies/products you see leading this recovery?

MR. FUHS: Generally speaking, logic chips connected with the multimedia PC come to mind—the graphics controllers, anything having to do with microperipherals, logic controllers, and so on. The advanced logic foundries like TSMC and Chartered will continue to do pretty well. They will probably have some pricing pressures in the next one to two years because of the general overcapacity. The fabless companies are going to have a field day, and as far as their cost structure is concerned, and they are the ones that are actually making out like a bandit with this downturn. We would expect some of the foundries to do relatively well if they are focused in advanced logic, but as I said there is going to be pricing pressure for wafers out there. The other area that will probably recover from the capacity perspective would be the advanced ASIC areas, especially the PLD and ASSP areas. These devices tend to use the self-aligned silicide process, and it is that kind of capacity, along with the multilevel metallization capacity, that we expect to see coming back first.

OPERATOR: #7, you may ask your question.

CALLER #7: Continuing on about the rate, or how quickly we will change and enter a growth period, I'd like to understand your viewpoint on what from the end-user standpoint, either events or issues, will trigger either an acceleration or a deceleration of the conversion to growth in 1997 and 1998.

MR. FUHS: Whatever makes a PC box ship. It comes down to that. Unfortunately, that is the simplistic and most significant answer. There are other areas to look at however, such as telecommunications and networking. The implementation of MPEG-2, for example.

MR. PAKDAMAN: I think one significant difference between this downturn and previous cycles is that we are riding on a much larger semiconductor and end-user market, and our forecast for the year 2000 is still above a $300 billion semiconductor market, even if prices do not tend to stay as robust as they did in 1994 and 1995, particular for the DRAM market. We really do believe that unit demand and end-user markets are very, very strong. All our forecasts show some sort of flattening or softness in the market for the next year or two, but every indication in the market is that we will see a pretty strong growth toward the latter part of the decade. So the truth of the matter is that the semiconductor revolution that we have experienced in the past two to three years is real, and today we are dealing with fluctuations at the top of a much larger pool.

MR. FUHS: Some of the products that may contribute to the advanced logic recovery might be some of the digital consumer products, DVD systems, digital cameras. These will help fuel the move to digital and are part of the underlying strength of the market. How that translates to equipment spending, those tend to be more secondary but related to the dynamic of why we believe advanced logic will probably be the first one to recover.

OPERATOR: #21, you may ask your question.

CALLER #21: We talk a lot about the downturn, but through 1997, there's still going to be about $5 billion of quarterly spending. I just wanted to get your perspective on who will be the remaining winners in that period: front-end versus back-end or higher technology. Who's going to actually be selling this $5 billion worth of equipment?

MR. FUHS: The industry continues to invest in infrastructure and capacity because the industry is growing, albeit at a slower growth rate. The industry just does not shut down to zero, but companies will be primarily investing in advanced technology systems, such as intermetal dielectric 0.35-micron "gap fill" such as Novellus' SPEED product, as an example of a classification of a product that would do well. Deep-UV steppers are actually going to grow significantly through this time period. We are showing the number of deep-UV steppers growing from about 105 in 1996 to about the 270 level in 1998, and this is an example of a segment of the market that is showing strength.

What we are expecting is a shift to invest focused on trying to understand how to manufacture productively at 0.25-micron, and companies are going to invest in that technology and set up pilot production capacity for that.

MR. PAKDAMAN: In the area of process control, going beyond the 0.3-micron realm will entail a leap into a lot of unknowns. This pause period should allow the semiconductor manufacturers to make investments to understand what will be required. What we are seeing in terms of metrology and all areas of process control, not just for R&D but for pilot production, is really getting ready for an environment of volume production at these advanced linewidths. Those are the key drivers for the investments that we were seeing in 1997 and even into the first part of 1998.

CALLER #21: Would you anticipate branching out or some experimentation with new processes to cut costs in the future like someone that might have modular portable clean areas to cut down overall cleaning room costs, things like that, that might change the process, but in the long run, be cheaper? Would you anticipate much experimentation in this time period?

MR. FUHS: Yes, I think there will be some experimentation done. The production pressures are kind of off for the next couple of years. That is going to be an opening to perform that kind of an experimentation. As far as new processes and restructuring the fab, so to speak, there might be some of that. But I think that is going to be primarily in the R&D center first, early on and perhaps some of the fabs that are announced later in the cycle will implement some of those changes. Because the shells are being built and the fabs are being designed today, changing the structure of the fab is a little bit risky, a little bit slower to be accepted.

MR. PAKDAMAN: What we are starting to see and would expect in terms of investments have to do with statistical process control, and investments in information systems. We are seeing many of the common maladies of increasing capacity in a tight environment, where equipment is purchased to add capability rather than focusing on efficiency. Fabs are actually experiencing smaller throughputs because companies are not able to utilize the fab in the most efficient manner. With all of the past investment, there needs to be time now to go in and make sure that it is running efficiently. I think a lot of the investments, as far as changing how fabs operate, are going to be done as information systems and focus on trying to increase efficiency. I do not think it will go as deep as trying to change processes. We're still dealing with a rather conservative manufacturing environment and things do not change as fast as they do in R&D in what is actually seen on the production floor.

OPERATOR: #5, you may ask your question.

CALLER #5: I have a question about the Windows NT for impending release shortly. What effect does that have on demand and timing?

MR. FUHS: I'm not going to answer that question specifically with respect to how it will affect the capital spending recovery because I do not think it will have much of an impact. The issue with anything in the operating system area is, will the consumer buy it? Will the business people buy it and the answer is, yes, in time. If it drives PC units, then it will make the capital spending recovery happen a little faster, perhaps. But then look at all the anticipation everybody had on demand for Windows 95. I got a question last year at our Semicon/West seminar, "What do I think about the memory requirements for Windows 95 just blowing out the top of the memory demand?" My comment was, "I'm memory-constrained today because of the PowerPoint presentation I've got to do rather than going to a new operating system." The applications are what is going to drive the memory requirements necessarily and the PC demand. A year after NT comes out, applications will be developed for the NT to require more memory. That is what is going to drive demand directly related to NT. That is the normal course of events in the PC industry driving how many bytes go into a PC.

OPERATOR: #28, you may ask your question.

CALLER #28: You mentioned that you expect R&D expenditure of semiconductor makers to be stable. Do you expect the same for R&D expenditure of semiconductor equipment manufacturers?

MR. FUHS: We would expect that to remain fairly stable. Some companies that are in fairly good shape would probably increase their R&D relative to sales in this time period.

CALLER #28: I see. Thanks.

OPERATOR: #26, you may ask your question.

CALLER #26: I'm wondering, in Tables 1 and 2 you show from 1995 to 2001 that capital spending CAGR is greater than wafer fab equipment by about half a percent and in a couple of regions, Japan and Asia/Pacific, it's considerably higher, about 2-1/2 points higher. This is counter to my understanding of what's been going on in the last 10 years or so where an increasing portion of the capital spending is going toward wafer fab equipment, but you're showing that trend over a pretty long period of time here, six years, reversing. I wanted for you to comment on that. Is that something you think is going to continue?

MR. FUHS: Actually, it's remained fairly stable in history—I actually have that information here. By the way, that's been a consistent part of our forecast in every forecast we've published in the last two years. In the late 1980s, the average was just over 50 percent of the capital spending went into front-end, or wafer fab, equipment. In 1995, which was the peak year in the current cycle, it was slightly under 50 percent, so the trend in history is gradually declining, even if you go back further in history. The reasons for it are a couple. One has to do with the fact that the test and assembly part of the market, which is not in the wafer fab equipment number, but is in the capital spending number, includes testing equipment that has become more sophisticated. If I were to look at the equipment spending as a whole, I would probably say that it was stable relative to capital spending. Some of the assembly pieces of equipment and packaging issues associated with that are getting more complicated and complex, and that's growing a little bit faster. The second has to do with computer systems. Ten years ago, computer systems that were capitalized were a very small part of the total. Today, they account for between 7 and 9 percent of the total capital spending dollar. That's the answer in a nutshell.

MR. FUHS: We're right at one hour now, and we have limited this to one hour. I apologize to anyone who did not get a chance to ask their question. We are available to take questions after this call, but I want to thank you all for participating. I'd like to invite you to attend our Semicon/West seminar next week. It's on Thursday morning, July 18. For more information, please contact our conference desk at 800-457-8233 in the United States, or outside the U.S., the number is 805-298-3262. It will be held in the Sheraton Palace in San Francisco. Thanks for participating. Good-bye now.

END OF CONFERENCE CALL.

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Dataquest
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Perspective

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Market Analysis

The Dynamic Etch Equipment Market: 1995 Market Review and Projection

Abstract: *After two years of spectacular growth, the dry etch market in 1995 continued its skyward ascent with an eye-popping 79 percent growth, reaching U.S.$2.84 billion in sales and completing a three-year market expansion that resulted in the quadrupling of worldwide etch revenue. The market remains on track to achieve a solid growth in 1996. But 1997 will likely be a year of significant decline in the dry etch market as the chip industry continues to absorb the large capacity put on line during the fab-building frenzy of the prior years.*
By Calvin Chang

Dry Etch Market Summary

The worldwide dry etch equipment market grew 78.5 percent in 1995, the strongest growth in more than 10 years. Booming demand for dry etchers in 1995 was driven by a combination of memory and microcomponent capacity expansion, as well as increased average selling prices (ASPs) in all segments of the dry etch product mix.

Dielectric etch, including oxide and nitride applications, became a billion-dollar market in its own right and contributed the most to the overall etch growth. A rise in polysilicon and silicon trench etcher sales was in large part driven by the seemingly incessant addition of new memory capacity construction. Metal etchers also turned in a respectable showing, although with a comparatively modest 63.8 percent growth. Table 1 presents the makeup of the 1995 dry etch market, segmented by film applications, and their respective growth rates.

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(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

Table 1
1995 Dry Etch Segment Sales and Growth (Millions of U.S. Dollars)

Dry Etch Segment	Estimated 1995 Sales*	Percentage of Overall Dry Etch Market	1994-1995 Growth (%)
Dielectric Etch	1,264.3	44.5	87.3
Polysilicon/Silicon Trench	913.5	32.1	78.7
Metal Etch	663.9	23.4	63.8
Total Dry Etch	2,841.8	100.0	78.6

*Sales are for calendar year 1995 and exclude service and spares.
Source: Dataquest (August 1996)

Polysilicon Etch

The polysilicon etch market surged in 1995 as capacity was added to strengthen DRAM production. Nearly all new DRAM capacity added during the year was designated for 16Mb/64Mb production, usually with a minimum of four levels of polysilicon to etch. Riding on the success of its TCP 9400 polyetcher, Lam Research has gained the leadership spot with a rising market share in high-density polyetch, which now represents 32 percent of the overall polysilicon etch market (from 21 percent just two years ago). In low-density polysilicon etch, Applied Materials' workhorse P-5000 became the undisputed market leader, having taking the advantage of Lam's shifting focus toward the higher-ASP high-density etch market. In total polysilicon etch sales, including both high-density and low-density polyetch, Lam and Applied Materials were neck and neck, each with about a 36 percent share of the market. Hitachi was a distant third with a 13.3 percent share. With single-digit market shares were Tokyo Electron Ltd. (TEL), Tegal Corporation, and Sumitomo Metals, although all have increased sales in polysilicon etch during the year.

Long absent from the high-density polysilicon etch market, Applied Materials has completed its lineup of high-density etchers with its recent unveiling of the Silicon Etch DPS (Decoupled Plasma Source) Centura. A lot is riding on the DPS; Applied hopes that the new high-density source will allow it to extend its low-density dominance into the faster-growing high-density market.

Metal Etch

Applied Materials became the market leader in overall metal etch sales in 1995, displacing Lam Research, the metal etch leader of the previous year. Applied accomplished this by increasing its dominance in the low-density metal etch segment, where it attained nearly 74 percent in market share. The second-place low-density metal supplier, Lam Research, in contrast, had only a 12 percent share. Here again, Lam's conscious shift toward the high-density etch market is evident. Lam's shortfall in low-density metal was more than made up in high-density metal, where its share reached more than 50 percent, landing it the No. 1 spot from the previous high-density metal leader, Hitachi.

Metal etch is where high-density has attained the highest penetration, contributing more than 52 percent of the metal etch market, and the battle for future metal etch market share will be fought in the high-density arena. Although Lam has sprung ahead of Hitachi in high-density metal, Hitachi still has a formidable presence with its ownership of the largest high-density metal etcher installed base. Early this year, Applied Materials formally entered the high-density metal market with its introduction of the Metal Etch DPS Centura system. The battle for metal etch market share for the next few years will be fought among the three etch titans. Tegal, Sumitomo Metals, and the few other metal etch suppliers, however, will likely be significant but will remain niche players.

Dielectric Etch

Tokyo Electron, with its successful concentration of sales efforts into the Asia/Pacific region, retains its top spot in dielectric etch, with 34 percent of the market. Lam remains in the runner-up position, holding onto a 27.7 percent share. Breathing down Lam's neck, and getting closer, is Applied Materials, with 27.1 percent. These three vendors will continue to be fierce competitors in the largest etch segment. Dielectric etch accounts for 44 percent of the total etch market and is poised to take on a much greater share when the chip industry adopts damascene processes, starting in several years. High-density oxide etch will be a key technology enabler for the damascene process. Lam's recently introduced TCP 9100, targeting critical oxide etch applications below 0.35 micron, is the second serious contender for the high-density oxide market, after Applied's HDP Dielectric Etch Centura, which was introduced some three years ago. Compared with polysilicon and metal etch, high-density dielectric etch has been a laggard, with relatively meager 1995 sales of U.S.$119 million, representing only 15 percent of the high-density etch market. A principal reason is the limited choice of truly production-class tools. Lam's TCP 9100 and the new oxide entrants expected from other vendors within the next year could be what it takes to jump-start the high-density oxide market.

Table 2 presents 1995 dry etch revenue for the major suppliers. Low-density, high-density, and total dry etch sales results are shown with the percentage change in 1995 sales compared to 1994. The year 1995 was successful for the entire dry etch industry, with every vendor, big or small, reporting double-digit to triple-digit growth in sales.

Regional Segmentation

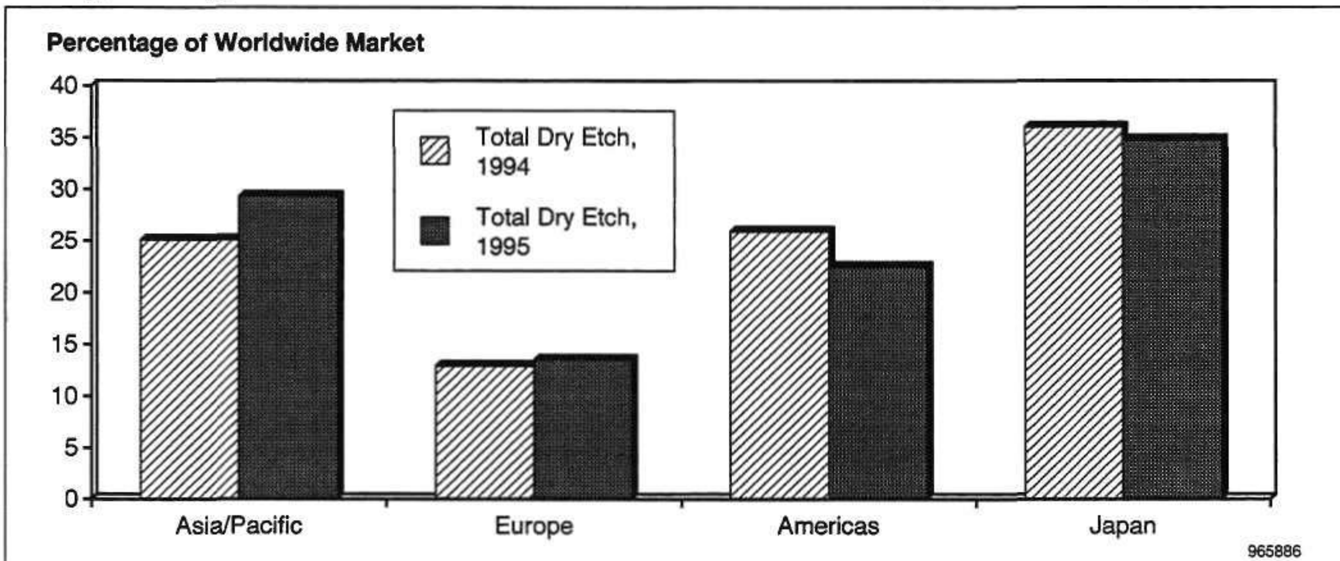
Figure 1 presents the change in the regional segmentation of the total dry etch equipment market from 1994 to 1995. Japan continues to be the largest etch market at $988 million, or 34.8 percent of the world market, down from 36 percent in 1994. The Americas region's share also declined, to less than 23 percent, from 26 percent in the previous year. The decline of the Japan and Americas' share of the etch consumption market is in contrast to the continuing rise of Asia/Pacific, which has now become the second-largest etch market. Sales of dry etchers in Asia/Pacific reached U.S.$831.3 million, or 29.3 percent of the total market, a far cry from the 12.7 percent the region represented in the world market only three years ago. Large capacity expansions, including DRAM and foundry in Korea and Taiwan, drove the bulk of the etch sales increase in Asia/Pacific. Europe's contribution to the etch consumption market remains steady at levels just a shade above the 1994 levels.

Table 2
Estimated 1995 Sales and Rankings for Dry Etch Equipment Manufacturers (Millions of U.S. Dollars)

1995 Rank	1994 Rank	Company	Estimated 1994 Sales	Estimated 1995 Sales	Change (%)
Low-Density Dry Etch Equipment					
1	1	Applied Materials	389.9	832.1	113
2	2	Lam Research	346.9	532.5	54
3	3	Tokyo Electron Ltd.	279.8	481.2	72
4	4	Tegal	28.9	34.4	19
		Others	94.1	152.5	62
		Total Low-Density Dry Etch	1,139.6	2,032.7	78
High-Density Dry Etch Equipment					
1	2	Lam Research	163.8	349.0	113
2	1	Hitachi	207.9	285.5	37
3	3	Applied Materials	25.1	72.4	188
4	4	Sumitomo Metals	22.2	51.2	131
5	5	Tegal	7.3	12.4	70
		Others	25.7	38.6	50
		Total High-Density Dry Etch	452.0	809.1	79
Total Dry Etch Equipment					
1	2	Applied Materials	415.0	904.5	118
2	1	Lam Research	510.7	881.5	73
3	3	Tokyo Electron Ltd.	279.8	481.2	72
4	4	Hitachi	208.4	285.5	37
5	6	Sumitomo Metals	22.2	51.2	131
6	5	Tegal	36.2	46.8	29
		Others	119.3	191.1	60
		Total Dry Etch	1,591.6	2,841.8	79

*Note: Sales are for calendar year 1995, and exclude service and spares
Source: Dataquest (August 1996)

Figure 1
Change in Regional Contributions to the Worldwide Total Dry Etch Market, 1994-1995



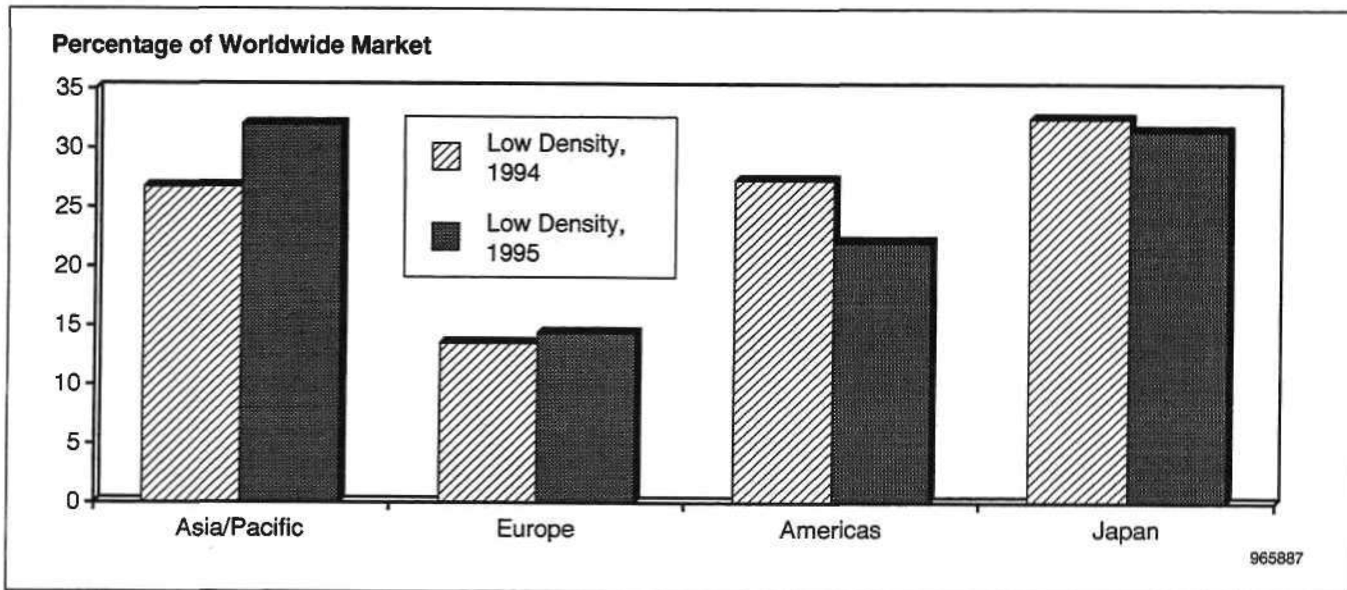
Source: Dataquest (August 1996)

Low-density etch in 1995 constituted 71.5 percent of the total dry etch market. Asia/Pacific jumped ahead of Japan to become the largest low-density etch market, with 32 percent of the worldwide market. Americas lost a significant share to end up with a little over 22 percent of the total low-density revenue. Europe grew modestly to finish 1995 with 14.4 percent of the market. Figure 2 shows the change from 1994 to 1995 in regional contributions to the worldwide low-density etch market. Figure 3 shows the corresponding distribution for the high-density etch market. All four regions in 1995 maintained their respective share of the worldwide high-density etch market. In terms of their percentage contribution to the high-density etch market, Americas and Asia/Pacific grew just a shade, while Japan and Europe gave up a modest amount.

Dry Etch Equipment Forecast

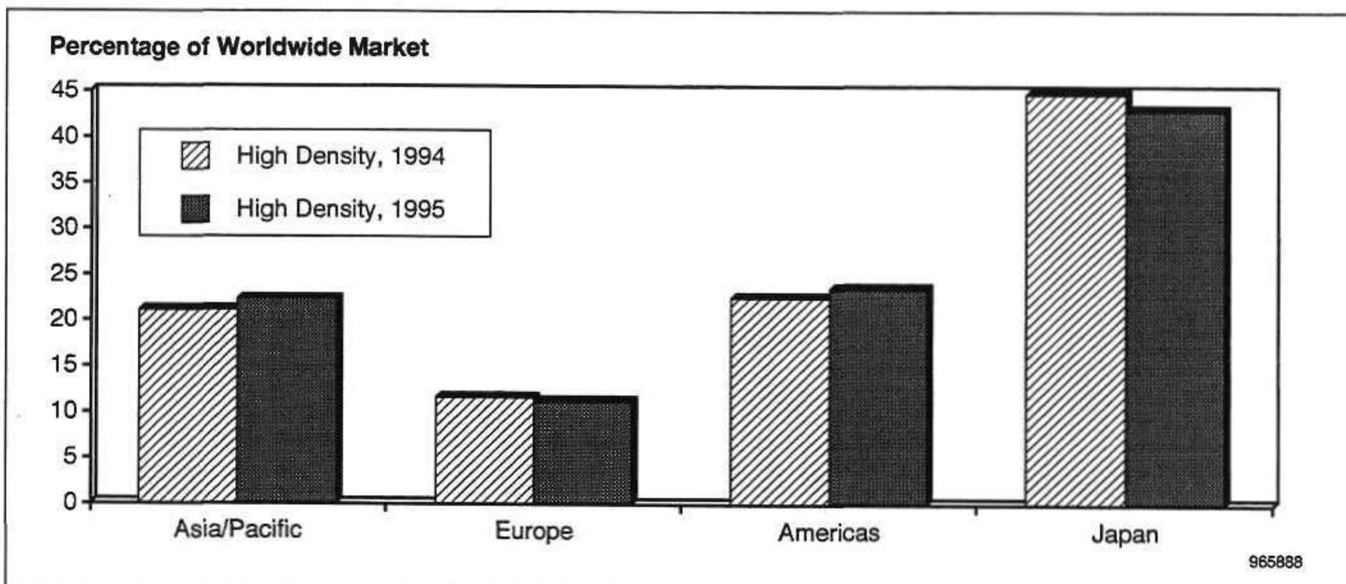
Dry etch equipment market growth is moderating after three years of dizzying megagrowth. Dataquest estimates that the worldwide dry etch equipment market will grow by 17 percent on a revenue basis in 1996 compared to 1995, versus a 17.1 percent rise in the overall wafer fab equipment market. Although Dataquest expects the dry etch market, as well as the overall equipment market, to show a significant contraction in 1997, the long-term outlook is very positive for the dry etch market.

Figure 2
Change in Regional Contributions to the Worldwide Low-Density Dry Etch Market, 1994-1995



Source: Dataquest (August 1996)

Figure 3
Change in Regional Contributions to the Worldwide High-Density Dry Etch Market, 1994-1995



Source: Dataquest (August 1996)

As device geometries shrink and the manufacturing process flow becomes more complex, the number of dry etch steps required in the process grows. More dry etch steps means greater unit demand of dry etch systems. Also, in the sub-0.5-micron linewidth regime, high-density plasma etchers will be imperative for critical etch applications. The adoption of high-density etch systems will displace the traditional low-density reactive ion etch (RIE) etch sources and provide the impetus for continuing growth in etch system shipments. The requirement of high-density etch in all film etch applications will also result in increases in average selling prices. Thus, growth in unit system demand and the higher ASPs that accompany the higher mix of advanced etch systems are the principal driving forces for the long-term growth in dry etch sales.

Table 3 presents Dataquest's forecast for dry etch equipment sales, segmented by film application. The year 1996 is shaping up to be solid, with growth expected in every dry etch segment except silicon trench etch. The current slowdown in DRAM investment is putting a damper on silicon trench etch, almost exclusively used for fabrication of DRAM trench capacitors. Looking beyond the slump of 1996 through 1997, however, silicon trench etch growth is projected to pick up steam quickly from the adoption of shallow trench isolation as well as the continuing use of trench capacitors in next-generation DRAM. Dry etch for polysilicon and polysilicon/silicide stack etch applications is also a DRAM-sensitive market. Dataquest projects a significant slowdown during the next couple of years while the chip manufacturers are busy absorbing the large memory IC capacity put on line during the fab-building frenzy of the past few years. Investment should begin to kick in for the 64Mb/256Mb generations of DRAM in 1999. Projected growth for polysilicon/polycide dry etch from 1995 to 2001 is a healthy 15.2 percent compound annual growth rate (CAGR).

Table 3
Worldwide Dry Etch Equipment Market History and Forecast, by Film Type (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Oxides	376.8	600.8	1,134.4	1,370.8	1,191.5	1,217.0	1,485.4	2,132.5	2,822.0	16.4
Plasma Nitride	15.9	24.6	46.7	51.9	46.4	46.4	58.9	77.9	99.7	13.5
LPCVD Nitride	23.9	34.3	64.4	73.1	64.1	62.3	74.6	100.5	128.6	12.2
Others	12.2	15.4	18.9	19.9	14.4	14.8	14.6	16.9	19.7	0.7
Metal	339.4	511.1	913.5	1,033.8	884.3	910.4	1,106.0	1517.7	1,928.6	13.3
Poly/Polycide	302.4	386.3	625.9	744.6	646.0	662.3	846.6	1,210.1	1,462.2	15.2
Silicon/Trench	12.3	19.1	38.0	29.9	24.4	40.8	52.0	71.8	99.1	17.3
Total Dry Etch Market	1,083.0	1,591.6	2,841.8	3,324.0	2,871.0	2,954.0	3,638.0	5,127.3	6,559.8	15.0

Source: Dataquest (August 1996)

As shown in Table 3, oxides etch is expected to remain the largest etch application segment and is projected to grow at a healthy clip, with a 16.4 percent CAGR from 1995 through 2001.

The trend in the semiconductor industry toward increasing use of multilevel interconnection is driving the demand for oxide. The number of interconnect layers in logic/ASIC devices could rise from an average of three layers in 1996 to five layers by the year 2000. In DRAM manufacturing, three interconnect layers, as opposed to today's two layers, will begin to be introduced at the shrink 64Mb generation a few years from now. Moreover, ASPs for oxide etch systems will continue to rise, with new advanced oxide etchers delivering superior performance that permits etch of ever-smaller contact and via holes with good profile control and selectivity. Increases in ASP and unit shipments of oxide etch are expected to help dielectric etch (including oxide, LPCVD nitride, PECVD nitride, and others) to raise its contribution to the overall dry etch market revenue, achieving more than U.S.$3 billion in sales, or 47 percent of the total etch market, by the year 2001.

A major concern surrounding the metal etch technology in the sub-0.5-micron regime is the reliability of metal interconnect. Multilayer stacked structures consisting of different metal films are now commonplace. Many of these films require different etch chemistries integrated in a flexible, multichamber platform. Also required is an in-situ clean module for the prevention of corrosion from etch residues. The increasing technology demand will drive the ASPs of future metal etch offerings. This, in conjunction with the continued rise in interconnect levels that drives the unit demand of metal etcher, bodes well for the overall health of the metal etch market for the remainder of the 1990s.

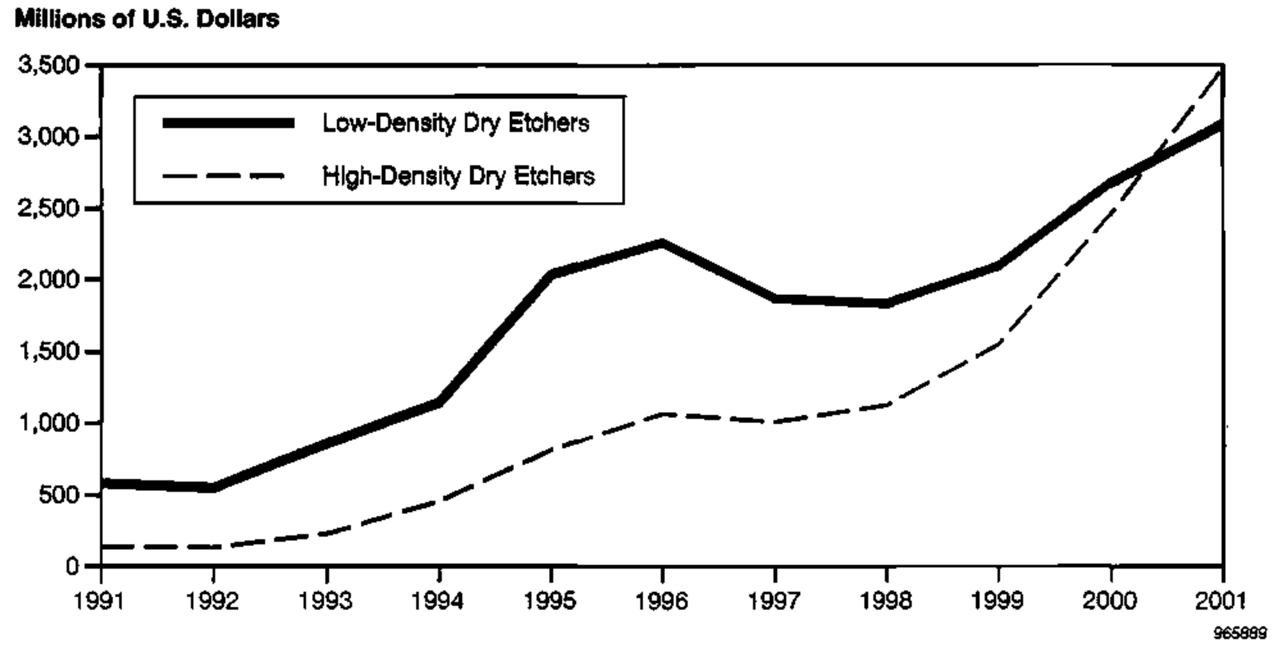
The long-term threat to metal etch is the possibility of an eventual adoption of (dual) damascene processes in semiconductor manufacturing. The rapid success in recent years of chemical mechanical polishing as an accepted planarization technology is fueling the belief that, as device geometries continue to shrink, fabrication of metal interconnect will be easier to achieve by deposition rather than by dry etch. It is almost a foregone conclusion that damascene processes will eventually be adopted in IC manufacturing, initially in advanced logic/ASIC devices and later in other devices. The question is when damascene will enter into production, and, hence, when metal etch sales will begin to be impacted. Dataquest believes that implementation of damascene processes will most likely begin at the 0.18-micron generation, which is projected to enter the scene after the year 2000. This means that there should be at least five more years of stable market opportunities for metal etch systems.

Mix and Match: High-Density versus Low-Density Etch

The dry etch market is now a two-tier market, with growth split between the conventional low-density plasma etch systems and advanced, high-density plasma etchers. The segmentation between low-density and high-density etch applications falls at about the 0.5-micron linewidth level.

The 4Mb/16Mb DRAM capacity expansions of recent years have boosted the demand for low-density etchers capable of fabricating features down to about the 0.5-micron level. For 0.35-micron etch and critical etch applications that require stringent profile control, selectivity, microloading, and pattern sensitivity, high-density etchers are imperative. High-density etchers, sporting a variety of sources (for example, Inductive-Coupled Plasma, Transformer-Coupled Plasma, High-Density Reflected Electron, and Decoupled Plasma Source), must be capable of operating in low pressure (from a few to 10 mTorr) without compromising wafer throughput. Dataquest believes that high-density etch will be the principal beneficiary of the growth in dry etch as device geometries continue to scale down. Figure 4 projects the worldwide dry etch equipment market, segmented by low-density and high-density etch sales.

Figure 4
Worldwide Dry Etch Equipment Market Segmented by Technology



Source: Dataquest (August 1996)

During the first half of the 1990s, high-density etch emerged from a modest beginning to become a vital part of the etch market, garnering more than 28 percent of total dry etch revenue in 1995. With the adoption of the 0.35-micron/0.25-micron processes and the spread of critical etch applications driving high-density etch demand, high density sales are expected to grow rapidly and capture nearly half of all dry etch sales by the year 2000. Although the wind is filling the sails of high-density etch, low-density etch will continue to be a mainstay of semiconductor manufacturing. Future semiconductor processes will consist of a combination of critical and noncritical steps. While the number of noncritical etch steps will decline as a percentage of overall process sequences, the decline will moderate and eventually taper to a stable level. The mix and match of high-density and low-density etchers to achieve the optimal overall productivity and cost of ownership will be the overriding theme that shapes the dry etch market.

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Perspective

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Market Analysis

Polysilicon Supply/Demand Update: The Industry Responds and Relief Is in Sight, but only after 1997

Abstract: *Polysilicon, the raw material for all silicon wafers supplying the semiconductor industry, has been under threat of shortage. In a Focus Report published in November 1995, Dataquest outlined the details of an impending shortage starting late in 1996. With the recent downgrading of semiconductor forecasts, the question is—will this shortage happen? With a continued strong wafer forecast driven by unit demand primarily, the shortage in polysilicon is inevitable. Since the report in November, there have been several announcements for increased polysilicon capacity. In this article, Dataquest provides an update to the supply and demand outlook for polysilicon.*
By Clark J. Fuhs

Why is Polysilicon Production Critical?

All single crystal silicon wafers manufactured for the semiconductor industry come from the same raw material—pure silicon. Industrial metal grade is not pure enough for semiconductor applications, so the silicon must be purified through chemical processing. The method initially converts the industrial-grade metal silicon to a gaseous or liquid silicon compound, such as silane or trichlorosilane, and then processes the chemical through distillation or another purification method to produce a very high-grade chemical. Once purified, the silicon-containing material is then broken down to its components through a form of thermal decomposition to produce semiconductor-grade silicon in the shape of rods or granules. Because this crystallization process produces a polycrystalline material, the industry refers to this material as polysilicon. This material, after being

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broken into usable-size pieces, is purchased by wafer manufacturers to melt before the single crystal growing process. The purification process is a semiconductor industry requirement, and therefore it becomes a potential bottleneck in the production of silicon wafers.

Supply-Side Forecast Through the Year 2001

Based on known and estimated expansion plans, Dataquest has developed a supply forecast for polysilicon production through the year 2001. This forecast is shown in Table 1. It should be noted that these figures refer to actual annual production estimates and not facility capacity at the end of the year. In many cases, we have factored ramp-up schedules to arrive at annual production estimates. We should note that these figures do not include production out of Ukraine, which has recently started again. Dataquest estimates current production at 100 tons per year, but we are unclear on ramp plans.

Demand Forecast for Polysilicon

Before presenting our actual demand forecast, a discussion about the approach, methodology, and assumptions used is in order. All our forecast analyses have as a starting basis the wafer slice forecast by wafer size, presented in Table 2 and in Dataquest's midyear 1996 forecast Market Trends Report (SEMM-WW-MT-9602, expected in early August 1996).

Using this data and forecast as a basis, the next step was to apply an estimate for the average number of grams of polysilicon used to manufacture one good polished wafer. In terms of grams per square inch, this figure varies among the different wafer sizes. For example, just over 3.1 grams per square inch was assumed for 100mm wafers, increasing to about 4.4 grams per square inch for 200mm wafers. The average per year varies based on the wafer size mix in the forecast. When these assumed values are multiplied and added, the result is gross polysilicon demand in kilotons per year.

Factors to Consider: Test Wafer Use and Wire Saws

In Dataquest's November report, we suggested two factors that could reduce polysilicon demand from the above methodology. The first was demand-related—the reduction in consumption of virgin test wafers, either by reduced test wafer use or by the alternate use of reclaimed wafers. For this update, we have factored in this reduced use in the overall silicon and wafer size forecast and therefore do not need to consider it in a special way here.

The second factor was the implementation of wire saw technology in the production process, which has the capability of increasing ingot yield. This was technology in its infancy a year ago, but technology leaders such as Shin-Etsu Handotai and Wacker Siltronic are understood to be applying the technology fairly aggressively today. In the process of making wafers, the grown ingot needs to be sliced into individual wafers. The most common approach is to use a diamond edge rotary saw with the cutting edge in the interior diameter for vibration stability, commonly referred to as an ID saw. In any sawing operation, sawdust is created, referred to as "kerf" loss, representing wasted polysilicon material.

Table 1
Worldwide Actual and Projected Polysilicon Annual Production by Supplier, 1993-2001 (Thousands of Metric Tons per Year)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
U.S. Production										
Advanced Silicon Materials	1.10	1.10	1.10	1.20	1.60	2.10	3.20	4.00	5.40	5.90
Hemlock Semiconductor	1.40	1.40	2.30	2.80	3.40	4.20	5.00	5.40	6.00	6.60
MEMC Granular Polysilicon	0.60	0.65	0.85	1.10	1.30	1.90	2.50	2.70	2.70	2.70
Mitsubishi Materials	0	0	0	0	0	0	0.80	1.50	1.50	1.50
Japan Production										
Kojundo Silicon (Hi-Silicon)	0.80	0.90	1.10	1.20	1.40	1.40	1.40	1.40	1.40	1.40
Komatsu Electronic Metals	0.03	0	0	0	0	0	0	0	0	0
Sumitomo Sitix	0.50	0.45	0.45	0.45	0.45	0.70	0.70	0.70	0.70	0.70
Tokuyama Corporation	1.10	1.15	1.65	1.65	2.20	3.00	3.00	3.00	3.50	4.00
European Production										
MEMC (Huls)	0.40	0.70	0.75	0.75	0.75	0.90	0.90	0.90	0.90	0.90
Wacker Siltronic	2.30	2.30	2.40	2.40	2.50	2.75	3.35	3.60	5.00	5.00
Worldwide Total	8.23	8.65	10.60	11.55	13.60	16.95	20.85	23.20	27.10	28.70

Source: Dataquest (July 1996)

Table 2
Worldwide Wafer Forecast by Diameter, 1993-2001 (Millions of Wafer Slices per Year)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Unit Distribution by Wafer Starts (Millions of Wafers)										
2 inches	1.0	1.0	0.9	0.9	0.4	0.3	0.2	0	0	0
3 inches	6.3	5.6	5.6	5.5	5.2	4.7	4.5	4.3	3.7	3.6
100mm	32.3	32.2	35.3	37.9	34.4	32.2	30.7	29.9	30.5	29.9
125mm	36.3	37.0	37.7	39.3	37.8	35.5	34.3	33.1	33.8	33.3
150mm	33.2	42.0	49.9	58.1	64.0	66.3	68.1	71.7	83.0	96.3
200mm	1.2	3.2	7.3	14.0	24.1	33.4	41.5	50.2	58.8	65.5
300mm		0	0	0	0	0	0	0.2	0.4	0.7
Total Wafers (M)	110.3	121.0	136.6	155.7	165.9	172.4	179.4	189.4	210.2	229.3
Average Wafer Diameter (Inches)	4.92	5.07	5.21	5.37	5.61	5.79	5.92	6.05	6.14	6.20

Source: Dataquest (July 1996)

Thin metal wire rotating at high speeds, in conjunction with an abrasive slurry/coolant, is the core concept of the wire saw. The cut consumes less distance between wafer slices, with less wasted material, and therefore polysilicon use becomes more efficient in terms of grams per wafer. We have assumed that kerf losses can be reduced by about 30 percent (we have heard of reductions from 20 to 50 percent).

Probable Demand Scenario Compared with Supply

Wire saw technology is factored into our polysilicon demand scenario; however, the technology will not be fully implemented across the entire installed production base for 200mm wafers and will be only moderately implemented into 150mm and smaller wafers (see Table 3).

By comparing the supply from Table 1 with the demand methodology and assumptions, we can create a supply and demand analysis that calculates either a shortage or the industry inventory levels from 1995 to 2001. This is shown in Table 4.

Dataquest estimates that the industry's stock inventory of polysilicon was 2,730 metric tons at the end of 1994 (1,730 in Japan), down to about 900 metric tons at the end of 1995 (725 in Japan). By the middle of 1996, we would expect this inventory to have been depleted, and indeed we are starting to hear of instances in which some wafer manufacturers will not be getting all the polysilicon they desire in the coming year. We believe these instances may be limited to smaller companies and companies that do not have an internal source of supply.

Table 3
Wire Saw Technology Market Penetration Assumptions (Percentage of Capacity at a Particular Diameter)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Percentage of Market by Wafer Size										
2 inches	0	0	0	0	0	0	0	0	0	0
3 inches	0	0	0	0	0	0	4	4	4	4
100mm	0	0	0	0	0	2	5	5	5	5
125mm	0	0	0	0	0	2	5	5	5	5
150mm	0	0	0	0	2	4	8	10	10	10
200mm	0	0	0	5	20	45	60	75	85	90
300mm	0	0	0	0	0	0	100	100	100	100

Source: Dataquest (July 1996)

Table 4
Polysilicon Supply/Demand Scenario—Probable Case (Wire Saw Technology Impact Included; Metric Kilotons per Year)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Polysilicon Demand	7.60	9.01	10.88	13.38	15.72	17.24	18.52	20.16	22.84	25.35
Polysilicon Production	8.23	8.65	10.60	11.55	13.60	16.95	20.85	23.20	27.10	28.70
Net Annual Surplus (or Deficit)	0.63	-0.36	-0.28	-1.83	-2.12	-0.29	2.33	3.04	4.26	3.35
Industry Stock (or Shortage)			2.73	0.90	-1.22	-0.29	2.33	5.37	9.63	12.98
Industry Stock Inventory (Months)			2.7	0.7	0	0	1.4	3.0	4.8	6.1

Source: Dataquest (July 1996)

By 1998, however, the production of polysilicon will again be above projected consumption because the polysilicon suppliers have stepped up investment in capacity. Announcements in the last nine months include Advanced Silicon Materials, MEMC Granular Polysilicon, and Mitsubishi Materials in the United States, and Wacker Siltronic in Europe. These capacity additions will put polysilicon production into the safe zone near the end of 1997, and we would expect polysilicon prices to ease somewhat at that time. However, we would expect buyers of polysilicon to maintain the position of purchasing all that is produced until 1999 in order to build the industry's capacity to a more comfortable two-month to three-month level, meaning that more significant price reductions will wait until then.

One interesting thing to note is that the industry has the capability to swing back into glut by the year 2000 should all plants announced be fully ramped. The price pressures from such a condition would cause investments in greenfield polysilicon plants to have unfavorable returns. Dataquest believes that polysilicon producers are likely to cut back the expansion plans noted in Table 1 after 1999 for these reasons.

A Look at the Highest Demand Scenario

Just for curiosity, what would the supply and demand picture look like if wire saws were not implemented beyond the 1995 level? This is a highly unlikely scenario, but it is one that would put an upper limit on polysilicon demand, in our view. This supply and maximum demand picture is presented in Table 5.

Clearly, this maximum demand picture represents a case for tight polysilicon supply until the year 2000, but it also shows that the plans for capacity additions already announced will adequately cover this demand. It is now highly probable that the next announcement in the polysilicon capacity arena will be about reduction rather than expansion.

Table 5
Polysilicon Supply/Demand Scenario—Maximum Demand Case (Minimum Wire Saw Technology Impact; Metric Kilotons per Year)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Polysilicon Demand	7.60	9.01	10.88	13.38	15.95	17.94	19.72	21.93	25.16	28.10
Polysilicon Production	8.23	8.65	10.60	11.55	13.60	16.95	20.85	23.20	27.10	28.70
Net Annual Surplus (or Deficit)	0.63	-0.36	-0.28	-1.83	-2.35	-0.99	1.13	1.27	1.94	0.60
Industry Stock (or Shortage)			2.73	0.90	-1.45	-0.99	1.13	2.40	4.33	4.94
Industry Stock Inventory (Months)			2.7	0.7	0	0	0.7	1.2	2.0	2.1

Source: Dataquest (July 1996)

Dataquest Perspective

With wafer unit demand forecasts intact, the inevitable shortage in polysilicon will happen later this year. The fact remains that industry inventories of polysilicon raw material have decreased in 1994 and 1995 because consumption exceeded production. Industry inventories in polysilicon will be exhausted during 1996. PC unit growth would have to decline to about 5 percent in 1996 to avoid this situation (which, by the way, would tend to drive the semiconductor market to an actual decline of more than 10 percent in 1996). Dataquest just does not see this happening.

Since the report on the supply/demand situation in November, there have been several announcements about increased polysilicon capacity. This will drive production to exceed consumption starting in late 1997 and continuing through the decade. However, the industry operates efficiently with some inventory in the channel, and it will take until 1999 for the industry to get back to the two-month inventory level considered to be the minimum for comfortable operation. So we would expect tight (although not short) conditions to exist in the market through 1999.

It appears that our forecast last November of a polysilicon shortage starting the second half of 1996 but lasting only a relatively short time (one year) is coming to pass. The industry effectively responded without the introduction of new suppliers into the market, thereby confirming a strong industry infrastructure. It is also interesting that most of the expansions and new plants are in the United States, which we believe is a response driven by two factors: the lower cost of capital in the United States than in Japan and the migration of production capacity recently of both fabs and wafer manufacturing facilities by foreign companies to the United States.

Will the impending polysilicon shortage hamper semiconductor industry growth? The danger is there, but we stop short of saying that semiconductor market revenue will suffer purely as a result of this particular shortage. The semiconductor companies will do everything in their power to prevent that. What can they do? Consumption of test wafers will be reduced relative to prime wafers, forced by the lack of availability. We suspect that specifications for prime wafers will have to be loosened temporarily in order to accept more of the production mix into prime product wafer starts. As virgin test wafer consumption is forced, the reclaimed wafer market should continue booming, although this should subside by the end of 1997. The initial shift may cause yields to suffer temporarily, but semiconductor companies will choose this route over wasting the wafer for no revenue.

A Review of Polysilicon Producers

There are only a handful of polysilicon producers in the world, and the top two producers supplied just about 45 percent of the world's requirements in 1995. The suppliers fit into three basic categories: captive, hybrid-captive, and merchant.

Captive Producers

Captive producers are silicon wafer manufacturers that have polysilicon production within their companies and consume virtually all the material internally. Sumitomo Sitix and MEMC Electronic Materials (Hüls) are considered captive producers by Dataquest. Also, Mitsubishi Materials has just announced a new joint-venture plant in the United States starting production in 1998. For now, Dataquest classifies this as a captive producer, although in the future a portion of this production may be made available to companies outside Mitsubishi Materials. All these producers use the trichlorosilane process in the production of polysilicon.

Hybrid-Captive Producers

The category of hybrid-captives designates silicon companies that produce polysilicon and that consume the majority of their production. A minority portion, therefore, is sold to other silicon wafer producers. However, for this class of producer, distribution outside the company is limited to a small number—either the amount of polysilicon or the number of companies to which polysilicon is sold. Two companies fall into this category.

MEMC Granular Polysilicon (formerly Albemarle Corporation)

The Granular Polysilicon division of MEMC Electronic Materials is the only producer of polysilicon in granular, or pellet, form. The nature of the proprietary fluidized bed reaction process creates polysilicon in this form rather than conventional rod or block form. Albemarle first commercialized this process in 1987 when it was a division of Ethyl Corporation. The plant in Pasadena, Texas, and the polysilicon operations were spun off to Albemarle Corporation in 1993. In 1995, MEMC acquired 85 percent of the operation and has restructured it as the Granular Polysilicon division of MEMC. Because this form of polysilicon requires special feeding equipment to be attached to the crystal growers, the material has gained only limited acceptance, and during 1995 it is estimated that MEMC has consumed 90 percent of the production from this plant. Because the amount of material now being shipped outside of MEMC represents less than 10 percent, Dataquest considers this operation to be a hybrid-captive. We understand that the granular polysilicon produced will be available for sale outside of MEMC, although it is expected that the vast majority of production will continue to be locked up by MEMC.

MEMC has just announced that it will invest in more internal production from this facility for production starting in 1997. The key advantages of the granular form are believed to be clearly evident for 300mm wafers, but we do not expect demand for polysilicon driven by 300mm wafers to be significant before 2002. After then, we would expect MEMC to aggressively expand the capacity of this operation.

Kojundo Silicon (Hi-Silicon)

Hi-Silicon Co. Ltd. (also known as Kojundo Silicon) is located in Yokkaichi City, Mie Prefecture, Japan. Hi-Silicon was formed in 1967 as a 50-50 joint venture between Mitsubishi Metal (now Mitsubishi Materials) and Osaka Titanium Company (now Sumitomo Sitix). In October 1987, Osaka Titanium announced that it had sold its 50 percent position in Hi-Silicon to Mitsubishi Metal for an undisclosed sum. Mitsubishi Materials Silicon currently consumes more than half the production from this operation, with the remainder distributed to a limited number of companies. For this reason, Dataquest considers Hi-Silicon a hybrid-captive producer.

Dataquest estimates that Hi-Silicon's production in 1995 expanded slightly to 1,200 tons, which will then grow and be capped at 1,400 tons in 1996 through 1998. Hi-Silicon uses the trichlorosilane process in producing polysilicon. A major expansion is forecast, with production starting to ramp during 1999.

Merchant Producers

Merchant producers are those companies that have a wide distribution of silicon wafer companies as customers. As is customary in this industry, consumption of polysilicon can be concentrated and can account for a large block of production capacity for even the largest producer. There are four merchant producers, and these four also happen to rank as the four largest producers.

Advanced Silicon Materials, Inc.

Even though Advanced Silicon Materials (ASiMI) is owned by Komatsu, a silicon wafer manufacturer, and Komatsu consumes a significant portion of capacity (but estimated at less than 50 percent), ASiMI's wide distribution qualifies it as a merchant supplier with over a dozen outside customers. ASiMI's plant is located in the Pacific Northwest region of the United States, in Moses Lake, Washington.

ASiMI manufactures polysilicon by a proprietary method that converts trichlorosilane first to monosilane gas. This method, known as the Komatsu method, refines the silane gas to high purity, then decomposes it into very high-purity polycrystalline silicon material. This high-grade material has advantages in the float-zone crystal growing process. An example of devices that use float-zone crystal is high-voltage power devices.

Dataquest estimates that ASiMI is running its plant at essentially full capacity, producing 1,200 metric tons during 1995. ASiMI is expanding its facilities to a 2,100-metric-ton capacity, to be completed later this year, and has announced a major new facility in Montana starting production in 1998. When both phases of the new plant are complete, it is expected that ASiMI's capacity will be 5,900 metric tons for all plants. It will be after 2000 before this capacity is realized, however.

In addition to its internal use of silane in polysilicon production, ASiMI is also a major supplier of high-purity silane to the semiconductor industry for processing applications such as epitaxy and chemical vapor deposition (CVD).

Hemlock Semiconductor Corporation

Initially formed as a wholly owned subsidiary of Dow-Corning, Hemlock built its first polysilicon plant starting production in 1963. Hemlock gets its name from the city where the plant was built—Hemlock, Michigan, a bit northwest of Detroit. In 1984, Hemlock became a joint-venture company, with two major silicon wafer manufacturers purchasing interests in the company. Shin-Etsu Handotai and Mitsubishi Materials Silicon own 24.5 percent and 12.25 percent, respectively, while Dow-Corning retained 63.25 percent ownership.

Hemlock takes the honor of being the largest producer of polysilicon, with an estimated production of 2,800 tons in 1995 (about 24 percent of the world's production) and capacity of 3,400 tons by the end of the year. Hemlock is expanding aggressively, bringing Phase I of an expansion fully on line in 1995, with a Phase II recently accelerated to be ready to start production at the beginning of 1997. No formal commitment has been made to Phase III, but Dataquest estimates that Hemlock will implement Phase III to start production in late 1999 or early 2000. This expansion will propel Hemlock clearly ahead of Wacker Siltronic as the largest producer of polysilicon.

Although a good portion of its capacity is allocated to the joint-venture companies, Hemlock enjoys a broad list of customers as a merchant supplier. Hemlock uses the trichlorosilane process to produce polysilicon rods and chunks. Its manufacturing techniques are linked to a chemical manufacturer, Dow-Corning, for a supply of the liquid trichlorosilane. Dow-Corning's plant in Midland, Michigan, is responsible for the production of this liquid chemical from metal silicon.

Hemlock is also a supplier of high-purity silicon tetrachloride, serving a niche market in fiber optics and some medical applications. This is a natural byproduct of the manufacturing process.

Tokuyama Corporation

Tokuyama is unique in the polysilicon market in one respect—it is the only company that is not at least partly owned by a silicon wafer manufacturer, and it is ranked as the third-largest polysilicon producer, with an estimated 1,650 tons of production in 1995. An improvement and expansion of the company's plant will take this total to 2,000 tons in 1996, and Tokuyama recently announced a new plant that will expand its capacity to 3,000 tons starting at the beginning of 1997.

Tokuyama Soda entered the polysilicon market in 1984, and by 1985, its 1,200-ton plant was the largest of its kind in Japan. Tokuyama also uses the trichlorosilane process in the production of polysilicon. Silicon tetrachloride, a high-grade byproduct of the process, is used by Tokuyama Soda as the raw material for a fumed silica used in several applications in electronics, including encapsulation materials for semiconductor packaging.

Wacker Siltronic AG

Wacker Siltronic AG has the distinction of being the most experienced company in the polysilicon manufacturing business. Initially built in the late 1950s, Wacker Siltronic's Burghausen facility continues to use the trichlorosilane process to produce polysilicon. Wacker has a completely integrated production system, similar to Tokuyama's, starting with raw silicon metal.

Wacker Siltronic has narrowly lost the lead in the production of polysilicon to Hemlock, producing an estimated 2,400 metric tons in 1995 (versus Hemlock's 2,800). Wacker Siltronic has continually expanded to meet its own and its customer's demands and is expected to double production by the year 2000.

Even though Wacker Siltronic consumes more than half its own production of polysilicon, it has a broad customer base in the silicon wafer market. This broad base of customers qualifies Wacker Siltronic as a merchant supplier. Wacker is also a major manufacturer of high-grade chlorosilanes and ultrapure hydrogen chloride, natural by-products of the manufacturing process, and through the Wacker Chemie group also produces fumed silica, used in electronics packaging and other consumer goods.

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Market Analysis

A Fresh Look at 200mm Wafer Supply and Demand: Still Tight Longer Term

Abstract: *The 200mm wafer market has been tight for many months. How are suppliers ramping to meet the need? In a Focus Report published by Dataquest in November 1995, we described an undersupply shaping up for 1996. Since that time, suppliers have significantly increased and accelerated their 200mm plant construction plans. Also, semiconductor manufacturers have placed emphasis on the reduction of test wafer consumption. But the lower and still-decreasing factory utilization rates in the semiconductor industry (caused by too much fab equipment) have given fabs the opportunity to convert from 150mm wafers to process the more cost-effective 200mm wafers. So where does that leave the balance for wafer supply? In this article, Dataquest provides an update to the supply and demand situation for 200mm wafers.*
By Clark J. Fuhs

Methodology for 200mm Wafer Supply and Demand

The analysis for this part of the market is relatively straightforward in concept. Demand is driven by fabs, their ramp-up schedules, whether the products produced require epitaxial wafers, and what the test wafer consumption ratio is during the ramp and life of the fab. Dataquest's analysis takes advantage of our comprehensive fab database to drive a bottom-up derivation of the 200mm wafer demand, using a fab-by-fab process. This demand is segmented by polished wafers, epitaxial wafers, and test/monitor wafers. Test and monitor use was based on each semiconductor company's usage styles and products produced (a higher percentage is used for higher revenue per square inch product segments, such as microprocessors), as well as the age of the fab. (Near the start-up, a higher percentage of test wafers is used.) Availability of supply was not considered.

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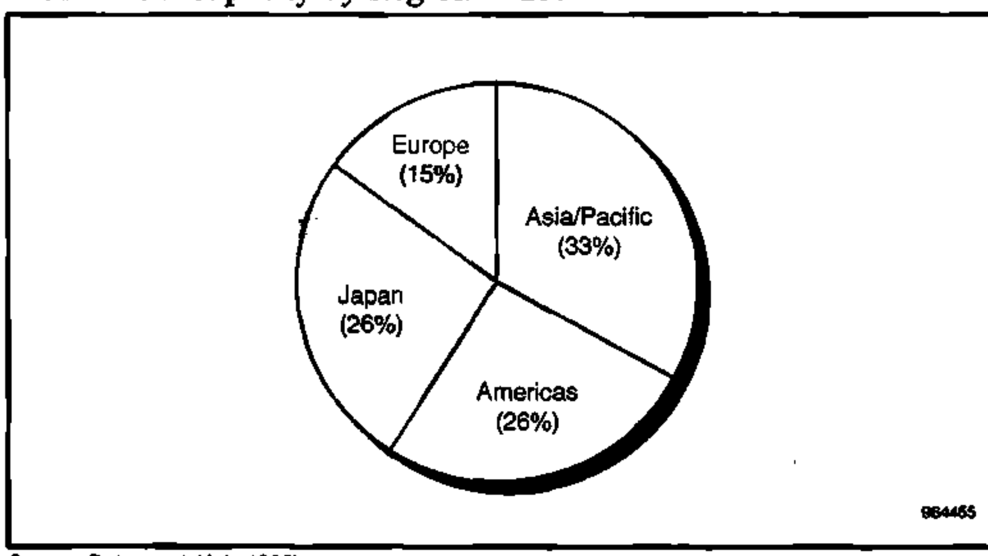
Supply is driven by silicon wafer manufacturing plant construction by the silicon wafer industry. New silicon wafer plants are required because the existing 150mm wafer plants cannot be upgraded cost-effectively—an entirely new toolset is required for manufacturing 200mm wafers. Dataquest recently completed a survey of the planned capacity expansions for the industry, and we have assumed some ramp schedules associated with these new plants.

Comparing these two parts of the market can describe the situation cleanly when considered within the concept of silicon plant utilization.

The Demand for 200mm Wafers Remains High

Demand for 200mm wafers is expected to increase to over 4.6 times the 1995 consumption by the year 2001. At the end of 1995, there were 49 fabs in operation processing 200mm wafers. Including several conversions from 150mm wafer fabs expected to occur in the next several years, such as all three Micron Technology fabs in Idaho, Dataquest expects 234 fabs to be in operation processing 200mm wafers by the year 2001. Not all these fabs have been announced to date, and we have taken a long-term approach when estimating this number. Figure 1 shows the capacity split by region in terms of 200mm wafer starts expected by the year 2001.

Figure 1
200mm Fab Capacity by Region in 2001



Source: Dataquest (July 1996)

What about all the fab delays the industry is experiencing today? In our fab-by-fab analysis, we were extremely conservative when taking into consideration fab announcements in 1997 and 1998, particularly if the primary product was memory. Although many fab delays have been announced and been realized, we elected in this analysis to anticipate further announcements of delays. We analyzed this factor on a company-by-company basis, giving the nod to industry technology and product leaders such as Toshiba, Samsung, IBM, Texas Instruments affiliates, and NEC while bringing under scrutiny many second-tier companies. Winbond, for example, with its connection to Toshiba, was viewed as a slow ramp-up fab during 1997 and 1998, while Hualon Microelectronics Corporation's Fab 2 project, originally planned for 1996, was assumed to be pushed out significantly into late 1998, although no formal commitment has been made. In this way, we have factored into our analysis the recent negative shorter-term forecast for capital spending just released by Dataquest.

The demand based on this analysis is summarized in Table 1 on a regional basis. We note that test wafer usage on a percentage basis is significantly lower than was the case in our November 1995 report. Although the absolute demand for test wafers is lower in our long-term outlook, the consumption of 200mm wafers for semiconductor products has been raised (by about 5 percent in the year 2000, as an example). This increased demand for product wafers is the direct result of the semiconductor industry's having the opportunity to convert fabs running 150mm wafers to the more cost-effective 200mm wafers.

Supply of 200mm Wafers: The Silicon Industry Has Responded

One year ago, silicon wafer suppliers were still getting used to being a profitable industry again after a very long dry spell. With much better free cash flow today, silicon wafer manufacturers have much longer visibility in their commitment to capacity expansion. A summary of the 200mm supplier survey is provided in Tables 2 and 3.

The committed supply of 200mm wafers is significantly higher than that outlined in Dataquest's November 1995 report (by about 30 percent for the year 2000, for example). Several of the major suppliers have recently announced major plants and expansion, including two by MEMC Electronic Materials. The newest joint venture in Malaysia, MEMC Kulim, was announced earlier this year, and the proposal of a second Taisil plant in Taiwan has also been factored into this analysis. Also, both Sumitomo Sitix and Wacker Siltronic have raised their production commitment for later in this decade. The major difference has been the introduction of aggressive ramp-up schedules from the smaller but fast-growing companies, namely UniSil, LG-Siltron, Showa Denko, and Toshiba Ceramics. The latter two are planning to put in a significant epitaxial wafer capacity, as well, in anticipation of the requirements for epitaxial wafers by some Japanese companies for the 64Mb DRAM.

Supply and Demand Compared: Industry Plant Utilization Is Key

In Dataquest's November 1995 report there was such a mismatch between supply and demand that presenting raw numbers alone conveyed a potential shortage. Now that suppliers have responded with committed capital investments, we should actually take a look at factory utilization trends. Silicon plant utilization is a metric that captures the supply/demand dynamics and the effect on prices and capital spending in the sector.

Table 4 shows the supply and demand comparison for both the total 200mm wafer market and the subset of epitaxial wafers. Also calculated is the implied factory utilization for the silicon industry. In 1996, Dataquest estimates that plant utilization is about 90.4 percent.

In today's environment, we are hearing comments like, "We are shipping everything we make." This indicates that 90 percent to 91 percent represents full capacity, and a calculated number significantly *above 90 percent*

Table 1
200mm Wafer Demand Forecast By Region, 1994-2001 (Thousands of Wafers per Month)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1994-2001
Americas									
Prime	23.5	69.5	146.5	216.6	319.1	428.1	540.6	632.6	60.1
Epitaxial	46.0	81.2	125.5	179.1	218.8	273.8	332.3	382.3	35.4
Test/Monitor	117.7	202.3	306.9	399.6	426.8	452.8	461.3	469.3	21.9
Total	187.2	353.0	578.9	795.3	964.7	1,154.7	1,334.2	1,484.2	34.5
Japan									
Prime	71.4	139.9	279.4	394.2	503.2	644.2	774.2	875.2	43.1
Epitaxial	11.6	16.6	18.6	26.1	47.1	72.1	100.1	140.1	42.8
Test/Monitor	124.5	182.9	320.9	389.4	421.7	439.8	469.0	441.7	19.9
Total	207.5	339.4	618.9	809.7	972.0	1,156.1	1,343.3	1,457.0	32.1
Europe									
Prime	24.0	52.0	111.0	147.0	185.0	234.0	293.0	342.0	46.2
Epitaxial	6.0	23.0	49.1	81.0	125.0	181.0	221.0	244.0	NA
Test/Monitor	51.7	80.0	149.7	182.9	211.7	233.5	249.1	257.0	25.8
Total	81.7	155.0	309.8	410.9	521.7	648.5	763.1	843.0	39.6
Asia/Pacific									
Prime	71.0	171.0	284.0	450.0	613.0	790.0	990.0	1184.0	49.5
Epitaxial	0	4.0	11.0	18.0	32.0	46.0	60.0	70.0	NA
Test/Monitor	65.9	147.6	207.9	301.7	353.1	383.2	404.8	419.7	30.3
Total	136.9	322.6	502.9	769.7	998.1	1,219.2	1,454.8	1,673.7	43.1
Worldwide									
Prime	189.9	432.4	820.9	1207.8	1620.3	2096.3	2597.8	3033.8	48.6
Epitaxial	63.6	124.8	204.2	304.2	422.9	572.9	713.4	836.4	44.5
Test/Monitor	359.7	612.9	985.6	1273.6	1413.2	1509.4	1584.2	1587.6	23.7
Total	613.2	1,170.1	2,010.7	2,785.6	3,456.4	4,178.6	4,895.4	5,457.8	36.7
Test/Monitor (% of Total)		58.7	52.4	49.0	45.7	40.9	36.1	32.4	29.1

NA = Not applicable
Note: Analysis is driven by bottom-up fab ramp schedules; it depends only on anticipated demand, with no supply issues taken into consideration.
Source: Dataquest (July 1996)

Table 2
Estimated Total 200mm Wafer Production Capacity, 1994-2001
(Thousands of Wafers per Month Average, Including Those Used for Epitaxial Deposition)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1994-2001
MEMC Electronic Materials (and All Joint Ventures)									
United States	50	75	75	150	230	280	320	320	
Japan	10	40	60	75	80	80	80	80	
Europe	20	20	40	60	80	80	80	80	
Posco-Huls, Korea	70	160	240	300	320	320	320	320	
Taisil, Taiwan	0	0	50	125	210	235	280	350	
MEMC Kulim, Malaysia	0	0	0	25	95	145	150	150	
Total	150	295	465	735	1,015	1,140	1,230	1,300	36.2
Komatsu (and All Joint Ventures)									
United States	0	0	0	0	80	110	130	130	
Japan	40	110	160	160	160	160	160	160	
Taiwan	0	0	0	40	80	100	100	100	
Total	40	110	160	200	320	370	390	390	38.5
LG Siltron									
Korea	20	70	160	220	310	380	420	420	
Total	20	70	160	220	310	380	420	420	54.6
Mitsubishi Materials (Includes Siltec)									
United States	0	0	50	80	80	120	170	170	
Japan	40	80	225	300	300	300	300	300	
Total	40	80	275	380	380	420	470	470	42.2
NSC Electron									
Japan	10	10	20	35	40	40	40	40	
Total	10	10	20	35	40	40	40	40	21.9

(Continued)

Table 2 (Continued)
Estimated Total 200mm Wafer Production Capacity, 1994-2001
(Thousands of Wafers per Month Average, Including Those Used for Epitaxial Deposition)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1994-2001
Shin-Etsu Handotai									
United States	80	120	120	160	220	240	240	240	
Japan	120	180	180	220	290	320	320	320	
Malaysia/Taiwan	100	200	220	250	280	290	290	290	
Total	300	500	520	630	790	850	850	850	16.1
Showa Denko									
Japan	0	0	0	25	45	50	80	100	
Total	0	0	0	25	45	50	80	100	NA
Sumitomo Sitix									
United States	0	0	0	50	100	150	200	200	
Japan	100	170	270	320	320	320	320	320	
Total	100	170	270	370	420	470	520	520	26.6
Toshiba Ceramics									
Japan	30	60	125	240	350	450	550	600	
Total	30	60	125	240	350	450	550	600	53.5
UniSil									
United States	0	20	55	85	115	125	125	125	
Total	0	20	55	85	115	125	125	125	NA
Wacker Siltronic									
United States	20	20	60	130	200	200	200	200	
Europe	75	100	115	120	145	165	200	200	
Total	95	120	175	250	345	365	400	400	22.8
All Companies									
Total	785	1,435	2,225	3,170	4,130	4,660	5,075	5,215	31.1

NA = Not applicable
Note: These annual figures represent average production estimates for each year. Because the industry is ramping up, the capacity of each company is likely to be slightly higher at the end of each year.
Source: Dataquest (July 1996)

Table 3
Estimated 200mm Epitaxial Wafer Production Capacity, 1994-2001
(Thousands of Wafers per Month Average)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1994-2001
MEMC Electronic Materials (and All Joint Ventures)									
United States	25	30	40	65	85	100	125	145	
Japan	0	0	0	0	0	0	0	0	
Europe	5	5	5	5	5	5	5	5	
Posco-Huls, Korea	0	0	0	0	0	0	0	0	
Taisil, Taiwan	0	0	0	10	20	30	40	55	
MEMC Kulim, Malaysia	0	0	0	0	0	0	0	0	
Total	30	35	45	80	110	135	170	205	31.6
Komatsu (and All Joint Ventures)									
United States	0	0	0	0	6	6	6	6	
Japan	10	10	10	10	10	10	10	10	
Taiwan	0	0	0	0	0	0	0	0	
Total	10	10	10	10	16	16	16	16	7.0
LG Siltron									
Korea	0	0	0	0	10	10	20	20	
Total	0	0	0	0	10	10	20	20	NA
Mitsubishi Materials (Includes Siltec)									
United States	0	0	5	15	40	60	60	60	
Japan	5	15	15	30	30	30	30	30	
Total	5	15	20	45	70	90	90	90	51.2
Shin-Etsu Handotai									
United States	15	30	30	30	35	45	45	45	
Japan	17	20	40	40	60	60	70	70	
Malaysia	0	0	0	0	0	0	0	0	
Total	32	50	70	70	95	105	115	115	20.1

(Continued)

Table 3 (Continued)
Estimated 200mm Epitaxial Wafer Production Capacity, 1994-2001
(Thousands of Wafers per Month Average)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1994-2001
Showa Denko									
Japan	0	0	0	15	20	30	45	50	
Total	0	0	0	15	20	30	45	50	NA
Sumitomo Sitix									
United States	4	23	62	74	74	80	80	80	
Japan	19	20	22	28	28	22	22	22	
Total	23	43	84	102	102	102	102	102	23.7
Toshiba Ceramics									
Japan	0	0	10	35	70	90	130	150	
Total	0	0	10	35	70	90	130	150	NA
Wacker Siltronic									
United States and Europe Combined	30	30	50	60	75	90	100	100	
Total	30	30	50	60	75	90	100	100	18.8
All Companies									
Total	130	183	289	417	568	668	788	848	30.8

NA = Not applicable
Note: These annual figures represent average production estimates for each year. Because the industry is ramping up, the capacity of each company is likely to be slightly higher at the end of each year.
Source: Dataquest (July 1996)

Table 4
Worldwide 200mm Wafer Supply and Demand Summary, 1994-2001
(Thousands of Wafers per Month)

	1994	1995	1996	1997	1998	1999	2000	2001
Total 200mm Wafer Demand	613	1,170	2,011	2,786	3,456	4,179	4,895	5,458
Total 200mm Wafer Supply	785	1,435	2,225	3,170	4,130	4,660	5,075	5,215
Implied Plant Utilization (%)	78.1	81.5	90.4	87.9	83.7	89.7	96.5	104.7
Total Epitaxial Demand	64	125	204	304	423	573	713	836
Total Epitaxial Supply	130	183	289	417	568	668	788	848
Implied Plant Utilization (%)	48.9	68.2	70.7	72.9	74.5	85.8	90.5	98.6

Source: Dataquest (July 1996)

would suggest a shortage. In the second half of 1995, the industry probably crossed over the 85 percent utilization level, and about this time we heard of spot situations involving allocations. We would therefore regard the industry as having *tight supply above 85 percent utilization*. Prices began increasing from late 1994 to 1995 as the 80 percent utilization level was crossed. We would therefore regard industry pricing as *firm or stable above 80 percent utilization.*

How do these levels compare with the industry in the late 1980s, when prices were in decline? Given the fact that the key wafer size in demand was 150mm, that capacity was added in excess in 1984 and 1985, and that plant utilization for the industry was not likely much above 70 percent, it is evident that we are in a different environment today.

The analysis in Table 4 suggests that the DRAM slowdown (which has always been included in Dataquest silicon and capital spending forecasts in the last year for 1997 and 1998) will ease the supply/demand situation starting as early as later in 1996 before a renewed tight market in late 1998. This is the case even though the supply capacity of 200mm wafers will have nearly tripled in three years from 1995! Equipment manufacturers supplying the wafer manufacturers will be very busy for the next couple of years.

Epitaxial plant utilization is likely to remain between 70 to 80 percent, even though our analysis indicates higher figures later in the decade. Epitaxial capacity is fairly easy to add through incremental equipment purchases. A significant portion of the demand starting in 1999 is anticipated to come from Japanese companies that may use epitaxial silicon layers for the 64Mb DRAM. Because the epitaxial wafer is highly profitable, we would expect the industry to respond with capacity accordingly and quickly.

Factoring in the "Soft Commitment"

In Dataquest's May 1996 survey of silicon companies, there were several companies that would not necessarily commit to increased capacity until these companies saw demand remain firm. We would classify this potential supply as "soft commitment." We have not included this capacity in the previous tables, but we have totaled the capacity impact of all those making soft commitments as a group. Table 5 shows the level and impact on factory utilization when this new capacity is added. The scenario is basically the same as the outlook without this capacity, except that actual shortages could perhaps be pushed out a year. Again, we expect the industry to

Table 5
Worldwide 200mm Wafer Supply and Demand Summary Including "Soft Commitment" Supplies, 1994-2001 (Thousands of Wafers per Month)

	1994	1995	1996	1997	1998	1999	2000	2001
Total Confirmed 200mm Supply	785	1,435	2,225	3,170	4,130	4,660	5,075	5,215
Total "Soft" 200mm Supply	-	-	-	-	45	170	445	595
Total Supply Base	785	1,435	2,225	3,170	4,175	4,830	5,520	5,810
Implied Plant Utilization (%)	78.1	81.5	90.4	87.9	82.8	86.5	88.7	93.9

Source: Dataquest (July 1996)

respond to the increased demand but would not expect to see factory utilization levels below 80 percent for a long time.

Dataquest Perspective

The supply of 200mm wafers is expected to be relatively tight for the remainder of this decade and into the next. The industry may receive a brief respite later in 1997 and into 1998, but we expect it to be short-lived, because the next capital spending cycle should be in place by late 1998. Table 6 represents a concise summary of the annual characteristics of the market in terms of supply, pricing, and utilization.

Table 6
Summary of 200mm Market Supply/Demand Characteristics By Year, 1996-2001

Year	Industry Plant Utilization (%)	200mm Supply	Price Trends
1996	90+	Very tight	Increasing
1997	88	Tight but easing	Firm to slight easing
1998	83-84	Good but tightening	Stable to firm
1999	87-90	Tight	Firm to increasing
2000	89-90+	Very tight	Increasing
2001	90+	Very tight	Increasing

Source: Dataquest (July 1996)

Will semiconductor revenue be affected by the tightness in the 200mm wafer market? The answer is no. There is enough flexibility in this market in the area of test wafers that product runs will not be touched because of the lack of wafers. We feel confident that the silicon supplier will respond with increased capital spending, but we do expect plant utilization to be watched very closely.

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August 5, 1996

To our clients,

This report replaces Dataquest's "1995 North American Semiconductor Gas Market" (SEMM-WW-DP-9602, May 6, 1996), shipped previously. This version corrects errors in the market share information presented in Table 5.

Please place this report in your binder and discard the previous version. Dataquest regrets the error and apologizes for any inconvenience. For further information, contact Senior Analyst Calvin Chang at (408) 468-8605 or cchang@dataquest.com.

Perspective

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Market Analysis

The 1995 North American Semiconductor Gas Market

Abstract: *The North American semiconductor gas market chalked up a stellar year in 1995 with estimated total sales of U.S.$421 million, a gain of 18.5 percent over 1994. Bulk gases and specialty gases both recorded the highest growth rate since Dataquest began tracking the semiconductor gas market in 1985. A monstrous increase of nearly 70 percent in North American semiconductor capital spending produced an unprecedented double-digit growth in nearly all categories of electronic gases.*

By Calvin Chang

The Bulk Gas Market

The North American bulk gas market is estimated to have reached U.S.$252.1 million in 1995, a growth of 11.3 percent from 1994. This is the first double-digit growth rate and the fastest growth rate ever recorded in bulk gas sales in 10 years. Table 1 shows the semiconductor bulk gas sales in North America from 1991 to 1995.

Nitrogen: Liquid Loses Share to On-Site

For the semiconductor bulk gas market, 1995 was indeed a banner year in which all segments grew during the year. The last time this occurred was in 1989. Although liquid nitrogen sales grew nicely in 1995, liquid nitrogen's share of overall nitrogen sales continued to decline. From 1991 to 1995, the liquid nitrogen share has shrunk from 59 percent to 51 percent of total nitrogen revenue. On-site nitrogen continues its march, gaining big sales and market share. In the same period, on-site plants' contribution to total nitrogen sales increased from 27 percent to 36 percent. Dataquest believes that

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Table 1
North American Semiconductor Bulk Gas Sales (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995*	CAGR (%) 1991-1995
Nitrogen Total	162.3	164.0	160.9	163.7	181.7	2.9
On-Site	44.2	51.5	54.9	55.8	65.4	10.3
Pipeline	22.8	21.4	19.3	29.6	29.9	7.1
Liquid	95.3	91.1	86.7	84.4	92.1	-0.8
Hydrogen	29.0	26.9	30.3	31.4	35.5	5.3
Oxygen	7.4	8.7	8.2	8.5	11.0	10.4
Argon	15.1	16.1	19.8	22.1	22.9	11.0
Other Bulk Gases (Helium, Carbon Dioxide)	NA	NA	NA	0.9	1.0	NM
Total	213.7	215.7	219.2	226.6	252.1	4.2
Year-to-Year Change (%)	-	0.9	1.6	3.4	11.3	-

*Preliminary
NA = Not available
NM = Not meaningful
Source: Dataquest (March 1996)

this development, which began several years ago, will continue. The continual migration toward building larger fabs, the lowest cost in nitrogen generation, and a business environment of relatively low-cost capital have all contributed to the continued increase in the adoption of on-site nitrogen plants in the semiconductor industry.

Other bulk gases, including argon, oxygen, and hydrogen all enjoyed healthy growth in 1995. Robust demand plus modest increases in average selling prices (price increases began in 1994) have contributed to the best bulk gas market since 1985.

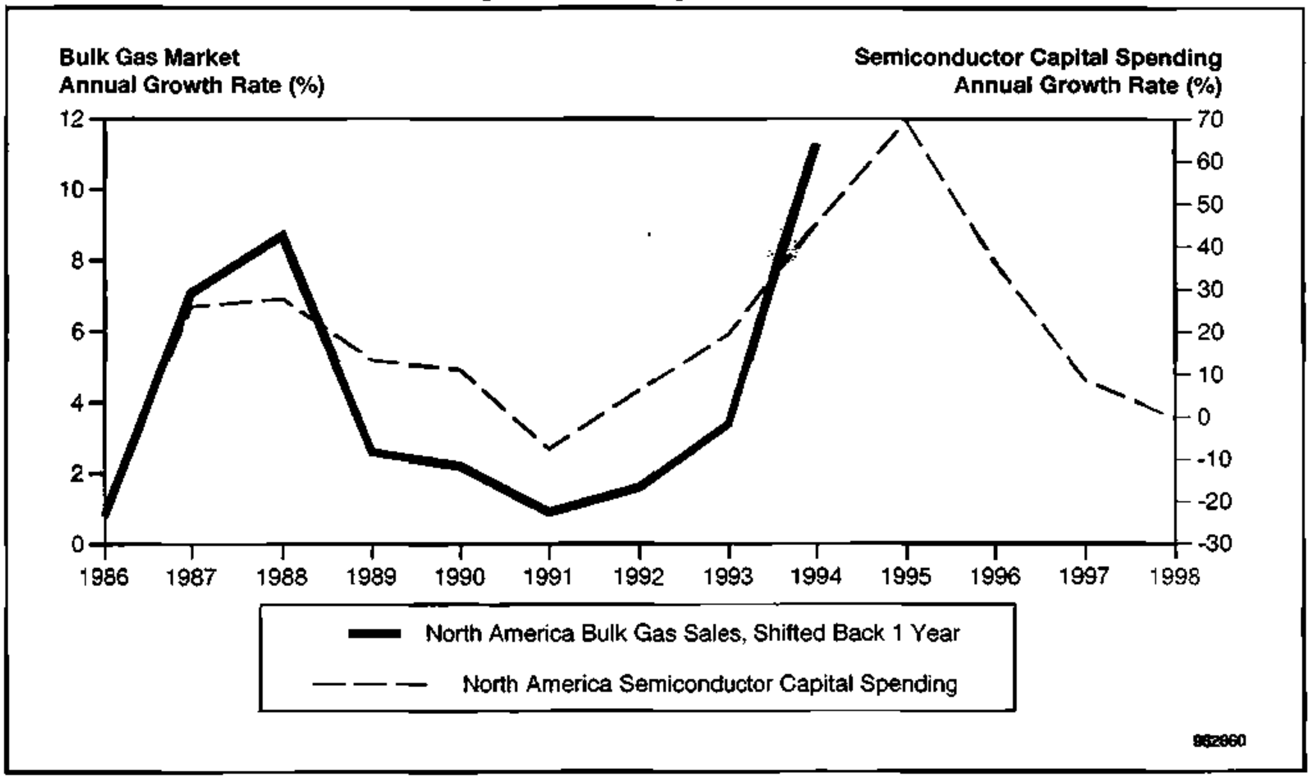
Semiconductor Capital Spending: The Engine Propelling the Growth

The 1995 bulk gas market data reaffirms the close correlation noted between the growth rate of semiconductor capital spending and that of the bulk gas market. The basis of this correlation has to do with new semiconductor fab construction and expansion, which will be populated with production equipment that uses bulk gases for purge, dilution, and processing.

It has been shown that the peak growth year for bulk gases lags the peak growth year in semiconductor capital spending by about one year. The one-year lag is consistent with the general time elapsing between the construction of a new fab, during which capital is spent, and the onset of ramp-up production, which produces a surge in bulk gas consumption.

Figure 1 shows the North American semiconductor capital spending growth rates and the bulk gas market growth shifted back one year to adjust for the effect of the time lag. As the figure shows, the bulk gas market growth trends coincidentally (scale-adjusted) with the level of capital spending. When capital spending increases, bulk gas consumption

Figure 1
Semiconductor Capital Spending as a Leading Indicator for the Bulk Gas Market



Source: Dataquest (May1996)

increases—in the following year. When capital spending declines, so does the bulk gas market. This link between semiconductor capital spending and the bulk gas market provides a convenient leading indicator for the health of the bulk gas market.

The figure shows that the semiconductor capital spending projection, as a leading indicator, suggests that the peak in capital spending in 1995 means that 1996 will be the last of a string of growth years in the bulk gas market. The projected slowdown in North American semiconductor capital spending in 1996 through 1998 could lead to a corresponding slowdown in the bulk gas market in 1997 through 1999.

The Specialty Gas Market

The semiconductor specialty gas market in North America struck gold in 1995. The market grew at an unprecedented 30 percent rate in 1995, with all major categories (silane precursors, dopants, plasma etchants, reactants, and atmosphere/purge) participating in double-digit growth rates. Table 2 shows the North American semiconductor specialty gas market in 1991 through 1995. Etchant gases continue to be the fastest-growing segment in specialty gases. Volume consumption of plasma etchant gases has been in large part driven by the increasing proportion of etch steps in IC fabrication processes. Silicon precursors saw an unusually high growth of 27 percent in 1995, as silane and dichlorosilane both registered sizable growth. Particularly notable is silane, which may be enjoying a resurgence from the

Table 2
North America Semiconductor Specialty Gas Sales (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995*	CAGR (%) 1991-1995
Silicon Precursors	22.0	22.2	25.5	26.2	33.3	10.9
Silane	15.6	15.6	17.3	19.2	23.5	10.8
Dichlorosilane	3.3	73.5	3.9	2.7	4.8	9.7
Trichlorosilane	2.0	2.2	3.0	3.0	3.5	14.8
Silicon Tetrafluoride	1.1	0.9	1.0	1.2	1.4	5.9
Disilane	0	0.01	0.01	0.04	0.1	NM
Dopants	7.4	7.5	12.7	14.9	20.2	28.8
Plasma Etchants	20.2	25.3	37.6	50.8	70.1	36.5
Reactant Gases	16.3	18.2	19.5	22.6	27.5	14.0
Atmosphere/Purge	11.9	13.6	14.7	15.3	17.8	10.7
Total	77.8	86.8	109.7	129.8	168.9	21.4
Year-to-Year Change (%)	22	12	26	18	30	-

*Preliminary
NM = Not meaningful
Source: Dataquest (March 1996)

increasing use of plasma-enhanced chemical vapor deposition (PECVD) of silane oxide in the fabrication of intermetal dielectric. Silane oxide has shown favorable polishing characteristics in the chemical mechanical polishing of wafers. Dopants are another bright area of growth that produced a 36 percent increase in sales in 1995.

Etchant Gas Market Boom Continues

Etchant gases sales continued to charge ahead in 1995, producing a 38 percent growth for the year. This is the fourth consecutive year of hypergrowth in plasma etchant gases, and it took etchants from less than 30 percent of specialty gas sales in 1992 to more than 42 percent in 1995. At this rate, etchants are expected to contribute to more than half of all specialty gas sales in just a few more years. In so, leadership in the supply of etchants will be the king-maker for the market leadership in overall specialty gases.

Table 3 provides a breakout of etchant gases and shows the 1992 through 1994 compound annual growth rate (CAGR) in each etchant gas. Freon 14 (CF_4), freon 116 (C_2F_6) and freon 23 (CHF_3) all grew at a CAGR of well over 35 percent during 1992 through 1994 and are expected to have shown even faster growth in 1995.

Dataquest believes that the perfluorocarbons (PFC) will continue to be a mainstay of semiconductor manufacturing processes in spite of the environmental concerns (for example, global warming) surrounding these plasma etchants. The industry has developed measures, in terms of abatement techniques such as PFC recovery, that will substantially reduce the emission of these substances into the environment.

Consumption of freon 115, an ozone-depletion substance banned by the Montreal Protocol, has essentially been eliminated. C_3F_8 is also experiencing drastically reduced demand.

Table 3
North America Semiconductor Plasma Etchant Gas Sales (Millions of U.S. Dollars)

	1992	1993	1994	CAGR (%) 1992-1994
CF_4 (Halo 14)	2.91	4.11	6.26	47
CF_4 (Halo 14/O_2)	0.29	0.41	0.76	61
CHF_3 (Freon 23)	1.94	3.12	4.22	47
C_2F_6 (Freon 116)	8.01	11.20	15.53	39
C_2ClF_5 (Freon 115)	0.001	0.004	0	NM
Other Halocarbons (13, 13b1, 21)	0.05	0.18	0.10	44
NF_3	5.09	7.38	9.40	36
SF_6	1.52	1.99	2.42	26
BCl_3	2.62	4.53	5.08	39
C_3F_8	0.09	0.14	0.03	-38
HF	0.27	0.33	0.94	88
Cl_2	1.30	1.95	2.75	46
ClF_3	0.003	0.004	0.100	493
HBr	1.00	2.02	2.67	63
Others (SiF_4 and Others)	0.09	0.25	0.64	173
North America Plasma Etchant Market	25.18	37.61	50.91	42
Year-to-Year Change (%)	-	49	35	-

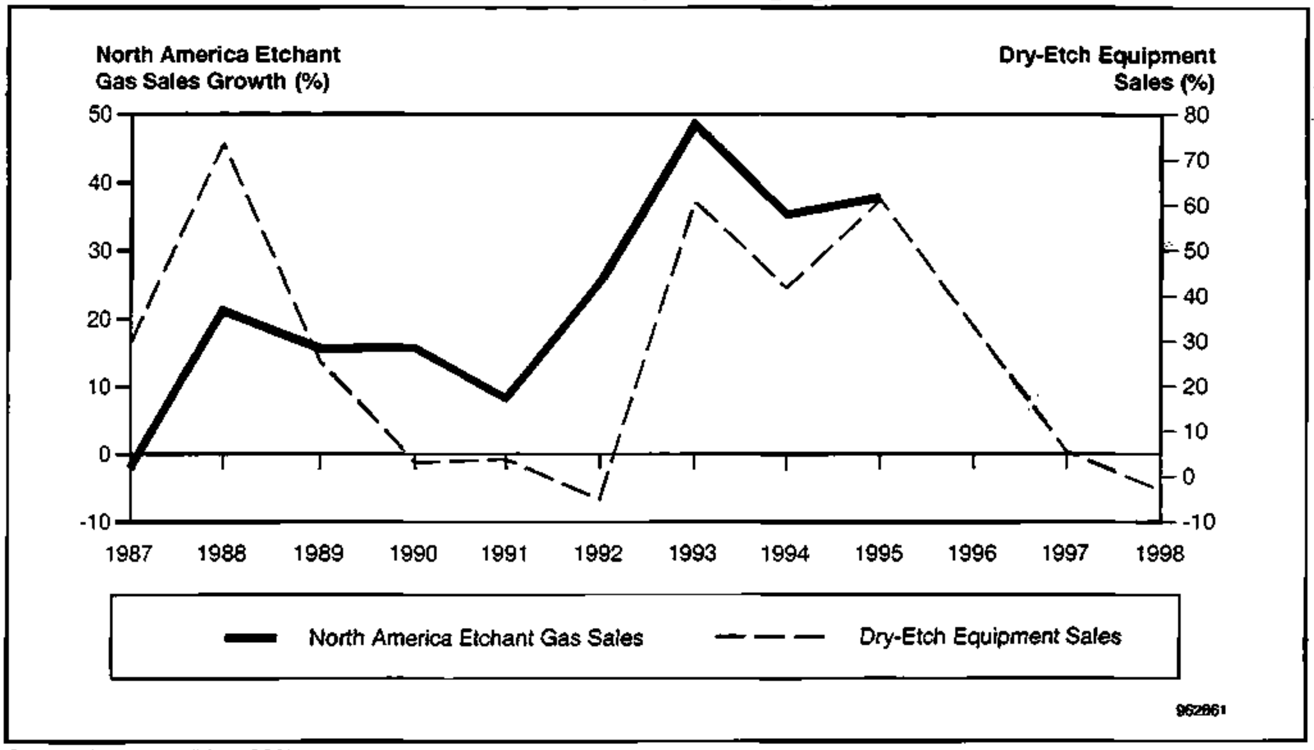
NM = Not meaningful
Source: Dataquest (March 1996)

NF_3, used in chamber clean, continues to be driven by increasing adoption of single-wafer chemical vapor deposition (CVD) and etch processes. Both BCl_3 and Cl_2 are used in metal etch, and their consumption will continue to be driven by the fabrication of ever-increasing levels of interconnect in ICs. HBr (as well as Cl_2) is used in dry etch of polysilicon and silicon and will maintain steady growth. ClF_3, a powerful etchant (and cleaning agent) relatively new to U.S. IC manufacturers, is expected to continue to rack up fast growth because of some of its unique properties and its currently modest sales.

Specialty Gases Growth Tied to Semiconductor Equipment Sales

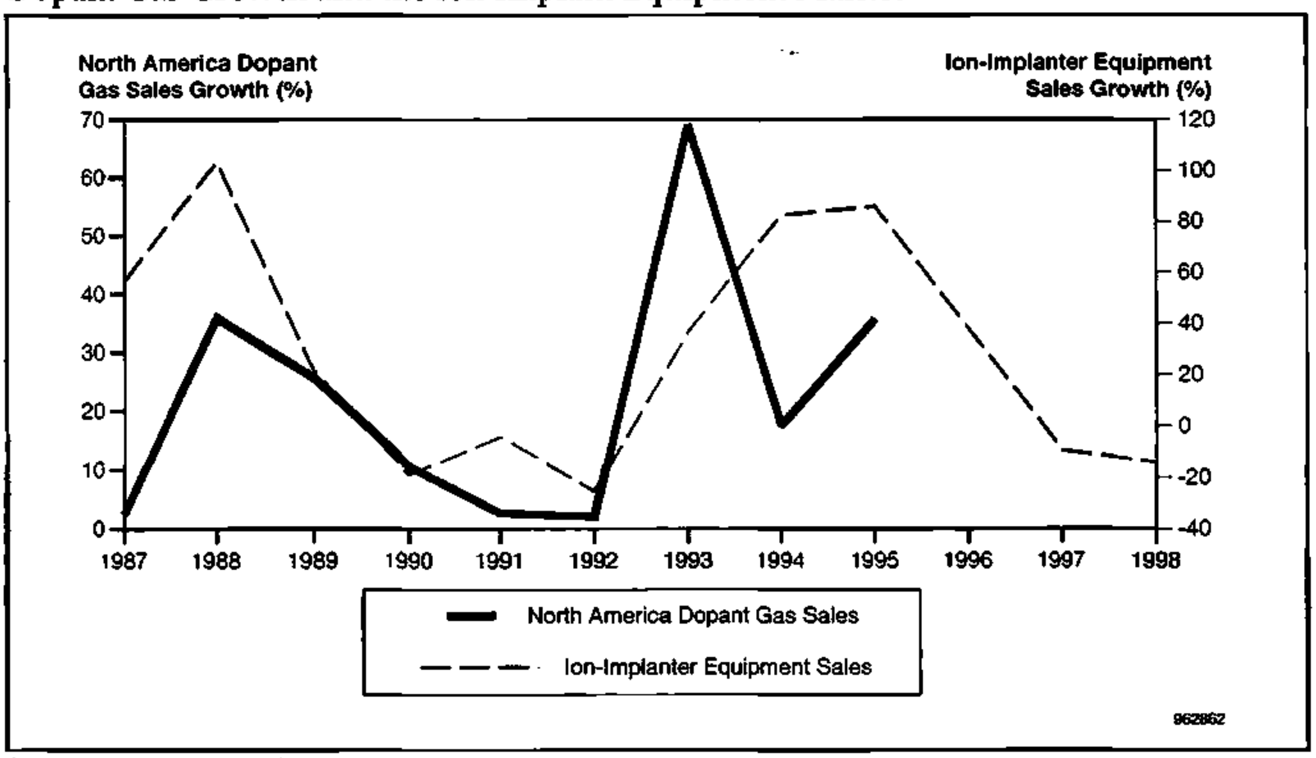
We have also observed that there exists a connection between some of the specialty gases and the semiconductor production equipment that consumes them. This connection has been noted in the sales of etchant gases and the dry-etch equipment market. Figure 2 shows that the growth of the etchant gas market trends nicely with the dry-etch semiconductor equipment market. Unlike the case of capital spending and the bulk gas market, there is, however, no time lag in the relation between the etchant market and the etch equipment market. This suggests that a reliable dry-etch equipment market projection can be used as a basis for developing a useful market projection for etchant gas sales. The analysis can be extended to other specialty gas markets, relating those gases to the sales of the semiconductor equipment that consumes them. Figure 3 shows the relation in year-to-year sales growth between the dopant gases and the ion implant equipment markets.

Figure 2
Plasma Etchant Market Growth and the Dry-Etch Equipment Market



Source: Dataquest (May1996)

Figure 3
Dopant Gas Growth and the Ion-Implant Equipment Market



Source: Dataquest (May1996)

Reactant Gases Sales Are Led by WF_6 and N_2O

The two pillars of the reactant gas market are WF_6 and N_2O. WF_6 is used in the deposition of tungsten and tungsten-silicide films. Tungsten deposition is an integral part of the fabrication process for vertical interconnects (tungsten plugs). The drive toward adoption of an ever-increasing level of interconnects in ICs will continue to boost the consumption of WF_6 in semiconductor manufacturing. Table 4 shows the sales of reactant gases for 1993 and 1994. As shown in the table, WF_6 has the largest market share and is also the fastest-growing reactant gas. N_20, a critical source gas for fabrication of advanced gate oxide, is expected to see even greater demand in the foreseeable future.

Table 4
North America Semiconductor Reactant Gas Market (Millions of U.S. Dollars)

	1993	1994	Growth (%) 1993-1994
NH_3	1.6	1.6	2
HCl	5.5	6.1	9
N_2O	4.8	5.8	21
WF_6	6.3	7.9	26
CO_2	0.5	0.4	-14
Others	0.2	0.2	18
Total	18.9	22.0	16

Source: Dataquest (March 1996)

North American Semiconductor Gas Market Share

Table 5 shows the North American semiconductor gas suppliers and their market share in the total, bulk, and specialty gas markets from 1992 to 1995. The four major gas companies (Air Liquide, Air Products and Chemicals, BOC Gases, and Praxair) together accounted for 88 percent of total electronic gas market sales in 1995. In bulk gases, the four majors collectively contributed 96 percent of the sales in North America.

In the fast-growing specialty gas market, Air Liquide and Matheson have gained market share in year from 1993 to 1995. Focusing on specialty gases, Matheson has displaced Praxair in the No. 3 position in specialty gases. For everyone in the specialty gas market, 1995 was, however, a bonanza year, with double-digit growth the norm and five suppliers romping home with more than 25 percent growth.

Dataquest Classification of Semiconductor Bulk and Specialty Gases

The following are classified as semiconductor bulk gases:

- Nitrogen (N; on-site, multicustomer pipeline, bulk liquid delivery)
- Oxygen (O_2)
- Hydrogen (H_2)
- Argon (Ar)

Table 5
North American Semiconductor Gas Suppliers Market Share Summary (Millions of U.S. Dollars)

	1992	1993	1994	1995*
Air Liquide	27.1	32.1	32.2	17.3
Air Products and Chemicals	121.2	131.7	148.2	82.8
BOC Gases	57.6	61.8	66.6	36.3
Matheson	10.9	16.3	20.3	13.4
Praxair	72.0	68.1	70.2	38.5
Scott Specialty	3.9	5.7	5.3	3.2
Solkatronic Chemicals	3.1	4.1	5.4	3.1
Tri-Gas	NA	2.5	1.3	1.5
Others	6.7	6.9	7.0	3.5
Total North American Semiconductor Gas Market	302.5	329.2	356.4	199.6
North American Bulk Gas Market				
Air Liquide	24.8	28.6	25.8	12.8
Air Products and Chemicals	101.3	101.6	110.8	60.2
BOC Gases	26.8	30.0	30.7	14.6
Praxair	57.2	50.7	52.0	28.1
Tri-Gas	NA	2.5	1.3	1.5
Others	5.6	5.8	5.9	3.0
Total North American Bulk Gas Market	215.7	219.2	226.6	120.2
North American Specialty Gas Market				
Air Liquide	2.3	3.5	6.3	4.5
Air Products and Chemicals	19.9	30.1	37.4	22.6
BOC Gases	30.8	31.8	35.8	21.7
Matheson	10.9	16.3	20.3	13.4
Praxair	14.8	17.4	18.2	10.4
Scott Specialty	3.9	5.7	5.3	3.2
Solkatronic Chemicals	3.1	4.1	5.4	3.1
Others	1.1	1.1	1.1	0.5
Total North American Specialty Gas Market	86.8	110.0	129.8	79.3

*First six months
NA = Not available
Source: Dataquest (March 1996)

The following are classified as semiconductor specialty gases (delivered in cylinders):

- Silicon precursor gases
  - SiH_4
  - SiH_2Cl_2
  - $SiHCl_3$
  - $SiCl_4$
- Dopant gases
  - AsH_3
  - PH_3
  - B_2H_6
  - BF_3, $B_{11}F_3$, PF_5, and others
- Etchant gases
  - CF_4
  - CF_4/O_2 (halo $14/O_2$)
  - CHF_3 (freon 23)
  - C_2F_6 (freon 116)
  - C_2ClF_5 (freon 115)
  - Other halocarbons (13, 13b1, 21)
  - NF_3
  - SF_6
  - BCl_3
  - C_3F_8
  - HF
  - Cl_2
  - ClF_3
  - HBr
  - SiF_4
- Reactant gases
  - NH_3
  - HCl
  - N_2O
  - WF_6
  - CO_2

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Micron's experienced management team has weathered prior dramatic challenges and shifts in the DRAM market. Dataquest expects the same for the long term. However, Micron clearly faces a stiff near-term challenge. For example, the spot market for 4Mb fast page mode (FPM) DRAM has abruptly shifted from the September 1995 sellers' market to a buyers' market today. Micron's stock fell during this period—from nearly $95 per share to the low $30s. In addition to the new DRAM pricing environment, Micron must manage a host of challenging 1996-to-1997 market transitions. These include transitions from 4Mb to 16Mb DRAM, from 6-inch to 8-inch wafers, and from FPM DRAM to extended data out (EDO) DRAM.

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"Lagging the Market" Strategy

Historically, Micron has successfully "lagged" the DRAM market in terms of technology. For example, when the market migrated from the 1Mb density to the 4Mb density during the early 1990s, Micron stayed with the older 1Mb density longer than many other suppliers and allowed other suppliers to lead the way to the then-emerging 4Mb product technology. At that time, some of Micron's competitors expected the 4Mb DRAM market to peak by 1993. By contrast, Micron correctly and profitably anticipated that the 4Mb density would reach its peak stage during the post-1993 period.

Once again, Micron appears to be "lagging the market" as some competitors accelerate their migration to the 16Mb density. Dataquest believes 1995 represented the high-water mark for unit shipments of 4Mb DRAM. Worldwide unit shipments totaled 1.3 billion or more units last year, with shipments forecast to drop to about 1.1 billion units for 1996. Dataquest expects that more than 800 million units of 16Mb DRAM will ship this year (versus 325 million units last year).

Micron also seems to be lagging the market shift from FPM DRAM to EDO DRAM. For example, during 1995 Micron touted its burst EDO (BEDO) DRAM. From Dataquest's perspective, BEDO to date has not won much market acceptance. Dataquest expects a 1996 market preference for 60ns EDO DRAM that could stretch into 1997. Micron likely is focusing much effort on EDO DRAM, given the market's preference. Later this year, the market will initiate a long-term migration to synchronous DRAM (SDRAM). Suppliers like Samsung, NEC, and Texas Instruments will lead the move to SDRAM.

Manufacturing Challenges

Micron faces critical manufacturing issues. Corporate attention focuses on converting Fab III (Boise, Idaho) from a 6-inch wafer facility to an 8-inch wafer facility.

8-Inch Wafer Conversion

A recent U.S. Securities and Exchange Commission (SEC) filing by Micron highlights this issue. Micron claims it had originally anticipated that Fab III would be substantially converted to 8-inch wafer processing by the end of calendar 1995. While considerable progress has been made, Micron now does not expect substantial conversion of Fab III before the middle of fiscal 1996. (The middle of Micron's fiscal 1996 is in late February and early March.)

We should note Micron is not the only semiconductor supplier challenged by the 8-inch wafer conversion. Dataquest estimates that just eight to 10 leading-edge semiconductor suppliers worldwide have made the migration. Most suppliers making the 8-inch transition seem to have a "hope for the best, prepare for the worst" strategy.

The use of 8-inch wafers meshes well with a 16Mb ramp-up. The use of 8-inch wafers would mean higher operating DRAM margins than 6-inch wafers. The 8-inch wafers generate nearly twice the number of DRAM die than 6-inch wafers. This applies to either 4Mb or 16Mb DRAMs. The use of

8-inch wafers would enable Micron to protect, to some degree, its 4Mb DRAM margins despite pricing declines. Micron's expertise in shrinking die means the company has enjoyed extremely high DRAM margins.

By early March 1996, the market should learn whether Micron has achieved substantial conversion of Fab III to 8-inch wafers. Should this conversion occur, Micron could rebound quickly and strongly. Should this not occur, Micron will remain under pressure until the 8-inch conversion does occur.

Capital Spending: $4 Billion by the End of Fiscal Year 1997?

The SEC filing also says that Micron's current expansion and capital-improvement projects were estimated to total $4 billion in remaining cash outlays. These projects include the conversion of Micron's several Boise fabs to process 8-inch wafers and the construction of a new 8-inch wafer manufacturing facility in Utah (Dataquest believes that at least half of the $4 billion budget would be for the new Utah fab). Micron expected the majority of the $4 billion cost to be incurred prior to the end of fiscal 1997. Micron's fiscal 1997 ends in early September 1997.

The SEC filing says that substantially all Micron's near-term cash flow from operations was expected to be dedicated to capacity-improvement programs. Historically, Micron responds to DRAM market softness; however, it does so by moving to the lower end of the price curve. Micron is also evaluating debt financing as a source of additional funds for timely completion of these projects. Because of changed DRAM market conditions, Micron is likely evaluating whether it still wants to spend $4 billion—or a lesser amount.

We expect the projects to continue. The 8-inch Utah fab's construction schedule likely will be delayed, and instead of producing wafers later this year, production might not start till 1997. Instead of being a major revenue contributor by early 1998, the Utah fab might not generate big revenue streams until late 1998.

What's Ahead for Micron

By mid-1996, the market will gain signals on the ability of Micron's management team to handle Micron's 1996 market and manufacturing challenges. A key second quarter 1996 milestone will be this: whether Micron makes a successful 8-inch conversion or encounters more delay. Another near-term milestone to watch for: Micron's ability to ramp up EDO DRAM, especially 60ns devices. Sooner or later, there should be some revision of the capital spending plans. Dataquest believes the Utah fab likely will move forward but under a slower schedule.

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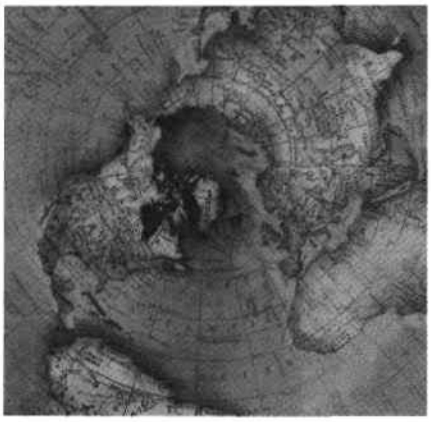
Market Trends

Dataquest



Dataquest

Midyear 1996 Forecast: Capital Spending, Wafer Fab Equipment, and Silicon

Market Trends

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Chapter 1
Executive Summary

Midyear 1996: Looking Past 1997, Setting Up for Growth in 1998

Overcapacity in the DRAM market, created by the massive spending from 1994 through the first part of 1996 and the normal DRAM product migration, is finally taking its toll, resulting in a faster-than-expected contraction in the wafer fab equipment market. We expect this contraction to be sharp and relatively deep but slightly shorter than historical norms, around 18 to 24 months. The key reason for the belief that the slowdown will be shorter than normal is the continued robust forecast for PC unit shipment growth through this decade.

What Happened?

Although Dataquest has been forecasting over the last year that a DRAM oversupply-driven capital spending slowdown would occur in 1997, the swift nature of its arrival still has shock value. We should point out why we were looking for a slowdown in capital spending.

The industry migration from 4Mb to 16Mb DRAMs would cause overcapacity even in the face a high bit demand growth. Why? Die size relationships mean that the average 16Mb DRAM has two to three times more bits per square inch than the 4Mb generation. Because capacity in the industry is built in wafers, this event causes a step-function increase in bit capacity of the industry. This usually happens in a hurry and is triggered by the new generation hitting a critical yield level of about 65 percent, estimated to have been hit by the end of 1995.

The complicating factor, and the reason for the severity of the downturn today, was the artificial demand created in 1995 by the anticipation of Windows 95, which, taken with the tight supply of memory last year, caused inventories to inflate to enormous levels. This corrected in the final quarter of last year, slightly in advance, but essentially on top, of the conversion timing, and now we have a double-barreled driver (demand and supply) for the DRAM price slide and capital spending downturn. These events together have increased the anticipated severity of the downturn.

How Are Semiconductor Companies Responding?

It is very normal in this type of a downturn to get a pocket of companies that will stay and continue to invest in the infrastructure. These companies today are IBM, Texas Instruments, and, on a moderate level, the Korean companies. Japanese companies, which were the companies that held on in the last cycle for a year or more, have already shut off spending, and these companies as a group will spend slightly less in dollar terms in 1996 than in 1995. Except for Taiwan Semiconductor Manufacturing Co., Chartered Semiconductor, and Macronix, Asian companies are cutting back dramatically, starting in the last couple of months. As a group, the DRAM manufacturers are responding more rapidly to the situation, cutting spending faster than in previous cycles.

The industry must now rely on the continued growth in personal computer unit sales, with added growth in telecommunications and networking products to create a unit demand picture that will keep this slowdown short-lived from a historical perspective. The wafer fab capacity bubble has burst in all regions and for most semiconductor products, most notably DRAMs, mixed-signal devices, and analog devices. Whereas the 1995 spending growth was almost entirely driven by DRAM and microcomponent capacity purchases, 1996 is a year of transition, and 1997 will be a year of investment in technology.

When and How Will the Recovery Occur?

Based on how capacity is migrating among device types, we believe the first areas of spending recovery will be in the advanced logic area, as early as mid-1997. Equipment companies positioned for these markets will have a more moderate slowdown and perhaps can grow through this time if they have advanced technology. The MCU, analog, mixed-signal, and telecom chip capacity will be next to recover, but probably not until the end of 1997 or early 1998. The DRAM segment, the root cause of the problem and the very last to recover, is not expected to resume robust spending until mid-to-late 1998. The next major and broad investment cycle will have momentum by 1999.

Dataquest believes that capital spending may be influenced in late 1997 through 1999 positively with the facility construction and purchase of equipment toward the world's first 300mm wafer fab. We have built this infrastructure investment into our model. However, our outlook for a significant 300mm equipment market will wait until well after 2000.

Highlights on the Wafer Fab Equipment Market

Wafer fab equipment spending is expected to grow 17 percent worldwide in 1996. The only reasons that 1996 remains a double-digit growth year are that there were strong backlogs coming out of 1995 and increased spending by some companies early in the year.

After three and a half strong expansion years from 1993 through 1996, equipment purchases in 1997 should decline markedly, followed by an essentially flat 1998. Investment in DRAM capacity will be curtailed as producers elect to convert their 4Mb DRAM capacity to 16Mb, which adds bit capacity through the instant increase in bits per square inch. Also, many Japanese DRAM facilities now running 150mm wafers will convert to 200mm wafers, further delaying the need for new equipment. DRAM-sensitive equipment technologies or capital-intensive segments will be affected more than logic-sensitive technologies. The next expansion should kick in by 1999, driven by 0.3-micron to 0.35-micron capacity expansion.

During the coming slowdown, there will be two kinds of purchasing behavior that equipment companies can take advantage of to buffer sales declines. The first behavior is tied to which types of capacity will be required early in the recovery cycle. If there is a heavier dependence on advanced logic or supply to the materials industry, these segments will fare better than DRAM or semiconductor capacity dependent segments.

Included in this category are the segments of nontube CVD, sputtering, metal etch, silicon epitaxy, maskmaking lithography, process control systems in the materials business, and rapid thermal processing (RTP).

The second purchasing behavior that will be prevalent over the next 12 to 18 months will be new processes and equipment directed at solving issues for 0.35-micron and 0.25-micron manufacturing. These segments will be those related primarily to deep-ultraviolet (deep-UV) lithography and inspection and 0.25-micron multilevel metallization schemes.

Highlights of the Silicon Market

The silicon market, driven by a strong long-term picture for semiconductor unit demand in general, will grow faster over the next six years than the last six years. As the industry transforms into a 200mm baseline, the outlook for silicon wafer manufacturers becomes brighter. Silicon manufacturers have answered the call for 200mm capacity with significantly increased capital outlays. We believe that silicon manufacturers' ramp plans in 200mm have been strategically and smartly measured, because the overcapacity of 1985 is being remembered, and we are not expecting that scenario to repeat.

Activity in 300mm wafer development has accelerated, particularly in Japan. Although no semiconductor company has yet to commit to purchasing equipment for a formally announced fab, we would expect at least two pilot fabs to attempt to come on line by 1999.

By the year 2000, Dataquest expects that fully 16 percent of merchant epitaxial silicon will be used for DRAMs, up from about 2 percent in 1995. We believe that for late-generation shrink versions of 16Mb and for 64Mb DRAMs, companies that employ the trench design will need to use epitaxial silicon. Also, other companies may decide to use epitaxial layers to solve specific yield issues at 0.25 micron; however, it may only be a single-generation solution.

The silicon has become recognized again as being strategic in the semiconductor manufacturing infrastructure. Will this continue? We believe it will, as long as silicon suppliers continue to concentrate on value-add processes and techniques as the equipment manufacturers have done, as well as adequately and smartly plan capacity additions.

Dataquest Perspective

Our forecast for capital spending and wafer fab equipment sales during the next six years assumes the excessive growth in 1995, which carried over into the first half 1996, will be sharply corrected in 1997. Our outlook for the future includes moderated growth in equipment spending in 1998, accelerating into the start of another boom in 1999, likely lasting into early 2001.

Where the PC goes, so go semiconductors. This is true from the perspective of the business forecast as well as the production line. Europe and Asia/Pacific, with very large capital spending upticks over the last several years—and expected to continue that trend—will continue to gain share in world production over the next several years.

The shifts and currents in semiconductor production trends mean that equipment and material suppliers will absolutely need a global presence in every sense of the word to remain competitive in the market. Product supply can no longer depend on local trends, as all major semiconductor companies have made it clear they are investing on a worldwide basis. However, local service and support are required to maintain customer satisfaction.

Taiwan is clearly the new major production growth area. We would expect Malaysia and Thailand to be the next major growth countries in three to five years. Evidence of this includes recent joint-venture fab announcements by Texas Instruments and others. Silicon plants are now being strategically placed, such as Shin-Etsu Handotai's Malaysian plant and recently announced joint venture in Taiwan, Komatsu's joint venture with Formosa Plastics in Taiwan, and MEMC Electronic Materials' joint ventures in both Korea (Posco-Hüls), Taiwan (Taisil), and Malaysia (MEMC-Kulim).

Further, the concept of contract manufacturing in semiconductors is clearly here to stay. Equipment and material suppliers could find themselves selling their technical products to an international team from several companies, including the manufacturer and the designer. However the emergence of the dedicated foundry company taking ownership of the process and manufacturing flow will tend to centralize this activity. Dataquest has started a research service—Semiconductor Contract Manufacturing Worldwide—to continue exploring the key trends in contract manufacturing and foundries, including technology trends and supply/demand balance through the decade.

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Chapter 2
Semiconductor Capital Spending Forecast

This chapter presents data on worldwide semiconductor capital spending by region. Capital spending in a region includes spending by all semiconductor producers with plants in that region. Components of capital spending are property, plant, and equipment expenditure for front-end and back-end semiconductor operations.

Chapter Highlights

This chapter will discuss the following highlights:

- On the heels of booming growth of 74 percent in 1995, global semiconductor capital growth will slow to 18 percent in 1996 to $45.3 billion. With excess capacity clearly present in the industry for the next year or two, capital spending is expected to contract 10 percent in 1997 and modestly recover in 1998 before the next capacity cycle starts in late 1998 into 1999.
- Capital spending in the Americas region grew at an accelerated 69 percent in 1995, with most of the investment growth in 1995 coming from U.S. companies connected with ASIC and logic products. Capital spending is decelerating in 1996 into 1997, but we expect that investment in advanced technology, coupled with the earlier capacity upturn from the advanced logic segment, will stabilize the region's spending later in 1997 and will lead the market's recovery in 1998 and 1999 as it did in 1993. We expect the Americas region to be the second-fastest-growing market as foreign multinationals and foundry company invest in capacity in the United States.
- Japan's 49 percent increase in capital spending in 1995 is only 37 percent on a yen basis, as Japanese companies look to invest outside Japan to optimize buying power. Japanese spending has essentially stopped growing and will actually decline about 2 percent in 1996. Because of the early cutback in spending, 1997 remains a flat capital spending year as well, with only modest growth in 1998. Lagging investment patterns in Japan are expected to continue throughout the decade.
- Japanese companies, however, grew spending during 1995 about 58 percent worldwide, spending a total of $12.0 billion, second only to Americas company spending of $13.8 billion and well ahead of the Asia/Pacific companies' $9.1 billion level. In 1996, however, with the quick brakes the Japanese have put on spending, Asia/Pacific companies will surpass Japanese company spending.
- Although spending on capacity has essentially stopped in Japan, two other types of investments are likely to be important in Japan now through 1998. First, Japanese companies will invest in any new technology and equipment targeted at the 0.25-micron production arena. Second, the Japanese companies will build shells in 1996 and 1997, initially at very low run rates, as a preparation to ramp when the market turns up.

- We are looking for continued growth for Europe of 22 percent in 1996 as production continues to ramp from Siemens, SGS-Thomson, and eight new fabs, most notably by GEC-Plessey and TEMIC. However, in part because we do not believe Siemens can sustain its current spending, we are calling for a 12 percent decline in spending in Europe for 1997 and a flat-to-down 1998 as we expect multinationals will ramp domestic memory fabs before Europe. Longer term, we still see Europe as a significant growth region for spending through the decade.
- The often erratic but sustained semiconductor capital spending growth in the Asia/Pacific region continued at the explosive rate of 112 percent in 1995. We expect a "moderated" growth of about 30 percent in 1996 as several new fab projects are built and equipped. However, the tide has turned in the DRAM area, and we are forecasting the Asia/Pacific region to be hit the hardest in 1997, with a nearly 15 percent decline in capital spending. Longer term, we expect Asia/Pacific to exhibit one of the most aggressive growth rates in capital spending of any region.
- However, several Asia/Pacific companies continue with their planned projects in expansion of foundry capacity, and new entries continue to be announced, with more expected. The reason for the continued interest in spending capital in this area comes from the fact that the core business is dependent on logic and PC unit demand rather than DRAM. The foundry industry is now a *strategic* industry rather than simply a tactical one.

Capital Spending Tables

A final list of the top 20 semiconductor capital spending companies in 1995 is presented in Table 2-1, and the comparable list for 1996 with projected spending is shown in Table 2-2. Capital spending details by region are provided in two tables in this chapter. Table 2-3 shows historical semiconductor capital spending by region for the years 1988 through 1995. Table 2-4 shows the capital spending forecast by region for the years 1995 through 2001. Yearly exchange rate variations can have a significant effect on the interpretation of the data for 1988 through 1996. For more information about the exchange rates used and their effects, refer to Appendix B.

And the Spending Binge Comes to an End ...

After a 24 percent growth in semiconductor capital spending in 1993, accelerated growth of 54 percent followed in 1994, and growth has now peaked at 74 percent worldwide during 1995. Based on our most recent capital spending survey, 1996 will have markedly slower growth of 18 percent. Nearly all of this growth has already occurred in the first half of this year, and we expect the spending contraction to begin in the second half of 1996, spilling into 1997.

The industry is now relying on the continued growth in PC unit sales, with added growth in telecommunications and networking products, to create a unit demand picture that will keep this slowdown short-lived from a historical perspective. The wafer fab capacity bubble has burst in all regions and for most semiconductor products, most notably DRAMs, mixed-signal devices, and analog devices. The 1995 spending growth was almost entirely driven by DRAM and microcomponent capacity

Table 2-1
Semiconductor Capital Spending—Top 20 Spenders, Comparison of 1994 and 1995 Worldwide Capital Spending (Millions of U.S. Dollars)

1995 Rank	1994 Rank	Company	1995	1994	Change (%)
1	1	Intel	3,550.0	2,419.0	46.8
2	2	Motorola	2,530.0	1,640.0	54.3
3	9	LG Semicon	2,258.1	800.0	182.3
4	3	NEC	2,010.1	1,117.3	79.9
5	5	Samsung	1,946.6	1,000.0	94.7
6	7	Toshiba	1,624.1	933.1	74.1
7	4	Fujitsu	1,592.1	1,072.6	48.4
8	6	Hitachi	1,497.6	969.9	54.4
9	11	Hyundai	1,492.4	700.0	113.2
10	14	IBM Microelectronics	1,150.0	525.0	119.0
11	12	Mitsubishi	1,118.2	675.3	65.6
12	8	Texas Instruments	1,079.3	825.0	30.8
13	10	SGS-Thomson	1,001.0	780.0	28.3
14	18	Micron Technology	960.0	387.0	148.1
15	19	Philips	959.0	385.0	149.1
16	16	Siemens AG	850.0	410.0	107.3
17	15	Matsushita	846.6	513.2	65.0
18	27	Chartered Semiconductor	786.7	176.7	345.2
19	20	Sanyo	647.0	356.1	81.7
20	13	Advanced Micro Devices	634.0	625.0	1.4
		Total Top 20 Companies	28,532.7	16,310.2	74.9
		Total Worldwide Capital Spending	38,308.1	22,085.2	73.5
		Top 20 Companies Percentage of Total	74.5	73.9	

Source: Dataquest (July 1996)

purchases, 1996 is a year in transition, and 1997 will be a year of investment in technology.

The first companies to cut back were the U.S. companies, as they tend to be more driven by short-term cost issues. The most severe slowdown in capital spending that is occurring today is in Japan, as the overcapacity in DRAM has caused Japanese companies to quickly draw the purse strings in hope of avoiding a more serious price erosion. The spending plans have already started to be cut back within DRAM companies in Taiwan, and we would expect this spending cutback to extend into Korea in late 1996 into 1997.

But meanwhile, the big three Korean companies are increasing spending a more modest 27 percent to a combined $7.2 billion in 1996, which is still above the industry in terms of growth. This above-industry growth has meant that all three large Korean companies are in the top five for capital

Table 2-2
Semiconductor Capital Spending—Top 20 Spenders, Comparison of 1995 and Projected 1996 Worldwide Capital Spending (Millions of U.S. Dollars)

1996 Rank	1995 Rank	Company	1996	1995	Change (%)
1	1	Intel	3,900.0	3,550.0	9.9
2	3	LG Semicon	2,688.8	2,258.1	19.1
3	5	Samsung	2,304.6	1,946.6	18.4
4	9	Hyundai	2,250.0	1,492.4	50.8
5	2	Motorola	2,100.0	2,530.0	-17.0
6	12	Texas Instruments	2,000.0	1,079.3	85.3
7	4	NEC	1,814.0	2,010.1	-9.8
8	14	Micron Technology	1,600.0	960.0	66.7
9	10	IBM Microelectronics	1,550.0	1,150.0	34.8
10	16	Siemens AG	1,450.0	850.0	70.6
11	6	Toshiba	1,441.9	1,624.1	-11.2
12	8	Hitachi	1,300.4	1,497.6	-13.2
13	7	Fujitsu	1,279.1	1,592.1	-19.7
14	22	TSMC	1,039.3	583.9	78.0
15	17	Matsushita	1,034.9	846.6	22.2
16	13	SGS-Thomson	1,000.0	1,001.0	-0.1
17	11	Mitsubishi	965.1	1,118.2	-13.7
18	18	Chartered Semiconductor	872.3	786.7	10.9
19	15	Philips	841.0	959.0	-12.3
20	20	Advanced Micro Devices	750.0	634.0	18.3
		Total Top 20 Companies	32,181.4	28,469.6	13.0
		Total Worldwide Capital Spending	45,344.0	38,308.1	18.4
		Top 20 Companies Percentage of Total	71.0	74.3	

Source: Dataquest (July 1996)

spending in 1996, as was shown in Table 2-2. As noted earlier, Japanese suppliers of memory cut back investment early in this cycle. Japanese companies as a group will actually spend 7 percent less in 1996 in dollar terms (6.5 percent growth in yen terms). As a result, only one Japanese company appears in the top 10 capital spenders in 1996—NEC. Most of the other Japanese companies do appear in the second 10. Intel still heads the list for 1996, as the microprocessor giant demand continues to be strong on a unit basis. Intel's capital spending growth has slowed primarily because yield ramps on its new fabs have been better than expected, so Intel therefore needs less equipment to produce the same unit volume. Motorola, the long-time No. 2 spender, has dropped to No. 5 as the demand for telecom-related chips softened in conjunction with the overcapacity in this area.

Table 2-3
Worldwide Capital Spending History by Region, 1988-1995
(Includes Merchant and Captive Semiconductor Companies) (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Americas	3,319	3,833	4,320	3,895	4,135	4,943	7,194	12,147	18.8
Percentage Growth	26.6	15.5	12.7	-9.8	6.2	19.5	45.5	68.8	
Japan	4,454	5,415	5,732	5,702	3,958	4,413	6,667	9,910	9.6
Percentage Growth	81.2	21.6	5.9	-0.5	-30.6	11.5	51.1	48.6	
Japan (Billions of Yen)	579	748	826	787	500	491	679	931	2.0
Percentage Growth	62.6	29.2	10.4	-4.7	-36.4	-2.0	38.3	37.1	
Europe	951	1,198	1,598	1,248	1,188	1,738	2,504	4,137	17.2
Percentage Growth	7.5	26.0	33.4	-21.9	-4.8	46.3	44.0	65.2	
Asia/Pacific	1,024	1,884	1,580	2,300	2,318	3,238	5,720	12,115	40.4
Percentage Growth	89.6	84.1	-16.2	45.6	0.8	39.7	76.6	111.8	
Worldwide	9,748	12,331	13,230	13,145	11,599	14,333	22,085	38,308	23.7
Percentage Growth	49.8	26.5	7.3	-0.6	-11.8	23.6	54.1	73.5	

Source: Dataquest (July 1996)

Table 2-4
Worldwide Capital Spending Forecast by Region, 1995-2001
(Includes Merchant and Captive Semiconductor Companies) (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Americas	12,147	14,828	13,461	14,599	18,453	24,571	29,721	16.1
Percentage Growth	68.8	22.1	-9.2	8.5	26.4	33.2	21.0	
Japan	9,910	9,692	9,566	10,331	12,730	16,829	20,495	12.9
Percentage Growth	48.6	-2.2	-1.3	8.0	23.2	32.2	21.8	
Japan (Billions of Yen)	931	1,042	1,028	1,111	1,369	1,809	2,203	15.4
Percentage Growth	37.1	12.0	-1.3	8.0	23.2	32.2	21.8	
Europe	4,137	5,058	4,444	4,317	5,637	7,725	9,718	15.3
Percentage Growth	65.2	22.3	-12.1	-2.9	30.6	37.0	25.8	
Asia/Pacific	12,115	15,766	13,470	13,668	17,134	26,653	36,781	20.3
Percentage Growth	111.8	30.1	-14.6	1.5	25.4	55.6	38.0	
Worldwide	38,308	45,344	40,942	42,915	53,954	75,777	96,715	16.7
Percentage Growth	73.5	18.4	-9.7	4.8	25.7	40.4	27.6	

Source: Dataquest (July 1996)

A mostly new crowd of Taiwanese companies that entered the DRAM manufacturing business, spending over $1 billion collectively in 1995, increased spending feverishly in the first half of 1996 and has likely spent more than in all of 1995 already. However, the spending planned for the second half of the year has been predominantly delayed, mostly into 1997, likely later, and, in some cases, indefinitely (read late 1998 or 1999).

TSMC debuts on the top 20 list for 1996 with an estimated $1.04 billion spent on capacity, as foundry capacity expansion has now evolved into a major trend. TSMC and Macronix, a company that we understand does some second-source work for TSMC, are the two major Taiwanese companies still maintaining the spending plans set early in the year for 1996. This industry has transformed into a dedicated bona fide business and is no longer a specialized way to use excess capacity. There are several companies that we understand will try to enter the foundry business as a result of today's overcapacity. Unless these companies commit to the foundry business in the long term, their success at entering the market will be limited. Gone are the days when the "temporary" foundry can exist. Customers of foundry are now requiring long-term relationships and contracts for winning their capacity business.

It is very normal in this type of a downturn to get a pocket of companies that will stay and continue to invest in the infrastructure or that have niches that maintain growth, thus supporting an increase in spending. These companies in 1996 include IBM (advanced 16Mb DRAM to support systems), Texas Instruments (primarily digital signal processors, or DSPs, and logic), TSMC (foundry), Siemens (advanced DRAM), Lucent Technologies (modem chipsets and the Cirrus Logic foundry), and Chartered Semiconductor (foundry). All of these companies have continued to increase investment during 1996. Micron Technology may be the surprise of 1996 to some, particularly because it has delayed the Lehi, Utah fab. However, it has been spending aggressively in Boise, Idaho, upgrading the facilities for 200mm production and advanced technology for the 16Mb generation. We would expect Micron to return to 1995 levels at least in 1997.

With the cutback of the big Japanese players in the industry and with some smaller companies continuing to be aggressive in spending plans, the concentration of capital spending by the top 20 has decreased in 1996 by a few percentage points to 71 percent.

How Long Will This Downturn Last? How Will Capacity Be Absorbed?

Our longer-term forecast projects that this contraction will be sharp and relatively deep, but slightly shorter than historical norms, about 18 to 24 months. The key reason for the belief that the slowdown will be shorter than normal is the continued robust forecast for PC unit shipment growth worldwide through this decade, driving the need for silicon. We also do not see a stoppage in advanced technology investment, indicating a belief in the customer base of a strong end-user market for semiconductors. Overall semiconductor product demand is expected to remain strong longer term, with sustained growth through 2001 with a compound annual growth rate (CAGR) of 15.5 percent (see Chapter 5).

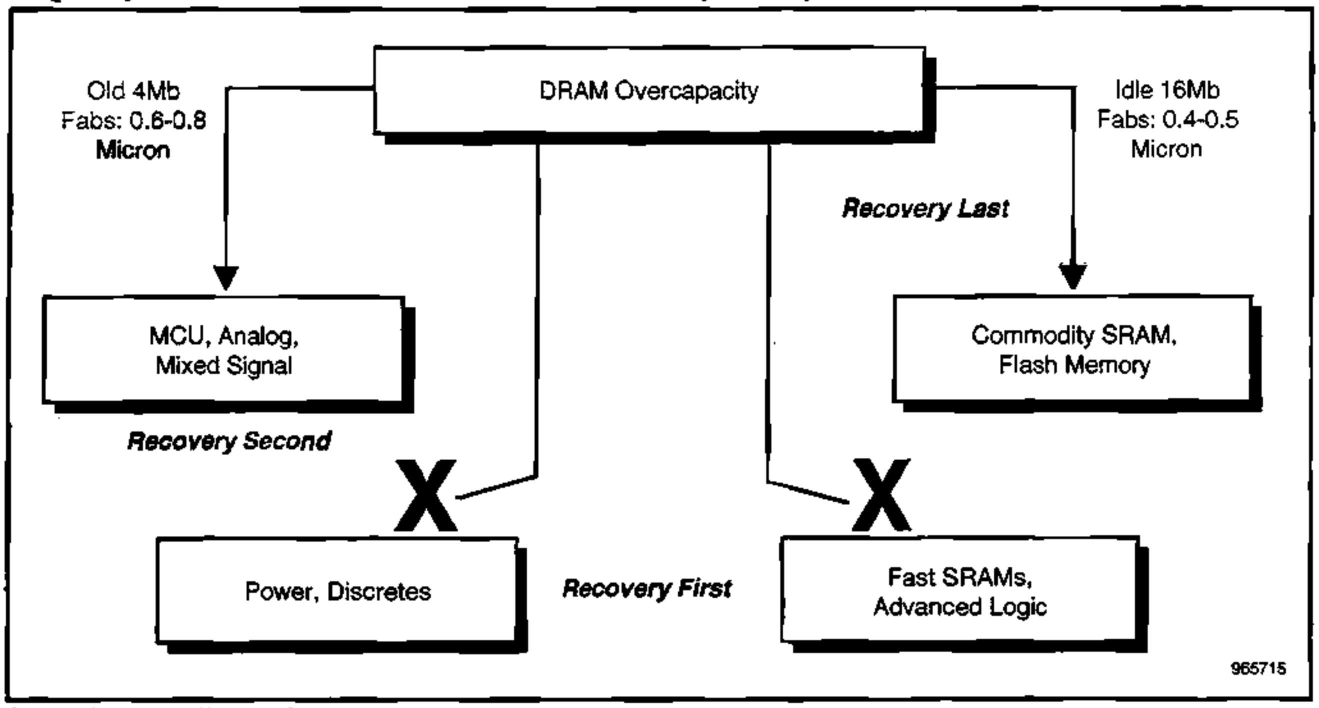
How will the industry recover? What are the anticipated dynamics? Today, the industry is primarily experiencing a DRAM oversupply coupled with a product transition. In order to determine how capital spending may recover, it is important to understand how this excess capacity may migrate or trickle to other areas in semiconductor capacity.

There are two general blocks of capacity now available from today's conditions (see Figure 2-1). These two blocks are being redirected into other semiconductor product areas today. The first comprises old 4Mb DRAM fabs that cannot run 16Mb chips. These are limited to two-level metal and are 0.6-micron to 0.8-micron technology. Microcontrollers, telecommunications chips, mixed-signal ICs, and analog ICs are quite happy being processed in these fabs. It is likely that most of these fabs in Japan and some in Korea will migrate into this area. The power and discrete chips have specialized processes not found in old DRAM fabs, so these segments are relatively isolated from extraneous supply impacts because significant time and money is required to convert. We therefore expect capital spending patterns to be closely tied to demand in this specialty segment.

The second block of capacity comprises idle or underused advanced 16Mb capacity, which is limited today to two-level metal but at 0.4 micron to 0.5 micron. Because these fabs generally lack the process sequences of self-aligned silicide and three-level metal or more (which requires chemical mechanical polishing at 0.5 micron), they cannot be effectively redirected to advanced logic or fast SRAM. Therefore, they are limited to commodity SRAM, flash, other nonvolatile memory, or a limited span of logic products. We expect most of these plants to remain somewhat idle through the overcapacity period.

Based on how this capacity is migrating, we believe that the first areas of spending recovery will be in the advanced logic area, as early as mid-1997. Equipment companies positioned for these markets will have a more moderate slowdown and perhaps can grow through this time if they have advanced technology. The MCU, analog, mixed-signal, and telecom chip capacity will be next to recover, but probably not until the end of 1997 or

Figure 2-1
Capacity Trickle in the Semiconductor Industry Today



Source: Dataquest (August 1996)

early 1998—Motorola will be a key company to watch. The DRAM segment, the root cause of the problem and the very last to recover, is not expected to resume robust spending until mid-to-late 1998. The next major and broad investment cycle will have momentum by 1999.

Our model does not include significantly more 16Mb DRAM capacity expansion until late 1998 into 1999. In the two "pause" years, we believe DRAM manufacturers will concentrate on converting capacity away from 4Mb toward 16Mb, which increases bits per square inch processed, then concentrate on shrinks to squeeze out value per square inch before a capital cycle starts again. Further, in Japan, we expect that many 4Mb/16Mb fabs now running 150mm wafers will convert to 200mm wafers, further gaining efficiency and productivity from the capital investment. Although this will increase the demand for silicon and 200mm wafers, it will likely delay the capital spending cycle by six to nine months.

Through 2001, we project a six-year worldwide capital spending CAGR of 16.7 percent, slightly ahead of the semiconductor consumption growth. We believe that capital spending may be influenced in late 1997 through 1999 positively with the facility construction and equipment purchases for the world's first 300mm wafer fab. We have built this infrastructure investment in our model.

A couple of years ago, Dataquest introduced a model that quantifies the overinvestment and underinvestment picture for wafer fab equipment and semiconductor capacity. Although the early 1990s created and sustained a net underinvestment, this picture was corrected to create about a 37 percent overinvestment by the end of 1995 (see Chapter 3 and Figures 3-1 and 3-2). Clearly this was in the danger zone, and we are seeing the results of this overinvestment today. By the end of 1998, should our forecasts for investment and semiconductor demand be on target, we would expect the industry to return to a 16 percent net underinvestment, setting the stage for a robust recovery starting in 1999.

Are Spending Levels Forecast Too High Relative to Semiconductors?

As capital spending as a percentage of semiconductor revenue exceeds 27 percent in 1996, clearly high by historical standards and creating overcapacity, a question is being asked often. What spending level is dangerous? What spending level is normal?

The industry normally cycles through overcapacity and undercapacity, because there is an inherent lag time between capital investment decisions and productive capacity. This will never go away. But we are experiencing levels of spending today that we have not seen since 1984; should we return to the spending levels of the late 1980s, the current downturn will clearly last longer than we are forecasting.

We think the industry is structured differently today, and there is a valid reason why higher levels of investment as a percentage of revenue than in the late 1980s are justified today.

We would split the market into four periods: before 1985, 1985 to 1992, 1993 to 2001(?), and 2002 and after. We will describe the conditions and trends in the production market and manufacturing infrastructure during these periods.

Before 1985: An Immature Manufacturing Industry

Characteristics of the period are:

- The semiconductor manufacturing infrastructure was fairly immature, characterized by large integrated systems companies, mostly in the United States.
- Manufacturing technology was favored over efficient use of capital, and device performance was favored over yield.
- Capital equipment manufacturers did not assume complete ownership of processes and system performance.
- These factors led to a capital spending ratio between 26 percent and 30 percent of revenue.

Two things happened to change the structure. First, the semiconductor downturn in 1985 ended up being extremely bloody, and, second, the emergence of the Japanese producer introduced a true manufacturing efficiency element into the infrastructure.

1985 through 1992: Becoming Manufacturing-Smart

The Japanese manufacturing ethic and the losses incurred during the 1985 downturn introduced the need for the industry to become more efficient in its manufacturing infrastructure. Several things happened:

- A focus developed on manufacturing productivity and yield.
- SEMATECH was formed, in part as a result of the need to coordinate this effort in the United States.
- Equipment companies were expected to take, and accepted, the ownership of the process and system performance parameters.
- Equipment performance and productivity increased substantially.
- Fab factory automation migrated from robotics to computer-controlled systems, and statistical process control became commonplace.
- The emergence of the Korean manufacturing power provided momentum for this transition.

By 1992, manufacturers had increased yields, and fab productivity was up dramatically. During this period, it was natural for the industry not to be required to spend as much on capital equipment, because the return per dollar spent was very high. Capital spending decreased to an artificially low 18 percent of revenue, on average.

Once yields achieved high levels and system productivity approached the point at which it was impractical to continue for most equipment types (to do otherwise would mean decreased equipment utilization), the return from these activities were diminished. The industry then entered the next period.

1993 through 2001 (?): Growth

As the industry built an efficient manufacturing infrastructure, it was now ready for the emergence of the semiconductor as the enabling technology in many electronic systems, and the industry entered an era of prosperity. Semiconductors have become the productivity engine for the world's business, implementing communications systems and the power of the PC to improve worker efficiency. Characteristics we are now experiencing are:

- Unit growth in semiconductors has required manufacturers to invest in capacity for growth.
- Profitability has attracted new entrants with a concentration on manufacturing.
- Dedicated contract manufacturing has emerged as a new manufacturing model for the industry, enabled because of equipment efficiencies and the need to separate manufacturing from device innovation.

When the industry reached the point at which returns from yield and productivity from equipment had diminishing returns, the capital spending ratio could no longer be maintained at artificially low levels. We believe the current equilibrium level is about 22 percent of semiconductor revenue.

Further, because of the growth in the device market, this boom has been unprecedented in the industry in terms of length and levels of growth in capital spending. This has been the result of the industry adjusting to a new, higher spending level and of the increased unit demand.

Beyond 2001: A Maturing Manufacturing Infrastructure

With the emergence of dedicated contract manufacturing, Dataquest believes that the industry's manufacturing infrastructure will evolve so that the foundry becomes an integral part of the manufacturing environment, as been the case with electronic equipment in general (Solectron is an example).

The foundry business model requires high equipment utilization, and we expect that sometime in the next five years this will influence the capital efficiency and decrease the capital spending ratio to perhaps 20 percent of revenue. This will not become evident until contract manufacturing increases in scope, from the estimated 9 percent of semiconductor production in 1995 to levels that could approach 35 percent to 45 percent by the year 2010.

The Americas Market Will Exhibit Strategic Strength Long Term

Capital spending in the Americas region grew at an accelerated 69 percent in 1995, with most of the investment growth in 1995 coming from U.S. companies connected with ASIC and logic products. Capital spending is decelerating in 1996 and into 1997, but Dataquest expects that investment in advanced technology, coupled with the earlier capacity upturn from the advanced logic segment, will stabilize the region's spending later in 1997 and will lead the market's recovery in 1998 to 1999 as it did in 1993. Dataquest is currently forecasting that the Americas region will be the second-fastest-growing region, at a 16.1 percent CAGR for 1995 through 2001, driven by the recent low cost of capital and the need for foreign multinational and foundry manufacturers to build fabs in the United States to be closer to their customers.

The relatively strong growth in capital spending had been driven by the ongoing growth in PCs, telecommunications, and networking. This key driver has not disappeared, as these products have seen increasing use as tools to increase workplace productivity. Electronic products with increased semiconductor content have created enormous demand for microprocessors, microcontrollers, SRAM, programmable logic and memory, standard logic, and peripheral controllers. The U.S. companies dominate many of these market segments. These segments combined are expected to maintain fairly stable growth rates over the next few years, with PC growth slowing (however, still maintaining a 17 percent CAGR) and networking and telecommunications expanding. The near-term market for PCs has remained robust worldwide, despite the slower growth and penetration into the U.S. home market.

New products and services, such as personal communicators, interactive television, and video on demand provide the potential for enormous growth in semiconductor sales longer term, especially for highly integrated complex logic and signal-processing chips that will be the core engines of future systems.

Although the strategic strength of the core logic products enables a healthy and flourishing semiconductor production environment, it is also one that is less volatile in capital spending. In the boom years of 1994 and 1995, the Americas region grew at somewhat lower than the market rates. This trait will also enable the Americas market to grow in capital spending at faster than market rates (or remain more stable) in the slower years, such as 1997 and 1998. We believe companies will strategically invest in technologically advanced capacity to preserve competitive advantage.

Capital investment trends in the Americas region for 1996 have a definite split personality. While Intel is finishing up expansion of Fab 11.2 in New Mexico and ramping Fab 12 in Arizona, it has reduced spending from initial expectations because of increased yields. Micron Technology stopped investments in Lehi, Utah, but continues aggressive expansion and conversion to 200mm at all three fabs in Boise, Idaho. Memory-sensitive plant expansions such as Fujitsu's Gresham, Oregon, plant and Integrated Device Technology's Oregon fab have been delayed or have slower ramps, yet IBM has been very aggressive in its Burlington, Vermont, expansion of 16Mb DRAM production thus far. Logic investment has seen a slowdown as well, with LSI Logic's push out of its Oregon fab, the delay of Motorola's North Carolina PowerPC fab, and the slow ramp-up of Advanced Micro Devices' Fab 25 in Austin, Texas. Yet Cirrus Logic and Lucent Technologies have increased spending dramatically to ramp fabs in the eastern United States, with Atmel expanding aggressively in Colorado and Rockwell's emerging success creating opportunity for equipment companies in California. SGS-Thomson has remained aggressive in spending in the United States, placing finishing touches on its new Arizona facility, as well as starting up Fab 4 in Carrollton, Texas. Texas Instruments remains aggressive, spending in capacity expansion for DSP chip capacity. Although it is not likely that either Samsung or TSMC will place equipment into their new U.S. fabs in 1996, capital spending on the shells is progressing.

Japan: DRAM Capacity Additions Stop, Investment in Technology Under Way

Japan's 49 percent increase in capital spending in 1995 is only 37 percent on a yen basis as Japanese companies look to invest outside Japan to optimize buying power. Japanese spending has essentially stopped growing and actually will decline about 2 percent in 1996. Because of the early cutback in spending, 1997 remains a flat capital spending year, as well, with only modest growth in 1998.

Some of the Japanese electronics giants that experienced good profit growth in 1995, driven by semiconductor operations, have seen those profits evaporate with the precipitous fall of DRAM prices. Although spending on capacity has essentially stopped, two other types of investment are likely to be important in Japan now through 1998.

First, Japanese companies will invest in any new technology and equipment targeted at the 0.25-micron production arena. This technology will not likely be in volume production until 1999, but the Japanese companies are expected to take advantage of this slowdown to understand and progress down the learning curve on these new process technologies. Second, the Japanese companies found that the shells built in 1990 and 1991 became an asset during the ramp in 1993 and 1994. By building a fab shell, equipped with a skeleton equipment set, they were positioned to more quickly ramp up production when the market turned up. We see that same pattern repeating, so we would expect several new fabs to be started in 1996 and 1997, although at very low run rates. Once these fabs are in place, the Japanese companies can continue to review the market every six months, making course corrections in April and October, as they have been doing through the last cycle ramp.

Although new facilities by Japanese companies will come on line outside Japan throughout the rest of this decade, DRAM investments inside Japan are really the only driving force today, although diversification has come to the forefront again in Japan. Japanese companies will continue to invest but will grow outside Japan faster than within Japan. We are therefore forecasting a below-average CAGR of 12.9 percent for the Japan region for 1995 through 2001.

One bright spot is that a PC boom could emerge in Japan over the next year or two, spawned by the networking infrastructure that is being built. This would breathe new life into the Japanese semiconductor market and our forecast would be brightened a bit. We do not think that even a PC boom, however, would create a forecast different from several percentage points below the world average. The fundamentals of Japanese production capacity are still too heavily concentrated in DRAMs, with no clear future direction emerging as yet, which keeps us from being more optimistic about capital activities in Japan.

Europe Sustains Presence as a Growth Market

After a growth bubble of 46 percent in 1993, higher than expected, European spending "moderated" to a slower-than-market growth rate in 1994 after multinationals (Intel) substantially completed the majority of their expansions in 1993. The growth of 44 percent in 1994 is nonetheless extremely healthy, primarily being fueled by the European companies themselves—the ever-present SGS-Thomson, Philips expanding in Nijmegen, the Netherlands, and Ericcson equipping its expansion.

Europe continued to attract capital in 1995, growing 65 percent. Large multinationals are still present, with Motorola upgrading the Scotland fab bought from Digital Equipment Corporation, the new IBM/Philips venture in Germany, Analog Devices' expansion in Ireland, Texas Instruments' continued expansion in Italy, and the IBM/Siemens fab's continued ramp of 16Mb DRAMs in France. The key expansion is Siemens' new fab in Dresden, which was the key driver pulling Siemens into the top 10 in capital spending worldwide in 1996. Like the United States, Europe is experiencing slowdowns this year. Although SGS-Thomson and Siemens remain strong, Philips and the Japanese companies have pulled back investment in capacity significantly. We are looking for continued growth in 1996 of 22 percent as production continues to ramp from these and eight new fabs, most notably by GEC Plessey and TEMIC. However, in part because we do not believe that Siemens can sustain its current spending, we are calling for a 12 percent decline in spending in Europe for 1997 and a flat-to-down 1998 because we expect multinationals will ramp domestic memory fabs before Europe. Samsung has announced a fab to come on line in Europe but as yet is undecided about the exact location or timing.

Europe is viewed as a strategic location for production longer term to take better advantage of European and 16Mb DRAM growth in the future, driven by the PC production boom, without import tariffs. We therefore expect Europe to be a nearly average investment region in the long term, with a six-year CAGR of 15 percent.

Asia/Pacific Investing Focusing on Foundry as the DRAM Falls

The often erratic but sustained semiconductor capital spending growth in the Asia/Pacific region continued at the explosive rate of 112 percent in 1995. We expect a "moderated" growth of about 30 percent in 1996 as several new fab projects are built and equipped. However, the tide has turned in the DRAM area, and we are forecasting the Asia/Pacific region to be hit the hardest in 1997, with a nearly 15 decline in capital spending. Longer term, we expect Asia/Pacific to exhibit among the most aggressive growth in capital spending of any region. Dataquest forecasts a 1995-through-2001 CAGR of 20.3 percent.

Spending in 1995 and early 1996 came primarily from two areas, DRAMs and foundry capacity. The Korean conglomerates are continuing their relentless DRAM capacity expansion plans, although more moderately in 1996. We do expect these companies to succumb to the inevitable reality of overcapacity, with significant cutbacks for 1997.

The real story of interest in 1995 and 1996 is the new Taiwan players. Vanguard International brought on its new DRAM fab late last year, and PowerChip Semiconductor and Nan Ya Plastics, among others, brought new DRAM capacity on line late last year and early 1996. All of these are targeted at 16Mb DRAM running 200mm wafers. Current players such as TI/Acer and Mosel Vitelic were also increasing their spending with new projects. But the tide has turned quickly, likely accelerated by the fact that the Taiwanese stock market is very close to the U.S. stock market in its reaction to bad news. Many companies in DRAM are now cutting back feverishly to save near-term profitability.

However, Taiwan chip companies TSMC, Macronix, and United Microelectronics Corporation, along with Chartered Semiconductor in Singapore and Submicron Technology in Thailand, continue with their plans to expand foundry capacity. InterConnect Technology, with its new foundry fab in Malaysia, is part of what we believe will be several new entries into this business. The reason for the continued interest in spending capital in this area comes from the fact that the core business is dependent on logic and PC unit demand rather than DRAM. Further, Dataquest estimates that only about 32 percent of the contracted manufacturing of semiconductors originates from fabless companies. The remainder is from integrated device manufacturers (IDMs) that wish to place the manufacturing of lower value-added products away from their own facilities in order to maximize resources and cost, that wish to reduce investment risks using foundries as an extension of their own capacity, or that wish to use the more advanced technology of foundries (in some cases) as a growth strategy.

The last few years have seen the flourishing of the dedicated foundry, mostly in Asia/Pacific. It is still believed that the largest concentration of foundry capacity in the world today, however, is in Japan, with companies like Rohm, Seiko-Epson, Sharp, and other large integrated companies. But with the investment trends in Asia/Pacific, the lead will likely change within the next five years.

However, the appetite for leading-edge foundries has caused another transformation. With the cost of capital increasing and with a higher level needed for leading-edge equipment, foundry companies have established longer-term contracts with customer companies, sometimes involving capital infusions toward production equipment and sometimes involving technology. In return, customer companies are looking for dedicated capacity allocations. Many joint venture have been announced in the last year, and we expect this trend to continue. The foundry industry is now a strategic industry rather than simply a tactical one. With this transformation nearly complete, we are starting to see the dedicated investment to build new foundry capacity.

Who's Investing Where?

In our recently completed capital spending survey, Dataquest gathered information on how money is being spent. Table 2-5 summarizes how companies based in different regions are spending their money abroad for 1995, and Table 2-6 summarizes this for 1996. About 79 percent of the money spent went into domestic economies worldwide in 1995, and that ratio increased slightly to 80 percent in 1996 as companies tend to cut back externally first.

Asia/Pacific companies have historically placed all their investments domestically, but 1994 was the first year of diversification, which continued in 1995. Asia/Pacific companies spent about 4 percent of their money abroad in 1995, increasing to about 6 percent in 1996. We would expect this ratio to increase significantly over the next two to three years. European companies have been the most aggressive capital exporters historically, placing only 59 percent of their investment inside Europe. This figure grew slightly to 63 percent in 1996 and should expand in 1997 as European companies rein in spending.

Japanese companies are very close to the worldwide average, with about 77 percent domestic investment in 1995, rising to 80 percent in 1996. Americas region companies are also high domestic spenders, with about 73 percent staying at home for both years.

The Americas and Japanese regions are net investors, while European and Asia/Pacific regions are net beneficiaries of that investment. This parallels those regions being net exporters and net importers of semiconductors, respectively.

Table 2-5
Regional Investment Patterns of Semiconductor Manufacturers in 1995 (Millions of U.S. Dollars)

	Worldwide	Americas	Japan	Europe	Asia/Pacific	Percentage of World Spending
American Companies	13,840.3	10,112.2	655.1	1,423.3	1,649.6	36.1
Japanese Companies	12,042.3	1,328.7	9,247.7	738.7	727.3	31.4
European Companies	3,301.5	420.2	7.2	1,936.0	938.1	8.6
Asia/Pacific Companies	9,124.0	285.5	0	38.9	8,799.6	23.8
All Companies	38,308.1	12,146.6	9,910.0	4,136.9	12,114.6	100.0
Growth from 1994 (%)	73.5	68.8	48.6	65.2	111.8	

Source: Dataquest (July 1996)

Table 2-6
Regional Investment Patterns of Semiconductor Manufacturers in 1996 (Millions of U.S. Dollars)

	Worldwide	Americas	Japan	Europe	Asia/Pacific	Percentage of World Spending
American Companies	17,261.3	12,598.0	742.4	2,019.3	1,901.5	38.1
Japanese Companies	11,201.5	1,051.5	8,949.2	603.3	597.4	24.7
European Companies	3,802.0	359.7	0	2,412.5	1,029.8	8.4
Asia/Pacific Companies	13,079.2	818.8	0	23.0	12,237.4	28.8
All Companies	45,344.0	14,828.1	9,691.7	5,058.2	15,766.1	100.0
Growth from 1995 (%)	18.4	22.1	-2.2	22.3	30.1	

Source: Dataquest (July 1996)

Although all regions are spending in Asia/Pacific and all multinational regions are investing in Europe, only North American companies have the strategic vision to invest in Japan. Japanese companies are also investing on a worldwide basis. We believe this is one of the key elements necessary in a strategic plan for a semiconductor company to be competitive on a global basis.

Dataquest Perspective

The capital spending boom experienced in 1993 through the first half of 1996 is over, and the industry is now in what we would characterize as an 18-to-24-month pause, with investment in capacity initially declining and stabilizing as demand catches up to supply. The marked downturn in the DRAM investment cycle was triggered in part by the 1x16 configuration of the 16Mb DRAM achieving yields of about 60 percent to 65 percent, which occurred near the end of 1995.

In the second half of 1995, a complicating factor entered the picture—the larger-than-actual anticipated demand for memory created by the introduction of Windows 95, which, taken with the tight supply of memory last year, caused inventories to inflate to enormous levels. This situation started correcting in the final quarter of last year, slightly in advance, but essentially on top of, the yield trigger for the 16Mb DRAM conversion timing. Now we have a double-barreled driver (demand and supply) for the DRAM price slide and capital spending downturn. These events have increased the anticipated severity of the downturn.

The industry is now relying on the continued growth in personal computer unit sales, with added growth in telecommunications and networking products, to create a unit demand picture that will keep this slowdown short-lived from a historical perspective. The wafer fab capacity bubble has burst in all regions and for most semiconductor products, most notably DRAMs, mixed-signal devices, and analog devices. The 1995 spending growth was almost entirely driven by DRAM and microcomponent capacity purchases, 1996 was a year of transition, and 1997 is a year of investment in technology.

Based on how capacity is migrating among device types, Dataquest believes that the first area of spending recovery will be advanced logic, as early as mid-1997. Equipment companies positioned for these markets will have a more moderate slowdown and perhaps can grow through this time if they have advanced technology. The microcontroller (MCU), analog, mixed-signal, and telecom chip capacity will be next to recover, but this will probably not occur until the end of 1997 or early 1998. The DRAM segment, the root cause of the problem and the very last to recover, is not expected to resume robust spending until mid-to-late 1998. The next major and broad investment cycle will have momentum by 1999.

We believe that capital spending may be influenced in late 1997 through 1999 positively with facility construction and equipment purchases for the world's first 300mm wafer fab. We have built this infrastructure investment into our model.

Chapter 3
Wafer Fab Equipment Forecast

This chapter presents data on worldwide spending by region for wafer fabrication equipment. Wafer fab equipment spending in a region includes spending by all semiconductor producers with plants in that region. Included are all classifications of equipment for front-end semiconductor operations.

Chapter Highlights

This chapter will discuss the following highlights:

- Wafer fab equipment spending growth in 1995 exceeded 1994, with 77 percent growth worldwide. However, overcapacity has gripped the industry, and wafer fab equipment growth will slow markedly to 17 percent in 1996 and suffer a decline in 1997.
- The only reasons that 1996 remains a double-digit growth year are that there were strong backlogs coming out of 1995 and because some companies increased spending early in the year. The second half of 1996 is expected to be lower than the first half.
- Segment growth in 1995 and the first half of 1996 was being led by DRAM and capital spending-sensitive equipment, with steppers, implant, wafer inspection, and factory automation equipment exhibiting significantly stronger-than-market growth. We believe the second half of 1996 and 1997 will concentrate on advanced technology equipment and some capacity additions in the advanced logic area.
- A purchasing behavior that will be prevalent over the next 12 to 18 months will be new processes and equipment directed at solving issues for 0.35-micron and 0.25-micron manufacturing. These segments will be those related primarily to deep-UV lithography and inspection and 0.25-micron multilevel metallization process schemes.
- Dataquest's model that measures the net cumulative underinvestment or overinvestment indicates that by the end of 1995, the semiconductor manufacturing world was overinvested in wafer fab equipment to the tune of $7.0 billion, or 37 percent of the market. This is above the peaks exhibited in 1984 and 1989, so it is no surprise that excess capacity has emerged during 1996 in the DRAM market, where capacity has been added recently.
- After four strong expansion years in 1993 through 1996, equipment purchases in 1997 should decline, followed by a flat 1998. The next expansion should kick in by late 1998 or 1999, driven by 0.3-micron to 0.35-micron capacity expansion. The worldwide wafer fab equipment market is forecast to grow at 16.2 percent CAGR between 1995 and 2001, slightly above the semiconductor market growth.
- We have factored in an infrastructure investment in equipment for late 1997 through 1999, which will affect the forecast size of the markets positively. This additional investment will be for initial equipment to fill a couple of 300mm fabs to run silicon by 1999. The bulk of this 300mm equipment bubble occurs in 1998. However, our outlook for a significant 300mm equipment market will wait until 2001 to 2002.

This chapter presents historical and forecast data on the worldwide wafer fabrication equipment market, by region and by key equipment segment. In this midyear forecast for wafer fab equipment, we have chosen to focus our forecast of equipment categories on specific segments and issues, namely:

- The annual investment theme for 1995 to 2000
- Steppers and automatic photoresist processing equipment (track)
- Dry etch and chemical mechanical polishing (CMP)
- Silicon epitaxy, chemical vapor deposition (CVD), and physical vapor deposition (PVD)
- Diffusion and RTP
- Ion implantation (medium current, high current, and high voltage)
- Segments that will fare best the next two years

These segments of the equipment market represent not only the majority of all wafer fab equipment expenditure in the world today, but also embody the key technological capability for advanced device production. Highlights of some of the factors affecting individual equipment segment forecasts also are presented.

Equipment spending in a region refers to spending by all companies—both domestic and foreign—within the region. We note also that yearly exchange rate variations can have a significant effect on 1989-through-1996 data appearing in the tables in this chapter. Appendix B details the exchange rates used in this document.

Table 3-1 provides historical market data, by geographic region for 1989 through 1995, and Table 3-2 shows forecast market data, by geographic region for 1995 through 2001. Table 3-3 shows historical data for key equipment segments for 1989 through 1995. Table 3-4 provides forecast data for key equipment segment for the years 1995 through 2001.

Table 3-1
Worldwide Wafer Fab Equipment Market History, by Region, 1989-1995
(Millions of U.S. Dollars)

	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Americas	1,657	1,589	1,519	1,576	2,118	3,190	5,179	20.9
Change (%)	7.9	-4.1	-4.4	3.8	34.4	50.6	62.3	
Japan	2,813	2,996	3,012	2,098	2,450	3,661	6,352	14.5
Change (%)	23.9	6.5	0.5	-30.3	16.8	49.4	73.5	
Europe	721	764	641	641	988	1,370	2,316	21.5
Change (%)	8.7	6.0	-16.1	0.0	54.1	38.6	69.1	
Asia/Pacific	820	522	832	783	1,312	2,567	5,208	36.1
Change (%)	58.1	-36.4	59.5	-5.8	67.5	95.7	102.9	
Total Wafer Fab Equipment	6,011	5,871	6,003	5,098	6,868	10,787	19,054	21.2
Change (%)	20.6	-2.3	2.3	-15.1	34.7	57.1	76.6	

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (July 1996)

Table 3-2
Worldwide Wafer Fab Equipment Market Forecast by Region, 1995-2001
(Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Americas	5,179	6,217	5,453	6,163	7,797	10,530	13,105	16.7
Change (%)	62.3	20.1	-12.3	13.0	26.5	35.1	24.5	
Japan	6,352	6,423	5,272	5,635	7,011	9,679	11,694	10.7
Change (%)	73.5	1.1	-17.9	6.9	24.4	38.1	20.8	
Europe	2,316	2,642	2,428	2,486	3,124	4,253	5,520	15.6
Change (%)	69.1	14.1	-8.1	2.4	25.7	36.1	29.8	
Asia/Pacific	5,208	7,026	5,607	5,616	7,448	11,757	16,570	21.3
Change (%)	102.9	34.9	-20.2	0.2	32.6	57.8	40.9	
Total Wafer Fab Equipment	19,054	22,309	18,760	19,900	25,380	36,219	46,889	16.2
Change (%)	76.6	17.1	-15.9	6.1	27.5	42.7	29.5	

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (July 1996)

Table 3-3
Wafer Fab Equipment Revenue History by Equipment Segment, 1989-1995
(Millions of U.S. Dollars)

Equipment Segment	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Worldwide Fab Equipment	6,011	5,871	6,003	5,098	6,868	10,787	19,054	21.2
Change (%)	20.5	-2.3	2.2	-15.1	34.7	57.1	76.6	
Steppers	1,181	1,052	979	646	1,007	1,833	3,332	18.9
Track	322	317	364	353	500	695	1,413	27.9
Maskmaking Lithography	69	47	48	53	52	79	82	2.9
Direct Write E-Beam	70	76	50	26	23	35	38	-9.7
Other Lithography[1]	122	119	107	80	97	90	80	-6.8
Total Lithography/Track	1,764	1,612	1,549	1,158	1,679	2,732	4,944	18.7
Automated Wet Stations	243	268	291	286	285	468	928	25.0
Other Clean Process	134	132	143	103	198	213	389	19.5
Dry Strip	121	118	119	123	138	213	369	20.4
Dry Etch	670	690	717	682	1,083	1,592	2,842	27.2
Chemical Mechanical Polishing	NS	NS	11	20	44	64	197	NA
Total Etch and Clean	1,168	1,208	1,281	1,213	1,748	2,548	4,724	26.2

(Continued)

Table 3-3 (Continued)
Wafer Fab Equipment Revenue History by Equipment Segment, 1989-1995
(Millions of U.S. Dollars)

Equipment Segment	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Tube CVD	220	259	268	213	283	442	780	23.5
Nontube Reactor CVD	388	457	474	437	585	885	1,803	29.2
Sputtering	320	359	425	446	584	1,012	1,567	30.3
Silicon Epitaxy	75	68	89	84	83	114	207	18.4
Other Deposition[2]	170	153	147	119	115	101	124	-5.1
Total Deposition	1,173	1,296	1,403	1,300	1,650	2,553	4,480	25.0
Diffusion	332	325	326	246	342	490	773	15.1
RTP	25	33	46	36	45	76	154	35.2
Total Thermal Nondeposition	357	358	372	283	388	567	927	17.2
Medium-Current Implant	131	114	108	83	108	242	384	19.6
High-Current Implant	301	250	228	164	233	391	550	10.6
High-Voltage Implant	25	7	18	16	18	27	119	30.1
Total Ion Implantation	457	370	353	263	359	659	1,053	14.9
Optical Metrology	74	59	59	40	43	67	98	4.8
CD-SEM	81	88	93	78	83	154	313	25.4
Thin Film Measurement	NS	NS	43	58	72	100	196	NA
Patterned Wafer Inspection	116	105	90	109	144	281	535	29.1
Auto Unpatterned Detection	37	45	41	30	32	56	111	20.1
Other Process Control[3]	369	313	307	228	270	446	601	8.5
Total Process Control	676	609	632	542	644	1,103	1,854	18.3
Factory Automation	195	216	227	194	250	412	686	23.3
Other Equipment	222	202	185	146	151	213	386	9.6
Total FA/Other Equipment	417	418	412	340	401	625	1,072	17.0
Total Wafer Fab Equipment	6,011	5,871	6,003	5,098	6,868	10,787	19,054	21.2

NS = Not surveyed
NA = Not applicable
[1]Includes contact/proximity, projection aligners, and X-ray lithography
[2]Includes evaporation, MOCVD, and MBE
[3]Includes auto review/classification, manual detection/review, and other process control equipment
Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (July 1996)

Table 3-4
Wafer Fab Equipment Revenue Forecast by Equipment Segment, 1995-2001
(Millions of U.S. Dollars)

Equipment Segment	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Worldwide Fab Equipment	19,054	22,309	18,760	19,900	25,380	36,219	46,889	16.2
Change (%)	76.6	17.1	-15.9	6.1	27.5	42.7	29.5	
Steppers	3,332	3,768	2,673	3,019	4,126	6,140	7,619	14.8
Track	1,413	1,573	1,235	1,367	1,908	2,671	3,460	16.1
Maskmaking Lithography	82	149	187	217	271	332	422	31.4
Direct Write E-Beam	38	49	36	43	54	68	98	17.2
Other Lithography[1]	80	85	77	77	86	107	127	8.0
Total Lithography/Track	4,944	5,624	4,208	4,722	6,445	9,317	11,727	15.5
Automated Wet Stations	928	1,071	954	1,004	1,245	1,694	2,274	16.1
Other Clean Process	389	497	438	445	515	695	938	15.8
Dry Strip	369	431	385	402	493	702	928	16.6
Dry Etch	2,842	3,324	2,871	2,954	3,638	5,127	6,560	15.0
Chemical Mechanical Polishing	197	252	268	323	456	677	985	30.8
Total Etch and Clean	4,724	5,575	4,917	5,128	6,347	8,896	11,685	16.3
Tube CVD	780	872	746	788	974	1,358	1,711	14.0
Nontube Reactor CVD	1,803	2,182	1,955	2,068	2,556	3,690	5,017	18.6
Sputtering	1,567	1,798	1,573	1,638	2,046	2,888	3,775	15.8
Silicon Epitaxy	207	277	272	299	389	524	694	22.4
Other Deposition[2]	124	118	89	85	96	118	136	1.6
Total Deposition	4,480	5,247	4,635	4,878	6,061	8,579	11,333	16.7
Diffusion	773	886	737	760	932	1,301	1,650	13.5
RTP	154	239	255	284	382	578	689	28.4
Total Thermal Nondeposition	927	1,124	992	1,044	1,314	1,879	2,340	16.7
Medium-Current Implant	384	435	340	325	394	599	769	12.3
High-Current Implant	550	714	561	551	764	1,212	1,604	19.5
High-Voltage Implant	119	152	102	108	150	235	333	18.7
Total Ion Implantation	1,053	1,301	1,003	985	1,309	2,047	2,705	17.0

(Continued)

Table 3-4 (Continued)
Wafer Fab Equipment Revenue Forecast by Equipment Segment, 1995-2001
(Millions of U.S. Dollars)

Equipment Segment	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Optical Metrology	98	103	76	81	106	146	183	11.0
CD-SEM	313	339	264	307	421	574	722	15.0
Thin Film Measurement	196	232	210	225	291	364	464	15.4
Patterned Wafer Inspection	535	609	501	532	670	998	1,266	15.4
Auto Unpatterned Detection	111	145	138	132	143	175	244	14.1
Other Process Control[3]	601	776	665	666	776	1,080	1,500	16.5
Total Process Control	1,854	2,204	1,853	1,942	2,408	3,337	4,379	15.4
Factory Automation	686	834	793	798	1,023	1,498	1,876	18.2
Other Equipment	386	399	359	404	473	667	844	13.9
Total FA/Other Equipment	1,072	1,234	1,152	1,201	1,496	2,164	2,720	16.8
Total Wafer Fab Equipment	19,054	22,309	18,760	19,900	25,380	36,219	46,889	16.2

[1]Includes contact/proximity, projection aligners, and X-ray lithography
[2]Includes evaporation, MOCVD, and MBE
[3]Includes auto review/classification, manual detection/review, and other process control equipment
Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (July 1996)

Annual Investment Themes for 1996 through 2001

Behind our equipment and segment forecasts are assumptions about how semiconductor producers will perform and invest. These are summarized in Table 3-5 for the years 1996 through 2001. The following areas are considered: the availability of profits for reinvestment, memory versus logic growth, technology shifts, and brick and mortar versus equipment purchases.

When Will Demand Expand to Meet Capacity? An Update to the Overinvestment or Underinvestment Model

In Dataquest's forecasts for the last couple of years, we have shown a model that provided a measure of the net cumulative overinvestment or underinvestment in wafer fab equipment to support capacity needs in the industry. Because equipment purchases precede actual capacity on line by a number of months or quarters, this model could be viewed as a gross leading indicator of capacity shortages and excesses. The results of this model are closer to a 1.5-year to three-year indicator of turning points in the equipment industry. The methodology of the net cumulative investment (NCI) model is linked to our longer-range forecast model.

Table 3-5
Annual Driving Forces and Investment Themes for Wafer Fab Equipment, 1996-2001

	1996	1997	1998	1999	2000	2001
Logic Semiconductor Unit Growth	Moderate	Moderate to Solid	Solid	Solid	Strong	Solid
Investment in Logic Capacity	Moderate	Moderate	Solid	Solid	Strong	Solid
Memory Semiconductor Unit (Not Bit) Growth	Moderate	Weak	Moderate	Solid	Strong	Moderate
Investment in Memory Capacity	Moderate	Dead	Weak	Moderate	Strong	Solid
Front-End Equipment versus Facilities Loading of Capital	Balanced	Facilities	Facilities	Equipment	Equipment	Balanced
Primary Technologies Invested	0.35-0.5 micron	0.3-0.5 micron	0.3-0.4 micron	0.25-0.4 micron	0.25-0.4 micron	0.2-0.35 micron

Note: Scale = strong > solid > moderate > weak > dead
Source: Dataquest (August 1996)

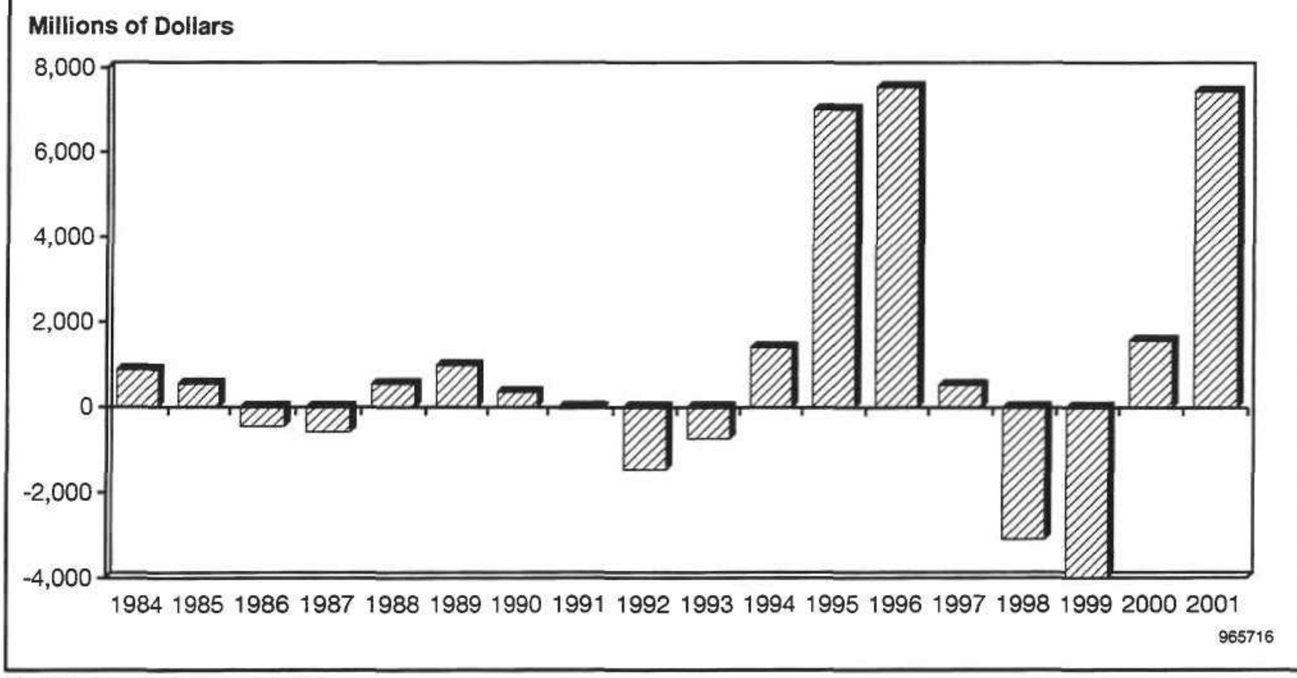
This methodology starts with a few key assumptions and baselines:

- Long-term growth rates for semiconductors and wafer fab equipment are correlated. In other words, semiconductor revenue and profits are needed before money can be spent on equipment and vice versa.
- Also, net cumulative investment equals zero over time ... meaning that in a noncyclical environment where annual growth rates are constant, investment and capacity are at equilibrium at all times. Of course, this industry cycles through overinvestment and underinvestment.
- The output is a tangible number and is in dollars of over or under-investment at year's end. However, the more useful output of the model divides this gross dollar number by the wafer fab equipment market size. The result is a percentage of market figure that is repeatable in level from cycle to cycle.
- To take into consideration the long-term growth of the semiconductor and equipment industries, the model has a factor allowing the fundamentals of the industry to change over time.

A net positive or negative investment is calculated relative to the long-term growth baseline annually and then added to the prior year. The calculation resulted in a dollar value *net cumulative* overinvestment or underinvestment and has correlated well with historical patterns.

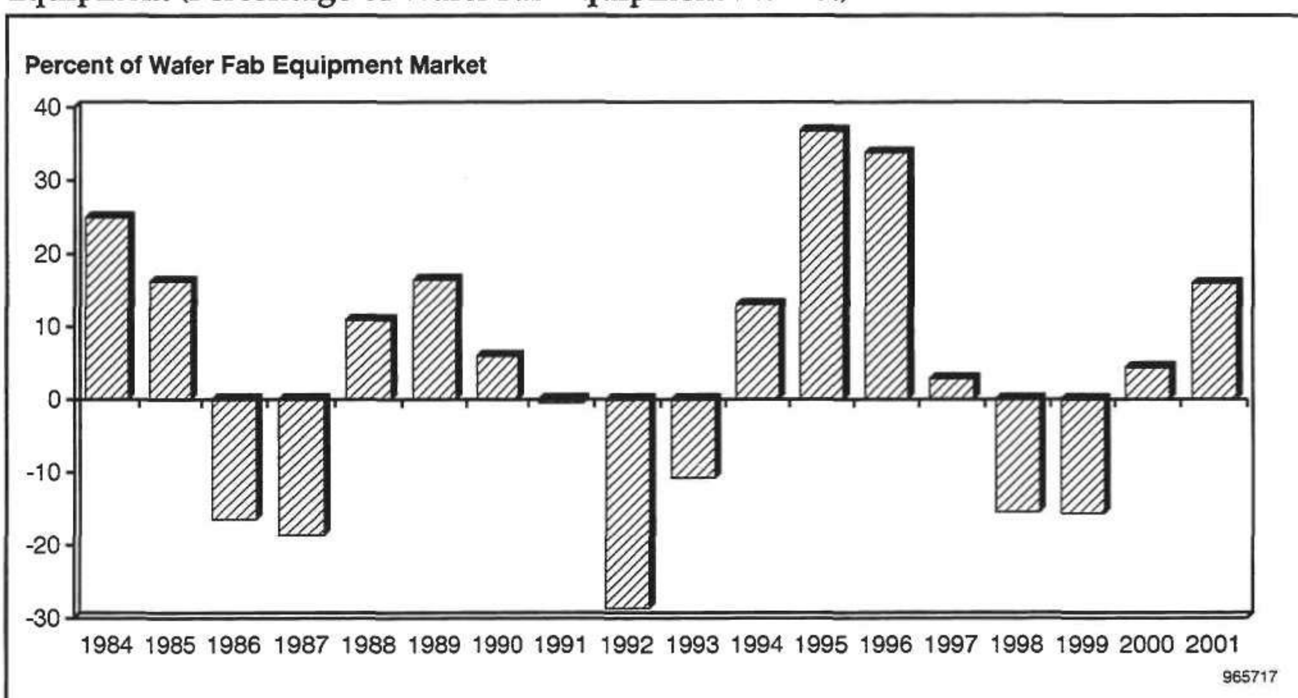
Figures 3-1 and 3-2 show the most recent results of the model, little changed from our previous forecast update. In absolute dollar terms, by the end of 1995 the industry was $7.0 billion overinvested, or 37 percent of the wafer fab equipment market, exceeding levels witnessed during the 1984 and 1989 peaks. These levels are occurring for two basic reasons. First, PC unit demand continued to show annual growth in the range of the low twenties. About one-third of the semiconductor industry and over one-half of the capital spending on new capacity is to support this demand.

Figure 3-1
Net Cumulative Overinvestment and Underinvestment of Semiconductor Wafer Fab Equipment (Millions of U.S. Dollars)



Source: Dataquest (August 1996)

Figure 3-2
Net Cumulative Overinvestment and Underinvestment of Semiconductor Wafer Fab Equipment (Percentage of Wafer Fab Equipment Market)



Source: Dataquest (August 1996)

Second, the DRAM market had not yet converted to run the more silicon-efficient 16Mb DRAM, placing this investment cycle about seven years behind the last cycle. DRAM bit demand generally runs at 50 percent annually, and DRAM manufacturing has depended on increasing unit densities (increasing the bits per square inch) to meet this demand. Shrinks of existing generations alone bring only 15 percent to 25 percent annual bit per square inch efficiencies, while converting a fab running 4Mb DRAMs to 16Mb DRAMs would increase bits per square inch by two to three times. Because low yields of the wider-configuration DRAM held back the economic conversion of the market, top-line bit demand is translating to square inch demand (silicon) and the equipment to run it. Because the equipment being installed is fully convertible to run 16Mb DRAMs, we can think of these fabs building "pent-up supply" in bits. Once 16Mb DRAM yields (for the 1x16 configuration) exceeded 60 percent to 65 percent, it is more economical to run these lines, and DRAM prices eroded.

We have factored into the model an investment in a couple of 300mm fabs starting in late 1997 through 1999, with the bulk in 1998. This is considered an equipment "bubble demand" because the equipment will be shipped into a nonproductive fab (meaning no semiconductor revenue will be generated initially).

With our forecast for a momentum-style growth in 1996 and two pause years in 1997 and 1998, the model indicates a reacceleration of equipment spending starting in 1999.

When Will Demand Expand to Meet Capacity? A Fundamental Set of Analyses

The NCI model described above is only a tool to indicate possible future turning points and should not be relied on to actually forecast capacity supply versus demand absolutely. A more fundamental, basic approach is required—looking at square inches of silicon capacity. How many wafers can be processed, and by what type of process, is much more enlightening in measuring capacity than measuring it for a particular device type. Capacity is very fluid; a stepper does not care whether the picture it takes is for a DRAM, SRAM, or logic device. But there are limits in transferring capacity. For example, logic processes have specialized process techniques that are not found in DRAMs and vice versa. SRAMs can use a DRAM equipment mix or a logic-oriented process scheme; the latter tends to have faster access times.

There are two major markets we can isolate in order to understand basic capacity supply and demand—the DRAM market and the foundry market. The latter is particularly interesting for two reasons. First, foundry capacity has tended to be more heavily oriented toward logic and ASIC processes, giving us a second perspective on capacity versus supply. Second, the major customer base for the foundry is the fabless company, whose products tend to be those that are placed within the PC logic and graphics chipsets. Because PCs now account for about one-third of all semiconductor use, about two-thirds of all DRAM consumption, and are the main engine for the current semiconductor boom, looking at PC-related capacity issues is important for understanding potential equipment market turning points.

The details of these analyses are provided in other reports, such as Dataquest's *DRAM Supply/Demand Quarterly Statistics* and ongoing research on the foundry market. A summary of the basic results and impacts will be given here.

In any supply/demand trend, there is a cycle between oversupply and undersupply. Investment in capacity tends to be in reaction to these situations and there is inevitably overshoot in both directions. Analysis is based on square inches of silicon and not on revenue, bit-demand, or unit demand. If demand for silicon area exceeds supply, the market is technically in undersupply. We will refer to the maximum undersupply point as the market "pinch point."

The following are the basic conclusions and impacts:

- The DRAM market's pinch point was during 1995, and, with the conversion to a more silicon-efficient (in terms of bits per square inch) 16Mb triggered, it caused the industry to step into oversupply quickly. This condition is expected to last into early 1998.
- The foundry market is split. There is oversupply at 0.6 micron and higher, but the market is in undersupply at 0.5 micron and below. The market is expected to remain in undercapacity at 0.5 micron through early 1997.
- 1996 is a year of transition and spotty investment in capacity. DRAM prices crashed early in the year. The market begins to transition to the 16Mb during the year, and prices will continue to decline gradually into 1997. Foundry prices are expected to be firm for advanced technology but edge downward during the year.
- 1997 will be a year of contraction, with weak DRAM capacity investment but continued strong investment in technology with logic capacity growth coming back later in the year. But the foundry capacity expansions will likely lose steam through the year into 1998. We expect DRAM investment to decline some 20 to 30 percent, with logic investment increasing 5 to 10 percent.
- 1998 will be a frustrating year. Even though DRAM capacity is likely to see its peak oversupply in 1997, significant reinvestment will not likely occur until late in 1998 or 1999 as companies delay investment and Japanese companies finish 200mm conversions. As the foundry market approaches oversupply, logic investment will cool. Yet we expect that semiconductor demand will begin to accelerate, signaling a underlying strength in the market and anticipation of the eventual upturn.
- 1999 becomes the first growth year in the next boom cycle. DRAM investment is likely to pick up again, while foundry investment will lag. U.S. logic capacity will likely be strong and lead foundry investment out of the pause. By 2000, the next equipment boom will be well under way and likely to last into 2001.

Highlights of Key Equipment Segment Markets and Forecasts

Steppers and Track

From 1989, the peak year of stepper shipments at more than 950 units, the market tumbled to less than 400 tools shipped in 1992 before recovering. During this DRAM-sensitive ramp, the industry experienced its first year exceeding 1,000 steppers shipped, indeed 1,228 steppers were shipped in 1995. The peak year will be this year, in which we expect over 1,300 steppers to ship. Shifts in the product mix toward higher-priced i-line systems and wide field lenses have also driven up average selling prices (ASPs). This trend will be offset somewhat in 1996 by the weak yen to drive a revenue increase of 13 percent on a dollar basis in 1996, slightly below the market growth. The stepper segment, being capacity-sensitive, is forecast to lag the market's performance in 1997 and 1998 and then lead market growth starting in 1999.

Stepper revenue is forecast to grow at a 14.8 percent CAGR, slightly below the market average for 1995 through 2001. Our forecast for stepper unit growth over the five-year forecast horizon remains modest, about 4.5 percent CAGR between 1995 and 2001.

With the adoption of phase-shift mask technology and off-axis illumination techniques, as well as conventional i-line tools with variable NA, i-line is clearly a viable technology down to the 0.3-micron regime and will continue to dominate the overall stepper technology mix through the year 2000. Excimer/deep-UV steppers will begin to represent a more significant portion of the product mix from 1997 onward for use in below-0.3-micron devices and ICs with large chip areas such as advanced microprocessors that require large field size capability. Dataquest believes that field size pressures accompanied by shrinking geometry will drive the industry toward step-and-scan (or step-and-stitch) technologies for the majority of excimer/deep-UV shipments, beginning in 1997.

Track equipment is forecast to grow at a 16.1 percent CAGR between 1995 and 2001, essentially equivalent to the industry growth of 16.2 percent. Although we believe that the rapid shift in the product mix toward higher-priced systems was recently completed, we do expect another product shift to occur in the track market, associated with the ramp of deep-UV steppers, which require more sophisticated environmental control systems and will translate to higher ASPs.

Etch and Clean: Dry Etch and Chemical Mechanical Polishing

Dataquest began covering the chemical mechanical polishing (CMP) market in 1993. At this time, Dataquest includes the post-CMP clean system, usually sold in conjunction with a CMP tool, as part of the cleaning segment, and not in the CMP segment. (This will likely change when statistics are collected for 1996 because there are many systems sold today as integrated CMP and clean.) The year 1994 was a time of evaluating the technology and gaining experience with it in production before widespread adoption into production.

In 1995, that adoption started, with CMP systems growing 208 percent to $197 million. Even though the application appears to be limited to devices with at least three levels of metal, which tends to exclude the DRAM market, the acceptance of the technology into logic and particularly the foundry market has been the key turning point. Based on the demand of the customer, however, and because of the introduction of more robust equipment, we now believe most foundries offer CMP at 0.5 micron.

These systems are used to remove material from the surface of the wafer, resulting in a flat surface over the entire wafer. This global planarization, primarily of dielectric layers, is required to achieve high yields in devices where three or more levels of metal are used. Today's advanced logic and ASIC devices are fueling this market growth. Dataquest believes that this technology and market will become a major part of semiconductor manufacturing in the long run.

If we were to make a forecast based purely on technology driving the market, we would not be slowing the CMP market forecast in 1997 and 1998. However, we believe that time will see some holding back of capital investment, and history has shown us that even advanced, emerging technologies are rarely spared in a capital slowdown. Nevertheless, CMP is our fastest-growing segment, with a 31 percent CAGR for 1995 through 2001.

Dry etch systems continue to exhibit strong revenue growth, with a CAGR of 15 percent forecast for the years 1995 through 2001. Unit shipments are expected to grow as greater multilevel interconnect process capacity is brought online, increasing the need for dielectric and metal capacity. Relatively strong ASP growth will lend additional momentum to dry etch revenue growth as new high-density plasma systems for 0.35-micron applications enter the market and multichamber cluster tools continue to increase their presence. The success of CMP will hold etch below market growth, however, particularly in metal etch, as stringer removal becomes a nonissue.

Deposition: CVD, PVD, and Silicon Epitaxy

CVD equipment sales are predicted to grow at a 17.3 percent annualized rate from 1995 through 2001, above overall equipment growth. The steady growth in multilevel interconnect capacity will continue to generate demand for dielectric and metal CVD systems. ASP growth will also contribute to revenue growth as more highly integrated systems with improved productivity and particle control appear in the marketplace. Advanced dielectric deposition systems utilizing high-density plasma (HDP) sources have been introduced and will gain momentum for intermetal dielectric (IMD) applications for sub-0.5 micron processes. Metal CVD will continue to exhibit strong growth, driven by blanket tungsten for contact and via plugs, CVD barrier metals such as CVD titanium nitride, and dichlorosilane (DCS) tungsten silicide for shrink 16Mb and 64Mb DRAMs. For these reasons, the forecast for nontube CVD systems outperforms tube furnaces.

Sputter deposition systems are forecast to grow at an annualized rate of 15.8 percent for 1995 through 2001. As in the case of dry etch and CVD equipment, continued expansion of multilevel interconnect process capacity is the primary driver behind sputter system growth. Rapid growth in average system ASP helped to drive total revenue growth before 1995, primarily from the quick and expanding dominance of Applied Materials in the market. With Applied now accounting for more than 50 percent of the market, the bulk of the ASP increases are behind us. Changes in system architecture, pioneered by the Applied Materials Endura system, will continue to yield improvements in film properties, equipment productivity, and defect density. This is a market segment that will be somewhat buffered from a slowdown in DRAM investment, as the fundamental growth in the number of metal layers in ASICs and logic devices drives a more stable outlook.

The shift from batch to single-wafer epitaxial systems has been the primary driver of epitaxial deposition systems, given the need for 200mm epitaxial wafer capacity for CMOS logic applications. However, this capacity is more expensive than wafer suppliers would like, so we expect the concept of "minibatches" to emerge as a viable production strategy, as it has in CVD. Moore Technologies is known to have such a product on the market. A strong automotive, power, and discrete device market has increased demand for the specialty batch units, and growth in this segment actually exceeded CMOS logic in 1995 and continues to be strong in 1996. There are clear indications that epitaxial layers will be required for some 64Mb DRAMs (see Chapter 4). This, an increased product mix of logic semiconductors at the 200mm wafer capacity, and sustained demand for discrete devices and power ICs will be the primary drivers for epitaxial deposition equipment growth. In fact, epitaxial reactors are expected to be a star performer with an average annual growth of 22 percent and will be somewhat insulated from the near-term slowdown.

Thermal Nondeposition Processes: Diffusion and RTP

Diffusion systems are expected to demonstrate a CAGR of 13.5 percent for 1995 through 2001. Newer vertical systems will be configurable as multitube clusters with integrated dry clean capability to compete with single-wafer cluster tools. Tube systems will also incorporate small batch capabilities to offer greater flexibility for custom and semicustom circuit manufacturers.

RTP will grow at an annualized rate of 28.4 percent for 1995 through 2001. This market grew much faster than we anticipated, nearly doubling in 1994 and slightly more than doubling in 1995. The growth in 1994 was primarily fueled by the growing acceptance of self-aligned silicide processes in logic process flows. The growth in 1995 comes from new offerings in the market from Applied Materials, CVC, and Mattson Technology, and from the expansion of the application into traditional tube diffusion steps. The real growth for this segment will come from transitioning of the thermal "nondepositing" processes away from diffusion tubes and into single-wafer RTP systems for 300mm wafers. We have factored in a large complement of systems into initial 300mm facilities starting in late 1997, largely contributing to the higher-than-market growth. RTP systems are primarily used today for salicide anneals and some implant drive-ins and are largely driven by logic and ASIC capacity.

Dataquest believes that batch tube systems will continue to resist penetration by RTP in areas such as well drive, BPSG reflow, and thermal oxidation because of the demonstrated cost-of-ownership benefits in these areas, at least through 200mm wafers. For 300mm wafers, there will also be a strong desire on the part of the semiconductor manufacturer to continue to use the batch tube systems since these systems offer much better cost efficiencies.

Ion Implantation

Overall ion implantation system revenue is forecast to grow at a CAGR of 17 percent for the years 1995 through 2001. This market segment will continue to be one of the most volatile, because of the highly device-specific nature of the implant segments and because of the dependence on new fab capacity for unit growth. The fastest-growing segment is expected to be high-energy implantation, which is evoking intense interest because of its potential for process simplification and manufacturing cost reduction. The first year of true production ramp is expected to occur in 1998 as 0.4-micron technologies become mainstream, although early adopters such as Samsung have placed high-voltage implant into 16Mb DRAMs.

New implant systems will continue to offer improvement in uniformity, particle control, charging, and wafer throughput. The number of implant steps requiring medium-current ion sources is expected to grow faster than high-dose implant steps, again driven by the higher worldwide semiconductor logic component, with the shallow junctions preferentially driving the trend toward medium-current implants.

However, our forecast does not reflect this trend, with medium-current implant sales lagging the market with only 12.3 percent CAGR. Why?

Recently Eaton Corporation, Applied Materials, and Genus Inc. have introduced expanded capability to existing systems or new systems that are targeted to compete in more than one segment. For example, Applied Materials' 9500 systems now basically have a range to cover both high-current and medium-current capabilities, and Genus' new 1520 model expands the range effectively across high-voltage and medium-current. Traditional batch medium-current systems are effectively being squeezed out of the market. This is occurring because equipment utilization rates for implanters tend to be among the lowest in the fab. Semiconductor manufacturers, in an effort to increase utilization and reduce cost, are tending to buy equipment with broader ranges.

There are medium-current applications that will still require dedicated medium-current systems, namely high-tilt (greater than 42 degree) implants and V_T adjustment implants. However, these will be better executed using implanters with single-wafer end stations rather than the traditional batch systems.

Dataquest is investigating the redefinition of ion implant segments in order to capture this market dynamic better.

The Segments That Will Fare Best in the Next Two Years

During the coming slowdown, there will be two kinds of purchasing behavior that equipment companies can take advantage of to buffer sales declines. The first behavior is tied to which types of capacity will be required early in the recovery cycle. If there is a heavier dependence on advanced logic or supply to the materials industry, these segments will fare better than DRAM-dependent or semiconductor capacity-dependent segments. Included in this category are the segments of nontube CVD, sputtering, silicon epitaxy, maskmaking lithography, and process control systems in the materials business and RTP.

The second purchasing behavior that will be prevalent over the next 12 to 18 months will be purchasing of new processes and equipment directed at solving issues for 0.35-micron and 0.25-micron manufacturing. By no means will this listing be complete, but we will highlight a few of these areas here.

The movement to deep-UV lithography will pick up steam through this slowdown. The unit forecast for deep-UV steppers is for more than 200 systems to ship in 1998, up from the 100 or so shipping today. There are several equipment segments that will benefit from this movement — those inspection and process control systems that must operate in the deep-UV wavelength to detect defects and materials on the surface of the wafer, namely mask inspection and thin-film measurement equipment. Thin-film measurement is key to intralevel and interlevel metal interconnect and storage capacitance applications. Thin-film measurement systems are used in line to monitor the in-etch, lithography (photoresist), deposition, and diffusion steps. Although this market was driven by logic applications more than memory production, in the past several years, DRAM manufacturers have begun integrating thin-film measurement stations into their process lines.

Chemical mechanical polishing systems are becoming more robust and able to meet tighter specifications. Japanese and Asia/Pacific companies are just beginning to investigate these systems. Although dielectric CMP is relatively common, metal CMP is still emerging. Above three levels of metal, it becomes more beneficial to implement a metal CMP step to the process.

Although high-density etch has been in use and has relatively high market penetration for polysilicon and metal etch, almost no high-density etchers are used in oxide or dielectric etch. The need exists for such a robust process, and Lam Research has just introduced a system that could help penetrate this market yet to be won.

Gap-fill dielectric CVD has been a highly competitive development arena. Novellus Systems appears to have product momentum with its Speed product line. We believe this product area offers a way for companies to effectively buffer the current slowdown.

Wafer cleaning systems can also offer an area in which a company's technology can shine. The recent announcement by Steag AG in Germany of its vapor dryer was built into a successful strategy when it sold these systems as part of an integrated automated wet clean station. Wafers are placed in the dryer system after a wet cleaning process to dry but do not spin. Instead, they are pulled from a bath of isopropyl alcohol (IPA) and water in a controlled fashion into an IPA vapor atmosphere. As the wafer is pulled out, the liquid sheets off the surface, leaving *no* water spots, which often hold killer residue defects. The concept of automating cleaning processes will be a key product issue over the next few years.

Dataquest Perspective

Wafer fab equipment spending is expected to grow 17 percent worldwide in 1996. The only reasons that 1996 remains a double-digit growth year are that there were strong backlogs coming out of 1995 and that there was increased spending by some companies early in the year.

After three and a half strong expansion years in 1993 through 1996, equipment purchases in 1997 should decline markedly, followed by an essentially flat 1998. Investment in DRAM capacity will be curtailed as producers elect to convert their 4Mb DRAM capacity to 16Mb, which adds bit capacity through the instant increase in bits per square inch. Also, many Japanese DRAM facilities now running 150mm wafers will convert to 200mm wafers, further delaying the need for new equipment. DRAM-sensitive equipment technologies or capital-intensive segments will be affected more than logic-sensitive technologies. The next expansion should kick in by 1999, driven by 0.3-micron to 0.35-micron process capacity expansion.

Dataquest has factored in an infrastructure investment in equipment for late 1997 through 1999, which will affect the forecast size of the markets positively. This additional investment will be for initial equipment to fill a couple of 300mm fabs to run silicon by 1999. However, our outlook for a significant 300mm equipment market will wait until well after 2000.

During the coming slowdown, there will be two kinds of purchasing behavior that equipment companies can take advantage of to buffer sales declines. The first behavior is tied to which types of capacity will be required early in the recovery cycle. If there is a heavier dependence on advanced logic or supply to the materials industry, these segments will fare better than DRAM-dependent or semiconductor capacity-dependent segments. Included in this category are the segments of nontube CVD, sputtering, metal etch, silicon epitaxy, maskmaking lithography, and process control systems in the materials business and RTP.

The second purchasing behavior that will be prevalent over the next 12 to 18 months will be purchasing new processes and equipment directed at solving issues for 0.35-micron and 0.25-micron manufacturing. These segments will be those related primarily to deep-UV lithography and inspection and 0.25-micron multilevel metallization schemes.

Chapter 4
Silicon Wafer Forecast

Dataquest's current forecast for regional silicon wafer demand reflects significant silicon wafer growth in 1995 and 1996, with slower growth in 1997 and 1998 as the industry migrates from the 4Mb DRAM to the more silicon-efficient 16Mb DRAM (in terms of bits per square inch). A resumption of accelerated growth starting in late 1998 into 1999 and beyond is in line with an increased PC unit, telecommunications equipment, and, therefore, semiconductor consumption forecast worldwide. Our latest forecast, along with highlights of some of the key factors affecting the regional markets, is presented below.

Silicon Forecast Tables

Tables in this chapter include Dataquest's most recent forecasts of regional unit silicon wafer consumption. Tables 4-1 through 4-5 detail unit consumption by region. Individual forecasts of major product segments such as prime, epitaxial, and test and monitor wafers are included. Tables 4-6 through 4-10 present regional forecasts for wafer size distribution.

The 200mm Wafer Ramps Up—Suppliers Have Responded with Capacity

Dataquest has been studying the subject of 200mm wafers and their ramp rate closely over the last two years, particularly in light of the massive number of announcements in fab capacity and requirements through the rest of the decade. We are expecting that more than 200 fabs processing 200mm wafers will be on line by the year 2000. Future demand for 200mm product wafers has been affected positively by the semiconductor industry's excess capacity. Why? Semiconductor companies now have some time to convert 150mm fabs to the more cost-effective 200mm wafers. This has added incremental product wafer demand to the industry at 200mm wafers. A large factor in 200mm demand, the consumption of test wafers, is expected to grow more slowly than once thought as semiconductor manufacturers have responded to the tight supply of wafers by accelerating test wafer reduction programs. However, the industry is consuming just under the ratio of one test wafer for every product wafer. This compares with the industry average of about one test wafer per seven product wafers for sizes below 200mm. By the year 2000, we now expect this ratio to be one test wafer for over three product wafers.

Wafer suppliers have answered the need with several new wafer plants and billions of dollars of committed investment. We continue to believe that the ramp of 200mm wafers will be supply-constrained from time to time through the decade, although the faster-than-anticipated conversion to the 16Mb DRAM will mean adequate supply to meet demand in 1997 and early 1998.

In this forecast update, we have revised the forecast for 200mm wafers—again upward—to reflect not only the expected fab activity in each region but also the dramatic increase in the supply commitment being made by the silicon manufacturers since our last forecast update. Dataquest's cur-

Table 4-1
Forecast of Captive and Merchant Silicon* and Merchant Epitaxial Wafers by Region (Millions of Square Inches)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Worldwide Total Silicon + Epitaxial	2,096.7	2,446.2	2,907.6	3,523.8	4,102.2	4,544.7	4,943.8	5,449.7	6,221.1	6,924.4	11.9
Merchant and Captive Silicon*	1,848.2	2,151.7	2,520.3	3,003.8	3,515.6	3,902.9	4,210.1	4,601.8	5,216.6	5,768.6	11.5
Epitaxial Silicon	248.5	294.5	387.3	520.0	586.6	641.8	733.7	847.9	1,004.5	1,155.8	14.2
Americas Total Silicon + Epitaxial	650.9	716.9	829.0	943.1	1,046.4	1,149.2	1,257.2	1,400.5	1,583.6	1,751.1	10.9
Merchant and Captive Silicon*	522.8	560.7	634.2	696.4	770.8	851.2	926.9	1,024.7	1,153.7	1,267.2	10.5
Epitaxial Silicon	128.1	156.2	194.8	246.7	275.6	298.0	330.3	375.8	429.9	483.9	11.9
Japan Total Silicon + Epitaxial	972.8	1,134.3	1,277.9	1,483.4	1,675.0	1,803.6	1,949.3	2,111.9	2,363.8	2,598.2	9.8
Merchant and Captive Silicon*	885.8	1,045.2	1,159.5	1,319.7	1,492.5	1,602.7	1,712.7	1,841.3	2,026.8	2,201.3	8.9
Epitaxial Silicon	87.0	89.1	118.4	163.7	182.5	200.9	236.6	270.6	337.0	396.9	15.9
Europe Total Silicon + Epitaxial	235.0	289.6	353.8	457.7	514.5	562.6	606.5	658.9	756.0	828.4	10.4
Merchant and Captive Silicon*	211.1	253.4	297.7	373.6	415.4	451.6	480.0	511.9	586.5	637.1	9.3
Epitaxial Silicon	23.9	36.2	56.1	84.1	99.1	111.0	126.5	147.0	169.5	191.3	14.7
Asia/Pacific Total Silicon + Epitaxial	238.0	305.4	446.9	639.6	866.3	1,029.3	1,130.8	1,278.4	1,517.7	1,746.7	18.2
Merchant and Captive Silicon*	228.5	292.4	428.9	614.1	836.9	997.4	1,090.5	1,223.9	1,449.6	1,663.0	18.1
Epitaxial Silicon	9.5	13.0	18.0	25.5	29.4	31.9	40.3	54.5	68.1	83.7	21.9

*Includes prime, test, and monitor wafers
Source: Dataquest (July 1996)

Table 4-2
Forecast Growth Rates of Captive and Merchant Silicon* and Merchant Epitaxial Wafers by Region (Percentage of MSI)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Worldwide Total Silicon + Epitaxial	2.5	16.7	18.9	21.2	16.4	10.8	8.8	10.2	14.2	11.3
Merchant and Captive Silicon*	1.2	16.4	17.1	19.2	17.0	11.0	7.9	9.3	13.4	10.6
Epitaxial Silicon	13.2	18.5	31.5	34.3	12.8	9.4	14.3	15.6	18.5	15.1
Americas Total Silicon + Epitaxial	10.0	10.1	15.6	13.8	11.0	9.8	9.4	11.4	13.1	10.6
Merchant and Captive Silicon*	3.2	7.2	13.1	9.8	10.7	10.4	8.9	10.6	12.6	9.8
Epitaxial Silicon	52.1	21.9	24.7	26.6	11.7	8.1	10.8	13.8	14.4	12.6
Japan Total Silicon + Epitaxial	-6.9	16.6	12.7	16.1	12.9	7.7	8.1	8.3	11.9	9.9
Merchant and Captive Silicon*	-5.9	18.0	10.9	13.8	13.1	7.4	6.9	7.5	10.1	8.6
Epitaxial Silicon	-16.3	2.4	32.9	38.3	11.5	10.1	17.8	14.4	24.5	17.8
Europe Total Silicon + Epitaxial	1.8	23.2	22.2	29.4	12.4	9.3	7.8	8.6	14.7	9.6
Merchant and Captive Silicon*	1.5	20.0	17.5	25.5	11.2	8.7	6.3	6.6	14.6	8.6
Epitaxial Silicon	3.9	51.5	55.0	49.9	17.8	12.0	14.0	16.2	15.3	12.9
Asia/Pacific Total Silicon + Epitaxial	30.7	28.3	46.3	43.1	35.4	18.8	9.9	13.1	18.7	15.1
Merchant and Captive Silicon*	31.4	28.0	46.7	43.2	36.3	19.2	9.3	12.2	18.4	14.7
Epitaxial Silicon	14.5	36.8	38.5	41.7	15.3	8.5	26.3	35.2	25.0	22.9

*Includes prime, test, and monitor wafers
Source: Dataquest (July 1996)

Table 4-3
Forecast of Captive and Merchant Silicon* Wafers by Region (Millions of Square Inches)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Worldwide Total Silicon*	1,848.2	2,151.7	2,520.3	3,003.8	3,515.6	3,902.9	4,210.1	4,601.8	5,216.6	5,768.6	11.5
Merchant Silicon	1,728.2	2,026.7	2,373.3	2,929.8	3,441.6	3,828.9	4,136.1	4,527.8	5,142.6	5,694.6	11.7
Captive Silicon	120.0	125.0	147.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	0
Americas Total Silicon*	522.8	560.7	634.2	696.4	770.8	851.2	926.9	1,024.7	1,153.7	1,267.2	10.5
Merchant Silicon	450.8	486.7	547.2	647.4	721.8	802.2	877.9	975.7	1,104.7	1,218.2	11.1
Captive Silicon	72.0	74.0	87.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	0
Japan Total Silicon*	885.8	1,045.2	1,159.5	1,319.7	1,492.5	1,602.7	1,712.7	1,841.3	2,026.8	2,201.3	8.9
Merchant Silicon	848.8	1,008.2	1,117.5	1,297.7	1,470.5	1,580.7	1,690.7	1,819.3	2,004.8	2,179.3	9.0
Captive Silicon	37.0	37.0	42.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	0
Europe Total Silicon*	211.1	253.4	297.7	373.6	415.4	451.6	480.0	511.9	586.5	637.1	9.3
Merchant Silicon	206.1	248.4	291.7	370.6	412.4	448.6	477.0	508.9	583.5	634.1	9.4
Captive Silicon	5.0	5.0	6.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0
Asia/Pacific Total Silicon*	228.5	292.4	428.9	614.1	836.9	997.4	1,090.5	1,223.9	1,449.6	1,663.0	18.1
Merchant Silicon	222.5	283.4	416.9	614.1	836.9	997.4	1,090.5	1,223.9	1,449.6	1,663.0	18.1
Captive Silicon	6.0	9.0	12.0	0	0	0	0	0	0	0	NA

NA = Not applicable
*Includes prime, test, and monitor wafers
Source: Dataquest (July 1996)

Table 4-4
Forecast Growth Rates of Captive and Merchant Silicon* by Region(Percentage of MSI)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Worldwide Total Silicon*	0.3	16.4	17.1	19.2	17.0	11.0	7.9	9.3	13.4	10.6
Merchant Silicon	0	17.3	17.1	23.4	17.5	11.3	8.0	9.5	13.6	10.7
Captive Silicon	2.9	4.2	17.6	-49.7	0	0	0	0	0	0
Americas Total Silicon*	0.3	7.2	13.1	9.8	10.7	10.4	8.9	10.6	12.6	9.8
Merchant Silicon	0	8.0	12.4	18.3	11.5	11.1	9.4	11.1	13.2	10.3
Captive Silicon	2.9	2.8	17.6	-43.7	0	0	0	0	0	0
Japan Total Silicon*	-5.2	18.0	10.9	13.8	13.1	7.4	6.9	7.5	10.1	8.6
Merchant Silicon	-5.1	18.8	10.8	16.1	13.3	7.5	7.0	7.6	10.2	8.7
Captive Silicon	-7.5	0	13.5	-47.6	0	0	0	0	0	0
Europe Total Silicon*	11.6	20.0	17.5	25.5	11.2	8.7	6.3	6.6	14.6	8.6
Merchant Silicon	11.9	20.5	17.4	27.0	11.3	8.8	6.3	6.7	14.7	8.7
Captive Silicon	0	0	20.0	-50.0	0	0	0	0	0	0
Asia/Pacific Total Silicon*	25.9	28.0	46.7	43.2	36.3	19.2	9.3	12.2	18.4	14.7
Merchant Silicon	22.6	27.4	47.1	47.3	36.3	19.2	9.3	12.2	18.4	14.7
Captive Silicon	NM	50.0	33.3	-100.0	NA	NA	NA	NA	NA	NA

NM = Not meaningful
NA = Not applicable
*Includes prime, test, and monitor wafers
Source: Dataquest (July 1996)

Table 4-5
Forecast of Merchant Prime and Test/Monitor Wafers by Region (Millions of Square Inches)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Worldwide Merchant Silicon	1,728.2	2,026.7	2,373.3	2,929.8	3,441.6	3,828.9	4,136.1	4,527.8	5,142.6	5,694.6	11.7
Growth Rate (%)	1.0	17.3	17.1	23.4	17.5	11.3	8.0	9.5	13.6	10.7	
Prime	1,382.5	1,595.1	1,841.6	2,228.8	2,517.1	2,745.2	2,966.1	3,287.0	3,809.9	4,295.1	11.6
Test and Monitor	345.7	431.6	531.7	701.0	924.5	1,083.7	1,170.0	1,240.8	1,332.7	1,399.5	12.2
Americas Merchant Silicon	450.8	486.7	547.2	647.4	721.8	802.2	877.9	975.7	1,104.7	1,218.2	11.1
Growth Rate (%)	3.3	8.0	12.4	18.3	11.5	11.1	9.4	11.1	13.2	10.3	
Prime	360.6	380.0	417.5	464.8	484.8	514.9	572.9	647.8	761.9	854.6	10.7
Test and Monitor	90.2	106.7	129.7	182.6	237.0	287.3	305.0	327.9	342.8	363.6	12.2
Japan Merchant Silicon	848.8	1,008.2	1,117.5	1,297.7	1,470.5	1,580.7	1,690.7	1,819.3	2,004.8	2,179.3	9.0
Growth Rate (%)	-5.8	18.8	10.8	16.1	13.3	7.5	7.0	7.6	10.2	8.7	
Prime	679.0	792.1	871.5	1,010.0	1,100.4	1,174.2	1,256.8	1,365.3	1,511.4	1,668.5	8.7
Test and Monitor	169.8	216.1	246.0	287.7	370.1	406.5	433.9	454.0	493.4	510.8	10.0
Europe Merchant Silicon	206.1	248.4	291.7	370.6	412.4	448.6	477.0	508.9	583.5	634.1	9.4
Growth Rate (%)	1.6	20.5	17.4	27.0	11.3	8.8	6.3	6.7	14.7	8.7	
Prime	164.9	200.2	223.6	283.4	288.0	306.3	320.0	341.1	404.2	447.9	7.9
Test and Monitor	41.2	48.2	68.1	87.2	124.4	142.3	157.0	167.8	179.3	186.2	13.5
Asia/Pacific Merchant Silicon	222.5	283.4	416.9	614.1	836.9	997.4	1,090.5	1,223.9	1,449.6	1,663.0	18.1
Growth Rate (%)	28.1	27.4	47.1	47.3	36.3	19.2	9.3	12.2	18.4	14.7	
Prime	178.0	222.8	329.0	470.6	643.9	749.8	816.4	932.8	1,132.4	1,324.1	18.8
Test and Monitor	44.5	60.6	87.9	143.5	193.0	247.6	274.1	291.1	317.2	338.9	15.4

Source: Dataquest (July 1996)

Table 4-6
Worldwide Wafer Size Distribution Forecast, 1993-2000
(Percentage Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Percentage Square Inches by Diameter											
2 Inches	3.14	0.2	0.1	0.1	0.1	0	0	0	0	0	0
3 Inches	7.07	2.1	1.6	1.4	1.1	0.9	0.7	0.6	0.6	0.4	0.4
100mm	12.17	18.7	16.0	14.8	13.1	10.2	8.6	7.6	6.7	6.0	5.3
125mm	19.02	33.0	28.8	24.7	21.2	17.5	14.9	13.2	11.6	10.3	9.1
150mm	27.38	43.3	47.0	47.0	45.1	42.7	40.0	37.7	36.0	36.5	38.1
200mm	48.67	2.7	6.4	12.2	19.4	28.6	35.8	40.8	44.8	46.0	46.0
300mm	109.56		0	0	0	0	0	0	0.4	0.8	1.1
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		2,097	2,446	2,908	3,524	4,102	4,545	4,944	5,450	6,221	6,924
Growth (%)		2.5	16.7	18.9	21.2	16.4	10.8	8.8	10.2	14.2	11.3
Unit Distribution by Wafer Starts (Millions of Wafers)											
2 Inches	3.14	1.0	1.0	0.9	0.9	0.4	0.3	0.2	0	0	0
3 Inches	7.07	6.3	5.6	5.6	5.5	5.2	4.7	4.5	4.3	3.7	3.6
100mm	12.17	32.3	32.2	35.3	37.9	34.4	32.2	30.7	29.9	30.5	29.9
125mm	19.02	36.3	37.0	37.7	39.3	37.8	35.5	34.3	33.1	33.8	33.3
150mm	27.38	33.2	42.0	49.9	58.1	64.0	66.3	68.1	71.7	83.0	96.3
200mm	48.67	1.2	3.2	7.3	14.0	24.1	33.4	41.5	50.2	58.8	65.5
300mm	109.56		0	0	0	0	0	0	0.2	0.4	0.7
Total Wafers (M)		110.3	121.0	136.6	155.7	165.9	172.4	179.4	189.4	210.2	229.3
Average Wafer Diameter (Inches)		4.92	5.07	5.21	5.37	5.61	5.79	5.92	6.05	6.14	6.20

Source: Dataquest (July 1996)

Table 4-7
The Americas Wafer Size Distribution Forecast, 1993-2000
(Percentage Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Percentage Square Inches by Diameter											
2 Inches	3.14	0.1	0.1	0.1	0.1	0	0	0	0	0	0
3 Inches	7.07	1.3	1.2	1.1	1.0	0.9	0.7	0.6	0.5	0.3	0.3
100mm	12.17	26.3	22.0	20.5	17.7	14.4	12.6	11.2	10.2	9.1	8.2
125mm	19.02	31.9	26.5	22.3	19.2	16.2	14.3	12.5	10.8	9.7	8.7
150mm	27.38	36.5	41.7	42.8	40.1	36.2	32.0	30.8	29.6	30.5	31.5
200mm	48.67	3.9	8.5	13.2	21.9	32.3	40.4	44.8	48.2	49.2	49.5
300mm	109.56	-	0	0	0	0	0	0.1	0.7	1.2	1.8
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		651	717	829	943	1,046	1,149	1,257	1,401	1,584	1,751
Growth (%)		10.0	10.1	15.6	13.8	11.0	9.8	9.4	11.4	13.1	10.6
Unit Distribution by Wafer Starts (Millions of Wafers)											
2 Inches	3.14	0.2	0.2	0.3	0.3	0	0	0	0	0	0
3 Inches	7.07	1.2	1.2	1.3	1.3	1.3	1.1	1.1	1.0	0.7	0.7
100mm	12.17	14.1	13.0	14.0	13.7	12.4	11.9	11.6	11.7	11.8	11.8
125mm	19.02	10.9	10.0	9.7	9.5	8.9	8.6	8.3	8.0	8.1	8.0
150mm	27.38	8.7	10.9	13.0	13.8	13.8	13.4	14.1	15.1	17.6	20.1
200mm	48.67	0.5	1.3	2.2	4.2	6.9	9.5	11.6	13.9	16.0	17.8
300mm	109.56	-	0	0	0	0	0	0.01	0.1	0.2	0.3
Total Wafers (M)		35.6	36.6	40.4	42.9	43.4	44.6	46.6	49.8	54.4	58.8
Average Wafer Diameter (Inches)		4.83	5.00	5.11	5.29	5.54	5.72	5.86	5.98	6.09	6.16

Source: Dataquest (July 1996)

Table 4-8
Japan Wafer Size Distribution Forecast, 1993-2000
(Percentage Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Percentage Square Inches by Diameter											
2 Inches	3.14	0	0	0	0	0	0	0	0	0	0
3 Inches	7.07	1.7	1.5	1.4	1.1	0.9	0.8	0.7	0.6	0.5	0.4
100mm	12.17	13.2	11.5	10.4	9.5	7.9	6.9	6.2	5.6	5.0	4.5
125mm	19.02	36.7	32.2	29.4	26.4	22.9	20.0	18.3	16.7	15.2	13.5
150mm	27.38	46.9	50.2	49.8	49.7	46.7	46.1	45.7	44.6	45.1	47.4
200mm	48.67	1.5	4.6	9.0	13.3	21.6	26.2	29.1	32.0	33.2	32.8
300mm	109.56	-	0	0	0	0	0	0	0.5	1.0	1.4
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		973	1,134	1,278	1,483	1,675	1,804	1,949	2,112	2,364	2,598
Growth (%)		-6.9	16.6	12.7	16.1	12.9	7.7	8.1	8.3	11.9	9.9
Unit Distribution by Wafer Starts (Millions of Wafers)											
2 Inches	3.14	0	0	0	0	0	0	0	0	0	0
3 Inches	7.07	2.3	2.4	2.5	2.3	2.1	2.0	1.9	1.8	1.7	1.5
100mm	12.17	10.6	10.7	10.9	11.6	10.9	10.2	9.9	9.7	9.7	9.6
125mm	19.02	18.8	19.2	19.8	20.6	20.2	19.0	18.8	18.5	18.9	18.4
150mm	27.38	16.7	20.8	23.2	26.9	28.6	30.4	32.5	34.4	38.9	45.0
200mm	48.67	0.3	1.1	2.4	4.1	7.4	9.7	11.7	13.9	16.1	17.5
300mm	109.56	-	0	0	0	0	0	0	0.1	0.2	0.3
Total Wafers (M)		48.6	54.2	58.8	65.5	69.2	71.3	74.8	78.4	85.6	92.3
Average Wafer Diameter (Inches)		5.05	5.16	5.26	5.37	5.55	5.67	5.76	5.85	5.93	5.99

Source: Dataquest (July 1996)

Table 4-9
European Wafer Size Distribution Forecast, 1993-2000
(Percentage Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Percentage Square Inches by Diameter											
2 Inches	3.14	0.3	0.2	0.1	0.1	0	0	0	0	0	0
3 Inches	7.07	2.5	1.7	0.7	0.6	0.4	0.2	0.2	0.1	0.1	0.1
100mm	12.17	25.9	22.0	20.5	20.0	13.9	11.0	9.2	7.5	7.1	6.2
125mm	19.02	30.5	29.5	21.7	18.7	14.0	11.3	9.8	7.6	7.0	6.4
150mm	27.38	36.7	42.3	43.0	40.8	36.5	34.9	30.6	27.3	26.8	27.9
200mm	48.67	4.1	4.3	14.0	19.8	35.2	42.6	50.2	57.5	59.0	59.4
300mm	109.56		0	0	0	0	0	0	0	0	0
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		235	290	354	458	515	563	607	659	756	828
Growth (%)		1.8	23.2	22.2	29.4	12.4	9.3	7.8	8.6	14.7	9.6
Unit Distribution by Wafer Starts (Millions of Wafers)											
2 Inches	3.14	0.2	0.2	0.1	0.1	0	0	0	0	0	0
3 Inches	7.07	0.8	0.7	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0.1
100mm	12.17	5.0	5.2	6.0	7.5	5.9	5.1	4.6	4.1	4.4	4.2
125mm	19.02	3.8	4.5	4.0	4.5	3.8	3.3	3.1	2.6	2.8	2.8
150mm	27.38	3.1	4.5	5.6	6.8	6.9	7.2	6.8	6.6	7.4	8.4
200mm	48.67	0.2	0.3	1.0	1.9	3.7	4.9	6.3	7.8	9.2	10.1
300mm	109.56	-	0	0	0	0	0	0	0	0	0
Total Wafers (M)		13.2	15.3	17.0	21.2	20.5	20.7	20.9	21.1	23.9	25.7
Average Wafer Diameter (Inches)		4.77	4.90	5.14	5.24	5.65	5.88	6.08	6.30	6.35	6.41

Source: Dataquest (July 1996)

Table 4-10
Asia/Pacific Wafer Size Distribution Forecast, 1993-2000
(Percentage Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Percentage Square Inches by Diameter											
2 Inches	3.14	0.8	0.6	0.4	0.2	0.1	0.1	0.1	0	0	0
3 Inches	7.07	5.6	2.9	2.2	1.6	1.2	0.9	0.8	0.8	0.6	0.5
100mm	12.17	13.7	13.0	12.0	9.7	7.4	5.9	5.0	4.2	3.6	3.0
125mm	19.02	23.1	20.8	17.8	14.0	10.8	8.5	7.0	5.9	5.1	4.4
150mm	27.38	54.1	52.3	49.7	45.1	46.6	40.9	35.5	33.3	34.3	35.6
200mm	48.67	2.7	10.4	17.9	29.4	33.9	43.7	51.6	55.7	56.0	55.9
300mm	109.56	-	0	0	0	0	0	0	0.1	0.4	0.6
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		238	305	447	640	866	1,029	1,131	1278	1518	1747
Growth (%)		30.7	28.3	46.3	43.1	35.4	18.8	9.9	13.1	18.7	15.1
Unit Distribution by Wafer Starts (Millions of Wafers)											
2 Inches	3.14	0.6	0.6	0.6	0.4	0.4	0.3	0.2	0	0	0
3 Inches	7.07	1.9	1.3	1.4	1.4	1.4	1.3	1.3	1.4	1.3	1.2
100mm	12.17	2.7	3.3	4.4	5.1	5.3	5.0	4.6	4.4	4.5	4.3
125mm	19.02	2.9	3.3	4.2	4.7	4.9	4.6	4.2	4.0	4.1	4.0
150mm	27.38	4.7	5.8	8.1	10.5	14.7	15.4	14.7	15.5	19.0	22.7
200mm	48.67	0.1	0.7	1.6	3.9	6.0	9.2	12.0	14.6	17.5	20.1
300mm	109.56	-	0	0	0	0	0	0	0.01	0.06	0.10
Total Wafers (M)		12.9	14.9	20.3	26.1	32.8	35.8	37.0	40.0	46.4	52.5
Average Wafer Diameter (Inches)		4.85	5.10	5.29	5.59	5.80	6.05	6.24	6.38	6.45	6.51

Source: Dataquest (July 1996)

rent forecast for the year 2000 represents a level now about equal to what the wafer manufacturing industry has committed to supply to date, and our forecast in general now is more purely a demand forecast. Although we are stopping short of calling a shortage of 200mm wafers to the point of restricting ramp-up plans, buyers of wafers will experience firm-to-rising prices again by 1999 and may be placed on allocation from time to time.

In a recent Dataquest Perspective ("A Fresh Look at 200mm Wafer Supply and Demand: Still Tight," SEMM-WW-DP-9603, July 22, 1996) we have detailed the updated analysis for demand and supply of 200mm wafers.

Polysilicon to Remain Short from Now through 1997 and Tight in 1998

The industry has been consuming more polysilicon than it has produced since 1994, and we expect that to continue through 1997, depleting industry reserves later this year. However, several new plant commitments have been made, and polysilicon production will again exceed supply starting in 1998. The polysilicon market is expected to remain tight through 1998, but the threat of shortage after 1997 seems to have disappeared through our forecast horizon. More details are included in a recent Dataquest Perspective ("Polysilicon Supply/Demand Update," SEMM-WW-DP-9604, July 22, 1996).

What about 300mm Wafers?

Now that the wafer size has been settled and the time horizon for the first 300m plant(s) has been proposed, we initiated a forecast for consumption of 300mm wafers. The level is still very low before the year 2000; however, the recent goal of a fab to come on line by 1998 or 1999 means that 300mm wafers will be made and significant activity will be occurring in R&D. Although no company has yet stated a firm commitment for a fab, there has been significant activity on the development front. Most of the activity recently has been centered in Japan, and NEC and Texas Instruments have recently been noticeably more aggressive. A new consortium of Japanese companies, Selete (Semiconductor Leading Edge Technologies Inc.), has been formed there to spearhead the 300mm technology development. Motorola and Samsung continue to be among the companies mentioned in conjunction with a possible 300mm fab, as well.

Silicon wafer manufacturers have noticeably ramped commitment, as at least five different companies have announced or have committed to pilot lines for 300mm wafer production. The earliest of these starts production in late 1997, with the latest coming on line during 1999.

Although no semiconductor company has yet to commit to purchasing equipment for a formally announced fab, we would expect at least two pilot fabs trying to come on line by 1999. We should hear announcements during 1996 (in fact, one may be very close in Japan), and we would expect initial equipment to ship by the end of 1997.

We believe the first commercially productive plant will be started around 2001 to 2003 (after the feasibility noted above), with serious volume ramp-up in the years 2003 to 2005. This would be consistent with shrink

0.25-micron technology being primarily produced on 300mm wafers. This means that 200mm wafers represent at least a two-technology-generation wafer size, and fabs being built today may have longer lives than history would indicate.

Further details and issues regarding the move toward 300mm wafers will be included in a Dataquest Perspective document to be published in the next couple of months.

Epitaxial Wafer Trends: Are There DRAMs in the Future?

Sales of merchant epitaxial wafers by the wafer suppliers accounted for 520 million square inches (MSI) in 1995. About 65 percent of these wafers were used for CMOS logic applications, while only 2 percent were used for DRAM products. The remainder were shipped into the power/discrete device segments. By the year 2000, Dataquest expects that fully 16 percent of merchant epitaxial silicon will be used for DRAMs, primarily driven by two factors. The CMOS logic application remains dominant at 54 percent.

First, trench capacitor designs benefit from the use of epitaxial silicon. It is believed that both IBM and Siemens are currently using epitaxial silicon, while Toshiba has been using hi-wafers (wafers that include a hydrogen bake surface treatment to reduce surface contamination) to improve the performance of its trench capacitor design. We believe that for late-generation shrink versions of 16Mb and for 64Mb DRAMs from companies that employ the trench design (which include the companies noted, plus Texas Instruments and its affiliated fabs and perhaps including Hitachi), epitaxial silicon will have to be used.

Second, even in the stacked capacitor design, some companies (primarily in Japan) are finding that epitaxial silicon can be used to enhance yield by eliminating the very localized silicon "pit" defect that has recently become important at the 0.25-micron level technology in larger wafers (200mm and 300mm). Fujitsu is believed to be seriously evaluating and nearly committed to the use of epitaxial silicon, and several other Japanese companies, including Matsushita and Oki, also have epitaxial silicon under consideration for DRAMs.

Dataquest will watch this area of device construction technology very closely over the next several years, as there is a distinct possibility that this need for epitaxial silicon will be a single-generation need. At the 0.18-micron generation, the use of other capacitor dielectrics and electrode materials may enable companies to return to planar or simple stack structures, perhaps eliminating the driving need for the epitaxial layer.

Highlights of the Americas Region Silicon Wafer Market and Forecast

Silicon consumption in Americas grew 14 percent in 1995 to 943 million square inches, and we expect a milder, 11 percent growth in 1996. Demand for microprocessor and other logic chips has been and will continue to be the key driver behind increased silicon demand in Americas, and epitaxial wafer demand will be focused on CMOS logic.

Merchant epitaxial wafer consumption increased 27 percent in 1995 to 247 MSI, driven in large part by microprocessor manufacturers, such as Intel and AMD, which build their microprocessors on epitaxial wafers. Strength in the automotive and discrete segments of the chip market have also been much stronger than expected. By 2000, epitaxial silicon will account for 27 percent of the square inches consumed in the Americas region—the highest concentration in any region.

Dataquest's longer-term forecast for Americas silicon consumption remains firm, primarily because we believe that the United States will attract a larger share of foreign multinational fabs, such as those recently announced by Hyundai, TSMC, Samsung, and others to be announced. We are projecting that total silicon MSI will grow at a 10.6 percent CAGR for 1995 through 2001.

Highlights of the Japanese Silicon Wafer Market and Forecast

Our Japan silicon consumption forecast has slightly increased from our last update, with the silicon market growing 16 percent to 1,483 MSI in 1995, with continued moderate growth in 1996 and softening in 1997 and 1998 as the industry migrates to 16Mb DRAMs.

Unlike Americas, with its sizable CMOS epitaxial wafer market, Japan's merchant epitaxial wafer market is more focused on discrete and bipolar applications today. Therefore, a recovery in the economy will have more of an effect on the growth of Japan's epitaxial wafer market, and early indications are that it has kicked into gear. Epitaxial demand grew 38 percent in 1995 after a 33 percent increase in 1994. Another growth year is expected in Japan in 1996, although it will be slower as companies use this time of excess capacity to begin to pull epitaxial deposition back inside.

Dataquest remains moderately conservative with its longer-term growth scenario for silicon wafer demand in Japan as the country continues to work through the evolution of its semiconductor production infrastructure (seen as being too heavily dependent on the DRAM). Investment patterns during 1995 suggested that Japanese semiconductor manufacturers are willing to come to the table and invest, preserving their stake in the memory business against the Korean companies. The desired shift of the Japanese product mix to higher-value-added semiconductors had apparently been put aside until the current memory cycle subsided but has again come to the forefront. We are estimating that silicon demand will grow at a 9.8 percent CAGR for 1995 through 2001, the slowest growth of all regions.

Epitaxial silicon deposition will experience strong growth later in the decade as companies begin ramping the use of epitaxial layers into the

DRAM. As a result, we are calling for a CAGR of 17.8 percent for epitaxial wafer consumption in the coming six years, above the worldwide average of 15.1 percent.

Highlights of the European Silicon Wafer Market and Forecast

Demand for silicon wafers in Europe, as well as wafer fabrication equipment, remains heavily dependent on the fab activities of foreign semiconductor firms. With increased presence from European companies, the outlook for silicon consumption has brightened.

The European market grew 29 percent in 1995 to 458 MSI. European silicon demand will moderate significantly in 1996 through 1998. Siemens Dresden and other DRAM production, and U.S. multinationals Intel, Motorola, and Texas Instruments will continue to ramp to answer the demand in Europe, helping silicon consumption grow another 12 percent in 1996. This is lower growth than anticipated six months ago, however, as ramp schedules for fabs in Europe to support the telecommunications sector have been reduced recently. The longer-term picture for Europe remain moderately healthy, with a 10.4 percent CAGR through the year 2001.

Epitaxial wafer demand in the region increased dramatically in 1995 to 84 MSI, growing 50 percent. This has been a direct result of production ramps by Intel in Ireland, Philips, IBM in France, and Siemens in Germany. In the near term, epitaxial wafer demand increases will come from predominantly European producers, primarily from the power/discrete segment. Later in the decade, the DRAM capacity will ramp and the migration to epitaxial silicon in DRAMs from multinationals with fabs in Europe will drive the epitaxial market to a CAGR over 4 percent above polished bare wafer consumption through the decade.

Highlights of the Asia/Pacific Silicon Wafer Market and Forecast

Silicon consumption grew at a 43 percent pace in 1995, the largest growth rate of any region in the world. Production is expanding at a fierce pace and not expected to ease through 1997, as many large 200mm fab projects are in various stages of construction and start-up. As the Asia/Pacific region collected nearly the largest proportion of 1995 capital, the trend for high silicon consumption growth will continue unabated with the exception of 1998, when we expect that the region will be caught in a period after foundry projects have just finished ramping up but before the next significant DRAM capacity expansion occurs.

The phenomenal growth in silicon consumption Asia/Pacific in 1995 was tied directly the manufacturing activities of the Korean DRAM producers. Growth will be seen here, but increased production in Taiwan, Singapore, Thailand, and, most recently, announced Malaysian fabs will also contribute to the growth. As these predominantly foundry fabs come on line in 1996 and beyond, they will provide some regional consumption stability as memory-related silicon consumption cools in 1997 and 1998. Taiwan, with its many new DRAM producers coming on line in 1996, will cause silicon consumption to grow in Asia/Pacific by nearly 35 percent again in 1996. Asia/Pacific remains the fastest-growing silicon consumer, with a five-year CAGR forecast of 18.2 percent.

Epitaxial wafer consumption will grow at the fastest rate in the Asia/Pacific region, as well, with a CAGR of 22 percent. However, this comes from a low base of consumption that will remain low. Although the foundries will require a significant portion of their capacity to consume epitaxial wafers, the DRAM fabs in the region do not use epitaxial wafers. With the exception of a few joint-venture fabs, the epitaxial consumption in Asia/Pacific DRAM capacity will remain quite low compared with other regions. Epitaxial wafer consumption will remain below 5 percent of total Asia/Pacific MSI by the year 2000 (compared with 16 percent worldwide).

Silicon Wafer Revenue Forecast

Dataquest has been tracking silicon wafer revenue and market share since 1985 but has always provided forecast information in terms of square inch area and unit wafer size distributions. With the announcement of the initial public offering of MEMC Electronic Materials earlier last year, we have initiated an industry revenue forecast.

Table 4-11 contains the revenue forecast for silicon wafers worldwide. Our methodology takes the wafer size distribution forecast in Table 4-6 and multiplies this matrix by our view of wafer price trends and test wafer consumption trends (by wafer size) in the forecast horizon. Dataquest does not publish a specific wafer price forecast, but does make comments on trend outlooks from time to time (see the Dataquest Perspective "A Fresh Look at 200mm Wafer Supply and Demand: Still Tight," SEMM-WW-DP-9603, July 22, 1996).

In our analysis, we have concluded that the revenue forecast would resemble the semiconductor industry more closely than the capital spending markets. The concept of semiconductor revenue per square inch is more closely tied to silicon consumption than raw wafer capacity of the industry, although this metric is cyclical. The six-year CAGR of 15.7 percent is about equal to the semiconductor forecast of 15.5 percent. This is consistent with the model that semiconductor manufacturers will attempt to control the costs associated with manufacturing, which includes using silicon more efficiently in the future. This would tend to keep the growth rate of silicon revenue slightly below that of the semiconductor revenue. Yet our forecast does not reflect this, primarily because over the next several years the industry will be migrating to 200mm wafers, which have a silicon wafer revenue per square inch significantly higher than the smaller wafer sizes. Therefore, the mix shift will tend to increase the growth rates in revenue, bringing the forecast more in line with the semiconductor growth rates.

Table 4-11
Worldwide Merchant Silicon Wafer Revenue Forecast, 1993-2001
(Includes Polished, Virgin Test, and Epitaxial Silicon) (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Worldwide	3,564	4,583	6,298	7,867	8,729	9,544	11,137	13,359	15,120	15.7
Growth (%)	19.1	28.6	37.4	24.9	11.0	9.3	16.7	20.0	13.2	

Source: Dataquest (July 1996)

Dataquest Perspective

The silicon market, driven by a strong long-term picture for semiconductor unit demand in general will grow faster over the next six years than the last six years. As the industry transforms into a 200mm baseline, the outlook for silicon wafer manufacturers becomes brighter. Silicon manufacturers have answered the call for 200mm capacity with significantly increased capital outlays. We believe silicon manufacturers' ramp plans in 200mm have been strategically and smartly measured because the overcapacity situations of 1985 are being remembered, and we are not expecting that scenario to be repeated.

Activity in 300mm wafer development has accelerated, particularly in Japan. Although no semiconductor company has yet to commit to purchasing equipment for a formally announced fab, we would expect at least two pilot fabs with the goal of coming on line by 1999.

By the year 2000, Dataquest expects that fully 16 percent of merchant epitaxial silicon will be used for DRAMs, up from about 2 percent in 1995. We believe that for late-generation shrink versions of 16Mb and for 64Mb DRAMs from companies that employ the trench design, epitaxial silicon will be needed. Also, other companies may decide to use epitaxial layers to solve specific yield issues at 0.25 micron, although it may be only a single-generation solution.

The silicon has become recognized again as being strategic in the semiconductor manufacturing infrastructure. Will this continue? We believe it will, as long as silicon suppliers continue to concentrate on value-add processes and techniques, as the equipment manufacturers have done, and as long as they adequately and smartly plan capacity additions.

Chapter 5
Semiconductor Consumption Forecast

This chapter presents data on the worldwide semiconductor market by region. The regional semiconductor market, or regional semiconductor consumption, deals with where chips are consumed; this contrasts with regional semiconductor production, which deals with where chips are manufactured. The data presented here is for the merchant market and do not include the value of chips made by captive semiconductor manufacturers for internal use.

This is an excerpt from the semiconductor five-year forecast published by Dataquest (*Semiconductor Five-Year Forecast Trends—Spring 1996,* SEMM-WW-MT-9601, May 13, 1996). Further details regarding this forecast can be found in that publication.

Yearly exchange rate variations can have a significant effect on the 1989 through 1996 data in the following tables. For more information about the exchange rates used and their effects, refer to Appendix B.

Semiconductor Consumption

Table 5-1 shows revenue and growth from semiconductor shipments for the years 1989 through 1995 broken down by region. Table 5-2 shows revenue and growth from semiconductor shipments for the years 1995 through 2001 broken down by region.

Table 5-1
Worldwide Semiconductor Consumption History by Region—Merchant Semiconductor Companies Only (Millions of U.S. Dollars)

	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Americas	17,070	16,540	16,990	20,430	27,926	35,939	48,349	18.9
Percentage Growth	7.7	-3.1	2.7	20.2	36.7	28.7	34.5	
Japan	21,491	20,257	22,496	20,579	24,645	31,010	42,164	11.9
Percentage Growth	3.5	-5.7	11.1	-8.5	19.8	25.8	36.0	
Europe	9,498	10,415	11,014	12,218	15,461	20,819	28,341	20.0
Percentage Growth	11.9	9.7	5.8	10.9	26.5	34.7	36.1	
Asia/Pacific	6,280	7,333	9,194	12,034	17,486	22,812	32,417	31.5
Percentage Growth	9.2	16.8	25.4	30.9	45.3	30.5	42.1	
Worldwide	54,339	54,545	59,694	65,261	85,518	110,580	151,271	18.6
Percentage Growth	6.8	0.4	9.4	9.3	31.0	29.3	36.8	

Source: Dataquest (July 1996)

Table 5-2
Worldwide Semiconductor Consumption Forecast by Region—Merchant Semiconductor Companies Only (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Americas	48,349	52,478	60,217	70,352	85,481	104,579	122,044	16.7
Percentage Growth	34.5	8.5	14.7	16.8	21.5	22.3	16.7	
Japan	42,164	41,244	45,286	51,144	60,212	71,693	79,723	11.2
Percentage Growth	36.0	-2.2	9.8	12.9	17.7	19.1	11.2	
Europe	28,341	31,479	35,734	41,079	48,433	56,828	65,295	14.9
Percentage Growth	36.1	11.1	13.5	15.0	17.9	17.3	14.9	
Asia/Pacific	32,417	37,411	43,004	51,258	62,121	76,736	91,162	18.8
Percentage Growth	42.1	15.4	15.0	19.2	21.2	23.5	18.8	
Worldwide	151,271	162,612	184,241	213,833	256,247	309,836	358,224	15.5
Percentage Growth	36.8	7.5	13.3	16.1	19.8	20.9	15.6	

Source: Dataquest (July 1996)

Chapter 6
Semiconductor Production Forecast

This chapter presents data on the worldwide semiconductor production by region. Semiconductor production is defined by the place where the wafers are fabricated, and regional semiconductor production includes all production in the region, including merchant and captive producers and all foreign producers. For instance, Americas region semiconductor production includes Digital Equipment Corporation and Delco fabs as well as Japanese company and European company fabs in North America.

Yearly exchange rate variations can have a significant effect on the data up to 1996 in the following tables. For more information about the exchange rates used and their effects, refer to Appendix B.

The semiconductor industry has a global manufacturing infrastructure. Production of semiconductors is constantly shifting among regions as new capital flows toward areas of relative lower capital cost and higher growth of consumption. Dataquest reviews some of the trends, and potential impacts, for the future.

Historical Semiconductor Production

Table 6-1 shows the historical semiconductor production for 1989 through 1995 by region. Dataquest follows a methodology that employs our fab database, estimating the memory, microcomponent, logic, and analog/power/discrete production components separately and estimating net production among regions for foundry activity. This approach provides insight into production trends for front-end manufacturing.

Because of the reclassification of the MOS portion of IBM Microelectronics' business as merchant, the captive production figures changed dramatically in 1993. However, IBM's bipolar production, which is consumed internally, is still classified as captive by Dataquest.

Captive Semiconductor Production

Semiconductor production from captive manufacturers is estimated to be $1.81 billion in 1995, down from just under $2 billion in 1994. IBM has restructured and entered the merchant semiconductor market as of 1993. Dataquest has reclassified IBM's MOS semiconductor production to merchant, but the bipolar products (exclusively used internally) are still reported as captive. This part of IBM's business will be converted to MOS over the next three to five years, and this resulted in a lower figure for captive production in 1995 and future years.

Many captive producers may consider the move to merchant to take better advantage of the worldwide growth of semiconductors, leveraging their investments in plant and equipment for higher return in a larger end-user base. Still others may elect to take advantage of the now evolving and maturing foundry business, electing to contract out their manufacturing rather than invest in expensive new facilities for their relatively small production base. We have not, however, included any such movement

Table 6-1
Worldwide Semiconductor Production History by Region—Merchant and Captive Semiconductor Company Sales (Millions of U.S. Dollars)

	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Total Americas	22,232	24,202	26,039	29,207	32,643	39,617	49,535	14.3
Merchant	18,464	20,453	22,275	24,998	30,942	37,887	47,882	17.2
Captive	3,768	3,749	3,764	4,209	1,701	1,730	1,653	-12.8
Percentage Growth	8.3	8.9	7.6	12.2	11.8	21.4	25.0	
Percentage Worldwide	37.6	40.8	40.4	41.5	37.3	35.2	32.4	
Total Japan	28,527	26,384	28,338	28,273	35,515	45,289	61,106	13.5
Merchant	28,119	25,977	27,925	27,914	35,515	45,289	61,106	13.8
Captive	408	407	413	359	0	0	0	-100.0
Percentage Growth	6.7	-7.5	7.4	-0.2	25.6	27.5	34.9	
Percentage Worldwide	48.2	44.5	44.0	40.1	40.6	40.3	39.9	
Total Europe	6,451	6,350	6,979	8,589	11,741	15,463	20,711	21.5
Merchant	5,782	5,723	6,396	7,957	11,421	15,243	20,551	23.5
Captive	669	627	583	632	320	220	160	-21.2
Percentage Growth	10.2	-1.6	9.9	23.1	36.7	31.7	33.9	
Percentage Worldwide	10.9	10.7	10.8	12.2	13.4	13.7	13.5	
Total Asia/Pacific	1,974	2,392	3,097	4,391	7,636	12,095	21,732	49.2
Merchant	1,974	2,392	3,097	4,391	7,636	12,095	21,732	49.2
Captive	NA	NA	NA	NA	NA	NA	NA	
Percentage Growth	5.7	21.2	29.5	41.8	73.9	58.4	79.7	
Percentage Worldwide	3.3	4.0	4.8	6.2	8.7	10.8	14.2	
Worldwide	59,184	59,328	64,453	70,460	87,535	112,464	153,084	17.2
Percentage Growth	7.6	0.2	8.6	9.3	24.2	28.5	36.1	
Merchant	54,339	54,545	59,693	65,260	85,514	110,514	151,271	18.6
Percentage Growth	6.8	0.4	9.4	9.3	31.0	29.2	36.9	
Captive	4,845	4,783	4,760	5,200	2,021	1,950	1,813	-15.1
Percentage Growth	17.4	-1.3	-0.5	9.2	-61.1	-3.5	-7.0	

NA = Not applicable
Source: Dataquest (July 1996)

toward merchant or fabless business in our captive production forecast. The four largest captive producers account for nearly 70 percent of the $1.81 billion in 1995. These producers are IBM (bipolar only), Delco Electronics, Digital, and Northern Telecom.

Restatement of Regional Semiconductor Production from 1992: Foundry

Dataquest recently completed a detailed characterization of the foundry industry. As a result of this work, we have determined that a higher proportion of Americas region semiconductor production is being outsourced to Asia, and particularly Japan, than previously thought. We therefore felt an obligation to restate the regional production statistics from 1992.

Table 6-2 shows Dataquest's estimates for the net import and export of foundry services among the regions. Clearly, the foundry industry is real and represents a key change in the semiconductor industry manufacturing infrastructure. We continue to expect U.S. companies in particular, both fabless companies and IDMs, to continue to expand their use of foundries in Asia/Pacific and Japan for semiconductor manufacturing.

Table 6-2
Net Regional Semiconductor Production by Foundry, Dedicated and IDM Foundries Included (Millions of U.S. Dollars)

	1992	1993	1994	1995
Americas	-491	-1,312	-1,781	-2,325
Japan	250	584	689	885
Europe	-75	-181	-301	-300
Asia/Pacific	316	909	1,393	1,740

Note: Positive number reflects net export, negative number reflects net import.
Source: Dataquest (July 1996)

The Move toward Asia Continues; European Growth Rests Temporarily

Some may find that the production trends of the last three years may contain two or three surprises. Of no surprise is the strong growth in Asia/Pacific production, over 14 percent of worldwide production in 1995. The strength in Asia/Pacific DRAM producers and the emergence of the foundry market have been, and will continue to be in the long term, the key drivers of that growth. Expected regional capital spending and electronic equipment production will certainly maintain this production trend.

European production has expanded from just under 11 percent of the semiconductors produced in 1991 to 13.5 percent in 1995. This is also remarkable in that the last four years have been good overall growth years, resulting in the region's production nearly tripling in four years. Why the move to Europe? With the region's economies recovering and the PC boom continuing, Europe has attracted PC production, particularly in the United Kingdom. Semiconductor production has moved along with the PC, with Intel and DRAM producers worldwide taking part. Also, the acceleration of telecommunications-related semiconductor production benefits the European companies. Dataquest believes that, although multinationals will continue to invest heavily in Europe, the trend is in a holding pattern now in part because of the concentration of spending growth in Asia/Pacific and the recent pause in telecommunications equipment production.

There has been a significant relative decline in the percentage of the world's production being done in the United States. Over the last three years, Americas region production decreased from about 42 percent to 32 percent of the world's production overall. This is despite the fact that U.S. companies have increased their share of the worldwide semiconductor market in the same period. Several factors are at work here. First, North American multinational companies have been investing heavily overseas. North America has been a net exporter of capital for several years now, as foreign companies have yet to balance the scales with investments inside the United States. This trend should stabilize over the next several years, as Japanese, Taiwanese, and Korean companies have started to accelerate their investment in the United States.

Second, although U.S. companies are recognized as technology leaders, they have recently begun calling on foreign producers to manufacture their products in the foundry market. Fabless companies have been the key driver of the market to this point, but starting in 1994, we saw a major shift in the integrated device manufacturer (or IDM, a merchant supplier of semiconductors that has a fab) to increase use of foundries. This imbalance in the concentration of foundry capacity is starting to make U.S. semiconductor companies a little nervous and has actually impressed upon key foundry suppliers the importance of beginning to build production in the United States. In fact, TSMC recently announced plans to build a major fab in the United States, and we believe that other foundry companies are likely to follow. Clearly, users of foundry have stated a preference for close access to the fab. Any foundry provider who has capacity in the United States is likely to have a more stable customer base than those that do not.

And third, although Japanese and European companies have invested somewhat outside their own countries, these companies have remained "patriots of the domestic economy" and have kept the vast majority of investment within the region, with perhaps the exceptions of NEC and SGS-Thomson. This, along with the strong DRAM market over the last three years, has stabilized the Japanese production proportion over the last two years at approximately a 40 percent share of the production market. However, as we now fully realize, the DRAM market is cyclical, and Japanese foundries will feel pressure from Asia/Pacific producers, so we expect a resumption of the gradual decay in the base of production in Japan through the rest of the decade.

Semiconductor Production Trends: The Accelerating Shift to Asia/Pacific

Table 6-3 shows forecast semiconductor production by region for 1995 through 2001. The major trend is the growth of the Asia/Pacific region, mostly at the expense of Japan. Companies like TSMC and United Microelectronics Corporation in Taiwan, Chartered Semiconductor in Singapore, and SubMicron Technology in Thailand will continue to build capacity faster than the worldwide market. Further, new DRAM companies (Vanguard, PowerChip, and Nan Ya) have sprung up in Taiwan, which is likely to further erode Japanese DRAM share. By 2001, Dataquest believes that Asia/Pacific will expand to over 18 percent on a revenue basis.

The Americas region will remain steady on a percentage basis, as the lower cost of capital and clear leadership in technology and innovative design motivate companies to invest in the United States. Also, Asia/Pacific companies have begun a regional production diversification program, with several major fabs earmarked for the United States. European production share is expected to expand slightly, with a product mix shifting to contain a higher memory component, driven by the need for proximity to PC production, as more DRAM capacity is added by large

Table 6-3
Worldwide Semiconductor Production Forecast by Region—Merchant and Captive Semiconductor Company Sales (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Total Americas	49,535	54,064	62,319	73,364	86,635	103,238	117,012	15.4
Merchant	47,882	52,524	60,800	71,848	85,074	101,626	115,348	15.8
Captive	1,653	1,540	1,519	1,516	1,561	1,612	1,664	0.1
Percentage Growth	25.0	9.1	15.3	17.7	18.1	19.2	13.3	
Percentage Worldwide	32.4	32.9	33.5	34.1	33.6	33.1	32.5	
Total Japan	61,106	64,232	69,827	78,263	92,249	109,992	125,737	12.8
Merchant	61,106	64,232	69,827	78,263	92,249	109,992	125,737	12.8
Captive	0	NA	NA	NA	NA	NA	NA	
Percentage Growth	34.9	5.1	8.7	12.1	17.9	19.2	14.3	
Percentage Worldwide	39.9	39.1	37.6	36.3	35.8	35.3	34.9	
Total Europe	20,711	22,390	25,689	29,771	35,905	43,397	50,880	16.2
Merchant	20,551	22,278	25,609	29,723	35,875	43,377	50,868	16.3
Captive	160	112	80	48	30	20	12	-35.1
Percentage Growth	33.9	8.1	14.7	15.9	20.6	20.9	17.2	
Percentage Worldwide	13.5	13.6	13.8	13.8	13.9	13.9	14.1	
Total Asia/Pacific	21,732	23,579	28,005	33,999	43,049	54,841	66,271	20.4
Merchant	21,732	23,579	28,005	33,999	43,049	54,841	66,271	20.4
Captive	NA	NA	NA	NA	NA	NA	NA	NA
Percentage Growth	79.7	8.5	18.8	21.4	26.6	27.4	20.8	
Percentage Worldwide	14.2	14.4	15.1	15.8	16.7	17.6	18.4	
Worldwide	153,084	164,264	185,840	215,397	257,838	311,468	359,900	15.3
Percentage Growth	36.1	7.3	13.1	15.9	19.7	20.8	15.5	
Merchant	151,271	162,612	184,241	213,833	256,247	309,836	358,224	15.5
Percentage Growth	36.9	7.5	13.3	16.1	19.8	20.9	15.6	
Captive	1,813	1,652	1,599	1,564	1,591	1,632	1,676	-1.3
Percentage Growth	-7.0	-8.9	-3.2	-2.2	1.7	2.6	2.7	

NA = Not applicable
Source: Dataquest (July 1996)

internationals very late in the decade. Japan's share of production is likely to continue to erode as the cost of capital remains high and as Japanese companies increasingly invest in capacity overseas.

Dataquest Perspective

Where the PC goes, so go semiconductors. This is true from the perspective of the business forecast as well as the production line. Europe and Asia/Pacific, with very large capital spending upticks over the last several years—and expected to continue that trend—will continue to gain share in world production over the next several years.

The shifts and currents in semiconductor production trends mean that equipment and material suppliers will absolutely need a global presence in every sense of the word to remain competitive in the market. Product supply can no longer depend on local trends, as all major semiconductor companies have made it clear they are investing on a worldwide basis. However, local service and support are required to maintain customer satisfaction.

Taiwan is clearly the new major production growth area. We would expect Malaysia and Thailand to be the next major growth countries in three to five years. Evidence of this includes recent join-venture fab announcements by Texas Instruments and others. Silicon plants are now being strategically placed, such as Shin-Etsu Handotai's Malaysian plant and recently announced joint venture in Taiwan, Komatsu's joint venture with Formosa Plastics in Taiwan, and MEMC's joint ventures in both Korea (Posco-Hüls), Taiwan (Taisil), and Malaysia (MEMC-Kulim).

Further, the concept of contract manufacturing in semiconductors is clearly here to stay. Equipment and material suppliers could find themselves selling their technical products to an international team from several companies, including the manufacturer and the designer. However, the emergence of the dedicated foundry company, taking ownership of the process and manufacturing flow, will tend to centralize this activity. Dataquest has started a research service, Semiconductor Contract Manufacturing Worldwide, to continue to explore the key trends in contract manufacturing and foundries, including technology trends and supply/demand balance, through the decade.

Appendix A
Economic Assumptions, Second Quarter 1996

With the reorganization of The Dun & Bradstreet Corporation and its split into several independent companies, as well as the recent acquisition of Dataquest by the Gartner Group, we have temporarily lost access to regional macroeconomic outlooks and country-specific economic indexes and forecasts. The most recent version we have available is from February 1996, which is somewhat dated. We have just made arrangements to re-establish this service and do expect to be able to publish a summary of world economic assumptions for our next report near the end of 1996. Unfortunately, we did not have this service established in time for the publishing deadline of this report.

If you would like to receive a copy of the February 1996 economic assumptions report, please contact your account representative or Dataquest's Inquiry Center.

Appendix B
Exchange Rates

Dataquest does not forecast exchange rates per se; however, we do forecast semiconductor-related markets in several regions of the world, and we use the U.S. dollar as a common currency for intermarket comparisons and aggregation. In general, in the forecast period, Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. For the forecasts presented here:

- Actual monthly exchange rates were used for all months in the historical interval up to May 1996.
- The May 1996 exchange rate was then assumed to hold for June through December 1996 and throughout 1997 to 2001.

Dataquest uses an average annual exchange rate to convert annual revenue from local currency values to U.S. dollar values. Table B-1 outlines the rates used in the forecasts presented here.

Table B-1
Exchange Rates per U.S. Dollar

Country	1995	1996*	U.S.Dollar Appreciation 1995-1996 (%)*
Australia (Dollar)	1.35	1.29	-4.75
Austria (Schilling)	10.06	10.52	4.54
Belgium (Franc)	29.42	30.72	4.43
Canada (Dollar)	NA	1.36	NM
China (Renminbi)	NA	8.35	NM
Denmark (Krone)	5.59	5.88	5.08
European Union (ECU)	0.77	0.80	3.72
Finland (Markka)	4.37	4.68	7.10
France (Franc)	4.97	5.09	2.36
Germany (Mark)	1.43	1.50	4.54
Great Britain (Pound)	0.63	0.66	3.97
Greece (Drachma)	231.34	241.89	4.56
Hong Kong (Dollar)	7.74	7.73	-0.02
India (Rupee)	32.38	34.65	7.00
Ireland (Punt)	0.62	0.64	2.44
Italy (Lira)	1,628.21	1,567.31	-3.74
Japan (Yen)	93.90	107.05	14.00
Malaysia (Ringgit)	2.51	2.52	0.46
Mexico (Peso)	6.41	7.48	16.77
Netherlands (Guilder)	1.60	1.67	4.31
New Zealand (Dollar)	1.52	1.47	-3.51

(Continued)

Table B-1 (Continued)
Exchange Rates per U.S. Dollar

Country	1995	1996*	U.S.Dollar Appreciation 1995-1996 (%)*
Norway (Krone)	6.33	6.47	2.31
Portugal (Escudo)	149.77	153.99	2.82
Singapore (Dollar)	1.43	1.41	-1.13
South Africa (Rand)	NA	4.10	NM
South Korea (Won)	770.57	781.03	1.36
Spain (Peseta)	124.40	125.07	0.54
Sri Lanka (Rupee)	NA	54.07	NM
Sweden (Krona)	7.14	6.73	-5.67
Switzerland (Franc)	1.18	1.21	2.67
Taiwan (Dollar)	26.48	27.25	2.92
Thailand (Baht)	24.91	25.28	1.49

*Estimated
NA = Not tracked until 1996
NM = Not meaningful
Source: Dataquest (June 1996)

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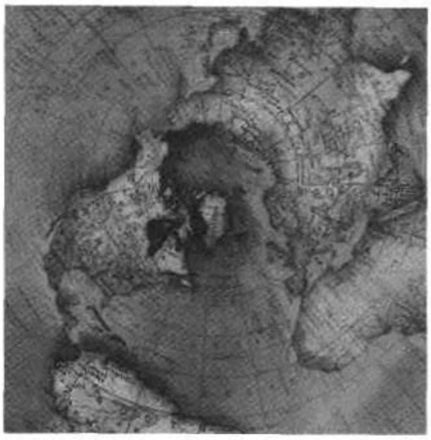

Dataquest

Semiconductor Five-Year Forecast Trends—Spring 1996

Market Trends

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-MT-9601
Publication Date: May 13, 1996
Filing: Market Trends

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Chapter 1
Introduction and Assumptions

Dataquest Semiconductor Group analysts provide a semiconductor device revenue forecast twice a year, in April and October. These revenue forecasts, which cover a five-year horizon, comprise forecasts for the major product families and the four main geographic semiconductor-consuming regions. This document, completed in April 1996, is the latest of these forecasts. Although revenue is subject to the vagaries of exchange rate variations, it is the most useful means to consolidate the forecasts of widely differing products and the most meaningful measure of markets and companies. Unit forecasts, which underlie the microcomponent and memory IC forecasts, are dollarized to arrive at the revenue forecast presented here. Average annual exchange rates are used for revenue history, and the most recent "average" exchange rate is extended into the five-year forecast horizon. Dataquest does not forecast exchange rates.

The forecast is presented in two local currencies in Appendixes A and B, in yen for the Japanese market forecast in Appendix A and in ECU for the European market forecast in Appendix B. The Americas market and the Asia/Pacific-ROW market are forecast only in U.S. dollars.

In 1996, the "North America" market has been expanded to include the total North and South America region and will be known as the "Americas" region from this point forward. This matches the divisions found in Dataquest's 1995 market share data.

Forecast Summary

The PC market, now the dominant market for semiconductors, grew nearly 26 percent in 1995. Semiconductors grew by 37 percent as demand continued to outstrip supply and DRAM average selling prices (ASPs) continued strong, at $25 per megabyte. DRAM revenue growth, which was 66 percent in 1993 and 60 percent in 1994, reached 81 percent in 1995. The brakes on this growth were applied early in 1996 as ASPs tumbled. The declining DRAM ASPs lead a number of factors that have aligned to take our 1996 forecast down to a surprising 7.6 percent growth. Beside DRAM, some other factors causing our 1996 forecast to drop under 8 percent are excess inventories, slowing markets, and a stronger yen. Inventory problems occurred as the fourth quarter PC market was well below expectations, leaving the first half of 1996 struggling with an inventory correction. Triggered by this correction, DRAM prices tumbled with prices per megabyte going from $25 in 1995 to under $15 early in 1996. Although we had anticipated DRAM price erosion in 1996, this price erosion occurred far sooner and faster than we had forecast last fall.

It is important to recognize that these corrections do not signal an evaporating market. Although the semiconductor end markets have slowed, they are still healthy. Dataquest's PC unit forecast for 1996 is still at 19 percent worldwide. If these problems were not severely impacting revenue, we would still be forecasting growth between 15 percent to 22 percent. Table 1-1 shows the impact of the major downside factors on our 1996 forecast.

Table 1-1
Changes in 1996 Forecast (Percent)

	October 1995 Forecast	This Forecast	Change to Dollar Growth (%)	Change to 1996 Worldwide Forecast (%)
DRAM Revenue Growth (%)	33	1*	-32	-8
Non-DRAM Product Growth (%)	18	14*	-4	-3
Yen/Dollar Exchange Rate	93.90	107.05	-12	-3
Total Growth in 1996 (%)	22.1	7.6	-14.5	-14.5

*Excludes change in yen/dollar exchange rate
Source: Dataquest (May 1996)

Both DRAM and Japan represent about one-fourth of the total semiconductor market, so their impact on the worldwide 1996 forecast shows up proportionately in the right column. If the 1996 yen-dollar exchange rate does not differ from 1995, the 3 percent change to the worldwide forecast would bring it back to double digits. If DRAM prices rebound more than expected, the growth could move the forecast up into the "normal" 15 percent range. This forecast is highly leveraged off of the fortunes of these two items.

Forecast Highlights

The following are the highlights of this forecast:

- Growth in 1996 drops under 8 percent after 37 percent growth in 1995.
- The PC market slows in 1996 to 19 percent unit growth versus 26 percent in 1995.
- The MPU market slows along with PC market. Price reductions bring 96 growth down to 17 percent.
- The DRAM price per bit will decline nearly 50 percent in 1996. Even with a high rate of bit growth, revenue growth will be nonexistent.
- Non-DRAM products will grow by 14 percent in 1996, growth consistent with historical rates.
- The Asia/Pacific regional market will exceed Japan in 1998 and will grow to 25 percent of the world market in 2000.
- The Americas forecast has decreased. Even with a 17 percent 1995 through 2000 compound annual growth rate (CAGR), the Americas will lose 1 percent of the world market (to 33.7 percent) by 1999 as Americas growth slows.
- Like the Americas, the European market's growth has been revised downward to a 17 percent CAGR from 1995 through 2000. Nonetheless, the European market share will remain at 18 percent over the forecast period.

We expect the semiconductor market to pass the $300 billion mark in 2000, as the adjustments seen in 1996 will not greatly impact the long-term growth of the market.

Exchange Rates

The following exchange rates are used for the 1994 through 1999 forecast:

- ¥107.05 per dollar
- ECU 0.774 per dollar

The following chapters will discuss the forecast by product and region in more detail.

Chapter 2

Worldwide Forecast by Product Family

The growth by product in 1995 as well as the past five-year CAGR and forecast 1995-through-2000 CAGR is shown in Table 2-1.

Memory ICs will show much slower growth as the five-year compounded growth rate of 16 percent brings memory IC growth back in line. Microcomponent growth, as well, will slow as the Americas market grows more slowly and prices stabilize. Logic ICs and analog ICs are settling into 14 percent growth rates, growth more consistent with the growth of electronic equipment markets. Discrete devices have gained greater growth potential with the lead of power and radio frequency (RF) transistors. Despite the growth potential of logic ICs, analog ICs, discrete devices, and optical semiconductors and the slowdown of memory IC growth, microcomponent and memory ICs will continue to increase their share of the semiconductor market at the expense of these other categories.

The tables on the following pages provide the complete five-year forecast by product type for the worldwide semiconductor market.

Worldwide Forecast Data

Tables 2-2 through 2-5 provide the five-year forecast by product type for the worldwide semiconductor market.

Table 2-1
Worldwide Semiconductor Growth by Product Type (Revenue in Millions of Dollars)

	1995 Revenue	1994-1995 Growth (%)	CAGR (%) 1990-1995 Actual	CAGR (%) 1995-2000 Forecast
Microcomponents	34,513	30.7	29.2	17.6
Memory Total	55,421	64.4	34.6	16.5
Logic/ASIC Total	22,961	22.0	13.5	13.8
Analog ICs	17,607	15.4	14.8	14.7
Monolithic IC Total	130,502	38.5	24.8	16.1
Hybrid ICs	1,935	16.2	8.5	1.4
Total ICs	132,437	38.2	24.4	15.9
Discrete Devices	14,023	30.3	12.8	11.6
Optical Semiconductors	4,811	23.7	14.8	12.1
Total Semiconductor	151,271	36.9	22.6	15.4

Source: Dataquest (May 1996)

Table 2-2
Worldwide Semiconductor Market, Six-Year Revenue History, 1990-1995 (Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	9,584	11,774	14,359	19,947	26,408	34,513	29.2
Memory Total	12,559	13,197	15,626	23,550	33,704	55,421	34.6
Bipolar Memory	431	356	318	244	199	160	-18.0
MOS Memory	12,128	12,841	15,308	23,306	33,505	55,261	35.4
Logic/ASIC Total	12,182	12,972	12,918	15,956	18,821	22,961	13.5
Bipolar Logic	3,742	3,272	2,875	2,835	2,713	2,337	-9.0
MOS Logic	8,440	9,700	10,043	13,121	16,108	20,624	19.6
Analog ICs	8,845	9,517	10,180	12,513	15,263	17,607	14.8
Monolithic IC Total	43,170	47,460	53,083	71,966	94,196	130,502	24.8
Hybrid ICs	1,289	1,395	1,335	1,463	1,665	1,935	8.5
Total ICs	44,459	48,855	54,418	73,429	95,861	132,437	24.4
Discrete Devices	7,674	8,035	8,155	9,083	10,763	14,023	12.8
Optical Semiconductors	2,412	2,804	2,688	3,006	3,889	4,811	14.8
Total Semiconductor	54,545	59,694	65,261	85,518	110,513	151,271	22.6

Source: Dataquest (May 1996)

Table 2-3
Worldwide Semiconductor Market, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	34,513	39,945	46,524	54,885	65,532	77,645	17.6
Memory Total	55,421	55,749	64,213	75,098	93,666	118,680	16.5
Bipolar Memory	160	119	108	93	79	71	-15.0
MOS Memory	55,261	55,630	64,105	75,005	93,587	118,609	16.5
Logic/ASIC Total	22,961	24,910	27,692	31,906	37,212	43,748	13.8
Bipolar Logic	2,337	2,012	1,644	1,415	1,219	1,066	-14.5
MOS Logic	20,624	22,898	26,048	30,491	35,993	42,682	15.7
Analog ICs	17,607	19,562	21,698	25,147	29,531	34,911	14.7
Monolithic IC Total	130,502	140,166	160,127	187,036	225,941	274,984	16.1
Hybrid ICs	1,935	1,947	2,009	2,030	2,055	2,075	1.4
Total ICs	132,437	142,113	162,136	189,066	227,996	277,059	15.9
Discrete Devices	14,023	15,300	16,517	18,481	21,044	24,251	11.6
Optical Semiconductors	4,811	5,199	5,588	6,286	7,207	8,526	12.1
Total Semiconductor	151,271	162,612	184,241	213,833	256,247	309,836	15.4

Source: Dataquest (May 1996)

Table 2-4
Worldwide Semiconductor Market, Historic Revenue Growth, 1990-1995 (Percentage Revenue Growth over Preceding Year)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	22.7	22.9	22.0	38.9	32.4	30.7	29.2
Memory Total	-20.8	5.1	18.4	50.7	43.1	64.4	34.6
Bipolar Memory	-6.3	-17.4	-10.7	-23.3	-18.4	-19.6	-18.0
MOS Memory	-21.3	5.9	19.2	52.2	43.8	64.9	35.4
Logic/ASIC Total	3.4	6.5	-0.4	23.5	18.0	22.0	13.5
Bipolar Logic	-2.9	-12.6	-12.1	-1.4	-4.3	-13.9	-9.0
MOS Logic	6.5	14.9	3.5	30.6	22.8	28.0	19.6
Analog ICs	13.5	7.6	7.0	22.9	22.0	15.4	14.8
Monolithic IC Total	-0.2	9.9	11.8	35.6	30.9	38.5	24.8
Hybrid ICs	-5.8	8.2	-4.3	9.6	13.8	16.2	8.5
Total ICs	-0.3	9.9	11.4	34.9	30.5	38.2	24.4
Discrete Devices	4.8	4.7	1.5	11.4	18.5	30.3	12.8
Optical Semiconductors	0.2	16.3	-4.1	11.8	29.4	23.7	14.8
Total Semiconductor	0.4	9.4	9.3	31.0	29.2	36.9	22.6

Source: Dataquest (May 1996)

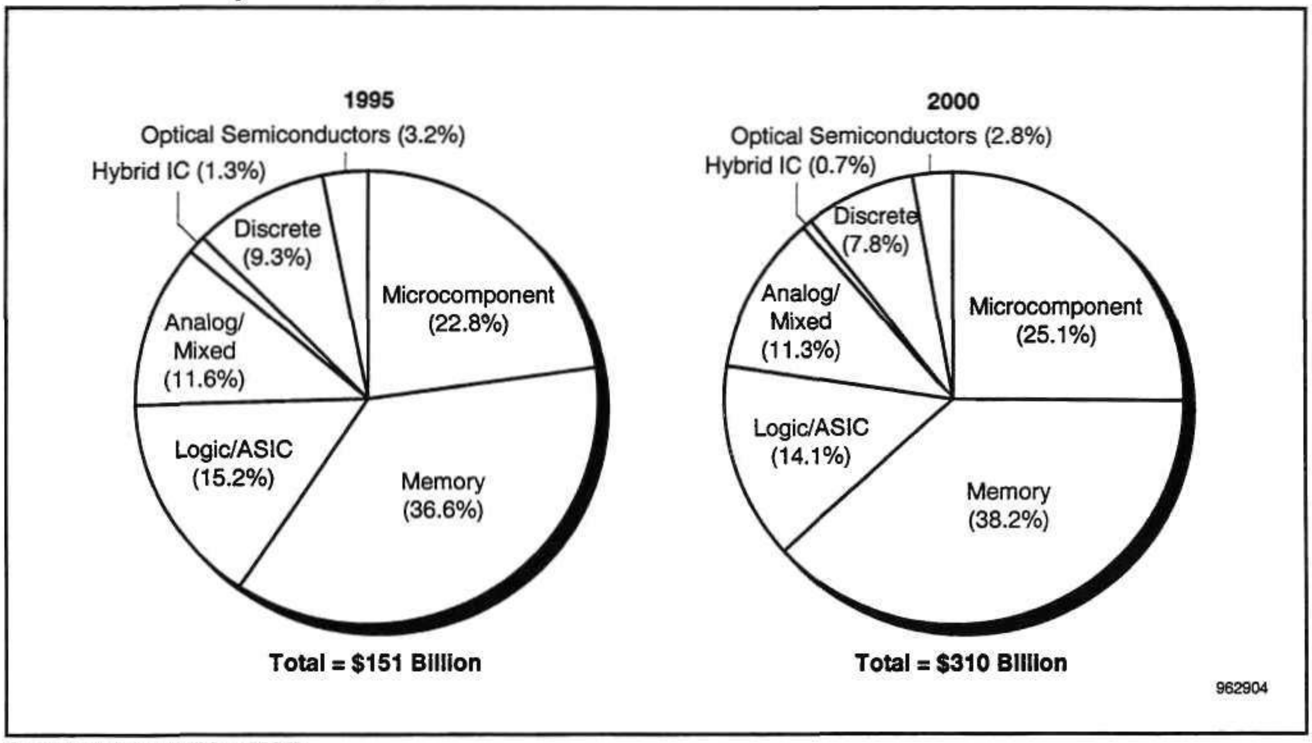
Table 2-5
Worldwide Semiconductor Market, Forecast Five-Year Revenue Growth (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	30.7	16.1	16.5	18.0	19.4	18.5	17.6
Memory Total	64.4	0.6	15.2	17.0	24.7	26.7	16.5
Bipolar Memory	-19.6	-25.6	-9.2	-13.9	-15.1	-10.1	-15.0
MOS Memory	64.9	0.7	15.2	17.0	24.8	26.7	16.5
Logic/ASIC Total	22.0	8.5	11.2	15.2	16.6	17.6	13.8
Bipolar Logic	-13.9	-13.9	-18.3	-13.9	-13.9	-12.6	-14.5
MOS Logic	28.0	11.0	13.8	17.1	18.0	18.6	15.7
Analog ICs	15.4	11.1	10.9	15.9	17.4	18.2	14.7
Monolithic IC Total	38.5	7.5	14.2	16.8	20.8	21.7	16.1
Hybrid ICs	16.2	0.6	3.2	1.0	1.2	1.0	1.4
Total ICs	38.2	7.4	14.1	16.6	20.6	21.5	15.9
Discrete Devices	30.3	9.1	8.0	11.9	13.9	15.2	11.6
Optical Semiconductors	23.7	8.1	7.5	12.5	14.7	18.3	12.1
Total Semiconductor	36.9	7.6	13.3	16.1	19.8	20.9	15.4

Source: Dataquest (May 1996)

The impact of these varying rates of growth by product is shown in Figure 2-1. In 1995, the PC-driven combination of microcomponent and memory ICs gained market share rapidly, going from 54 percent of the worldwide market in 1994 to almost 60 percent of the market in 1995. In 1992, memory and microcomponent ICs combined to share only 46 percent of the semiconductor market. This gain in market share driven by PC growth will slow. As the figure shows, memories and microcomponents will only gain a 3 percent share in the coming five-year period, after gaining 12 percent in the past five years. All other semiconductor categories, logic ICs, analog ICs, discrete devices and optical semiconductors, will lose market share, but at a slower pace than in the past.

Figure 2-1
Market Share by Product, 1995 and 2000



Source: Dataquest (May 1996)

Chapter 3
Worldwide Semiconductor Forecast by Region

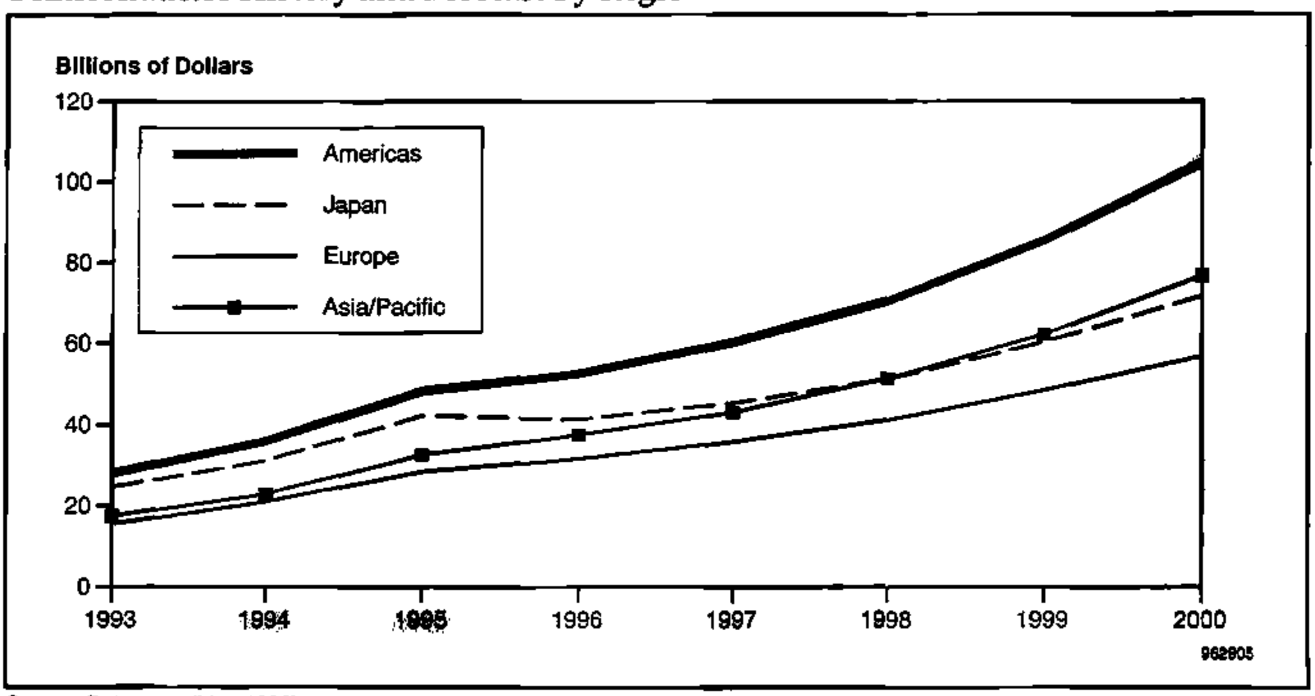
The worldwide revenue forecast is broken into the four constituent regional revenue shipment forecasts in Figure 3-1. A significant feature of this figure is the passing of Japan by Asia/Pacific in revenue by 1998.

The 1993-through-1995 period showed remarkable consistency in the growth of all regions; the three-year compounded growth rates for the Americas, Japan, Europe, and Asia/Pacific regions were 33 percent, 27 percent, 32 percent, and 39 percent, respectively. In the coming five years, these growth rates will drop by half, and regional differences will become more pronounced. Although we have forecast differing growth rates by region, the forecast still does not suggest a major downturn in the coming five years, only a period of adjustment. The negative growth shown for Japan in 1996 is because of an expected dollar devaluation; the growth would be nearly 12 percent in yen.

The regional revenue data for the five-year semiconductor forecast is listed in Table 3-1 and the annual growth by region in Table 3-2.

The effect of this forecast on the share of the total market by region is provided in Figure 3-2, where the lower anticipated growth for the Japanese market results in a continuing decline of the Japanese market share of the total market. The decline in the Japanese market is neatly mirrored by the rise in the Asia/Pacific market; these changes are tightly related with the shift of Japanese manufacturing to Asia/Pacific sites enhancing the growth of Asian markets.

Figure 3-1
Semiconductor History and Forecast by Region



Source: Dataquest (May 1996)

Table 3-1
Total Semiconductor Consumption by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	48,349	52,478	60,217	70,352	85,481	104,579	16.7
Japan	42,164	41,244	45,286	51,144	60,212	71,693	11.2
Europe	28,341	31,479	35,734	41,079	48,433	56,828	14.9
Asia/Pacific	32,417	37,411	43,004	51,258	62,121	76,736	18.8
Semiconductor Total	151,271	162,612	184,241	213,833	256,247	309,836	15.4

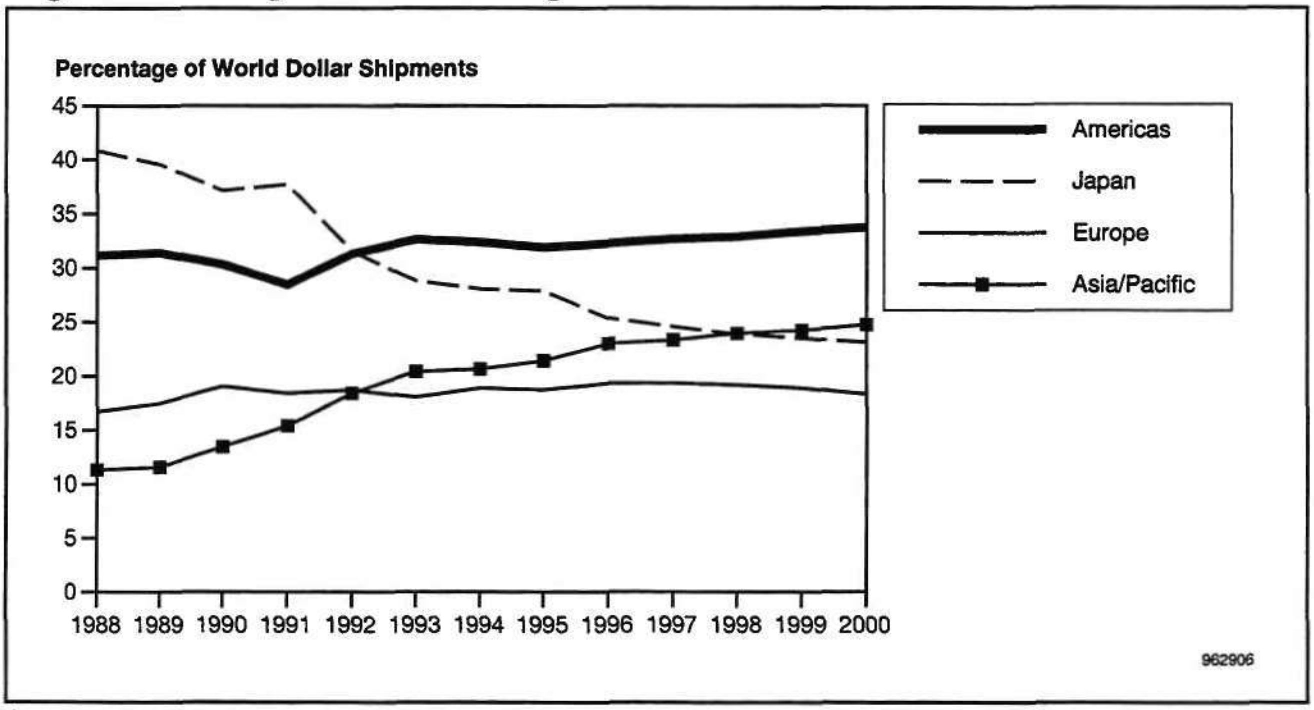
Source: Dataquest (May 1996)

Table 3-2
Total Semiconductor Growth Forecast by Region (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	35.2	8.8	14.7	16.8	21.5	22.3	16.7
Japan	36.0	-2.2	9.8	12.9	17.7	19.1	11.2
Europe	35.6	11.1	13.5	15.0	17.9	17.3	14.9
Asia/Pacific	42.0	15.4	15.0	19.2	21.2	23.5	18.8
Semiconductor Total	36.9	7.6	13.3	16.1	19.8	20.9	15.4

Source: Dataquest (May 1996)

Figure 3-2
Regional Consumption as a Percentage of Total



Source: Dataquest (May 1996)

Chapter 4

Americas Forecast by Product Family

The five-year forecast for the Americas market (the more inclusive successor to the North America region) is based on the following assumptions:

- The Americas PC market is slowing. Windows 95 didn't materialize as *the* strong driver of growth. Many businesses are waiting for Windows NT before the next big hardware/software upgrade cycle. This slowing of PC demand in the business community coupled with a saturation of the home PC market has left the forecast unit growth in 1996 at 13 percent. The lowered growth expectation has impacted all PC-related business (more than 50 percent of the Americas semiconductor market).
- Pentium processors pushed up microprocessor (MPU) revenue strongly in 1995. With Intel's Pentium price reductions, a slowing Americas market, and no looming Pentium Pro changeover in 1996, MPU market growth is expected to drop to about half of 1995's 24 percent growth.
- High-ASP semiconductors, such as x86 processors and single in-line memory modules (SIMMs), will continue to be strongly consumed in the Americas and added to PCs or motherboards manufactured in the Asia/Pacific region.
- Price reductions in Pentium processors and free-falling DRAM prices will accelerate the consumption of higher-performance MPUs and larger DRAM configurations. The same money will buy twice the PC in 1996; a prospect that may develop new customers but that also runs the risk of alienating home PC consumers who may tire of the treadmill nature of PC buying and six-month obsolescence.
- Because of the strong computer market, microcomponent and memory ICs grew from 61 percent of semiconductor revenue in the Americas market in 1994 to 68 percent in 1995, a somewhat unnatural spurt of growth that will not be repeated in 1996. We expect this share to drop to 67 percent in 1996, because memory IC revenue growth will lag all other major device families. By the year 2000, microcomponent and memory ICs will account for 70 percent of semiconductor revenue in the Americas, a slow ramp from 1995's 68 percent.
- DRAM price-per-bit declines of 40 percent to 50 percent will be offset by increased bit demand, but this will barely keep DRAM revenue growth positive in 1996.
- Discrete device growth (22 percent in 1994 and 30 percent in 1995) increasingly comes from the use of power MOS field-effect transistors (MOSFETs) and insulated gate bipolar transistors (IGBTs) in switching power supplies and peripheral drivers and the increasing use of RF devices. MOSFETs and IGBTs showed 37 percent and 59 percent growth in 1995, respectively. These devices will continue to post double-digit growth in 1996.

Tables 4-1 through 4-4 provide details of the Americas semiconductor market.

Table 4-1
Americas Semiconductor Market, Six-Year Revenue History, 1990-1995 (Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	3,381	3,916	5,282	7,620	9,839	12,421	29.7
Memory Total	4,485	4,641	5,837	8,868	12,535	20,530	35.6
Bipolar Memory	160	131	130	83	66	55	-19.2
MOS Memory	4,325	4,510	5,707	8,785	12,469	20,475	36.5
Logic/ASIC Total	4,101	4,070	4,287	5,549	6,323	7,528	12.9
Bipolar Logic	1,417	1,200	1,102	1,090	901	741	-12.2
MOS Logic	2,684	2,870	3,185	4,459	5,422	6,787	20.4
Analog ICs	2,404	2,397	2,689	3,304	3,820	3,995	10.7
Monolithic IC Total	14,371	15,024	18,095	25,341	32,517	44,474	25.3
Hybrid ICs	245	245	309	288	347	378	9.1
Total ICs	14,616	15,269	18,404	25,629	32,864	44,852	25.1
Discrete Devices	1,611	1,389	1,603	1,811	2,212	2,870	12.2
Optical Semiconductors	313	332	423	486	697	627	14.9
Total Semiconductor	16,540	16,990	20,430	27,926	35,773	48,349	23.9

Source: Dataquest (May 1996)

Table 4-2
Americas Semiconductor Market, Five-Year Revenue Forecast 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	12,421	14,073	16,182	18,779	21,950	25,575	15.5
Memory Total	20,530	21,145	24,297	28,647	36,710	47,307	18.2
Bipolar Memory	55	40	33	27	20	17	-20.9
MOS Memory	20,475	21,105	24,264	28,620	36,690	47,290	18.2
Logic/ASIC Total	7,528	8,400	9,581	11,074	12,887	15,320	15.3
Bipolar Logic	741	675	576	504	422	360	-13.4
MOS Logic	6,787	7,725	9,005	10,570	12,465	14,960	17.1
Analog ICs	3,995	4,575	5,315	6,232	7,329	8,652	16.7
Monolithic IC Total	44,474	48,193	55,375	64,732	78,876	96,854	16.8
Hybrid ICs	378	345	352	370	385	400	1.1
Total ICs	44,852	48,538	55,727	65,102	79,261	97,254	16.7
Discrete Devices	2,870	3,225	3,650	4,190	4,895	5,700	14.7
Optical Semiconductors	627	715	840	1,060	1,325	1,625	21.0
Total Semiconductor	48,349	52,478	60,217	70,352	85,481	104,579	16.7

Source: Dataquest (May 1996)

Table 4-3
Americas Semiconductor Market, Historic Revenue Growth, 1990-1995 (Percentage Revenue Growth over Preceding Year)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	20.9	15.8	34.9	44.3	29.1	26.2	29.7
Memory Total	-24.6	3.5	25.8	51.9	41.4	63.8	35.6
Bipolar Memory	-11.1	-18.1	-0.8	-36.2	-20.5	-16.7	-19.2
MOS Memory	-25.1	4.3	26.5	53.9	41.9	64.2	36.5
Logic/ASIC Total	5.8	-0.8	5.3	29.4	13.9	19.1	12.9
Bipolar Logic	-2.6	-15.3	-8.2	-1.1	-17.3	-17.8	-12.2
MOS Logic	10.9	6.9	11.0	40.0	21.6	25.2	20.4
Analog ICs	8.0	-0.3	12.2	22.9	15.6	4.6	10.7
Monolithic IC Total	-3.2	4.5	20.4	40.0	28.3	36.8	25.3
Hybrid ICs	-3.5	0	26.1	-6.8	20.5	8.9	9.1
Total ICs	-3.2	4.5	20.5	39.3	28.2	36.5	25.1
Discrete Devices	-1.7	-13.8	15.4	13.0	22.1	29.7	12.2
Optical Semiconductors	-4.9	6.1	27.4	14.9	43.4	-10.0	14.9
Total Semiconductor	-3.1	2.7	20.2	36.7	28.1	35.2	23.9

Source: Dataquest (May 1996)

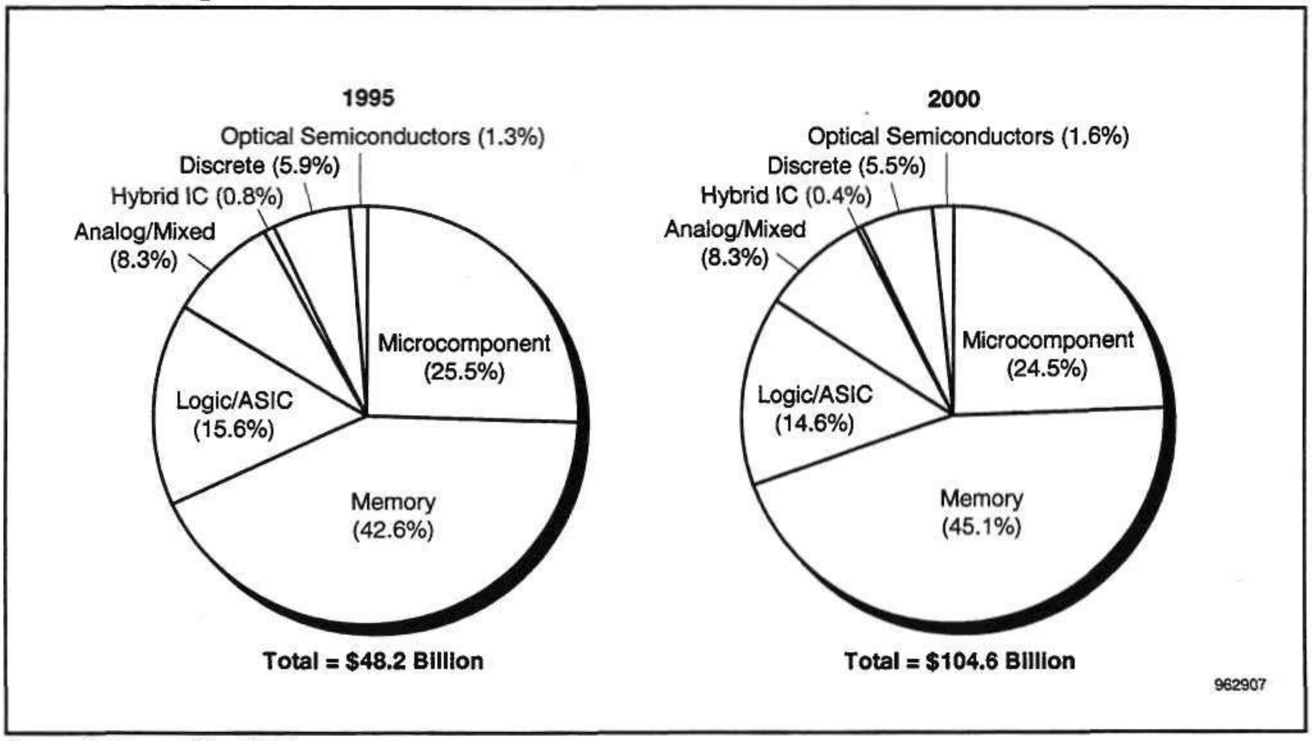
Table 4-4
Americas Semiconductor Market, Forecast Five-Year Revenue Growth (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	26.2	14.2	15.0	16.0	16.9	16.5	15.5
Memory Total	63.8	3.0	14.9	17.9	28.1	28.9	18.2
Bipolar Memory	-16.7	-27.3	-17.5	-18.2	-25.9	-15.0	-20.9
MOS Memory	64.2	3.1	15.0	18.0	28.2	28.9	18.2
Logic/ASIC Total	19.1	11.6	14.1	15.6	16.4	18.9	15.3
Bipolar Logic	-17.8	-8.9	-14.7	-12.5	-16.3	-14.7	-13.4
MOS Logic	25.2	13.8	16.6	17.4	17.9	20.0	17.1
Analog ICs	4.6	14.5	16.2	17.3	17.6	18.1	16.7
Monolithic IC Total	36.8	8.6	14.9	16.9	21.9	22.8	16.8
Hybrid ICs	8.9	-8.7	2.0	5.1	4.1	3.9	1.1
Total ICs	36.5	8.5	14.8	16.8	21.7	22.7	16.7
Discrete Devices	29.7	12.4	13.2	14.8	16.8	16.4	14.7
Optical Semiconductors	-10.0	14.0	17.5	26.2	25.0	22.6	21.0
Total Semiconductor	35.2	8.8	14.7	16.8	21.5	22.3	16.7

Source: Dataquest (May 1996)

The effect of the Americas forecast on the relative consumption by product is shown in Figure 4-1. With 68 percent of the revenue in the Americas stemming from microcomponents and memories, the Americas market is highly dependent on the health of data processing. With lowered growth expectations in these two product types, we expect that market shares will hold more constant than in the past, with microcomponents actually losing 1 percent over the next five years. Logic ICs will lose a 1 percent share as bipolar logic declines.

Figure 4-1
Product Comparison, Americas Market, 1995 and 2000



Source: Dataquest (May 1996)

Chapter 5

Japan Forecast by Product Family

The five-year semiconductor forecast for the Japanese market is based on the following assumptions:

- Growth had been accelerating in Japan after the disastrous revenue decline in 1992, but this three-year growth period is slowing. A 36 percent dollar growth in 1995 will be followed by a 2 percent decline in 1996. Although the past three years have had dollar revenue enhancements because of the yen-to-dollar depreciation, the 1996 forecast includes a dollar appreciation of 14 percent, turning a 12 percent yen-based growth in 1996 to a 2 percent decline in dollars.
- The Japanese market is fundamentally sound. PC growth in Japan will drop from the 58 percent seen in 1995 to above 30 percent. The continued migration of electronic equipment manufacturing to Asia/Pacific sites is a factor that will reduce revenue growth over the forecast period, but this migration has been somewhat stunted by constraints in growing Asian infrastructures. The result of this migration is that the Japanese market will drop from 28 percent of worldwide shipments in 1994 to slightly over 23 percent in the year 2000, a lower loss of share than our past forecasts, because depreciation is expected to slow the rate of migration.
- Microcomponents will show Japan's strongest product growth in 1996 as the MPU category is dominated by the dollar-based x86 devices from Intel. The other product categories, more strongly supplied by domestic suppliers in yen-based revenue, are impacted by the devalued dollar exchange rate. The weak 1996/1995 growth of MCU, analog, optical semiconductor, and discrete is due to sluggish consumer equipment production.
- Microcomponents show the strongest five-year compounded growth in Japan. The 21 percent compounded growth forecast for PC shipments in Japan provides comparable growth for the MPU category.
- MCU, analog IC, and optical semiconductor growth in Japan will be reduced by the offshore production shift of consumer electronics, the biggest application for these devices in Japan.
- MOS memory revenue will decline by 16 percent in dollars (negative 4 percent in yen). Even with strong PC growth, the bit growth will be insufficient to bring revenue into positive growth as ASPs drop by half. DRAM consumption in Japan has been pumped up by robust growth in SIMM production, which will be impacted by any possible slowdown in worldwide PC shipments. Prices are weakening for other memory products like SRAM, flash, and MROMs.
- Optical semiconductors showed a 32 percent growth in 1995, a considerable increase over the 21 percent seen in 1994. An explosive increase in the consumption of optically oriented computer peripherals such as CD-ROM players, scanners, and laser/LED printers has helped to fuel this growth over the past two years. This growth will be blunted in 1996 and beyond as this multimedia frenzy slows. It is not expected that new growth opportunities in DVD will be seen in the optical semiconductor category until the end of the forecast period (the year 2000).

Tables 5-1 through 5-4 provide details on the Japanese semiconductor market.

Table 5-1
Japanese Semiconductor Market, Six-Year Revenue History, 1990-1995 (Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	2,974	3,579	3,269	3,987	5,603	7,829	21.4
Memory Total	4,390	4,393	4,175	5,697	7,344	12,337	23.0
Bipolar Memory	194	165	138	127	98	82	-15.8
MOS Memory	4,196	4,228	4,037	5,570	7,246	12,255	23.9
Logic/ASIC Total	4,931	5,351	4,849	5,712	7,111	8,772	12.2
Bipolar Logic	1,441	1,277	1,016	1,001	1,118	988	-7.3
MOS Logic	3,490	4,074	3,833	4,711	5,993	7,784	17.4
Analog ICs	2,723	3,094	2,903	3,278	4,048	4,744	11.7
Monolithic IC Total	15,018	16,417	15,196	18,674	24,106	33,682	17.5
Hybrid ICs	776	860	750	820	889	1,034	5.9
Total ICs	15,794	17,277	15,946	19,494	24,995	34,716	17.1
Discrete Devices	2,969	3,432	3,077	3,423	3,916	4,681	9.5
Optical Semiconductors	1,494	1,787	1,556	1,728	2,097	2,767	13.1
Total Semiconductor	20,257	22,496	20,579	24,645	31,008	42,164	15.8

Source: Dataquest (May 1996)

Table 5-2
Japanese Semiconductor Market, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	7,829	8,558	10,130	12,001	14,286	16,934	16.7
Memory Total	12,337	10,409	11,853	13,481	17,163	22,162	12.4
Bipolar Memory	82	63	60	55	49	45	-11.3
MOS Memory	12,255	10,346	11,793	13,426	17,114	22,117	12.5
Logic/ASIC Total	8,772	8,934	9,663	10,919	12,501	14,180	10.1
Bipolar Logic	988	824	637	546	486	437	-15.1
MOS Logic	7,784	8,110	9,026	10,373	12,015	13,743	12.0
Analog ICs	4,744	4,801	4,846	5,331	5,922	6,612	6.9
Monolithic IC Total	33,682	32,702	36,492	41,732	49,872	59,888	12.2
Hybrid ICs	1,034	1,045	1,075	1,075	1,075	1,075	0.8
Total ICs	34,716	33,747	37,567	42,807	50,947	60,963	11.9
Discrete Devices	4,681	4,708	4,845	5,232	5,813	6,641	7.2
Optical Semiconductors	2,767	2,789	2,874	3,105	3,452	4,089	8.1
Total Semiconductor	42,164	41,244	45,286	51,144	60,212	71,693	11.2

Source: Dataquest (May 1996)

Table 5-3
Japanese Semiconductor Market, Historic Revenue Growth, 1990-1995 (Percentage Revenue Growth over Preceding Year)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	11.7	20.3	-8.7	22.0	40.5	39.7	21.4
Memory Total	-24.6	0.1	-5.0	36.5	28.9	68.0	23.0
Bipolar Memory	1.6	-14.9	-16.4	-8.0	-22.8	-16.3	-15.8
MOS Memory	-25.5	0.8	-4.5	38.0	30.1	69.1	23.9
Logic/ASIC Total	2.7	8.5	-9.4	17.8	24.5	23.4	12.2
Bipolar Logic	-1.1	-11.4	-20.4	-1.5	11.7	-11.6	-7.3
MOS Logic	4.3	16.7	-5.9	22.9	27.2	29.9	17.4
Analog ICs	-0.4	13.6	-6.2	12.9	23.5	17.2	11.7
Monolithic IC Total	-6.2	9.3	-7.4	22.9	29.1	39.7	17.5
Hybrid ICs	-7.7	10.8	-12.8	9.3	8.4	16.3	5.9
Total ICs	-6.3	9.4	-7.7	22.3	28.2	38.9	17.1
Discrete Devices	-3.6	15.6	-10.3	11.2	14.4	19.5	9.5
Optical Semiconductors	-3.7	19.6	-12.9	11.1	21.4	32.0	13.1
Total Semiconductor	-5.7	11.1	-8.5	19.8	25.8	36.0	15.8

Source: Dataquest (May 1996)

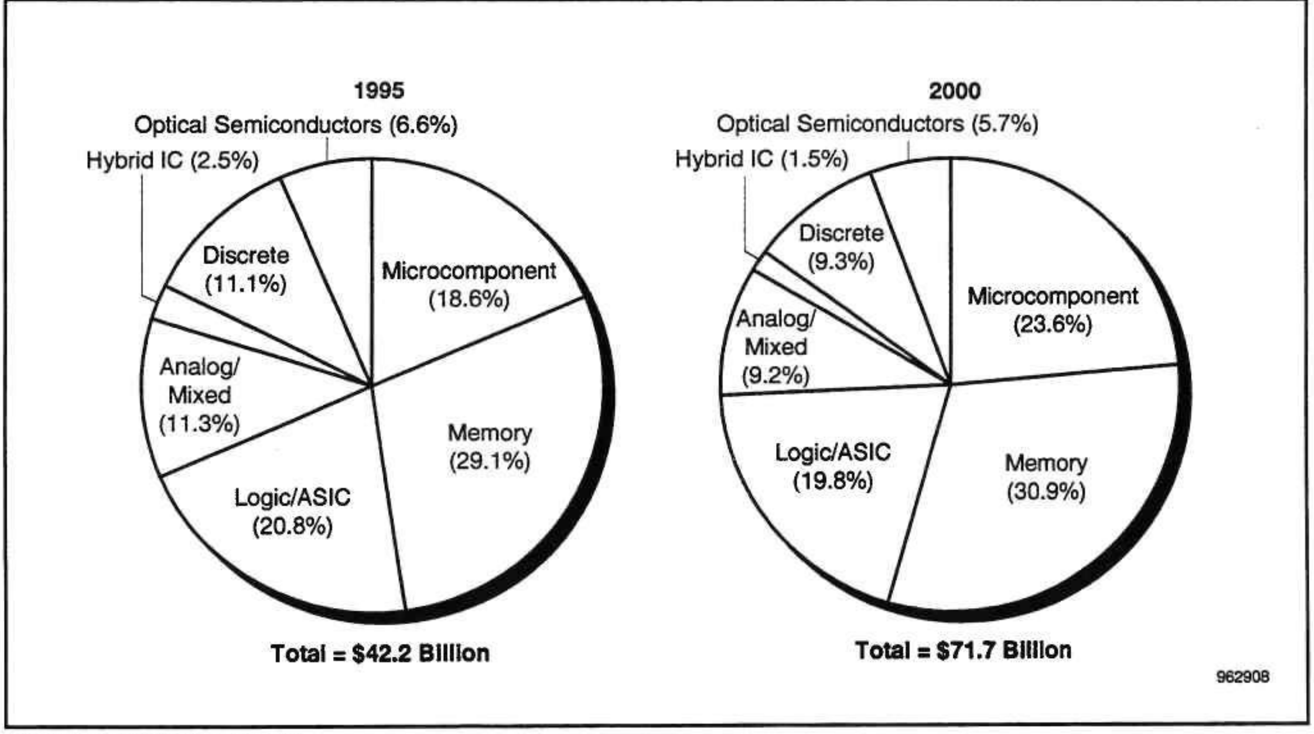
Table 5-4
Japanese Semiconductor Market, Forecast Five-Year Revenue Growth (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	39.7	9.3	18.4	18.5	19.0	18.5	16.7
Memory Total	68.0	-15.6	13.9	13.7	27.3	29.1	12.4
Bipolar Memory	-16.3	-23.2	-4.8	-8.3	-10.9	-8.2	-11.3
MOS Memory	69.1	-15.6	14.0	13.8	27.5	29.2	12.5
Logic/ASIC Total	23.4	1.8	8.2	13.0	14.5	13.4	10.1
Bipolar Logic	-11.6	-16.6	-22.7	-14.3	-11.0	-10.1	-15.1
MOS Logic	29.9	4.2	11.3	14.9	15.8	14.4	12.0
Analog ICs	17.2	1.2	0.9	10.0	11.1	11.7	6.9
Monolithic IC Total	39.7	-2.9	11.6	14.4	19.5	20.1	12.2
Hybrid ICs	16.3	1.1	2.9	0	0	0	0.8
Total ICs	38.9	-2.8	11.3	13.9	19.0	19.7	11.9
Discrete Devices	19.5	0.6	2.9	8.0	11.1	14.2	7.2
Optical Semiconductors	32.0	0.8	3.0	8.0	11.2	18.5	8.1
Total Semiconductor	36.0	-2.2	9.8	12.9	17.7	19.1	11.2

Source: Dataquest (May 1996)

Figure 5-1 illustrates the effect of the Japanese market forecast on the relative consumption by product. The figure highlights three main trends. First, microcomponents are expected to track PC growth in Japan. Second, memory IC price erosion will hold memory growth down over the forecast period. Third, the non-DRAM, non-MPU devices will decline in market share as these devices increasingly move toward offshore equipment production. With a memory and microcomponent market share that is 20 percent less than that of the Americas, the Japanese market has had less dependence on the PC. Personal computers will make strong gains in the Japanese market in the coming years.

Figure 5-1
Product Comparison, Japanese Market, 1995 and 2000



Source: Dataquest (May 1996)

Chapter 6

Europe Forecast by Product Family

The five-year semiconductor forecast for the European market, shown on the following pages, is based on these assumptions:

- With two consecutive years of growth exceeding 35 percent, the European market has shown considerably more strength than we had expected. This growth, based on the PC and personal communications booms, is expected to moderate in 1996.
- The European PC market, which grew by 25 percent in 1995, is still expected to do more than 20 percent in 1996. Declining prices for DRAM will limit the semiconductor ride on this boom, however.
- DRAM revenue will be flat in 1996. Double-digit growth will return in 1997, although at a compounded rate below 20 percent. The more stable prices seen in 1997 will result in DRAM revenue growth consistent with PC unit growth (17 percent).
- MCU growth continued strongly into 1995, with revenue growth exceeding 40 percent. ASP erosion and a slowing of demand will limit revenue growth in 1996, and beyond, to less than 20 percent.
- Shortages in discrete products enhanced the market in 1994 and 1995 as ASPs were kept high. In 1995, a 45 percent annual growth more than doubled the 19 percent seen in 1994. Discrete growth will drop into lower growth in 1996 (10 percent) and beyond (11 percent CAGR, 1995 through 2000).

Tables 6-1 through 6-4 provide details on the European semiconductor market.

Figure 6-1 illustrates the consumption by product changes for the European market over the forecast period. Unlike past years of memory and microcomponent market incursion, the product mix remains fairly consistent over the forecast period. By the year 2000, microcomponents and memory ICs are expected to account for 62 percent of semiconductor shipment revenue, up slightly from the 60 percent of 1995. The growth in microcomponents derives from all segments of the microcomponent category, the MPUs and microperipherals (MPRs) in computers and the microcontroller (MCU) and digital signal processor (DSP) ICs used in communications and consumer products.

Table 6-1
European Semiconductor Market, Six-Year Revenue History, 1990-1995 (Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	1,802	2,082	2,723	4,037	5,408	7,009	31.2
Memory Total	2,105	2,172	2,698	4,067	6,602	9,990	36.5
Bipolar Memory	55	43	38	27	28	19	-19.2
MOS Memory	2,050	2,129	2,660	4,040	6,574	9,971	37.2
Logic/ASIC Total	1,882	2,085	2,137	2,299	2,659	3,243	11.5
Bipolar Logic	510	443	388	363	329	291	-10.6
MOS Logic	1,372	1,642	1,749	1,936	2,330	2,952	16.6
Analog ICs	2,169	2,184	2,249	2,736	3,370	4,127	13.7
Monolithic IC Total	7,958	8,523	9,807	13,139	18,039	24,369	25.1
Hybrid ICs	157	178	151	179	178	239	8.8
Total ICs	8,115	8,701	9,958	13,318	18,217	24,608	24.8
Discrete Devices	1,895	1,828	1,826	1,769	2,108	3,053	10.0
Optical Semiconductors	405	485	434	374	575	680	10.9
Total Semiconductor	10,415	11,014	12,218	15,461	20,900	28,341	22.2

Source: Dataquest (May 1996)

Table 6-2
European Semiconductor Market, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	7,009	8,503	9,775	11,365	13,454	15,437	17.1
Memory Total	9,990	10,321	11,962	13,917	16,728	19,919	14.8
Bipolar Memory	19	13	13	10	9	8	-15.9
MOS Memory	9,971	10,308	11,949	13,907	16,719	19,911	14.8
Logic/ASIC Total	3,243	3,621	3,974	4,540	5,250	6,175	13.7
Bipolar Logic	291	251	203	174	151	134	-14.4
MOS Logic	2,952	3,370	3,771	4,366	5,099	6,041	15.4
Analog ICs	4,127	4,630	5,306	6,049	7,149	8,580	15.8
Monolithic IC Total	24,369	27,075	31,017	35,871	42,581	50,111	15.5
Hybrid ICs	239	249	245	248	258	263	1.9
Total ICs	24,608	27,324	31,262	36,119	42,839	50,374	15.4
Discrete Devices	3,053	3,367	3,603	3,985	4,491	5,178	11.1
Optical Semiconductors	680	788	869	975	1,103	1,276	13.4
Total Semiconductor	28,341	31,479	35,734	41,079	48,433	56,828	14.9

Source: Dataquest (May 1996)

Table 6-3
European Semiconductor Market, Historic Revenue Growth, 1990-1995 (Percentage Revenue Growth over Preceding Year)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	25.0	15.5	30.8	48.3	34.0	29.6	31.2
Memory Total	-15.4	3.2	24.2	50.7	62.3	51.3	36.5
Bipolar Memory	-22.5	-21.8	-11.6	-28.9	3.7	-32.1	-19.2
MOS Memory	-15.2	3.9	24.9	51.9	62.7	51.7	37.2
Logic/ASIC Total	-3.4	10.8	2.5	7.6	15.7	22.0	11.5
Bipolar Logic	-8.3	-13.1	-12.4	-6.4	-9.4	-11.6	-10.6
MOS Logic	-1.4	19.7	6.5	10.7	20.4	26.7	16.6
Analog ICs	39.4	0.7	3.0	21.7	23.2	22.5	13.7
Monolithic IC Total	7.0	7.1	15.1	34.0	37.3	35.1	25.1
Hybrid ICs	15.4	13.4	-15.2	18.5	-0.6	34.3	8.8
Total ICs	7.2	7.2	14.4	33.7	36.8	35.1	24.8
Discrete Devices	20.4	-3.5	-0.1	-3.1	19.2	44.8	10.0
Optical Semiconductors	14.4	19.8	-10.5	-13.8	53.7	18.3	10.9
Total Semiconductor	9.7	5.8	10.9	26.5	35.2	35.6	22.2

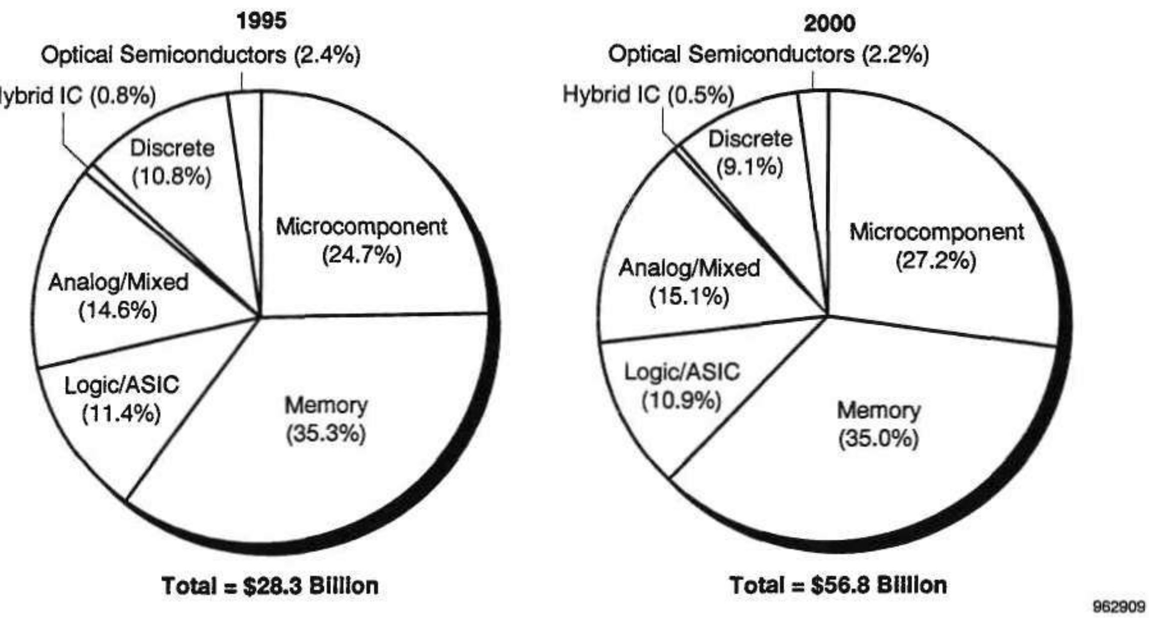
Source: Dataquest (May 1996)

Table 6-4
European Semiconductor Market, Forecast Five-Year Revenue Growth (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	29.6	21.3	15.0	16.3	18.4	14.7	17.1
Memory Total	51.3	3.3	15.9	16.3	20.2	19.1	14.8
Bipolar Memory	-32.1	-31.6	0	-23.1	-10.0	-11.1	-15.9
MOS Memory	51.7	3.4	15.9	16.4	20.2	19.1	14.8
Logic/ASIC Total	22.0	11.7	9.7	14.2	15.6	17.6	13.7
Bipolar Logic	-11.6	-13.7	-19.1	-14.3	-13.2	-11.3	-14.4
MOS Logic	26.7	14.2	11.9	15.8	16.8	18.5	15.4
Analog ICs	22.5	12.2	14.6	14.0	18.2	20.0	15.8
Monolithic IC Total	35.1	11.1	14.6	15.6	18.7	17.7	15.5
Hybrid ICs	34.3	4.2	-1.6	1.2	4.0	1.9	1.9
Total ICs	35.1	11.0	14.4	15.5	18.6	17.6	15.4
Discrete Devices	44.8	10.3	7.0	10.6	12.7	15.3	11.1
Optical Semiconductors	18.3	15.9	10.3	12.2	13.1	15.7	13.4
Total Semiconductor	35.6	11.1	13.5	15.0	17.9	17.3	14.9

Source: Dataquest (May 1996)

Figure 6-1
Product Comparison, European Market, 1995 and 2000



Source: Dataquest (May 1996)

Chapter 7
Asia/Pacific Forecast by Product Family

The five-year forecast for the Asia/Pacific region shown on the following pages is based on the following assumptions:

- The PC business was slower than expected in 1995 and will slow again in 1996. DRAM, SRAM, and MPU growth have been reduced in 1996. The combined MOS memory growth will decline to 10 percent after 74 percent in 1995. Microcomponent growth will drop from 30 percent in 1995 to 21 percent in 1996.
- Decreasing ASPs, down 40 percent over those of 1995, will offset much of the bit growth in Asia/Pacific, reducing DRAM revenue growth below 10 percent in 1996.
- SRAM ASPs are declining, but not falling. SRAM revenue growth will drop to less than half of the 60 percent growth seen in 1995.
- Asia/Pacific's microprocessor market is almost totally dominated by x86 architectures. With ever-shortening PC life cycles, most PC products are shipped without the MPU on-board—92 percent of motherboards, 83 percent of desktop PCs, and 80 percent of notebook computers from Taiwan are shipped this way. This trend will continue over the forecast period.
- China and the southern Asia/Pacific regions have shown strong growth in telecom and consumer equipment. High-end telecommunications equipment is being built in China, and the shipment of pagers and cellular phones continues to expand.
- A strengthening yen continues to drive electronic equipment production out of Japan and into the Asia/Pacific region. This production shift enhances the Asia/Pacific growth that comes with the growth of its own consuming markets. As a semiconductor consuming region, Asia/Pacific will pass Japan in 1998.

Tables 7-1 through 7-4 provide details on the Asia/Pacific semiconductor market.

Figure 7-1 shows the impact of the five-year product forecast on the relative shares of the total Asia/Pacific market. The combined memory-microcomponent IC share increased from 56 percent of the market in 1994 to 61 percent in 1995. Like the three other geographical regions, Asia/Pacific will see little gain in the memory-microcomponent market (to 64 percent in 2000) as prices correct and the PC market slows. Analog and logic ICs, less affected by price erosion, will maintain market position.

Table 7-1
Asia/Pacific Semiconductor Market, Six-Year Revenue History, 1990-1995 (Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	1,427	2,197	3,085	4,303	5,558	7,254	38.4
Memory Total	1,579	1,991	2,916	4,918	7,223	12,564	51.4
Bipolar Memory	22	17	12	7	7	4	-28.9
MOS Memory	1,557	1,974	2,904	4,911	7,216	12,560	51.8
Logic/ASIC Total	1,268	1,466	1,645	2,396	2,728	3,418	21.9
Bipolar Logic	374	352	369	381	365	317	-3.3
MOS Logic	894	1,114	1,276	2,015	2,363	3,101	28.2
Analog ICs	1,549	1,842	2,339	3,195	4,025	4,741	25.1
Monolithic IC Total	5,823	7,496	9,985	14,812	19,534	27,977	36.9
Hybrid ICs	111	112	125	176	251	284	20.7
Total ICs	5,934	7,608	10,110	14,988	19,785	28,261	36.6
Discrete Devices	1,199	1,386	1,649	2,080	2,527	3,419	23.3
Optical Semiconductors	200	200	275	418	520	737	29.8
Total Semiconductor	7,333	9,194	12,034	17,486	22,832	32,417	34.6

Source: Dataquest (May 1996)

Table 7-2
Asia/Pacific Semiconductor Market, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	7,254	8,811	10,437	12,740	15,842	19,699	22.1
Memory Total	12,564	13,874	16,101	19,053	23,065	29,292	18.4
Bipolar Memory	4	3	2	1	1	1	-24.2
MOS Memory	12,560	13,871	16,099	19,052	23,064	29,291	18.5
Logic/ASIC Total	3,418	3,955	4,474	5,373	6,574	8,073	18.8
Bipolar Logic	317	262	228	191	160	135	-15.7
MOS Logic	3,101	3,693	4,246	5,182	6,414	7,938	20.7
Analog ICs	4,741	5,556	6,231	7,535	9,131	11,067	18.5
Monolithic IC Total	27,977	32,196	37,243	44,701	54,612	68,131	19.5
Hybrid ICs	284	308	337	337	337	337	3.5
Total ICs	28,261	32,504	37,580	45,038	54,949	68,468	19.4
Discrete Devices	3,419	4,000	4,419	5,074	5,845	6,732	14.5
Optical Semiconductors	737	907	1,005	1,146	1,327	1,536	15.8
Total Semiconductor	32,417	37,411	43,004	51,258	62,121	76,736	18.8

Source: Dataquest (May 1996)

Table 7-3
Asia/Pacific Semiconductor Market, Historic Revenue Growth, 1990-1995 (Percentage Revenue Growth over Preceding Year)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	57.2	54.0	40.4	39.5	29.2	30.5	38.4
Memory Total	-1.6	26.1	46.5	68.7	46.9	73.9	51.4
Bipolar Memory	22.2	-22.7	-29.4	-41.7	0	-42.9	-28.9
MOS Memory	-1.9	26.8	47.1	69.1	46.9	74.1	51.8
Logic/ASIC Total	9.7	15.6	12.2	45.7	13.9	25.3	21.9
Bipolar Logic	-3.1	-5.9	4.8	3.3	-4.2	-13.2	-3.3
MOS Logic	16.1	24.6	14.5	57.9	17.3	31.2	28.2
Analog ICs	21.5	18.9	27.0	36.6	26.0	17.8	25.1
Monolithic IC Total	17.8	28.7	33.2	48.3	31.9	43.2	36.9
Hybrid ICs	-19.0	0.9	11.6	40.8	42.6	13.1	20.7
Total ICs	16.8	28.2	32.9	48.2	32.0	42.8	36.6
Discrete Devices	16.7	15.6	19.0	26.1	21.5	35.3	23.3
Optical Semiconductors	16.3	0	37.5	52.0	24.4	41.7	29.8
Total Semiconductor	16.8	25.4	30.9	45.3	30.6	42.0	34.6

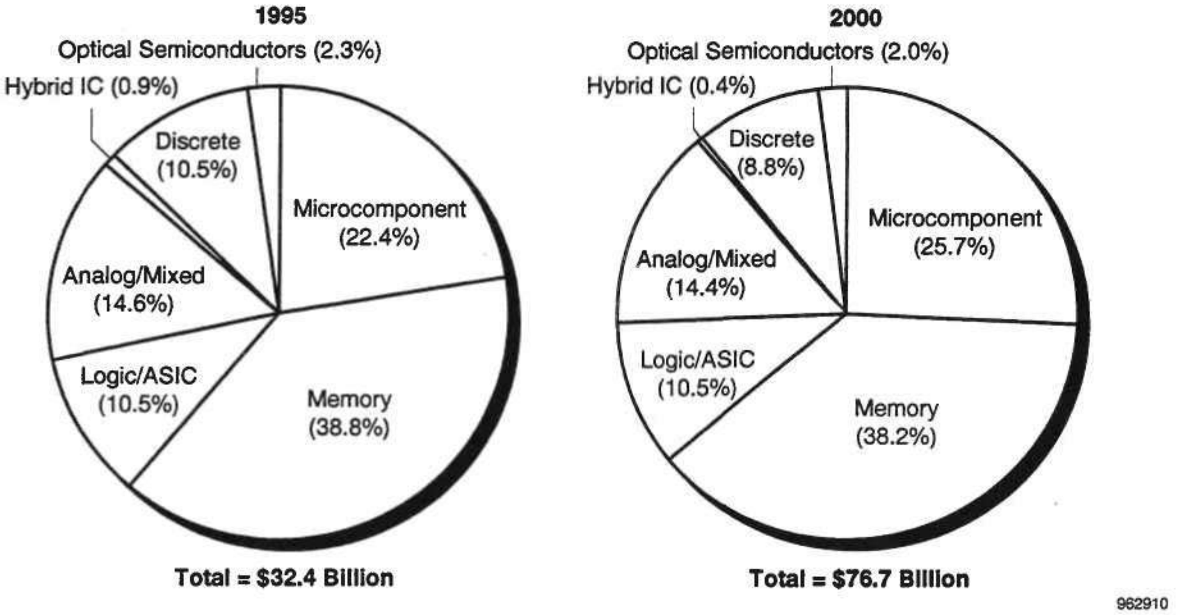
Source: Dataquest (May 1996)

Table 7-4
Asia/Pacific Semiconductor Market, Forecast Five-Year Revenue Growth (Percentage Revenue Growth over Preceding Year)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	30.5	21.5	18.5	22.1	24.3	24.3	22.1
Memory Total	73.9	10.4	16.1	18.3	21.1	27.0	18.4
Bipolar Memory	-42.9	-25.0	-33.3	-50.0	0	0	-24.2
MOS Memory	74.1	10.4	16.1	18.3	21.1	27.0	18.5
Logic/ASIC Total	25.3	15.7	13.1	20.1	22.4	22.8	18.8
Bipolar Logic	-13.2	-17.4	-13.0	-16.2	-16.2	-15.6	-15.7
MOS Logic	31.2	19.1	15.0	22.0	23.8	23.8	20.7
Analog ICs	17.8	17.2	12.1	20.9	21.2	21.2	18.5
Monolithic IC Total	43.2	15.1	15.7	20.0	22.2	24.8	19.5
Hybrid ICs	13.1	8.5	9.4	0	0	0	3.5
Total ICs	42.8	15.0	15.6	19.8	22.0	24.6	19.4
Discrete Devices	35.3	17.0	10.5	14.8	15.2	15.2	14.5
Optical Semiconductors	41.7	23.1	10.8	14.0	15.8	15.7	15.8
Total Semiconductor	42.0	15.4	15.0	19.2	21.2	23.5	18.8

Source: Dataquest (May 1996)

Figure 7-1
Product Comparison, Asia/Pacific Market, 1995 and 2000



Source: Dataquest (May 1996)

Chapter 8
Forecast by Product

Chapter 2 provided a brief discussion of the semiconductor product families. This chapter focuses on the individual products and summarizes the regional splits for each product category.

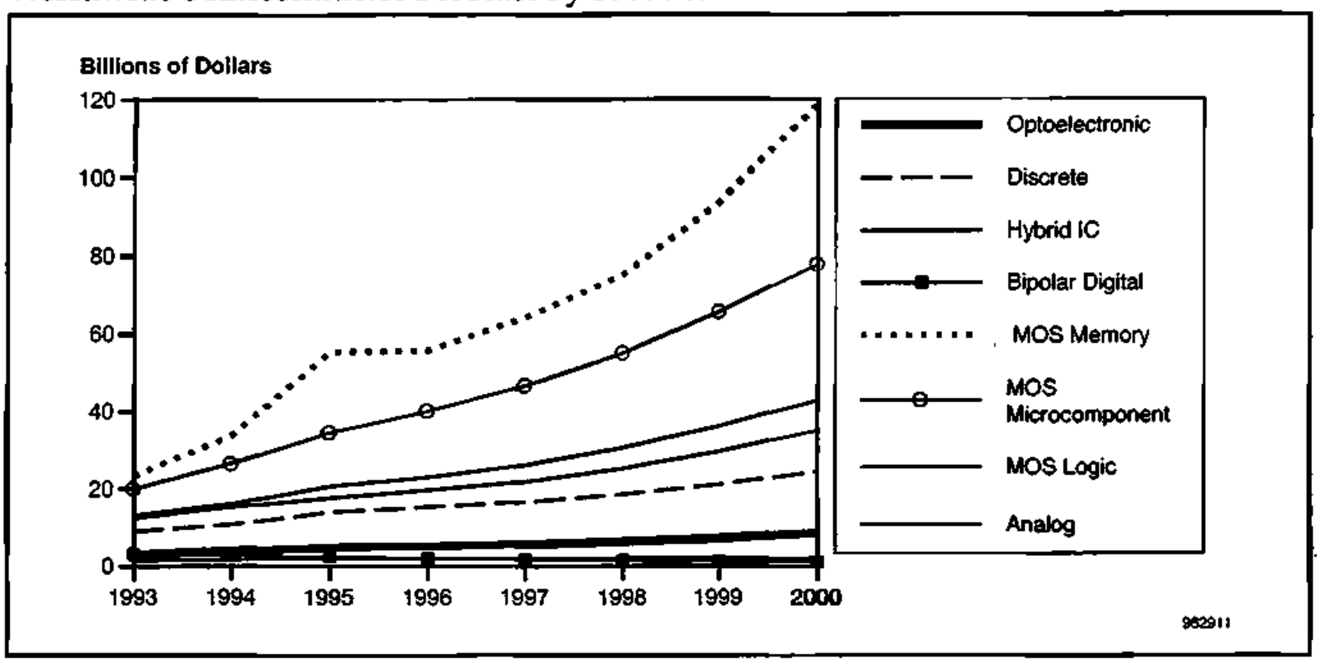
Figure 8-1 graphs the worldwide forecast by category for the forecast period. A major change to the forecast is the flat memory growth seen in 1996—a departure from last year's forecast, where we expected decelerating growth, but growth nevertheless. After this three-year correction period, memory revenue will again outpace microcomponent revenue growth, widening the gap toward the end of the forecast period.

Each of these major product categories is discussed in the following sections, and a regional forecast table is provided.

Microcomponent ICs

After six consecutive years of growth exceeding 20 percent, microcomponent growth is slowing. Growth will drop below 20 percent in 1996 and remain in the high teens for the duration of the forecast. The PC market is slowing somewhat and will post growth under 20 percent worldwide over the coming five years. Microprocessor ASPs will not rise as rapidly as in the recent past, and the slowing growth of PCs and multimedia peripherals will limit microperipheral growth. Communications and digital entertainment will keep DSP growth above 20 percent compounded. Microcontrollers continue to find new homes in every conceivable electronic product and will help hold the microcomponent CAGR near 18 percent. Table 8-1 shows the microcomponent growth by region for the coming five years, with some product detail presented below.

Figure 8-1
Worldwide Semiconductor Forecast by Product



Source: Dataquest (May 1996)

Table 8-1
Microcomponent IC Market, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	12,421	14,073	16,182	18,779	21,950	25,575	15.5
Japan	7,829	8,558	10,130	12,001	14,286	16,934	16.7
Europe	7,009	8,503	9,775	11,365	13,454	15,437	17.1
Asia/Pacific	7,254	8,811	10,437	12,740	15,842	19,699	22.1
Microcomponent IC Total	34,513	39,945	46,524	54,885	65,532	77,645	17.6

Source: Dataquest (May 1996)

Memory ICs

By accounting for 28 percent of total semiconductor revenue, DRAM has had an enormous effect on total semiconductor growth. With an 82 percent DRAM revenue growth in 1995, the semiconductor market grew by 37 percent; excluding DRAM revenue growth, all other semiconductor products showed a combined growth of 25 percent. In 1996, Dataquest anticipates no DRAM growth, a problem that will limit total semiconductor growth to 8 percent even as non-DRAM devices will grow by 14 percent on average.

Memory IC demand will continue unabated in 1996. The only difference is that we are in oversupply and prices have declined precipitously. The year 1996 marks the end of the DRAM shortage and the return to the "normal" declining price-per-bit scenario. Bit growth is expected to be substantial but not sufficient to counter the large price-per-bit declines that have dropped price-per-megabyte below $14. A compounded revenue growth rate of 17 percent for DRAM over the 1995-through-2000 period, although a drop from the past five years, will allow DRAM to grow faster than the semiconductor market and account for more than 30 percent of the semiconductor revenue in the year 2000. The five-year compounded growth for memory ICs has dropped to 16.5 percent. Despite a drop in revenue in Japan in 1996, all four regions will show double-digit CAGRs over the forecast period. Table 8-2 shows the memory IC forecast by region.

Table 8-2
Memory IC Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	20,530	21,145	24,297	28,647	36,710	47,307	18.2
Japan	12,337	10,409	11,853	13,481	17,163	22,162	12.4
Europe	9,990	10,321	11,962	13,917	16,728	19,919	14.8
Asia/Pacific	12,564	13,874	16,101	19,053	23,065	29,292	18.4
Memory IC Total	55,421	55,749	64,213	75,098	93,666	118,680	16.5

Source: Dataquest (May 1996)

Logic ICs

Logic ICs include a broad and dissimilar set of products. These products can be cut by standard or ASIC, bipolar or MOS. A traditional cut used in this forecast is that of process technology—bipolar logic and MOS logic, which more or less track an "old versus new" division. After a two-year respite from rapidly declining revenue in 1993 and 1995, bipolar logic returned to a 14 percent decline in 1995, a "normal" rate that we expect to continue into 1996 and beyond.

MOS logic showed a 28 percent growth in revenue in 1995 after 27 percent in 1994. We expect growth to drop to eleven percent in 1996 and then settle into a long-term 16 percent growth rate driven by the still strong MOS programmable logic device (PLD), MOS gate array, and MOS cell-based products. MOS ASIC is the major driver of the MOS logic category. The total logic data combines both bipolar and MOS logic, giving an aggregate growth of 22 percent for 1995 and a five-year CAGR of 14 percent over the forecast period. Table 8-3 gives the combined logic forecast.

Analog ICs

Consumer entertainment products, being largely audio and video, are intrinsically analog in nature and have typically consumed about 40 percent of all analog ICs. The big declines seen in 1992 in the consumer market, especially in Japan and Europe, severely impacted the growth of analog ICs, resulting in a growth of only 6 percent. Since 1992, analog ICs have shown a consistent 23 percent annual growth. In 1995, we saw a drop from this trend, with a 15 percent growth.

Analog ICs show a very equal distribution among the four regions, with the Americas having the smallest share at 23 percent and Japan the largest at 27 percent. This distribution is changing as consumer equipment manufacturing increasingly migrates to Asia/Pacific sites. The increasing presence of analog ICs in computer and communications applications is stabilizing growth in the Americas and Europe. Table 8-4 shows the analog IC growth rate by region over the forecast period.

Total Monolithic ICs

The combination of microcomponent, memory, logic, and analog ICs gives the total monolithic IC market. The five-year forecast for this summary category is shown in Table 8-5.

Table 8-3
Logic IC Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	7,528	8,400	9,581	11,074	12,887	15,320	15.3
Japan	8,772	8,934	9,663	10,919	12,501	14,180	10.1
Europe	3,243	3,621	3,974	4,540	5,250	6,175	13.7
Asia/Pacific	3,418	3,955	4,474	5,373	6,574	8,073	18.8
Logic IC Total	22,961	24,910	27,692	31,906	37,212	43,748	13.8

Source: Dataquest (May 1996)

Table 8-4
Analog IC Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	3,995	4,575	5,315	6,232	7,329	8,652	16.7
Japan	4,744	4,801	4,846	5,331	5,922	6,612	6.9
Europe	4,127	4,630	5,306	6,049	7,149	8,580	15.8
Asia/Pacific	4,741	5,556	6,231	7,535	9,131	11,067	18.5
Analog IC Total	17,607	19,562	21,698	25,147	29,531	34,911	14.7

Source: Dataquest (May 1996)

Table 8-5
Total Monolithic IC Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	44,474	48,193	55,375	64,732	78,876	96,854	16.8
Japan	33,682	32,702	36,492	41,732	49,872	59,888	12.2
Europe	24,369	27,075	31,017	35,871	42,581	50,111	15.5
Asia/Pacific	27,977	32,196	37,243	44,701	54,612	68,131	19.5
Monolithic IC Total	130,502	140,166	160,127	187,036	225,941	274,984	16.1

Source: Dataquest (May 1996)

Discrete Devices

Discrete devices showed a 30 percent revenue growth in 1995. Although the discrete device category has been losing market share because of the relentless integration of components, this category remains viable because power and RF devices are not readily integrated. Power transistors represent about one-third of discrete revenue and are expected to lead the discrete growth with a 14 percent CAGR. Table 8-6 gives the discrete forecast by region. The growing use of power discrete devices in power control and communications applications in the Americas has brought the compounded Americas growth rate back into double digits.

Table 8-6
Discrete Device Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	2,870	3,225	3,650	4,190	4,895	5,700	14.7
Japan	4,681	4,708	4,845	5,232	5,813	6,641	7.2
Europe	3,053	3,367	3,603	3,985	4,491	5,178	11.1
Asia/Pacific	3,419	4,000	4,419	5,074	5,845	6,732	14.5
Discrete Devices Total	14,023	15,300	16,517	18,481	21,044	24,251	11.6

Source: Dataquest (May 1996)

Optical Semiconductors

Even more than analog ICs or discrete devices, optical semiconductors find their primary market in consumer entertainment products. With scanners and copiers using charge-coupled devices (CCDs), CD-ROMs using laser diodes, and optical-fiber data links using semiconductor receivers and transmitters, the data processing market is showing an increasing impact on the optical semiconductor market. This impact was seen as a 24 percent revenue growth in 1995. Growth in 1996 is anticipated to be 8 percent as the computer peripherals and consumer markets slow. Laser diodes have continued to lead the growth in this category; 1996 shows a 36 percent revenue growth for this product type. The optical semiconductor forecast by region is given in Table 8-7.

Table 8-7
Optical Semiconductor Market by Region, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas	627	715	840	1,060	1,325	1,625	21.0
Japan	2,767	2,789	2,874	3,105	3,452	4,089	8.1
Europe	680	788	869	975	1,103	1,276	13.4
Asia/Pacific	737	907	1,005	1,146	1,327	1,536	15.8
Optical Semiconductors Total	4,811	5,199	5,588	6,286	7,207	8,526	12.1

Source: Dataquest (May 1996)

Chapter 9

Forecast by Technology

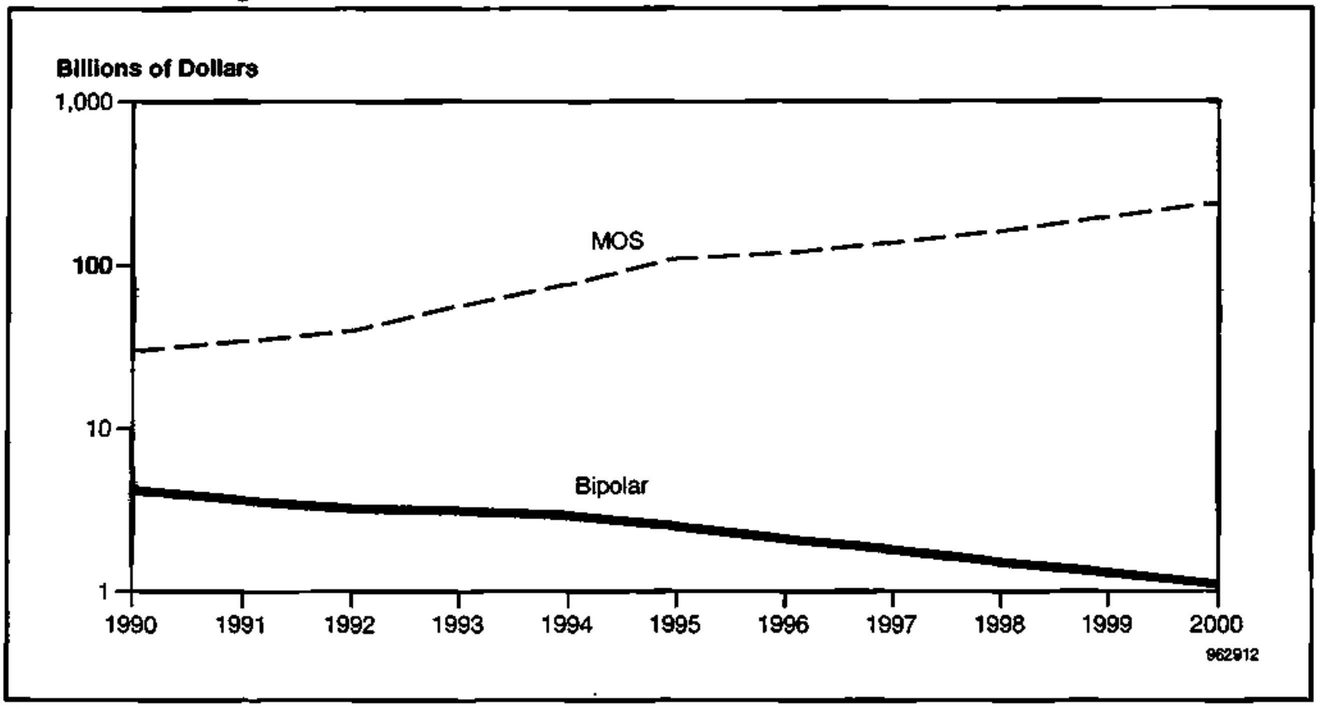
Digital MOS and Bipolar IC Forecast

The five-year IC forecast includes the process categories of MOS digital and bipolar digital ICs. This process split is still important for the logic IC category but is of decreasing importance for the memory IC category. For microcomponent ICs, the bipolar subsegment has become fairly irrelevant and is no longer reported or forecast separately.

The forecast data for digital ICs, by process, is plotted in Figure 9-1. The graph shows that the bipolar portion of the digital IC market is declining at a 12 percent CAGR over the forecast period. By the year 2000, bipolar digital ICs will have declined to less than 0.5 percent of the total digital IC market.

Tables 9-1 and 9-2 show the five-year history and forecast, respectively, for the bipolar and MOS portions of the three main digital IC categories. It can be seen that, as a memory IC process technology, bipolar has been in a rapid slide that is slowing as revenue becomes insignificant. Bipolar logic ICs accounted for 14 percent of logic IC revenue in 1994. By 2000, it is expected that bipolar logic will represent less than 3 percent of the logic IC revenue.

Figure 9-1
MOS versus Bipolar Forecast



Source: Dataquest (May 1996)

Table 9-1
Semiconductor Market by Process Technology, Six-Year Revenue History, 1990-1995 (Revenue in Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Bipolar Total	4,173	3,628	3,193	3,079	2,912	2,497	-9.8
Bipolar Memory	431	356	318	244	199	160	-18.0
Bipolar Logic	3,742	3,272	2,875	2,835	2,713	2,337	-9.0
MOS Total	30,152	34,315	39,710	56,374	76,021	110,298	29.6
MOS Micro	9,584	11,774	14,359	19,947	26,408	34,513	29.2
MOS Memory	12,128	12,841	15,308	23,306	33,505	55,261	35.4
MOS Logic	8,440	9,700	10,043	13,121	16,108	20,624	19.6
Total Digital IC	34,325	37,943	42,903	59,453	78,933	112,895	26.9

Source: Dataquest (May 1996)

Table 9-2
Semiconductor Market by Process Technology, Five-Year Revenue Forecast, 1995-2000 (Revenue in Millions of Dollars)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Bipolar Total	2,497	2,131	1,752	1,508	1,298	1,137	-14.6
Bipolar Memory	160	119	108	93	79	71	-15.0
Bipolar Logic	2,337	2,012	1,644	1,415	1,219	1,066	-14.5
MOS Total	110,298	118,473	136,677	160,381	195,112	238,936	16.7
MOS Micro	34,513	39,945	46,524	54,885	65,532	77,645	17.6
MOS Memory	55,261	55,630	64,105	75,005	93,587	118,609	16.5
MOS Logic	20,624	22,898	26,048	30,491	35,993	42,682	15.7
Total Digital IC	112,895	120,604	138,429	161,889	196,410	240,073	16.3

Source: Dataquest (May 1996)

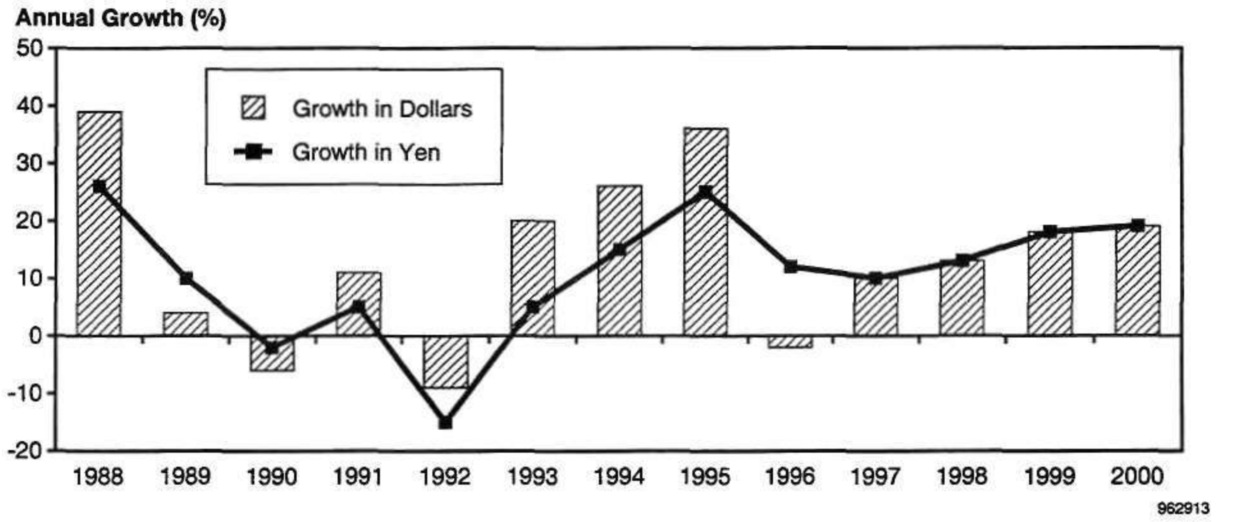
Appendix A

Japanese Revenue History and Forecast in Yen

Revenue growth in shipments to the Japan region differs according to whether the dollar or yen is used as the currency basis. As the dollar has typically weakened against the yen, Japanese growth has often been inflated by this exchange rate change. Figure A-1 shows the annual growth in each of these two currencies over both the historical 1988-through-1995 period and the forecast 1996-through-2000 period. Because Dataquest does not forecast exchange rates, the forecast growth rates are the same.

The following tables show the yen-based revenue shipment data for the Japan region. Tables A-1 and A-2 provide the Japanese revenue history and forecast, respectively, in yen. The historical exchange rates are shown at the bottom of these tables. Tables A-3 and A-4 show the annual growth associated with the year-to-year revenue growth. The rate of dollar appreciation against the yen for the period from 1990 through 1995 is shown at the bottom of Table A-3. Over the past five years, the dollar has declined in value, inflating the revenue growth of the Japanese market in dollars.

Figure A-1
Comparison of Revenue Shipment Growth in the Japan Region—Dollars versus Yen



Source: Dataquest (May 1996)

Table A-1
Japanese Semiconductor Market, Six-Year Yen Revenue History, 1990-1995 (Revenue in Billions of Yen)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	428	487	413	443	570	735	11.4
Memory Total	632	597	528	634	748	1,158	12.9
Bipolar Memory	28	22	17	14	10	8	-22.7
MOS Memory	604	575	510	619	738	1,151	13.8
Logic/ASIC Total	710	728	613	635	724	824	3.0
Bipolar Logic	208	174	128	111	114	93	-14.9
MOS Logic	503	554	485	524	610	731	7.8
Analog ICs	392	421	367	365	412	445	2.6
Monolithic IC Total	2,163	2,233	1,922	2,077	2,454	3,163	7.9
Hybrid ICs	112	117	95	91	91	97	-2.8
Total ICs	2,274	2,350	2,016	2,168	2,545	3,260	7.5
Discrete Devices	428	467	389	381	399	440	0.6
Optical Semiconductors	215	243	197	192	213	260	3.8
Total Semiconductor	2,917	3,059	2,602	2,741	3,157	3,959	6.3
Yen/U.S.$ Exchange Rate	144.00	136.00	126.45	111.20	101.81	93.90	

Source: Dataquest (May 1996)

Table A-2
Japanese Semiconductor Market, Five-Year Yen Revenue Forecast, 1995-2000 (Revenue in Billions of Yen)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	735	916	1,084	1,285	1,529	1,813	19.8
Memory Total	1,158	1,114	1,269	1,443	1,837	2,372	15.4
Bipolar Memory	8	7	6	6	5	5	-9.0
MOS Memory	1,151	1,108	1,262	1,437	1,832	2,368	15.5
Logic/ASIC Total	824	956	1,034	1,169	1,338	1,518	13.0
Bipolar Logic	93	88	68	58	52	47	-12.8
MOS Logic	731	868	966	1,110	1,286	1,471	15.0
Analog ICs	445	514	519	571	634	708	9.7
Monolithic IC Total	3,163	3,501	3,906	4,467	5,339	6,411	15.2
Hybrid ICs	97	112	115	115	115	115	3.5
Total ICs	3,260	3,613	4,022	4,582	5,454	6,526	14.9
Discrete Devices	440	504	519	560	622	711	10.1
Optical Semiconductors	260	299	308	332	370	438	11.0
Total Semiconductor	3,959	4,415	4,848	5,475	6,446	7,675	14.2
Yen/U.S.$ Exchange Rate	93.90	107.05	107.05	107.05	107.05	107.05	

Source: Dataquest (May 1996)

Table A-3
Japanese Semiconductor Market, Yen Revenue Growth, 1990-1995 (Percentage Revenue Growth in Yen)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	16.6	13.7	-15.1	7.3	28.7	28.9	11.4
Memory Total	-21.3	-5.5	-11.6	20.0	18.0	54.9	12.9
Bipolar Memory	6.0	-19.7	-22.2	-19.1	-29.4	-22.8	-22.7
MOS Memory	-22.2	-4.8	-11.2	21.3	19.1	56.0	13.8
Logic/ASIC Total	7.2	2.5	-15.7	3.6	14.0	13.8	3.0
Bipolar Logic	3.2	-16.3	-26.0	-13.4	2.3	-18.5	-14.9
MOS Logic	8.9	10.2	-12.5	8.1	16.5	19.8	7.8
Analog ICs	3.9	7.3	-12.8	-0.7	13.1	8.1	2.6
Monolithic IC Total	-2.2	3.2	-13.9	8.1	18.2	28.9	7.9
Hybrid ICs	-3.7	4.7	-18.9	-3.9	-0.7	7.3	-2.8
Total ICs	-2.2	3.3	-14.2	7.5	17.4	28.1	7.5
Discrete Devices	0.6	9.2	-16.6	-2.2	4.7	10.2	0.6
Optical Semiconductors	0.5	13.0	-19.0	-2.3	11.1	21.7	3.8
Total Semiconductor	-1.6	4.9	-14.9	5.3	15.2	25.4	6.3
U.S.$ Appreciation versus Yen	4.35	-5.56	-7.02	-12.06	-8.44	7.77	-8.20

Source: Dataquest (May 1996)

Table A-4
Japanese Semiconductor Market, Forecast Five-Year Yen Revenue Growth, 1995-2000 (Percentage Revenue Growth in Yen)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	28.9	24.6	18.4	18.5	19.0	18.5	19.8
Memory Total	54.9	-3.8	13.9	13.7	27.3	29.1	15.4
Bipolar Memory	-22.8	-12.4	-4.8	-8.3	-10.9	-8.2	-9.0
MOS Memory	56.0	-3.8	14.0	13.8	27.5	29.2	15.5
Logic/ASIC Total	13.8	16.1	8.2	13.0	14.5	13.4	13.0
Bipolar Logic	-18.5	-4.9	-22.7	-14.3	-11.0	-10.1	-12.8
MOS Logic	19.8	18.8	11.3	14.9	15.8	14.4	15.0
Analog ICs	8.1	15.4	0.9	10.0	11.1	11.7	9.7
Monolithic IC Total	28.9	10.7	11.6	14.4	19.5	20.1	15.2
Hybrid ICs	7.3	15.2	2.9	0	0	0	3.5
Total ICs	28.1	10.8	11.3	13.9	19.0	19.7	14.9
Discrete Devices	10.2	14.7	2.9	8.0	11.1	14.2	10.1
Optical Semiconductors	21.7	14.9	3.0	8.0	11.2	18.5	11.0
Total Semiconductor	25.4	11.5	9.8	12.9	17.7	19.1	14.2
U.S.$ Appreciation versus Yen	-7.77	14.00	0	0	0	0	2.66

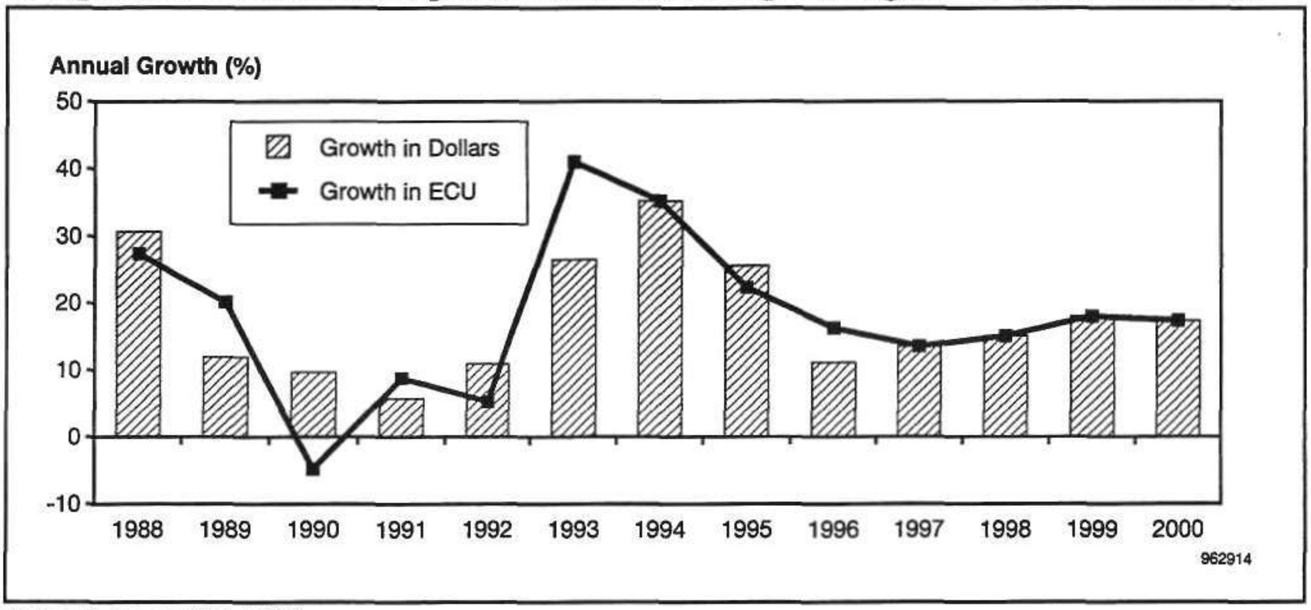
Source: Dataquest (May 1996)

Appendix B
European Revenue History and Forecast in ECU

Revenue growth in shipments to the European region differs whether the dollar or ECU is used as the currency basis. The dollar has not had any consistent long-term change with the ECU; the exchange rate in 1995 was essentially the same as in 1990, although there were annual fluctuations. Figure B-1 shows the annual growth in each of these two currencies over both the historical 1988-through-1995 period and the forecast 1996-through-2000 period. Because Dataquest does not forecast exchange rates, the forecast growth rates are the same.

Tables B-1 and B-2 provide the European revenue history and forecast in ECU. The historical exchange rates are shown at the bottom of these tables. Tables B-3 and B-4 show the annual growth associated with the year-to-year revenue growth. The rate of dollar appreciation against the ECU for the period from 1990 through 1995 is shown at the bottom of Table B-3. Over the past seven years, the exchange rate has shown little fluctuation, on average.

Figure B-1
Comparison of Revenue Shipment Growth in European Region—Dollars versus ECU



Source: Dataquest (May 1996)

Table B-1
European Semiconductor Market, Six-Year ECU Revenue History, 1990-1995 (Revenue in Millions of ECU)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	1,420	1,689	2,097	3,464	4,543	5,425	30.7
Memory Total	1,659	1,761	2,077	3,489	5,546	7,732	36.1
Bipolar Memory	43	35	29	23	24	15	-19.4
MOS Memory	1,615	1,727	2,048	3,466	5,522	7,718	36.7
Logic/ASIC Total	1,483	1,691	1,645	1,973	2,234	2,510	11.1
Bipolar Logic	402	359	299	311	276	225	-10.9
MOS Logic	1,081	1,332	1,347	1,661	1,957	2,285	16.1
Analog ICs	1,709	1,771	1,732	2,347	2,831	3,194	13.3
Monolithic IC Total	6,271	6,912	7,551	11,273	15,153	18,862	24.6
Hybrid ICs	124	144	116	154	150	185	8.4
Total ICs	6,395	7,057	7,668	11,427	15,302	19,047	24.4
Discrete Devices	1,493	1,483	1,406	1,518	1,771	2,363	9.6
Optical Semiconductors	319	393	334	321	483	526	10.5
Total Semiconductor	8,207	8,932	9,408	13,266	17,556	21,936	21.7
ECU/U.S.$ Exchange Rate	0.788	0.811	0.77	0.858	0.84	0.774	

Source: Dataquest (May 1996)

Table B-2
European Semiconductor Market, Five-Year ECU Revenue Forecast, 1995-2000 (Revenue in Millions of ECU)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	5,425	6,887	7,918	9,206	10,898	12,504	18.2
Memory Total	7,732	8,360	9,689	11,273	13,550	16,134	15.8
Bipolar Memory	15	11	11	8	7	6	-15.1
MOS Memory	7,718	8,349	9,679	11,265	13,542	16,128	15.9
Logic/ASIC Total	2,510	2,933	3,219	3,677	4,253	5,002	14.8
Bipolar Logic	225	203	164	141	122	109	-13.6
MOS Logic	2,285	2,730	3,055	3,536	4,130	4,893	16.5
Analog ICs	3,194	3,750	4,298	4,900	5,791	6,950	16.8
Monolithic IC Total	18,862	21,931	25,124	29,056	34,491	40,590	16.6
Hybrid ICs	185	202	198	201	209	213	2.9
Total ICs	19,047	22,132	25,322	29,256	34,700	40,803	16.5
Discrete Devices	2,363	2,727	2,918	3,228	3,638	4,194	12.2
Optical Semiconductors	526	638	704	790	893	1,034	14.5
Total Semiconductor	21,936	25,498	28,945	33,274	39,231	46,031	16.0
ECU/U.S.$ Exchange Rate	0.774	0.81	0.81	0.81	0.81	0.81	

Source: Dataquest (May 1996)

Table B-3
European Semiconductor Market, Historic Revenue Growth, 1990-1995 (Revenue Growth in ECU)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microcomponents	8.5	18.9	24.2	65.2	31.2	19.4	30.7
Memory Total	-26.6	6.2	17.9	68.0	58.9	39.4	36.1
Bipolar Memory	-32.8	-19.5	-16.1	-20.8	1.5	-37.5	-19.4
MOS Memory	-26.4	6.9	18.6	69.2	59.3	39.8	36.7
Logic/ASIC Total	-16.2	14.0	-2.7	19.9	13.2	12.4	11.1
Bipolar Logic	-20.4	-10.6	-16.8	4.2	-11.3	-18.5	-10.9
MOS Logic	-14.5	23.2	1.1	23.3	17.8	16.7	16.1
Analog ICs	21.0	3.6	-2.2	35.6	20.6	12.8	13.3
Monolithic IC Total	-7.1	10.2	9.2	49.3	34.4	24.5	24.6
Hybrid ICs	0.2	16.7	-19.5	32.1	-2.6	23.7	8.4
Total ICs	-7.0	10.4	8.7	49.0	33.9	24.5	24.4
Discrete Devices	4.5	-0.7	-5.2	8.0	16.7	33.4	9.6
Optical Semiconductors	-0.7	23.2	-15.0	-4.0	50.5	9.0	10.5
Total Semiconductor	-4.8	8.8	5.3	41.0	32.3	24.9	21.7
U.S.$ Appreciation versus ECU	-13.22	2.92	-5.06	11.43	-2.10	-7.86	-0.36

Source: Dataquest (May 1996)

Table B-4
European Semiconductor Market, Forecast Five-Year ECU Revenue Growth, 1995-2000 (Percentage Revenue Growth in ECU)

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Microcomponents	19.4	27.0	15.0	16.3	18.4	14.7	18.2
Memory Total	39.4	8.1	15.9	16.3	20.2	19.1	15.8
Bipolar Memory	-37.5	-28.4	0	-23.1	-10.0	-11.1	-15.1
MOS Memory	39.8	8.2	15.9	16.4	20.2	19.1	15.9
Logic/ASIC Total	12.4	16.8	9.7	14.2	15.6	17.6	14.8
Bipolar Logic	-18.5	-9.7	-19.1	-14.3	-13.2	-11.3	-13.6
MOS Logic	16.7	19.5	11.9	15.8	16.8	18.5	16.5
Analog ICs	12.8	17.4	14.6	14.0	18.2	20.0	16.8
Monolithic IC Total	24.5	16.3	14.6	15.6	18.7	17.7	16.6
Hybrid ICs	23.7	9.0	-1.6	1.2	4.0	1.9	2.9
Total ICs	24.5	16.2	14.4	15.5	18.6	17.6	16.5
Discrete Devices	33.4	15.4	7.0	10.6	12.7	15.3	12.2
Optical Semiconductors	9.0	21.3	10.3	12.2	13.1	15.7	14.5
Total Semiconductor	24.9	16.2	13.5	15.0	17.9	17.3	16.0
U.S.$ Appreciation versus ECU	-7.86	4.65	0	0	0	0	0.91

Source: Dataquest (May 1996)

Appendix C
Definitions

Analog ICs

Analog ICs are a group of semiconductors that deal with electrical signals and electrical power. Analog components carry information as voltage, current, frequency, phase, duty cycle, or other electronic parameters. Because they are not based on number values, analog information is not limited to a finite range of values and has no inherent quantization noise or quantization error. The downside is that analog signal information exists in the time domain and can be corrupted as the information-carrying parameter is influenced by noise, drift, bandwidth, and component instability—all the vagaries of time.

Bipolar

These are semiconductor devices that use bipolar transistors rather than MOS transistors. Bipolar transistors are found in both ICs and discrete products. Bipolar transistors are so named because they carry electricity with two different types of "carriers"—holes and electrons.

Digital ICs

Digital ICs handle numbers in the binary format of ones and zeros. Digital ICs comprise logic, microcomponent, and memory ICs. The number-handling nature of digital electronics makes the data more immune to physical changes in the electronic components.

Discrete Devices

A discrete semiconductor is defined as a single semiconductor component such as a transistor, diode, or thyristor. Although multiple devices may be present in a package, they are still considered discretes if they have no internal functional interconnection and are applied in the same manner as other discrete devices. Some discrete devices may actually be similar to ICs in having integrated protection and sensing circuitry. Even if a device is an integrated circuit, it will be considered a discrete if it is used like one.

Hybrid IC

A hybrid is an IC that mixes semiconductor technology with other electronic technologies in a single package. It is this mixing of technologies within the IC package that gives these products the "hybrid" IC name. Other technologies include thin and thick film resistors and chip capacitors. A multiple-chip IC is not a true hybrid IC and is counted in the monolithic IC category. The mixing of technologies is most often done for analog hybrid ICs. Because of this, hybrid ICs are often added to monolithic analog IC revenue to provide the total analog IC market.

IC

An integrated circuit is a chip in which multiple transistors and diodes are interconnected to perform an electronic function. The function-specific nature of an IC differentiates it from the nonspecific array of discrete transistors.

Logic

This is an electronic function where bits (one and zeros) are processed. This bit processing is defined by hardwiring, mask programming, or field programming. Microcomponents and memory ICs are logic ICs, but they are logic ICs that are either dedicated to a function (such as microperipherals and memory ICs) or are software programmable (such as microprocessors and microcontrollers). Logic ICs also include customer-specific logic ICs.

Microcomponent

A microcomponent is a digital IC that can be programmable such as a microprocessor (MPU), microcontroller (MCU), digital signal processor (DSP), or an application-specific logic device that provides a supporting function to an MPU, MCU, or DSP.

Monolithic IC

A monolithic IC is an IC formed on a single chip of semiconducting material. This designation has been applied more broadly to mean any device, even a multiple-chip packaged device, that does not contain other, nonsemiconductor, components. This differentiates monolithic ICs from hybrid ICs that may also be multiple-chip, but represent a "hybrid" in the sense of mixing other technologies within the IC package, such as film resistors or chip capacitors.

MOS

MOS is an acronym for metal oxide semiconductor, a type of transistor used in ICs and discrete devices. Although the actual device may use different materials than metal or oxide, this acronym is used to define the whole family of similar processes that provide an insulated gate field-effect transistor (FET). MOSFETs, like all field-effect transistors, differ from bipolar devices in having an insulated gate and only a single carrier of electrical current (either electrons or holes). MOSFETs are found in both N and P channel varieties. A special IC process combines both the N and P channel device in a complementary configuration, an arrangement known as CMOS.

Memory IC

Memory ICs are ICs that can store and retrieve logic bits. Two major memory types are read-only memories (ROM), preloaded with data, or random-access memories (RAM), where data can be both stored and accessed. RAM subcategories include DRAM and SRAM. Memory ICs that do not lose their data when power is removed are called nonvolatile memories. DRAM and SRAM do not retain data when power is removed from the device. ROM, EPROM, EEPROM, and flash memory ICs are non-volatile memory devices.

Optical Semiconductors

These devices are the semiconductor subset of optoelectronic products. This family includes light-sensing products such as photosensors and CCDs as well as light-emitting devices such as LEDs and lasers. Optocouplers and interrupters use both functions.

Semiconductors

These electronic components are manufactured by introducing impurities into a semiconductor material to create special current conducting devices such as diodes, bipolar transistors, and MOS transistors. Semiconducting material is so named because its conducting capability falls between the range of insulators and metallic conductors.

Appendix D
Historical Exchange Rates

Table D-1 shows 10 years of exchange rates of the yen and ECU versus the U.S. dollar. The appreciation of the dollar against these local currencies is given in the last two columns.

Table D-1
Exchange Rates

Year	Yen per U.S.$	ECU per U.S.$	U.S.$ Growth versus Yen (%)	U.S.$ Growth versus ECU (%)
1980	227	-	3.6	-
1981	221	-	-2.7	-
1982	248	-	12.2	-
1983	235	-	-5.2	-
1984	237	-	0.9	-
1985	238	-	0.4	-
1986	167	-	-29.8	-
1987	144	-	-13.8	-
1988	130	0.846	-9.7	-2.5
1989	138	0.908	6.2	7.3
1990	144	0.788	4.3	-13.2
1991	136	0.811	-5.6	2.9
1992	126.5	0.770	-7.0	-5.0
1993	111.2	0.858	-12.1	11.4
1994	101.8	0.840	-8.4	-2.1
1995	93.90	0.774	-7.8	-7.9

Source: Dataquest (May 1996)

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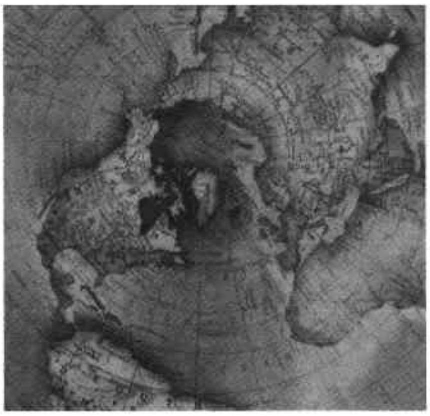

Dataquest

Year-End 1996 Forecast: Capital Spending, Wafer Fab Equipment, and Silicon Markets

Market Trends

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
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Year-End 1996 Forecast: Capital Spending, Wafer Fab Equipment, and Silicon Markets

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Chapter 1
Executive Summary Year-End 1996: Searching for Rays of Sunshine in the Storm

Overcapacity in the DRAM market has now trickled to most areas in semiconductor manufacturing. The second half of 1996 saw slightly sharper than expected contraction in shipments of wafer fab equipment. We have uncovered a number of facts that give us concern and issues that need to be reconciled during 1997 and 1998. These issues provide the basis for our belief that there is more downside risk than upside potential to our forecast in the next two years, even in the face of a strong end-use demand for semiconductor devices.

Wafer Fab Equipment Industry Backlog Status and Forecast

In the midyear forecast, Dataquest stated the belief that the 1996 shipment levels would be supported by the larger than normal backlogs at the equipment supplier. Our estimate was that the industry was at about a six-month backlog at the time, compared to a normal backlog of four months. It is not news to anyone that bookings for equipment have taken a dramatic fall since June and have put pressure on backlog levels. The industry has now shipped down backlog to more normal levels, and several companies are below normal.

If the fourth quarter 1996 run rate for wafer fab equipment shipments were to be held flat for all of 1997, the resulting decline would calculate to just over 15 percent for 1997. Our forecast of a slightly larger decline of 18 percent suggests we have not quite hit bottom yet, and indeed we are expecting bookings in the middle of 1997 to be disappointing after a number of months of firm orders in the first half. However, in the hope of improved bookings, we expect companies to continue to ship down backlog until a minimum three-month level is reached by the middle of 1997. At that time, quarterly shipment rates are expected to be reduced to booking levels. We do not expect sustainable bookings growth to support shipment growth until the second quarter of 1998.

Even in the face of strengthening semiconductor demand, Dataquest has a conservative view of the recovery. Why? The answer is that the fundamentals of the overcapacity simply do not allow a large volume spending recovery to occur before mid-1998, even in the mainstream logic sector.

Issues of Concern to Reconcile in 1997 and 1998

Too Many Fabs Starting and Spending Ratio Too High in 1997

It is very normal in a downturn to get a pocket of companies that will stay and continue to invest in the infrastructure in order to position themselves for the next cycle. In 1997, there are expected to be several companies continuing to make strategic investments. Examples of this are the U.S. fabs being built by Taiwan Semiconductor Manufacturing Company, Samsung, and Hyundai; the U.K. fab being built by Siemens; the array of initial joint-venture fabs, such as IBM/Toshiba, TwinStar, and Motorola/Siemens in the United States; Winbond, Powerchip, and Macronix in Taiwan, whose activities are tied to Japanese companies; and Texas Instruments' venture in Thailand and Korea (with Anam). In all, there are still 47 fabs coming on line in 1997, the same as in 1996 and a higher number than 1995. Even though the facilities will likely be equipped with a minimum equipment set and have slower ramp rates, the capacity coming on line in 1997 exceeds incremental demand.

Capital spending as a percentage of semiconductor revenue is also high at 24 percent. Dataquest believes that 35 to 40 fabs per year and a spending ratio of 22 percent represent an equilibrium for the industry.

Silicon Consumption in the DRAM Sector: Overcapacity Exists Well into 1998

As Dataquest has illustrated in earlier publications, the industry migration from 4Mb to 16Mb DRAMs would cause overcapacity even in the face of high bit demand growth. Die size relationships mean that the average 16Mb DRAM has two to three times more bits per square inch than the 4Mb generation. This means that wafer starts should actually decline for a period of two to three quarters as a result of this silicon efficiency.

Indeed, we have performed a quarterly analysis of the square inches consumed by the DRAM market and have calculated that 14 percent less silicon was required in the third quarter 1996, compared to the fourth quarter of 1995, to support DRAM bit demand. We are not expecting to return to fourth quarter 1995 silicon demand levels until second quarter 1997; yet in those six quarters, a lot of capacity will have been added. Current factory utilization rates for DRAM fabs is running around 70 percent, and we would expect utilization to continue falling in 1997, perhaps to a percentage in the low 60s. According to this fundamental analysis, capacity spending in DRAM is not expected to return until late in 1998.

The Equivalent of 40 Idle Fabs Has Been Created in Asia/Pacific and Japan

Probably our largest concern is that we believe *this is not just a DRAM thing anymore.* A startling fact became evident in the silicon market during our forecast process.

When we look at the actual consumption of 150mm wafers in Asia/Pacific and Japan together in 1995, the run rate is about 3.1 million wafers per month (37.2 million wafers in 1995). By the end of 1996, the 150mm wafer consumption into Japan and Asia/Pacific had fallen to 2 million wafers per month. Our 1997 forecast calls for a modest recovery to 27.3 million wafers, or about 2.3 million wafers per month. When comparing the 1995 consumption with the 1997 forecast, we see that capacity of about 800,000 wafers a month has been idled, or about the equivalent of 40 fabs! (This assumes fabs with 20,000 wafer starts per month.)

Our rough analysis indicates that about 14 of these "equivalent fabs" are in Korea, with the balance likely in Japan. Let's look at the makeup of these idle fabs, most of which are a result of the shutoff of 4Mb DRAM production.

In Korea, these fabs have been almost entirely redirected to the foundry market, and the result was a 25 percent reduction in prices in the middle of 1996. Both LG Semicon and Samsung have become very aggressive players in this market, and it is very likely that these companies will invest to upgrade the fabs to sub-0.5 micron technology. Our analysis of the foundry market without these extra fabs shows a market in oversupply in 1997 through 1999 by 15 percent to 25 percent. Foundry capacity supply and demand can be used as a proxy for mainstream logic capacity investment. This picture shows no fundamental driving force for renewed capital spending growth.

The fabs in Japan (equivalent to 26) fall into two areas. Japanese companies initially processed 16Mb DRAMs on 150mm wafers, and we estimate that perhaps 10 fabs worth of capacity is now available to be upgraded to run 200mm wafers. Because this will effectively double that square inch capacity of this block at a relatively low cost, the DRAM-driven recovery could be pushed back a bit. The other block of 16 equivalent fabs cannot be upgraded to run 16Mb DRAMs, so these will migrate to lagging processes such as those for microcontrollers, telecommunications chips, mixed-signal ICs, and analog ICs.

Silicon Wafer Forecast Overview

We anticipated that the second half of 1996 would be weaker in silicon demand, based on the migration from 4Mb to 16Mb DRAMs mentioned in earlier forecasts. However, starting about August, the silicon market flat out collapsed, with run rates by the end of 1996 about 20 percent below those of just six months earlier. These dynamics can mostly be explained by the activities in the DRAM market and inventory trends. As a result, the long-term absolute millions of square inches (MSI) of silicon shipment level was reduced about 5 percent compared with our last forecast, with the six-year compound annual growth rate (CAGR) at 11.1 percent.

Theoretically, silicon consumption into the DRAM sector should be recovering now. However, actual shipments from wafer manufacturers will lag by four to six months as inventories are worked down. We do expect recovery in silicon MSI shipment growth by the middle of 1997. Our quarterly model into the DRAM sector suggests run rates by fourth quarter 1997 should be 20 to 30 percent higher than current depressed levels. Our MSI growth forecast overall for 1997 is just over 7 percent. With end-use semiconductor and electronic equipment demand strengthening, we would expect accelerated growth in silicon consumption starting in the middle of 1997 and returning to double-digit MSI growth rates in 1998.

The silicon market, driven by a strong long-term picture for semiconductor unit demand in general, will grow faster over the next six years than the last six years. As the industry transforms into a 200mm baseline, the outlook for silicon wafer manufacturers becomes brighter. Silicon manufacturers have answered the call for 200mm capacity with significantly increased capital outlays. Activity in 300mm wafer development has accelerated, particularly in Japan with the Selete consortium. The increased visibility of I300I has also contributed to the first 300mm pilot fab announcement. We still expect only pilot volume activity in 300mm wafers through the year 2000.

Sales of merchant epitaxial wafers by the wafer suppliers accounted for 477 MSI in 1995. About 62 percent of these wafers were used for CMOS logic applications, while only 2 percent were used for DRAM products. The remainder was shipped into the power/discrete device segments. By the year 2000, Dataquest expects that fully 21 percent of merchant epitaxial silicon will be used for DRAMs, primarily driven by two factors. The CMOS logic application remains dominant at 52 percent. The overall epitaxial wafer market will experience a 19.4 CAGR from 1995 through 2001.

Dataquest Perspective: Be Prepared to Batten Down the Hatches

Dataquest believes that the wafer fab equipment market will be in for sluggish business conditions through the middle of 1998, before a sustainable bookings recovery can start, coming initially from DRAM capacity spending. Fundamentals of capacity supply and demand balance simply do not support a recovery occurring in 1997 for either memory or mainstream logic. The next 18 months are expected to be dominated by strategic investment by IC manufacturers, which includes production location positioning and investment in new technology.

Equipment areas such as chemical mechanical polishing (CMP) and epitaxial reactors will benefit from higher penetration of the technology, and rapid thermal processing (RTP) system suppliers will benefit from the much higher interest in this process in 300mm lines. Both deep-UV lithography and high-voltage implant are expected to benefit from increased penetration of the technology as well; however, suppliers of steppers and implanters will also be impacted from a dramatic falloff in their capacity-oriented businesses, namely i-line steppers and volume DRAM purchases.

Our outlook for the silicon wafer market is more optimistic. The end-unit semiconductor demand remains strong, so the silicon wafer manufacturers should lead the wafer fab equipment market by about a year. We do expect recovery in silicon MSI shipment growth by the middle of 1997, with double-digit growth returning in 1998.

The silicon market has become recognized again as being strategic in the semiconductor manufacturing infrastructure. Will this continue? We believe it will, as long as silicon suppliers continue to concentrate on value-add processes and techniques as the equipment manufacturers have done, as well as adequately and smartly plan capacity additions.

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Chapter 2
Semiconductor Capital Spending Forecast

This chapter presents data on worldwide semiconductor capital spending by region. Capital spending in a region includes spending by all semiconductor producers with plants in that region. Components of capital spending are property, plant, and equipment expenditure for front- and back-end semiconductor operations.

Chapter Highlights

This chapter will discuss the following highlights:

- On the heels of booming growth in 1995, 1996 was a year that turned from growth to decline, but net was just under 14 percent growth in capital spending. We saw two distinctly different markets in the past year. The first half was marked by many fab announcements, aggressive spending plans, and good bookings levels for equipment. The second half was the opposite: bookings collapsed, expansion delayed, and capital spending budgets cut.
- Our forecast for 1997 is for a 14 percent decline, with a relatively modest growth of 6 percent in 1998. This reflects our belief that industry overcapacity will delay a sustainable capital spending growth pattern until the middle of 1998.
- We would expect supply/demand dynamics to be fully corrected by early 1999, driving a robust resumption of growth in capital spending growing to just under $70 billion in the year 2000, from the just under $40 billion in 1998.
- Capital spending in the Americas region grew at an industry average 17 percent in 1996, as a mix of companies both cut and accelerated spending. We expect that investment in advanced technology, coupled with the earlier capacity upturn from the advanced logic segment and strategic investments, will stabilize the region's spending later in 1997 and will lead the market's recovery in 1998 to 1999 as it did in 1993. We expect the Americas region to be the second-fastest growing market as foreign multinationals and foundry companies invest in capacity in the United States.
- Japan's 9 percent increase in capital spending in 1996 was really a 5 percent decline on a yen basis, as Japanese companies were among the first to cut capital investment and retrench. Because of the early cutback in spending, the 1997 capital spending decline is slightly less than the worldwide average, with growth returning in 1998. Lagging investment patterns in Japan are expected to continue throughout the decade.
- Although spending on capacity has essentially stopped in Japan, two other types of investment are likely to be important in Japan now through 1998. First, Japanese companies will invest in any new technology and equipment targeted at the 0.25-micron production arena. Second, Japanese companies will build shells in 1997, initially at very low run rates, as a preparation to ramp when the market turns up.

- We are expecting Europe to be a reflection of the overall worldwide market because there is a good mix of multinational investment in the region. Europe is currently at equilibrium with the world, with a stable percentage of the demand and production mix. This stability is what has attracted more companies to produce in the region.
- The often erratic but sustained semiconductor capital spending growth in the Asia/Pacific region continued at a market-leading pace of 26 percent growth in 1996. However, the tide has turned in the DRAM area, and we are forecasting the Asia/Pacific region to be hit the hardest in 1997, with a 27 decline in capital spending and a flat-to-down 1998 as the foundry industry deals with oversupply. Longer term, we expect Asia/Pacific to exhibit among the most aggressive growth in capital spending of any region, but much closer to overall market growth rates than in the recent past.
- The foundry industry is now a *strategic* industry rather than simply a tactical one, but it is now also an industry that has become susceptible to the general industry overcapacity, with dramatically falling prices for processed wafers in the second half of 1996.

Capital Spending Methodology and Tables

Dataquest's forecast process has several cornerstones, including semiconductor production by region, a worldwide database of existing and planned fabs, and independent comprehensive surveys of the equipment and semiconductor companies.

The survey results are one input into our several forecasting models, which include analysis of trends in semiconductor production, raw silicon consumption, spending ratios, investment cycles, new fab and expansion activity, stepper-to-DRAM price-per-bit analysis, and semiconductor revenue per square inch.

A list of the top 20 semiconductor capital spending companies and their projected spending in 1996 is presented in Table 2-1, along with indications for 1997. Our surveys are completed in December, when many companies have not yet finalized their budgets for the upcoming year. We cannot, therefore, include very precise figures for 1997. We have provided some guidance for 1997 spending by company in order to provide some account guidance to our clients.

Capital spending details by region are provided in two tables in this chapter. Table 2-2 shows historical semiconductor capital spending by region for 1989 through 1995. Table 2-3 shows the capital spending forecast by region for 1995 through 2001. Yearly exchange rate variations can have a significant effect on the interpretation of the 1989 through 1996 data. For more information about the exchange rates used and their effects, refer to Appendix B.

Table 2-1
Semiconductor Capital Spending—Top 20 Spenders, Comparison of 1995 and Projected 1996 Worldwide Capital Spending (Millions of U.S. Dollars)

1995 Rank	1996 Rank	Company	1995 Capital Spending	1996 Capital Spending	Change (%)	Preliminary 1997 Estimate
1	1	Intel	3,550.0	3,400.0	-4.2	4,400-4,500
3	2	LG Semicon	2,258.1	2,747.5	21.7	2,250
12	3	Texas Instruments	1,079.3	2,300.0	113.1	1,100-1,200
5	4	Samsung	1,946.6	2,247.9	15.5	1,875
9	5	Hyundai	1,492.0	2,123.8	42.3	1,750
4	6	NEC	2,010.1	1,808.7	-10.0	See note
10	7	IBM Microelectronics	1,150.0	1,550.0	34.8	1,400
16	8	Siemens AG	850.0	1,450.0	70.6	1,250
6	9	Toshiba	1,624.1	1,437.7	-11.5	See note
14	10	Micron Technology	960.0	1,400.0	45.8	550
8	11	Hitachi	1,497.6	1,296.7	-13.4	See note
7	12	Fujitsu	1,592.1	1,275.4	-19.9	See note
2	13	Motorola	2,530.0	1,150.0	-54.5	650-750
13	14	SGS-Thomson	1,001.0	1,000.0	-0.1	900-950
17	15	Matsushita	846.6	962.8	13.7	See note
11	16	Mitsubishi	1,118.2	927.6	-17.0	See note
22	17	TSMC	583.9	901.8	54.4	750
18	18	Chartered Semiconductor	786.7	872.3	10.9	875-950
15	19	Philips	959.0	841.0	-12.3	730
44	20	Winbond	117.8	700.0	494.2	600
		Total Top 20 Companies	27,953.0	30,393.2	8.7	
		Total Worldwide Capital Spending	38,410.8	43,707.1	13.8	
		Top 20 Companies' Percentage of Total	72.8	69.5		

Note: Specific company information is not available for Japanese companies. However, Dataquest estimates that, as a group, Japanese companies will spend 12 percent to 15 percent less in 1997 than in 1996.
Source: Dataquest (January 1997)

Table 2-2
Worldwide Capital Spending by Region—Historical 1989-1995; Includes Merchant and Captive Semiconductor Companies (Millions of U.S. Dollars)

	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Americas	3,833	4,320	3,895	4,135	4,943	7,194	12,170	18.8
Percentage Growth	15.5	12.7	-9.8	6.2	19.5	45.5	69.2	
Japan	5,415	5,732	5,702	3,958	4,413	6,667	9,910	9.6
Percentage Growth	21.6	5.9	-0.5	-30.6	11.5	51.1	48.6	
Japan (Billions of Yen)	748	826	787	500	491	679	931	2.0
Percentage Growth	29.2	10.4	-4.7	-36.4	-2.0	38.3	37.1	
Europe, Middle East, and Africa	1,198	1,598	1,248	1,188	1,738	2,504	4,137	17.2
Percentage Growth	26.0	33.4	-21.9	-4.8	46.3	44.0	65.2	
Asia/Pacific	1,884	1,580	2,300	2,318	3,238	5,720	12,194	40.6
Percentage Growth	84.1	-16.2	45.6	0.8	39.7	76.6	113.2	
Worldwide	12,331	13,230	13,145	11,599	14,333	22,085	38,411	23.8
Percentage Growth	26.5	7.3	-0.6	-11.8	23.6	54.1	73.9	

Source: Dataquest (January 1997)

Table 2-3
Worldwide Capital Spending by Region—Forecast, 1995-2001; Includes Merchant and Captive Semiconductor Companies (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Americas	12,170	14,185	13,910	15,427	18,729	23,442	27,470	14.5
Percentage Growth	69.2	16.6	-1.9	10.9	21.4	25.2	17.2	
Japan	9,910	9,362	8,160	9,102	11,723	15,541	17,424	9.9
Percentage Growth	48.6	-5.5	-12.8	11.5	28.8	32.6	12.1	
Japan (Billions of Yen)	931	1,009	917	1,023	1,318	1,747	1,959	13.2
Percentage Growth	37.1	8.5	-9.1	11.5	28.8	32.6	12.1	
Europe, Middle East, and Africa	4,137	4,756	4,228	4,209	5,563	7,195	8,308	12.3
Percentage Growth	65.2	15.0	-11.1	-0.4	32.2	29.3	15.5	
Asia/Pacific	12,194	15,405	11,205	11,035	14,599	23,312	31,627	17.2
Percentage Growth	1,13.2	26.3	-27.3	-1.5	32.3	59.7	35.7	
Worldwide	38,411	43,707	37,503	39,773	50,614	69,490	84,829	14.1
Percentage Growth	73.9	13.8	-14.2	6.1	27.3	37.3	22.1	

Source: Dataquest (January 1997)

1996 Was a Very Dynamic Year

After a 24 percent growth in semiconductor capital spending in 1993, accelerated growth of 54 percent followed in 1994. Growth peaked at 74 percent worldwide during 1995, and 1996 transitioned from growth to decline with a slower 14 percent growth, based on our most recent capital spending survey. Nearly all of this growth occurred in the first half of the year, and spending contraction began in the second half of 1996 and is expected to spill into 1997.

The industry is now relying on the continued growth in personal computer unit sales, with added growth in telecommunications and networking products to create a unit demand picture that will be a healthy backdrop. The wafer fab capacity bubble has burst in all regions and for most semiconductor products, most notably DRAMs, mixed-signal, discrete, and analog. Whereas the 1995 spending growth was almost entirely driven by capacity purchases, 1996 was a year in transition, and 1997 and 1998 will be years of investment in technology.

The first companies to cut back were the U.S. companies, as they tend to be more driven by short-term cost issues. The Japanese companies quickly followed, as the overcapacity in DRAM has caused Japanese companies to quickly tighten the purse strings in hopes of avoiding a more serious price erosion. However, their Korean and Taiwanese counterparts did not fully cooperate until recently. Although Korean companies have already basically announced a 17 to 18 percent cutback in 1997 relative to 1996, the recent move to cut DRAM production significantly means more spending cuts are likely to come.

This above-industry growth for the big three Korean companies has meant that all three are in the top five for capital spending in 1996, and likely to remain among the top five in 1997. As noted earlier, Japanese suppliers of memory cut back investment early in this cycle. Japanese companies as a group will actually spend 6 percent less in 1996 in dollar terms (8 percent growth in yen terms). As a result, only two Japanese companies appear in the list of top 10 capital spenders in 1996—NEC and Toshiba. Most of the other Japanese companies do appear in the second 10. Intel still heads the list for 1996, as microprocessor demand continues to be strong on a unit basis. Intel's capital spending actually declined in 1996, however, primarily because yield ramps on its new fabs have been better than expected, so the company therefore needs less equipment to produce the same unit volume. Motorola, the long-time No. 2 spender, has dropped to No. 13 as the demand for telecom-related chips softened in conjunction with the overcapacity experienced in this area.

A mostly new crowd of Taiwanese companies that entered the DRAM manufacturing business, spending over $1 billion collectively in 1995, increased spending feverishly in the first half of 1996 and likely spent more in the first half than in all of 1995. However, the spending planned for the second half of last year has been predominantly delayed, mostly into 1997, likely later, and in some cases, indefinitely (read late 1998 or 1999).

TSMC debuts on the top 20 list for 1996 with an estimated $900 million spent on capacity, as foundry capacity expansion has now evolved into a major trend. TSMC has now joined Chartered Semiconductor on the list, and these two are the largest dedicated foundries. This industry has transformed into a bona fide business and is no longer a specialized way to use excess capacity. There are several companies that have entered the foundry business as a result of today's overcapacity. Unless these companies commit to the foundry business in the long term, their success in the market will be limited. Gone are the days when the "temporary" foundry can exist. Customers of foundry are now requiring long-term relationships and contracts for winning their capacity business.

It is very normal in this type of a downturn to get a pocket of companies that will stay and continue to invest in the infrastructure or have niches that maintain growth, thus supporting an increase in spending. These companies in 1996 include IBM (advanced 16Mb DRAM to support systems), Texas Instruments (primarily DSPs and logic), TSMC (foundry), Siemens (advanced DRAM), Lucent Technologies (modem chipsets and the Cirrus Logic foundry), and Chartered Semiconductor (foundry). All of these companies have continued to grow investment during the current year. Micron Technology may be the surprise of 1996 to some, particularly as it has delayed the Lehi, Utah, fab. However, it has been spending aggressively in Boise, Idaho, upgrading the facilities for 200mm production and advanced technology for the 16Mb generation. Micron's spending plans for 1997 have been dramatically curtailed.

Winbond also debuts in the top 20 list, primarily as a result of an alliance to manufacture chips for Toshiba. This is an example of a "strategic" investment pattern that we believe will be dominant, particularly in the first half of 1997.

With the cutback of the big Japanese players in the industry, and with some smaller companies continuing to be aggressive in spending plans, the concentration of capital spending by the top 20 has decreased in 1996 by a few percentage points to just under 70 percent.

How Will 1997 Look?

Six months ago, we believed that the logic sector would be in a position to drive a capacity recovery late in 1997. Developments in the last half of 1996 in Asia/Pacific company strategies and a deeper look into trends in silicon consumption have led us to change this belief. We now believe that, after a firmness in the first half of 1997 as a result of a set of "strategic" investment projects, the overcapacity of the industry will drive the second half of 1997 to be below the first half in capital spending.

Even in the face of the strengthening semiconductor demand currently under way today and the strong end-use electronic equipment and PC markets, Dataquest has a relatively conservative view of the recovery. Why? The answer is that the fundamentals of the overcapacity we are in today simply do not allow a large volume spending recovery to occur before mid-1998, even in the mainstream logic sector, which has traditionally been the part of the market less affected by the cycle.

We do not see a stoppage in advanced technology investment, indicating the continued belief in the customer base of a strong end-user market for semiconductors. In some respects, it is this and other "strategic" investments that are pushing out the timing of the recovery in our minds and leading to the current firmness in orders on the equipment side.

What do we mean by "strategic" investment? After the industry forcefully shut off the valve in the middle of 1996, companies have had time to reevaluate their spending plans. Because the end-use markets for semiconductors remain strong, many companies are investing "strategically," positioning themselves for market share increases and the next major ramp in capacity. Strategic investments include any fabs that open up new production market locations and those that are tied to partnerships and joint ventures. Of particular interest are those companies in a new alliance, where there are factors that are more important than the capacity being added, such as a strategic development or supply relationship.

There are at least 20 fabs starting or upgrading in 1997 that fall specifically into these categories, including the following:

- The U.S. fabs being built by TSMC, Samsung, and Hyundai
- The U.K. fab being built by Siemens
- The array of initial joint venture fabs such as IBM/Toshiba, TwinStar, and Motorola/Siemens in the United States
- Winbond, Powerchip, and Macronix in Taiwan, whose activities are tied to Japanese companies
- Mosel Vitelic, which is tied to Siemens
- Texas Instruments' ventures in Thailand and Korea (with Anam)

These are fabs that will not be stopped but will likely have slower ramp rates than planned. Also, the Korean companies are upgrading their older 4Mb DRAM fabs in order to run more advanced logic for the foundry market. A recent order announcement from ASM Lithography for deep-UV steppers from a Korean company is evidence of this activity.

Does the recent cancellation of a new joint-venture fab of Texas Instruments and Toyota signal the start of a trend that will lead to a worse 1997 than we expect? Only time will tell; however, there is more downside risk than upside potential, in our view, over the next two years. We will now review our concerns in the market to support this belief.

Why Are We Concerned about This Downturn Lasting into 1998?

Our longer-term forecast projects this contraction to be sharp and relatively deep, but lasting about an average length by historical norms—at least two years. Despite the strengthening demand in the semiconductor market, the overspending in the 18 months ending in the middle of 1996 represents a significant "lead balloon" that will drag and delay the spending recovery into later in 1998.

Overcapacity in the DRAM market has now trickled to most areas in semiconductor manufacturing. We have also uncovered a number of facts that give us concern and issues that need to be reconciled during 1997 and 1998. These issues provide the basis for our belief that there is more downside risk than upside potential to our forecast in the next two years, even in the face of a strong end-use demand for semiconductor devices. The key point to remember is that the industry needs a capacity driving force to resume *sustainable* growth prospects.

We have the following three concerns which we will expand on in this section:

- The number of fabs and spending ratio currently factored into in our forecast for 1997
- The consumption of silicon into the DRAM sector declining in the face of increasing bit demand
- Existing excess capacity, which we have now about quantified, being upgraded and redirected

Capital Spending Ratio and Planned Fabs Too High in 1997

With all the "strategic" investment happening in the world, 1997 is simply turning out to be looking "too good," if there is such a thing in this environment. In all, there are still just under 50 fabs that have been announced to come on line in 1997. Although this is significantly lower than the number revealed by a spot check of plans six months ago, this is the same number that started in 1996 and a higher number than the 40 or so in 1995. Even though the facilities will likely be equipped with a minimum equipment set and have slower ramp rates, the capacity coming on line in 1997 exceeds incremental demand. We estimate that silicon area demand, excluding test and monitor wafers, will grow about 4 percent in 1997, while we are expecting about 8 to 10 percent to be added to the capacity base during the year. For reference, about 13 to 14 percent more square inches of silicon capacity was added in total in 1996, compared to an incremental demand of 4 percent.

Capital spending as a percentage of semiconductor revenue, which is a significant figure of merit, is also high at 24 percent in 1997, after peaking at above 31 percent in 1996. We believe that to support long-term growth in the chip industry, about 35 to 38 fabs per year and a spending ratio of 22 percent represents an equilibrium level. This means that 1998 and 1999 are likely to be years under these equilibrium levels—our current forecast supports this. We would also expect that fab delays and outright cancellations will continue through 1997.

Silicon Consumption in the DRAM Market Declining!

As we have mentioned in past publications, the industry migration from 4Mb to 16Mb DRAMs would cause overcapacity even in the face a high bit demand growth. Die size relationships mean that the average 16Mb DRAM has two to three times more bits per square inch than the 4Mb generation. This means that wafer starts should actually decline for a period of two to three quarters as a result of this silicon efficiency. Indeed, we have performed a quarterly analysis of the square inches consumed by the DRAM market and have calculated that 14 percent less silicon is required in the third quarter of 1996 compared to the fourth quarter of 1995 to support DRAM bit demand (see Table 4-10 in Chapter 4).

We are not expected to return to fourth quarter 1995 silicon demand levels until second quarter 1997, yet in those six quarters, a lot of capacity will have been added. Current factory utilization rates for DRAM fabs are running at about 70 percent, and we would expect utilization to continue falling in 1997, perhaps to the low 60s. According to this fundamental analysis, capacity spending in DRAM is not expected to return until late in 1998.

Foundry Industry, Proxy for Logic Capacity, in Widespread Oversupply

Probably our largest concern is that we believe *this is not just a DRAM thing anymore.* A startling fact became evident about the silicon market during our forecast process.

When we look at the actual consumption of 150mm wafers in Asia/Pacific and Japan together in 1995, the run rate is about 3.1 million wafers per month (37.2 million wafers in 1995). By the end of 1996, the 150mm wafer consumption into Japan and Asia/Pacific had fallen to 2 million wafers per month. Our 1997 forecast calls for a modest recovery to 27.3 million wafers, or about 2.3 million wafers per month. When comparing the 1995 consumption with the 1997 forecast, we see that about 800,000 wafers a month capacity has been idled, or about the equivalent of 40 fabs! (This assumes fabs with 20,000 wafers start per month.)

Our rough analysis indicates that about 14 of these "equivalent fabs" are in Korea, with the balance likely in Japan. Let's look at the makeup of these idle fabs, most of which are a result of the shutoff of 4Mb DRAM production.

In Korea, these fabs have been almost entirely redirected to the foundry market, and the result has been a 25 percent reduction in prices during the middle of 1996. Both LG Semicon and Samsung have become very aggressive players in this market, and it is very likely that these companies will invest to upgrade the fabs to sub-0.5 micron technology. Our analysis of the foundry market without these extra fabs shows a market in oversupply in 1997 through 1999 by 15 to 25 percent. With the Korean capacity, the oversupply is much more severe, so much so in fact that we expect that many foundry suppliers will be forced to cut spending by late in 1997 in response.

Foundry capacity supply and demand can be used as a proxy for mainstream logic capacity investment. This picture shows no fundamental driving force for renewed capital spending growth.

The fabs in Japan (equivalent to 26) fall into two areas. Japanese companies initially processed 16Mb DRAMs on 150mm wafers, and we estimate that perhaps 10 fabs worth of capacity is now available to be upgraded to run 200mm wafers. Because this will effectively double that square inch capacity of this block at a relatively low cost, the DRAM-driven recovery could be pushed back a bit. The other block of 16 equivalent fabs cannot be upgraded to run 16Mb DRAMs, so these will migrate to lagging processes such as those for microcontrollers, telecommunications chips, mixed signal ICs, and analog ICs.

Two Possible Scenarios

These three issues together represent a possibly different scenario from our current forecast. One can think of the next two years as being one of two possible types of markets. Semiconductor companies could continue to invest strategically, keeping spending levels for 1997 high enough to not fully correct the excesses. This puts a drag on growth prospects for 1998. If the chip industry were to fully correct for the excesses of 1995 to 1996, the 1997 market could be significantly worse—perhaps down 25 to 30 percent, and recovery could be significant sequential growth in the second half of 1998. The first scenario represents our forecast scenario. The second, more dramatic, scenario represents the downside risk, given the facts of the day.

We believe that capital spending may be influenced in 1998 and 1999 positively with the facility construction and purchase of equipment toward the world's first 300mm wafer fabs. We have built this infrastructure investment in our model.

Over/Underinvestment Model Also Supports a Late 1998 Recovery Scenario

A few years ago, we introduced a model that quantifies the over/underinvestment picture for wafer fab equipment and semiconductor capacity. Although the early 1990s created and sustained a net underinvestment, this picture was corrected to create about a 36 percent overinvestment by the end of 1995 (see Chapter 3). Clearly, this was in the danger zone, and we are seeing the results of this overinvestment today. By the end of 1998, should our forecasts for investment and semiconductor demand be on target, we would expect the industry to return to being 15 percent net underinvested, just barely within the range to properly set the stage for a robust recovery in 1999.

The Americas Market Will Exhibit Strategic Strength Long Term

Capital spending in the Americas region grew at an industry-average 17 percent level in 1996, as a mix of companies both cut and accelerated spending. We expect that investment in advanced technology, coupled with the earlier capacity upturn from the advanced logic segment and strategic investments, will stabilize the region's spending later in 1997 and will lead the market's recovery in 1998 to 1999 as it did in 1993. We expect the Americas region to be the second fastest-growing market as foreign multinationals and foundry companies invest in capacity in the United States. Dataquest is forecasting the Americas region growing at a 14.5 percent CAGR for 1995 through 2001, driven by the relative low cost of capital and the need for foreign multinational and foundry manufacturers to be closer to their customers, building fabs in the United States.

The relatively strong growth in capital spending had been driven by the ongoing growth in PCs, telecommunications, and networking. This key driver has not disappeared, as these products have seen increasing use as tools to increase the productivity of the workplace. Electronic products with increased semiconductor content have created enormous demand for microprocessors, microcontrollers, SRAM, programmable logic and memory, digital signal processors (DSPs), standard logic, and peripheral controllers. The U.S. companies dominate many of these market segments. These segments combined are expected to maintain fairly stable growth rates over the next few years, with PC growth slowing (however, still maintaining a 17 percent CAGR) and networking and telecommunications expanding. The near-term market for PCs has remained robust worldwide, despite the slower growth and penetration into the U.S. home market.

New consumer digital products and services, such as personal communicators, interactive television, DVD systems, digital cameras, and video-on-demand, provide the potential for enormous growth in semiconductor sales longer term, especially for highly integrated complex logic and signal-processing chips that will be the core engines of future systems.

Although the strategic strength of core logic products enables a healthy and flourishing semiconductor production environment, it is also an environment that is less volatile in capital spending. In the boom years of 1994 and 1995, the Americas region grew at somewhat lower than the market rates. This trait will also enable the Americas market to grow in capital spending faster than market rates (or remain more stable) in the slower years, such as 1997 and 1998. We believe companies will strategically invest in technologically advanced capacity to preserve competitive advantage. Our forecast is for an essentially flat capital spending market in 1997 and a low double-digit growth in 1998.

Capital investment trends in the Americas region for 1996 have a definite split personality. While Intel has finished expansion of Fab 11.2 in New Mexico and ramping Fab 12 in Arizona, it has reduced spending because of increased yields. Micron Technology stopped investments in Lehi, Utah, but continued aggressive expansion and conversion to 200mm at all three fabs in Boise, Idaho. Memory-sensitive plant expansions such as Fujitsu's Greshem, Oregon, plant and Integrated Device Technology's Oregon fab have been delayed or have slower ramps, yet IBM has been very aggressive in its Burlington expansion of 16Mb DRAM production. Logic investment has seen a slowdown as well, with LSI Logic's pushout of its Oregon fab, the delay of Motorola's North Carolina MPU fab, and the slow ramp-up of Advanced Micro Devices' Fab 25 in Austin, Texas. Yet Cirrus Logic and Lucent Technologies have increased spending dramatically to ramp fabs in the eastern United States, with Atmel expanding aggressively in Colorado and Rockwell's emerging success creating opportunity for equipment companies in California. SGS-Thomson has remained aggressive in spending in the United States, placing finishing touches on its new Arizona facility, as well as starting up Fab 4 in Carrollton, Texas. Texas Instruments remains aggressive, spending in capacity expansion for DSP chip capacity. Although neither Samsung nor TSMC placed equipment into their new U.S. fabs in 1996, capital spending on the shells is progressing.

In 1997, we expect Intel and AMD to lead the charge for spending in the United States. Also, equipment orders are expected to be placed for the first fabs in the United States for Hyundai, Samsung, and TSMC. We would also expect logic-oriented companies with a primary capacity base in the United States to come back into the investment picture, finishing up projects started but left incomplete. We would be cautious about new projects being announced, however, as these companies will likely take advantage of the favorable foundry pricing environment before putting in place rather risky capital investment plans.

Japan: DRAM Capacity Additions Stop, Investment in Technology Under Way

Japan's 9 percent increase in capital spending in 1996 was really a 5 percent decline on a yen basis, as Japanese companies were among the first to cut capital investment and retrench. Because of the early cutback in spending, the 1997 capital spending decline is slightly less than the worldwide average, with growth returning in 1998. Lagging investment patterns in Japan is expected to continue throughout the decade.

Some of the Japanese electronics giants that experienced good profit growth in 1995, driven by semiconductor operations, have seen those profits evaporate with the precipitous fall of DRAM prices. While spending on capacity has essentially stopped, two other types of investments are likely to be important in Japan now through 1998.

First, Japanese companies will invest in any new technology and equipment targeted at the 0.25-micron production arena. This technology will not likely be in volume production until 1999, but the Japanese companies are expected to take advantage of this slowdown to understand and progress down the learning curve on these new process technologies. Second, the Japanese found that the shells built in 1990 and 1991 became an asset during the ramp in 1993 and 1994. By building a fab shell, equipped with a skeleton equipment set, they were positioned to more quickly ramp up production when the market turned up. We see that same pattern repeating, so we would expect several new fabs to be started in 1997, however at very low run rates. Once these fabs are in place, then the Japanese can continue to review the market every six months, making course corrections in April and October, as they have been doing through the last cycle ramp.

Although new facilities by Japanese companies will come on line outside Japan throughout the rest of this decade, DRAM investments inside Japan are really the only driving force today, although diversification has come to the forefront again in Japan. Japanese companies will continue to invest, but will grow to depend on production outside of Japan faster than within Japan. We are therefore forecasting a below-average CAGR of 9.9 percent in Japan for the years 1995 through 2001.

One bright spot is that a PC boom could emerge in Japan over the next year or two, spawned by the networking infrastructure that is currently being built. This would breathe new life in the Japanese semiconductor market, and our forecast would be brightened a bit. This PC boom would be seriously in jeopardy if the Japanese economy retracted into recession. We do not think that even a PC boom, however, would create a forecast different from several percentage points below the world average. The fundamentals of a Japanese production capacity are still too heavily concentrated in DRAMs, with no clear future direction emerging as yet, which keeps us from being more optimistic for capital activities in Japan.

Europe Sustains Presence as a Growth Market

After a higher-than-expected growth bubble of 46 percent in 1993, European spending "moderated" to a slower than market growth in 1994 as multinationals (Intel) substantially completed the majority of their expansions in 1993. The growth of 44 percent in 1994 is nonetheless extremely healthy, primarily being fueled by the Europeans themselves, with the ever-present SGS-Thomson, Philips, and Ericsson equipping their expansions. Europe continued to attract the capital in 1995, growing 65 percent. Large multinationals are still present, with Motorola upgrading the Scotland fab bought from Digital Equipment, the new IBM/Philips venture in Germany, Analog Devices expanding in Ireland, Texas Instruments expanding again in Italy, and the IBM/Siemens fab in France continuing to ramp 16Mb DRAMs.

Also, the key expansion is Siemens' new fab in Dresden, the key driver pulling Siemens into the top 10 in capital spending worldwide in 1996. As in the United States, Europe experienced slowdowns as well during 1996, with capital spending growing 15 percent. While SGS-Thomson and Siemens remained strong, Philips and the Japanese companies have significantly pulled back investment in capacity. However, partly because we do not believe Siemens can sustain their current spending, we are calling for an 11 percent decline in spending in Europe for 1997, and a flat-to-down 1998 as we expect multinationals will ramp domestic memory fabs before Europe. All three big Korean companies have now announced plans for fabs in Europe to come on line during 1999, with only Samsung undecided about the exact location.

We are expecting Europe to be a reflection of the overall worldwide market because there is a good mix of multinational investment currently in the region. Europe is currently at equilibrium with the world, with a stable percentage of the demand and production mix. This stability is what has attracted more companies to produce in the region. Europe is viewed as a strategic location for production longer term to take better advantage of European and 16/64Mb DRAM growth in the future, driven by PC production, without the import tariffs. We therefore expect Europe to be a near-average investment region in the long term, with a six-year CAGR of 12.3 percent.

Asia/Pacific Investments Focusing on Foundry Near Term as the DRAM Falls

The often erratic but sustained semiconductor capital spending growth in the Asia/Pacific region continued at a market-leading pace of 26 percent growth in 1996. However, the tide has turned in the DRAM area, and we are forecasting the Asia/Pacific region to be hit the hardest in 1997, with a 27 percent decline in capital spending and a flat-to-down 1998 as the foundry industry deals with oversupply. Longer term, we expect Asia/Pacific to exhibit among the most aggressive growth in capital spending of any region, but much closer to overall market growth rates than in the recent past, with a 17.2 percent CAGR for capital spending.

Spending in 1995 and early 1996 came primarily from two areas, DRAMs and foundry capacity. The Korean conglomerates are continuing their relentless DRAM capacity expansion plans, although more moderately in 1996. We do expect these companies to finally succumb to the inevitable reality of overcapacity, with significant cutbacks for 1997. The real story of interest in 1995 and 1996 were the new Taiwan players. But the tide has turned quickly, likely accelerated by the fact that the Taiwanese stock market is very close to the U.S. stock market in its reaction to bad news. Many companies in DRAM have been cutting back feverishly to save near-term profitability. Yet many companies in Taiwan are tied strategically to other companies outside the region, lending some investment stability there in the near term.

The foundry industry is now a *strategic* industry rather than simply a tactical one, but it is now also an industry that has become susceptible to the general industry overcapacity situation, with dramatically falling prices for processed wafers in the second half of 1996.

While Taiwan chip companies TSMC, Macronix, and UMC along with Chartered semiconductor in Singapore and SubMicron Technology in Thailand continued with their planned projects in expansion of foundry capacity, the Korean companies entered the foundry market very aggressively in the second half of 1996, causing us to be concerned about plans for 1997 and 1998 for the dedicated foundries.

The reason for the continued interest in spending capital and new entrants in this area comes from the fact that the core business is dependent upon the logic and PC unit demand rather than DRAM. Further, Dataquest estimates that only about 32 percent of the contracted manufacturing of semiconductors originates from fabless companies in 1995, but the trend for this share is increasing. The remainder is from integrated device manufacturers (IDMs) who wish to place manufacturing lower value-added products away from their own facilities in order to maximize resources and cost, or to reduce investment risks using foundries as an extension of their own capacity, or to use the more advanced technology of foundries (in some cases) as a growth strategy.

Who's Investing Where?

In our capital spending survey recently completed, Dataquest gathered picture of how money is being spent. Table 2-4 summarizes how companies based in different regions are spending their money abroad for 1995, and Table 2-5 summarizes the same for 1996. About 79 percent of money spent went into domestic economies worldwide in 1995, and that ratio increased slightly to 83 percent in 1996 as companies tend to cut back externally first.

Asia/Pacific companies have historically placed all of their investments domestically, but 1994 saw the first year of diversification, which continued in 1995. Asia/Pacific companies spent about 3.6 percent of their money abroad in 1995, and that is increasing to about 4.2 percent in 1996. We would expect this ratio to increase significantly over the next two to three years. Europeans have been the most aggressive capital exporters, historically, placing only 59 percent of their investment inside of Europe during 1995. This figure has grown slightly to 64 percent in 1996 and should expand in 1997 as European companies reign in spending.

Table 2-4
Regional Investment Patterns of Semiconductor Manufacturers in 1995 (Millions of U.S. Dollars)

	Worldwide	Americas	Japan	Europe, Middle East, and Africa	Asia/Pacific	Percentage of World Spending
American Companies	13,863.3	10,135.2	655.1	1,423.3	1,649.6	36.1
Japanese Companies	12,042.3	1,328.7	9,247.7	738.7	727.3	31.4
European Companies	3,301.5	420.2	7.2	1,936.0	938.1	8.6
Asia/Pacific Companies	9,203.8	285.5	0	38.9	8,879.4	24.0
All Companies	38,410.8	12,169.5	9,910.0	4,136.9	12,194.4	100.0
Percentage Growth from 1994	73.9	69.2	48.6	65.2	113.2	

Source: Dataquest (January 1997)

Table 2-5
Regional Investment Patterns of Semiconductor Manufacturers in 1996 (Millions of U.S. Dollars)

	Worldwide	Americas	Japan	Europe, Middle East, and Africa	Asia/Pacific	Percentage of World Spending
American Companies	15,657.8	12,289.5	445.3	1,503.4	1,419.5	35.8
Japanese Companies	11,268.8	1,045.2	8,916.5	751.0	556.1	25.8
European Companies	3,802.0	359.7	0	2,446.2	996.1	8.7
Asia/Pacific Companies	12,978.5	490.0	0	54.9	12,433.5	29.7
All Companies	43,707.1	14,184.5	9,361.8	4,755.5	15,405.3	100.0
Percentage Growth from 1995	13.8	16.6	-5.5	15.0	26.3	

Source: Dataquest (January 1997)

Japanese companies are very close to the worldwide average with about 77 percent domestic investment in 1995, rising to 79 percent in 1996. North American companies are also high domestic spenders, with about 73 percent staying at home for 1995 increasing to 78 percent in 1996. We would expect both of these groups to fluctuate between 70 and 80 percent long term, depending on market conditions.

The North American and Japanese regions are net investors, while European and Asia/Pacific regions are net beneficiaries of that investment. This parallels those regions being net exporters and net importers of semiconductors, respectively.

While all regions are spending in Asia/Pacific, and all multinational regions investing in Europe, only North American companies have the strategic vision to invest in Japan. Japanese companies are also investing on a worldwide basis. We believe this is one of the key elements necessary in a strategic plan for a semiconductor company to be competitive on a global basis.

Dataquest Perspective

The capital spending boom experienced in 1993 through the first half of 1996 is over, and the industry is now in what we would characterize as a two-year "pause," with investment in capacity initially declining and stabilizing as demand catches back up to supply.

Six months ago, we believed that the logic sector would be in a position to drive a capacity recovery late in 1997. Developments in the last half of 1996 in Asian company strategies, and a closer look into trends in silicon consumption, have led us to change this belief. We now believe that, after a firmness in the first half of 1997 as a result of a set of "strategic" investment projects, the overcapacity of the industry will drive the second half of 1997 to be below the first half in capital spending. Even in the face of strengthening semiconductor demand currently under way today, and strong end-use electronic equipment and PC markets, Dataquest has a relatively conservative view of the recovery. The fundamentals of the overcapacity situation we are in today simply do not allow a large volume spending recovery to occur before mid-1998, even in the mainstream logic sector, which has traditionally been the part of the market less affected by the cycle.

We do not see a stoppage in advanced technology investments, indicating the continued belief in the customer base of a strong end-user market for semiconductors. In some respects, it is this and other "strategic" investments that are pushing out the timing of the recovery in our mind, and leading to the current firmness in orders on the equipment side.

Overcapacity in the DRAM market has now trickled to most areas in semiconductor manufacturing. We have also uncovered a number of issues that need to be reconciled during 1997 and 1998. These issues provide the basis for our belief that there is more downside risk than upside potential to our forecast in the next two years. The key point to remember is that the industry needs a capacity driving force to resume *sustainable* growth prospects.

Our concerns are the following:

- The number of fabs and spending ratio currently factored into in our forecast for 1997 is still too high.
- The consumption of silicon into the DRAM sector has declined in the face of increasing bit demand.
- Existing excess capacity, which we have now about quantified, is being upgraded and redirected into the foundry market.

The foundry industry is now a *strategic* industry rather than simply a tactical one, but it is now also an industry that has become susceptible to the general industry overcapacity situation, with dramatically falling prices for processed wafers in the second half of 1996. Foundry capacity supply and demand can be used as a proxy for mainstream logic capacity investment. This picture shows no fundamental driving force for renewed capital spending growth near term.

By the end of 1998, should our forecasts for investment and semiconductor demand be on target, we would expect the industry to return to be net underinvested within the range to properly set the stage for a robust recovery in 1999. We believe that capital spending may be influenced in late 1998 and 1999 positively with the facility construction and purchase of equipment toward the world's first 300mm wafer fabs. We have built this infrastructure investment in our model.

Chapter 3
Wafer Fab Equipment Forecast

This chapter presents data on worldwide spending by region for wafer fabrication equipment. Wafer fab equipment spending in a region includes spending by all semiconductor producers with plants in that region. Included are all classifications of equipment for front-end semiconductor operations.

Chapter and Market Highlights

This chapter will address the following points:

- Overcapacity has gripped the industry and 1996 was a year that turned from growth to decline, but net was just under 12 percent growth in wafer fab equipment. We saw two distinctly different markets in the past year. The first half was marked by many fab announcements, aggressive spending plans, and good booking levels for equipment. The second half was the opposite: bookings collapsed, expansion delayed, and capital spending budgets were cut.
- The only reason 1996 remains a double-digit growth year is due to the strong backlogs coming out of 1995. Our estimate was that the industry was at about a six-month backlog at the time, compared to a normal backlog of four months. The bookings decline has put pressure on backlog levels, and the industry has shipped down backlog now to more normal levels, with several companies below normal.
- The second half of 1996 contained slightly more severe declines than we anticipated six months ago. If the fourth quarter 1996 run rate for wafer fab equipment shipments was held flat for all of 1997, the resulting decline would calculate to just over 15 percent for 1997. Our forecast for 1997 is for an 18 percent decline, which would suggest we believe we have not quite hit bottom yet, and indeed we are expecting bookings in the middle of 1997 to be disappointing.
- However, we anticipate that equipment companies, in the hope of improved bookings later in the year, will continue to ship down backlog in order to maintain a minimum financial performance, maintaining the run rates of fourth quarter 1996. We expect to reach a minimum three-month level backlog by the middle of the year 1997. At that time, with backlogs razor thin, quarterly shipment rates are expected to be reduced to booking levels, leading to a sales dip in the third quarter of this year.
- We do not expect sustainable bookings growth to support shipment growth until the second quarter of 1998, and shipment growth is expected to remain constrained until very late in the year, keeping 1998 as a single-digit growth year.
- We would expect supply/demand dynamics to be fully corrected by early 1999, driving a robust resumption of growth with the wafer fab equipment market growing to over $33 billion in the year 2000, from the just under $19 billion in 1998. The worldwide wafer fab equipment market is forecast to grow at 13.7 CAGR between 1995 and 2001, essentially equivalent to semiconductor market growth.

- We believe the market in 1997 and early 1998 will concentrate on advanced technology equipment. A purchasing behavior that will be prevalent in the near term will be new processes and equipment directed at solving issues for 0.35-micron and 0.25-micron manufacturing. These segments will be those related primarily to deep-UV lithography, silicon epitaxy, maskmaking equipment, 300mm technologies, and 0.25-micron multilevel metallization process schemes.
- Our model, which measures the net cumulative under- or overinvestment, indicates that by the end of 1995, the semiconductor manufacturing world was be overinvested in wafer fab equipment to the tune of $6.8 billion, or 36 percent of the market. This is above the peaks exhibited in 1984 and 1989, so it is no surprise that excess capacity has emerged during 1996 in the DRAM market where capacity has been added recently.
- We have factored in an infrastructure investment in equipment for late 1997 through 1999, which will affect the forecast size of the markets positively. This additional investment will be for initial equipment to fill a couple of 300mm fabs to run silicon by 1999. The bulk of this "300mm equipment bubble" occurs in 1998. However, our outlook for a significant 300mm equipment market will wait until 2001 through 2002.

This chapter presents historical and forecast data on the worldwide wafer fabrication equipment market, by region and by key equipment segment. In this year-end forecast outlook on wafer fab equipment, we have chosen to focus our forecast of equipment categories on specific segments and issues, namely:

- The annual investment theme for 1995 through 2000
- Steppers and automatic photoresist processing equipment (track)
- Dry etch and chemical mechanical polishing (CMP)
- Silicon epitaxy, CVD, and PVD
- Diffusion and RTP
- Ion implantation (medium current, high current, and high voltage)
- Segments that will fare best the next two years

These segments of the equipment market not only represent the majority of all wafer fab equipment expenditure in the world today, but also embody the key technological capability for advanced device production. Highlights of some of the factors affecting individual equipment segment forecasts also are presented.

Equipment spending in a region refers to spending by all companies—both domestic and foreign—within the region. Also, we note that yearly exchange rate variations can have a significant effect on 1989-through-1996 data appearing in the tables in this chapter. Appendix B details the exchange rates used in this document.

Tables in this chapter provide details on the following:

- Table 3-1: Historical market data, by geographic region, for the years 1989 through 1995
- Table 3-2: Forecast market data, by geographic region, for the years 1995 through 2001
- Table 3-3: Historical data for key equipment segments for the years 1989 through 1995
- Table 3-4: Forecast data for key equipment segment for the years 1995 through 2001

Table 3-1
Worldwide Wafer Fab Equipment Market, by Region—Historical, 1989-1995
(Millions of U.S. Dollars)

	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Americas	1,657	1,589	1,519	1,576	2,118	3,190	5,332	21.5
Percentage Change	7.9	-4.1	-4.4	3.8	34.4	50.6	67.1	
Japan	2,813	2,996	3,012	2,098	2,450	3,661	6,157	13.9
Percentage Change	23.9	6.5	0.5	-30.3	16.8	49.4	68.2	
Europe, Middle East, and Africa	721	764	641	641	988	1,370	2,313	21.4
Percentage Change	8.7	6.0	-16.1	0	54.1	38.6	68.8	
Asia/Pacific	820	522	832	783	1,312	2,567	5,208	36.1
Percentage Change	58.1	-36.4	59.5	-5.8	67.5	95.7	102.9	
Total Wafer Fab Equipment	6,011	5,871	6,003	5,098	6,868	10,787	19,010	21.2
Percentage Change	20.6	-2.3	2.3	-15.1	34.7	57.1	76.2	

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (January 1997)

Table 3-2
Worldwide Wafer Fab Equipment Market, by Region—Forecast, 1995-2001
(Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Americas	5,332	6,154	5,728	6,439	8,062	10,451	12,197	14.8
Percentage Change	67.1	15.4	-6.9	12.4	25.2	29.6	16.7	
Japan	6,157	6,263	5,129	5,614	7,253	9,739	10,803	9.8
Percentage Change	68.2	1.7	-18.1	9.5	29.2	34.3	10.9	
Europe, Middle East, and Africa	2,313	2,623	2,243	2,223	2,946	3,862	4,691	12.5
Percentage Change	68.8	13.4	-14.5	-0.9	32.5	31.1	21.5	
Asia/Pacific	5,208	6,205	4,339	4,110	5,716	9,425	13,298	16.9
Percentage Change	102.9	19.1	-30.1	-5.3	39.1	64.9	41.1	
Total Wafer Fab Equipment	19,010	21,245	17,439	18,386	23,976	33,477	40,988	13.7
Percentage Change	76.2	11.8	-17.9	5.4	30.4	39.6	22.4	

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (January 1997)

Table 3-3
Wafer Fab Equipment Revenue by Equipment Segment, Historical 1989-1995 (Millions of U.S. Dollars)

Equipment Segment	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Worldwide Fab Equipment	6,011	5,871	6,003	5,098	6,868	10,787	19,010	21.2
Change (%)	20.5	-2.3	2.2	-15.1	34.7	57.1	76.2	-
Steppers	1,181	1,052	979	646	1,007	1,833	3,332	18.9
Track	322	317	364	353	500	695	1,413	27.9
Maskmaking Lithography	69	47	48	53	52	79	82	2.9
Other Lithography[1]	192	195	158	106	120	125	118	-7.8
Total Lithography/Track	1,764	1,612	1,549	1,158	1,679	2,732	4,944	18.7
Automated Wet Stations	243	268	291	286	285	468	928	25.0
Other Clean Process	134	132	143	103	198	213	389	19.5
Dry Strip	121	118	119	123	138	213	343	18.9
Dry Etch	670	690	717	682	1,083	1,592	2,842	27.2
Chemical Mechanical Polishing	NS	NS	11	20	44	64	179	NA
Total Etch and Clean	1,168	1,208	1,281	1,213	1,748	2,548	4,680	26.0
Tube CVD	220	259	268	213	283	442	780	23.5
Nontube Reactor CVD	388	457	474	437	585	885	1,803	29.2
Sputtering	320	359	425	446	584	1,012	1,567	30.3
Silicon Epitaxy	75	68	89	84	83	114	207	18.4
Other Deposition[2]	170	153	147	119	115	101	124	-5.1
Total Deposition	1,173	1,296	1,403	1,300	1,650	2,553	4,480	25.0
Diffusion	332	325	326	246	342	490	773	15.1
RTP	25	33	46	36	45	76	154	35.2
Total Thermal Nondeposition	357	358	372	283	388	567	927	17.2
Medium-Current Implant	131	114	108	83	108	242	384	19.6
High-Current Implant	301	250	228	164	233	391	550	10.6
High-Voltage Implant	25	7	18	16	18	27	119	30.1
Total Ion Implantation	457	370	353	263	359	659	1,053	14.9
Optical Metrology	74	59	59	40	43	67	98	4.8
CD-SEM	81	88	93	78	83	154	313	25.4
Thin Film Measurement	NS	NS	43	58	72	100	196	NA
Patterned Wafer Inspection	116	105	90	109	144	281	535	29.1

Table 3-3 (Continued)
Wafer Fab Equipment Revenue by Equipment Segment, Historical 1989-1995 (Millions of U.S. Dollars)

Equipment Segment	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Auto Unpatterned Detection	37	45	41	30	32	56	111	20.1
Other Process Control[3]	369	313	307	228	270	446	601	8.5
Total Process Control	676	609	632	542	644	1,103	1,854	18.3
Factory Automation	195	216	227	194	250	412	686	23.3
Other Equipment	222	202	185	146	151	213	386	9.6
Total Factory Automation/Other Equipment	417	418	412	340	401	625	1,072	17.0
Total Wafer Fab Equipment	6,011	5,871	6,003	5,098	6,868	10,787	19,010	21.2

NS=Not surveyed
NA=Not applicable
[1]Includes contact/proximity, projection aligners, direct-write e-beam, and X-ray lithography
[2]Includes evaporation, MOCVD, and MBE
[3]Includes auto review/classification, manual detection/review, and other process control equipment
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (January 1997)

Table 3-4
Wafer Fab Equipment Revenue Forecast by Equipment Segment, 1995-2001 (Millions of U.S. Dollars)

Equipment Segment	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Worldwide Fab Equipment	19,010	21,245	17,439	18,386	23,976	33,477	40,988	13.7
Change (%)	76.2	11.8	-17.9	5.4	30.4	39.6	22.4	-
Steppers	3,332	3,768	2,556	2,913	4,157	6,034	7,101	13.4
Track	1,413	1,397	1,087	1,279	1,954	2,534	2,853	12.4
Maskmaking Lithography	82	179	184	190	247	336	410	30.8
Other Lithography[1]	118	105	89	88	106	131	139	2.7
Total Lithography/Track	4,944	5,448	3,916	4,469	6,464	9,036	10,502	13.4
Automated Wet Stations	928	1,062	912	945	1,161	1,559	1,977	13.4
Other Clean Process	389	447	389	391	453	601	754	11.7
Dry Strip	343	369	327	339	418	591	730	13.4
Dry Etch	2,842	3,317	2,797	2,847	3,506	4,695	5,756	12.5

Table 3-4 (Continued)
Wafer Fab Equipment Revenue Forecast by Equipment Segment, 1995-2001 (Millions of U.S. Dollars)

Equipment Segment	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Chemical Mechanical Polishing	179	221	241	301	437	637	905	31.0
Total Etch and Clean	4,680	5,416	4,666	4,823	5,975	8,082	10,121	13.7
Tube CVD	780	765	646	675	835	1,159	1,382	10.0
Nontube Reactor CVD	1,803	2,067	1,818	1,905	2,366	3,362	4,288	15.5
Sputtering	1,567	1,664	1,437	1,480	1,860	2,590	3,196	12.6
Silicon Epitaxy	207	274	262	283	368	486	603	19.5
Other Deposition[2]	124	115	83	78	90	108	118	-0.7
Total Deposition	4,480	4,886	4,246	4,422	5,518	7,705	9,587	13.5
Diffusion	773	740	611	624	805	1,133	1,345	9.7
RTP	154	188	200	230	315	460	530	22.9
Total Thermal Nondeposition	927	928	811	854	1,120	1,592	1,875	12.5
Medium-Current Implant	384	403	310	297	363	552	668	9.7
High-Current Implant	550	640	496	478	674	1,051	1,357	16.2
High-Voltage Implant	119	223	163	175	234	364	481	26.2
Total Ion Implantation	1,053	1,265	968	951	1,271	1,966	2,507	15.5
Optical Metrology	98	106	81	95	140	185	212	13.8
CD-SEM	313	345	267	316	446	606	711	14.7
Thin Film Measurement	196	209	184	201	257	338	418	13.5
Patterned Wafer Inspection	535	596	485	504	658	949	1,182	14.1
Auto Unpatterned Detection	111	127	101	106	134	190	245	14.1
Other Process Control[3]	601	717	604	589	692	965	1,260	13.1
Total Process Control	1,854	2,099	1,722	1,810	2,328	3,234	4,027	13.8
Factory Automation	686	830	788	739	910	1,280	1,630	15.5
Other Equipment	386	373	322	318	391	581	738	11.4
Total Factory Automation/Other Equipment	1,072	1,203	1,110	1,057	1,301	1,861	2,368	14.1
Total Wafer Fab Equipment	19,010	21,245	17,439	18,386	23,976	33,477	40,988	13.7

[1] Includes contact/proximity, projection aligners, direct-write e-beam, and X-ray lithography
[2] Includes evaporation, MOCVD, and MBE
[3] Includes auto review/classification, manual detection/review, and other process control equipment
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (January 1997)

Annual Investment Themes for 1996 through 2001

Behind our equipment and segment forecasts are assumptions about how semiconductor producers will perform and invest. These are summarized in Table 3-5 for the years 1996 through 2001. The following areas are considered: the availability of profits for reinvestment, memory versus logic growth, technology shifts, and brick and mortar versus equipment purchases.

When Will Demand Expand to Meet Capacity? An Update to the Over- or Underinvestment Model

In our forecasts over the last few years, we have shown a model that provided a measure of the net cumulative over- or underinvestment in wafer fab equipment to support capacity needs in the industry. As equipment purchases precede actual capacity on line by a number of months or quarters, this model could be viewed as a gross "leading indicator" to capacity shortages and excesses. The results of this model are closer to a 1.5-to-3-year indicator of turning points in the equipment industry. The methodology of the net cumulative investment (NCI) model is linked to our longer-range forecast model.

To review, our methodology starts with a few key assumptions and baselines:

- Long-term growth rates for semiconductors and wafer fab equipment are correlated. In other words, semiconductor revenue and profits are needed before money can be spent on equipment, and vice versa.
- Also, net cumulative investment equals zero over time—meaning that in a noncyclical environment where annual growth rates are constant, investment and capacity are at equilibrium at all times. Of course, our industry cycles through over- and underinvestment.

Table 3-5
Annual Driving Forces and Investment Themes for Wafer Fab Equipment, 1996-2001

	1996	1997	1998	1999	2000	2001
Logic Semiconductor Unit Growth*	Moderate	Moderate to solid	Solid	Strong	Solid	Solid
Investment in Logic Capacity*	Moderate	Moderate	Solid	Solid	Strong	Solid
Memory Semiconductor Unit (Not Bit) Growth*	Moderate	Weak	Moderate	Solid	Strong	Moderate to weak
Investment in Memory Capacity*	Moderate	Dead	Weak	Moderate	Strong	Solid to moderate
Front-End Equipment versus Facilities Loading of Capital	Balanced	Facilities	Facilities	Equipment	Equipment	Balanced
Primary Technologies Invested	0.35-0.5 micron	0.3-0.5 micron	0.3-0.4 micron	0.25-0.4 micron	0.25-0.4 micron	0.2-0.35 micron

*Scale: Strong > Solid > Moderate > Weak > Dead
Source: Dataquest (January 1997)

- The output is a tangible number, and is in dollars of over- or underinvestment at year-end. However, the more useful output of the model divides this gross dollar number by the wafer fab equipment market size. The result is a percentage of market figure that is repeatable in level from cycle to cycle.
- To take into consideration the long-term growth of the semiconductor and equipment industries changing over time—the model has a factor allowing the fundamentals of the industry to change over time.

A net positive or negative investment is calculated relative to the long-term growth baseline annually, and then added to the prior year. The calculation resulted in a dollar value net cumulative over- or underinvestment, and has correlated well with historical patterns.

We consider the region of plus 20 percent or higher, or minus 15 percent or lower net cumulative investment is necessary to place the wafer fab equipment market within the time frame of a "turning point" in the market.

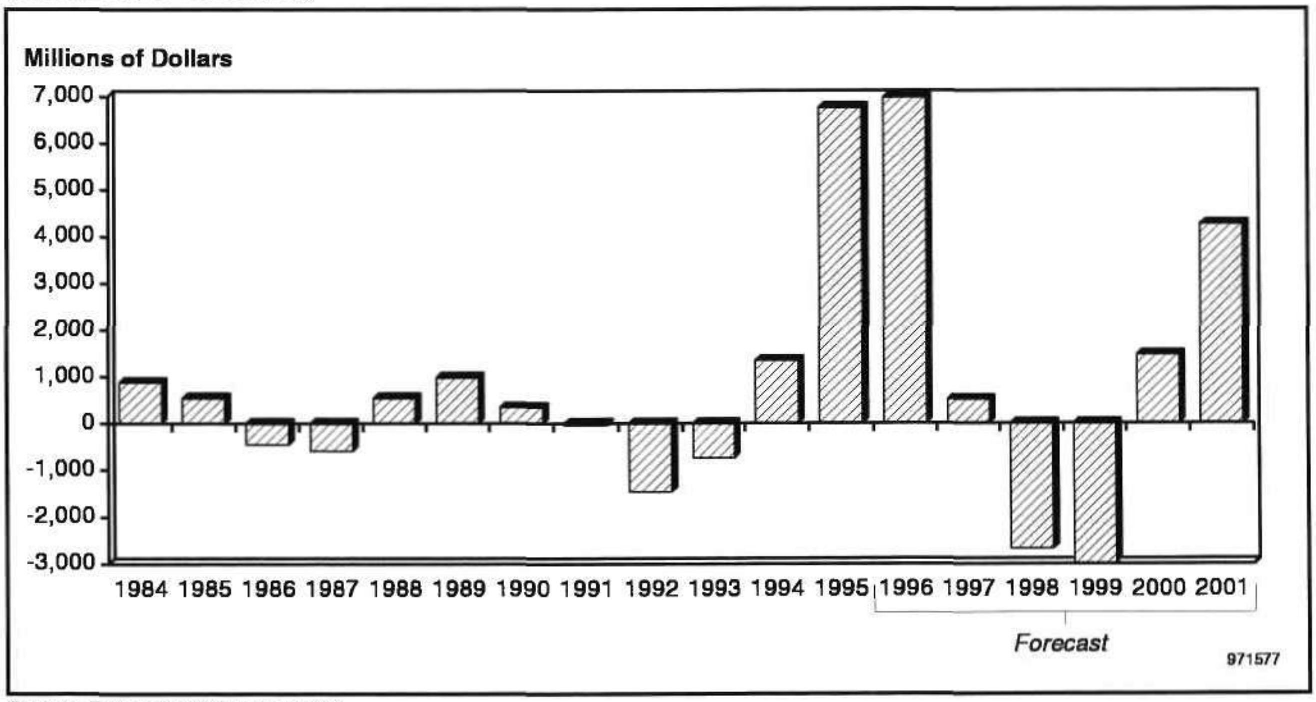
Figures 3-1 and 3-2 show the most recent results of the model, little changed from our midyear forecast update. In absolute dollar terms, by the end of 1995 the industry was $6.8 billion overinvested, or 36 percent of the wafer fab equipment market, exceeding levels witnessed during the 1984 and 1989 peaks. These levels were driven to these extended levels for two basic reasons. First, the PC unit demand was growing at low-20s annual growth rate in the early 1990s. About one-third of the semiconductor industry, and over one-half of the capital spending on new capacity is to support this demand.

Second, the DRAM market had not yet converted to run the more silicon-efficient 16Mb DRAM by the end of 1995, placing this past investment cycle about seven years behind the last cycle. As the equipment being installed since late 1994 is fully "convertible" to run 16Mb DRAMs, we can think of these fabs building "pent-up supply" in bits. The size of this overspending means that even with good fundamental demand in semiconductors, the industry will not be spared at least the average length of a downturn, namely, two years.

We have factored into the model an investment in a couple of 300mm fabs starting in late 1997 through 1999, with the bulk in 1998. This is considered an equipment "bubble demand" as the equipment will be shipped into a nonproductive fab (meaning no semiconductor revenue will be initially generated).

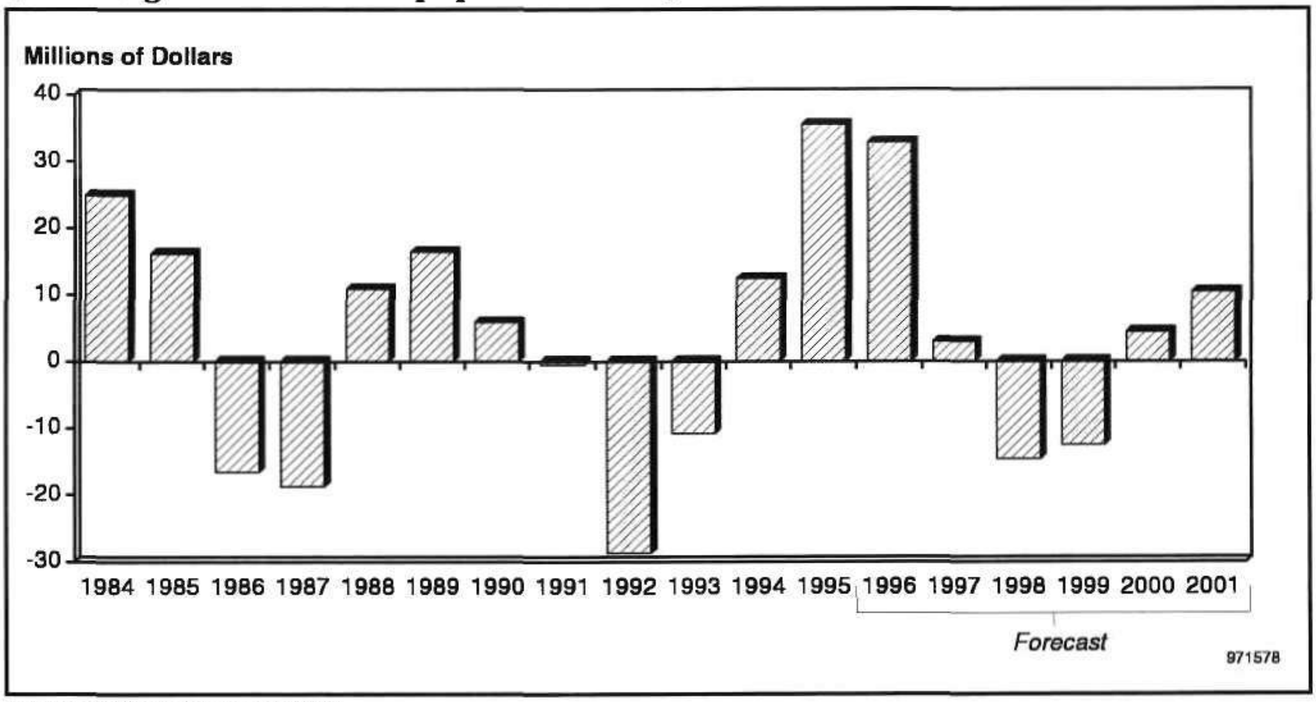
With our forecast for a momentum style growth in 1996, and two pause years in 1997 and 1998, the model indicates a reacceleration of equipment spending starting in 1999. This model also shows that if our forecast of an 18 percent decline for wafer fab equipment coupled with a 13 percent growth in semiconductors is met for 1997, the equipment market will still be net slightly overinvested by the end of 1997, and clearly not close to the levels necessary to indicate the market would be near a turning point. We would not enter the turning point region until the later half of 1998.

Figure 3-1
Net Cumulative Over- and Underinvestment of Semiconductor Wafer Fab Equipment (Millions of Dollars)



Source: Dataquest (January 1997)

Figure 3-2
Net Cumulative Over- and Underinvestment of Semiconductor Wafer Fab Equipment (Percentage of Wafer Fab Equipment Market)



Source: Dataquest (January 1997)

Fundamental Capacity Analyses and Annual Review—DRAM and Foundry

The NCI model described above is only a tool to indicate possible future turning points and should not be relied upon to actually forecast capacity supply versus demand absolutely. A more fundamental, basic approach is required—looking at square inches of silicon capacity. How many wafers can be processed, and of what type of process, is much more enlightening in measuring capacity than for a particular device type. Capacity is very fluid: A stepper does not care whether the picture it takes is for a DRAM, SRAM, or logic device. But there are limits in transferring capacity. For example, logic processes have specialized process techniques that are not found in DRAMs, and vice versa. SRAMs can use a DRAM equipment mix or a logic-oriented process scheme, the latter tending to have faster access times.

There are two major markets we can isolate in order to understand basic capacity supply and demand—the DRAM market and the foundry market. The latter is particularly interesting for two reasons. First, foundry capacity has tended to be more heavily logic and ASIC process oriented, giving us a second perspective on capacity versus supply. Second, the major customer base for the foundry is the fabless company, whose products tend to be those that are placed within the PC logic and graphics chipsets. As PCs now account for about one-third of all semiconductor use, about two-thirds of all DRAM consumption, and is the main engine for the current semiconductor boom, looking at PC-related capacity issues is important for understanding potential future equipment market turning points. Put simply, the foundry market can be used as a proxy for the mainstream logic supply and demand.

The details of these analyses are provided in other reports, namely, Dataquest's Quarterly DRAM Supply/Demand Report and ongoing research on the foundry market. A summary of the basic results and impacts will be given here.

In any supply/demand trend, there is a cycle between oversupply and undersupply. Investment in capacity tends to be in reaction to these situations, and there is inevitably overshoot in both directions. Analysis is based on square inches of silicon, and not on revenue, bit demand, nor unit demand. If demand for silicon area exceeds supply, the market is technically in undersupply.

Here are the basic conclusions and review of the market impacts by year:

- The DRAM market transitioned to oversupply very late in 1995. A high level of capacity investment continued until the middle of 1996, and with the conversion to a more silicon efficient 16Mb DRAM, this condition is expected to last into the middle of 1998. This window may be later if significant Japanese capacity is converted from 150mm wafers to 200mm wafers.
- The foundry market has also transitioned to oversupply. Investments in the dedicated foundry have continued to accelerate, while the overcapacity in U.S. logic manufacturers has meant a slightly lower demand. In the last half of 1996, the Korean manufacturers aggressively entered the market, driving prices down 25 percent for processed wafers.

- 1996—A year of transition and spotty investment in capacity. DRAM prices crashed early in the year. The market begins to transition to the 16Mb during the year, and prices will continue to decline gradually into 1997. Foundry prices collapsed late in the year.
- 1997—A year of contraction. Weak DRAM capacity investment, but continued strong investment in technology and strategic investments. But the oversupply in the foundry capacity means equipment purchases will likely lose steam quickly through the year. We expect DRAM investment to decline some 20 to 30 percent, while logic investment remains flat.
- 1998—A frustrating year. Even though DRAM capacity is likely to see its peak oversupply in 1997, significant reinvestment will not likely occur until late in 1998 or 1999 as companies delay investment and Japanese companies finish 200mm conversions. As the foundry market deals with oversupply and new entrants, logic investment will remain cool. Yet we expect that semiconductor demand will again begin to accelerate, signaling an underlying strength in the market and anticipation of the eventual upturn. U.S. logic investment will lead, but will remain subdued because of the redirection of production into the foundry market.
- 1999—The first growth year in the next boom cycle. DRAM investment is likely to pick up again, while foundry investment will lag. U.S. logic capacity will likely be strong and lead foundry investment out of the "pause." By 2000, the next equipment boom will be well under way and likely to last into 2001.

A more detailed discussion of the quantity of the silicon square inch oversupply is in Chapter 2 of this document.

Highlights of Key Equipment Segment Markets and Forecasts

Steppers and Track

From 1989, the peak year of stepper shipments at more than 950 units, the market tumbled to less than 400 tools in 1992 before recovering. During this DRAM-sensitive ramp, the industry experienced its first year exceeding 1,000 steppers shipped; indeed, 1,228 steppers shipped in 1995. The peak year was 1996, in which we currently estimate just under 1,400 steppers shipped into the market. Shifts in the product mix toward higher-priced deep-UV systems, i-line systems and wide field lenses have also driven up average selling prices (ASPs). This trend was offset somewhat in 1996 by the weak yen, to drive a revenue increase of 13 percent on a dollar basis in 1996, essentially at market growth. Steppers, being a capacity-sensitive segment, is forecast to lag the market performance in 1997 and 1998, and then lead market growth starting in 1999.

Stepper revenue is forecast to grow at 13.4 percent CAGR, slightly below the market average for 1995 through 2001. Our forecast for stepper unit growth over the five-year forecast horizon remains modest, about 4.3 percent CAGR between 1995 and 2001.

With the adoption of phase shift mask technology, off-axis illumination techniques, as well as conventional i-line tools with variable numerical aperture, i-line is clearly a viable technology down to the 0.3-micron regime and will continue to dominate the overall stepper technology mix through the 2000 time frame. Excimer/deep-UV steppers will begin to represent a more significant portion of the product mix from 1997 onward for use in below 0.3-micron devices, and ICs with large chip areas such as advanced microprocessors, which require large field size capability. Dataquest believes that field size pressures accompanied by shrinking geometry will drive the industry toward step-and-scan technologies for the majority of excimer/deep-UV shipments, beginning in 1997.

Track equipment is forecast to grow at a 12.4 percent CAGR between 1995 and 2001, slightly below the industry growth of 13.7 percent. While we believe that the rapid shift in the product mix toward higher-priced systems has been recently completed, we do expect another product shift to occur in the track market associated with the ramp of deep-UV steppers, which require more sophisticated environmental control systems, and will translate to slightly higher ASPs. Unit demand will parallel the stepper market, however.

Etch and Clean: Dry Etch and Chemical Mechanical Polishing (CMP)

Dataquest began covering the chemical mechanical polishing (CMP) market in 1993. At this time Dataquest includes the post-CMP clean system, usually sold in conjunction with a CMP tool, as part of the cleaning segment, and not in the CMP segment.

The year 1995 was a critical one for adoption of the technology into production, with CMP systems growing 180 percent to $179 million. Even though the application appears to be limited to devices with at least three levels of metal, which tends to exclude the DRAM market, the acceptance of the technology into logic and particularly the foundry market has been the key turning point. Based on the demand of the customer, however, and because of the introduction of more robust equipment, we now believe most foundries offer CMP at 0.5-micron. CMP is one of the few markets Dataquest believes will grow during 1997, albeit at single-digit levels, during the market contraction in 1997.

These systems are used to remove material from the surface of the wafer resulting in a flat surface over the entire wafer. This global planarization, primarily of dielectric layers, is required to achieve high yields in devices where three or more levels of metal are used. Today's advanced logic and ASIC devices are fueling this market growth. Dataquest believes that this technology and market will become a major part of semiconductor manufacturing in the long run. CMP is our fastest-growing segment with a 31 percent CAGR for the years 1995 through 2001.

Dry etch systems continue to exhibit long-term revenue growth, with a CAGR of 12.5 percent forecast for the years 1995 through 2001. Unit shipments are expected to grow as greater multilevel interconnect process capacity is brought online, increasing the need for dielectric and metal capacity. Relatively strong ASP growth will lend additional momentum to dry etch revenue growth as new high density plasma systems for 0.35-micron applications enter the market, and multichamber cluster tools continue to increase their presence. The success of CMP will hold etch below market growth, however, particularly in metal etch as stringer removal becomes a nonissue. The metal etch market will be the slowest-growing subsegment of the etch market through the year 2000, and may actually flatten altogether when dual damascene processes enter production around the turn of the decade.

Deposition: CVD, PVD, and Silicon Epitaxy

CVD equipment sales are predicted to grow at a 14 percent annualized rate from 1995 through 2001, only slightly above overall equipment growth. The steady growth in multilevel interconnect capacity will continue to generate demand for dielectric and metal CVD systems. ASP growth will also contribute to revenue growth, as more highly integrated systems with improved productivity and particle control appear in the marketplace. Advanced dielectric deposition systems utilizing HDP sources have been introduced and will gain momentum for intermetal dielectric (IMD) applications for sub-0.5 micron processes. Metal CVD will continue to exhibit strong growth, driven by blanket tungsten for contact and via plugs. For these reasons, the forecast for nontube CVD systems outperforms tube furnaces.

Sputter deposition systems are forecast to grow at an annualized rate of 12.6 percent for the years 1995 through 2001. As in the case of dry etch and CVD equipment, continued expansion of multilevel interconnect process capacity is the primary driver behind sputter system growth. Rapid growth in average system ASP has helped to drive total revenue growth prior to 1995, primarily from the quick and expanding dominance of Applied Materials in the market. With Applied now accounting for more than 50 percent of the market, the bulk of the ASP increases are behind us. Changes in system architecture, pioneered by the Applied Materials Endura system, will continue to yield improvements in film properties, equipment productivity, and defect density. This is a market segment that will be somewhat buffered from a slowdown in DRAM investment, as the fundamental growth in the number of metal layers in ASICs and logic devices drive a more stable outlook.

The need for single-wafer epitaxial systems has been the primary driver on epitaxial deposition systems, as the need for 200mm epitaxial wafer capacity for CMOS logic applications was needed. However, this capacity is more expensive than wafer suppliers would like, so we expect the concept of "minibatches" to emerge as a viable production strategy, as it has in CVD. Moore Technologies is known to have such a product on the market, but has yet to be widely accepted in the market. A strong automotive, power, and discrete device market has increased demand for the specialty batch units, and growth in this segment actually exceeded CMOS logic in 1995 and continued to be strong in early 1996. There are clear indications that epitaxial layers will be required for some 64Mb DRAMs (see Chapter 4). This, along with an increased product mix of logic semiconductors at 200mm wafer capacity, and sustained demand for discrete devices and power ICs will be the primary drivers for epitaxial deposition equipment growth. In fact, epitaxial reactors are expected to be a star performer with an average annual growth of 19.5 percent, and will be somewhat insulated from the near-term slowdown. We believe the subsegment of 200mm systems will actually grow through the 1997 contraction.

Thermal Nondeposition Processes: Diffusion and RTP

Diffusion systems are expected to demonstrate a CAGR of only 9.7 percent for 1995 through 2001. Newer vertical systems will be configurable as multitube clusters with integrated dry clean capability, to compete with single wafer cluster tools. Tube systems will also incorporate small batch capabilities to offer greater flexibility for custom and semicustom circuit manufacturers. Diffusion tubes are growing significantly slower than the market for two reasons. First, RTP processes are slowly penetrating steps that had been done by the tube furnace. While we believe this penetration will remain slow until a change to 300mm wafers, RTP will keep diffusion tube market growth below average. Second, and more serious in the near term, is the prospect of recently developed high voltage implant schemes actually starting to replace diffusion steps in logic processes.

RTP is expected to grow at an annualized rate of 22.9 percent for 1995 through 2001. This market grew much faster than we anticipated, nearly doubling in 1994 and slightly more than doubling in 1995. The growth in 1994 was primarily fueled by the growing acceptance of self-aligned silicide processes in logic process flows. The growth in 1995 comes from new offerings in the market from Applied Materials, CVC, and Mattson, and from the expansion of the application into traditional tube diffusion steps. The real growth for this segment will come from transitioning of the thermal "nondepositing" processes away from diffusion tubes and into single-wafer RTP systems for 300mm wafers. We have factored in a large complement of systems into initial 300mm facilities starting in late 1997, largely contributing to the higher-than-the-market growth. RTP systems are primarily used today for salicide anneals, and some implant drive-ins, and are primarily driven by logic and ASIC capacity.

Dataquest believes that batch tube systems will continue to resist penetration by RTP in areas such as well drive, BPSG reflow, and thermal oxidation because of the demonstrated cost of ownership benefits in these areas, at least through 200mm wafers. For 300mm wafers, there will also be a strong desire on the part of the semiconductor manufacturer to continue to use the batch tube systems, as these systems offer much better cost efficiencies.

Ion Implantation

Overall ion implantation system revenue is forecast to grow at a CAGR of 15.5 percent for the years 1995 through 2001. This market segment will continue to be one of the most volatile, because of the highly device specific nature of the implant segments and of the dependence on new fab capacity for unit growth. The fastest-growing segment is expected to be high energy implantation, which is evoking intense interest because of its potential for process simplification and manufacturing cost reduction. The first year of true production ramp is expected to occur in 1998 as 0.4-micron technologies become mainstream, although early adopters such as Samsung have placed high-voltage implant into 16Mb DRAMs. A recent process developed by Genus is attracting attention and gaining acceptance in logic processing, offering a technique to laterally isolate transistors. Near term, high voltage systems will decline in sales because of the current dependence on the DRAM market.

New implant systems will continue to offer improvement in uniformity, particle control, charging, and wafer throughput. The number of implant steps requiring medium current ion sources is expected to grow faster than high dose implant steps, again driven by the higher worldwide semiconductor logic component, with the shallow junctions preferentially driving the trend toward medium current implants.

However, our forecast does not reflect this trend, with medium current implant sales lagging the market with only 9.7 percent CAGR. Why? Recently Eaton, Applied Materials, and Genus have introduced expanded capability to existing systems or new systems that are targeted to compete in more than one segment. For example, Applied Materials' 9500 systems now basically have a range to cover both high current and medium current capabilities, and Genus' new 1520 model expands the range effectively across high voltage and medium current. Traditional batch medium current systems are effectively being "squeezed" out of the market. This is occurring because equipment utilization for implanters tend to be among the lowest in the fab. Semiconductor manufacturers, in an effort to increase utilization and reduce cost, are tending to buy equipment with broader ranges.

There are medium current applications that will still require dedicated medium current systems, namely high-tilt (greater than 42 degrees) implants and V_T adjustment implants. However, these will be better executed using implanters with single wafer end stations rather than the traditional batch systems.

Dataquest is investigating the "redefinition" of ion implant segments in order to better capture this market dynamic, as well as segment the components of the high-voltage implant segment into its well structure application (which performs implants at the 700- to 800-keV range) and the lateral isolation application (requiring implant energy greater than 1.5 MeV).

Segments That Will Fare Best the Next Two Years

During the coming slowdown, there will be two kinds of purchasing behaviors that equipment companies can take advantage of to buffer them from sales declines. The first behavior is tied to what types of capacity will be required early in the recovery cycle. While logic capacity will be a larger part of the mix, only advanced technology in the logic area is expected to grow during 1997, as well as equipment that supplies the maskmaking industry. Included in this category are the segments of nontube CVD, silicon epitaxy, maskmaking lithography, process control systems in the materials business, and RTP.

The second purchasing behavior that will be prevalent over the next 18 months will be new processes and equipment directed at solving issues for 0.35-micron and 0.25-micron manufacturing. By no means will this listing be complete, but we will highlight a few of these areas here.

The movement to deep-UV lithography will pick up steam through this slowdown. The unit forecast for deep-UV steppers is for more than 360 systems to ship in 1998, up from the 105 or so shipped during 1996.

There are several equipment segments that will benefit from this movement—those inspection and process control systems which must operate in the deep-UV wavelength in order to detect defects and materials on the surface of the wafer, namely, mask inspection and thin-film measurement equipment. Thin-film measurement is key to intra- and interlevel metal interconnect, and storage capacitance applications. Thin-film measurement systems are used in-line to monitor the in etch, lithography (photoresist), deposition, and diffusion steps. Although this market was driven by logic applications more than memory production, in the past several years DRAM manufacturers have begun integrating thin-film measurement stations into their process lines.

Chemical mechanical polishing systems are becoming more robust and able to meet tighter specifications. Japanese and Asian companies are just beginning to investigate these systems. While dielectric CMP is relatively common, metal CMP is still emerging. Above three levels of metal, it becomes more beneficial to implement a metal CMP step to the process.

Gap fill dielectric CVD has been a highly competitive development arena. Novellus Systems appears to have product momentum with its Speed product line. We believe this product area offers a way for companies to effectively buffer the current slowdown.

Silicon epitaxial reactors will benefit from the conversion and ramp of the industry in 200mm wafers, as wafer suppliers have to retool their epitaxial capability. Also the possible increased use of epitaxial layers for advanced DRAMs means increased need for epitaxial reactors.

Wafer cleaning systems can also offer an area where a company's technology can shine. The recent announcement by Steag AG in Germany of its vapor dryer was built into a successful strategy when the company sold these systems as part of an integrated automated wet clean station. Wafers are placed in the dryer system after a wet cleaning process to dry, but do not spin. Instead, they are pulled from a bath of IPA/water in a controlled fashion into an IPA vapor atmosphere. As the wafer is pulled out, the liquid sheets off the surface in such a way to not leave any water spots, which often hold killer residue defects. The concept of automating cleaning processes will be a key product issues over the next few years. Spray processors also address the key cost issue of chemical use per square inch of silicon. These systems may be more common in 300mm fabs.

Dataquest Perspective

Overcapacity has gripped the industry and 1996 was a year that turned from growth to decline, but net was just under 12 percent growth in wafer fab equipment. We saw two distinctly different markets in the past year. The first half was marked by many fab announcements, aggressive spending plans, and good bookings levels for equipment. The second half was the opposite: bookings collapsed, expansions were delayed, and capital spending budgets cut.

The only reason 1996 remains a double-digit growth year is that there were strong backlogs coming out of 1995. The bookings decline has put pressure on backlog levels, and the industry has shipped down backlog now to more normal levels, with several companies below normal. However we anticipate that equipment companies, in the hope of improved bookings later in the year, will continue to ship down backlog in order to maintain a minimum financial performance, maintaining the run rates of fourth quarter 1996. We expect to reach a minimum three-month level backlog by the middle of the year 1997. At that time, with backlogs razor thin, quarterly shipment rates are expected to be reduced to booking levels, leading to a sales dip in third quarter 1997.

We do not expect sustainable bookings growth to support shipment growth until the second quarter of 1998, and shipment growth is expected to remain constrained until very late in the year, keeping 1998 a single-digit growth year. We would expect supply/demand dynamics to be fully corrected by early 1999, driving a robust resumption of growth with the wafer fab equipment market growing to over $33 billion in the year 2000, from the just under $19 billion in 1998.

We believe the market in 1997 and early 1998 will concentrate on advanced technology equipment. A purchasing behavior that will be prevalent in the near term will be new processes and equipment directed at solving issues for 0.35-micron and 0.25-micron manufacturing. These segments will be those related primarily to deep-UV lithography, silicon epitaxy, maskmaking equipment, 300mm technologies, and 0.25-micron multilevel metallization process schemes.

We have factored in an infrastructure investment in equipment for late 1997 through 1999, which will affect the forecast size of the markets positively. This additional investment will be for initial equipment to fill a couple 300mm fabs to run silicon by 1999. However, our outlook for a significant 300mm equipment market will wait until well after 2000.

Chapter 4
Silicon Wafer Forecast

Dataquest's current forecast for regional silicon wafer demand reflects significant silicon wafer growth during the first half of 1996 similar to 1995, with a significant slowdown in the second half of 1996 carrying over into 1997. This slowdown is expected to be short-lived as strong semiconductor unit growth coupled with the essential completion of the migration from the 4Mb DRAM to the 16Mb DRAM. Our latest forecast, along with highlights of some of the key factors affecting the regional markets, is presented here.

Silicon Forecast Tables

Tables in this chapter include Dataquest's most recent forecasts of regional unit silicon wafer consumption. Three tables (4-1 through 4-3) detail unit consumption by region. Individual forecasts of major product segments such as prime, epitaxial, and test and monitor wafers are included. For the first time in this publication, the merchant epitaxial wafer market is forecast by application (Table 4-3). Also five tables (4-4 through 4-8) of worldwide and regional forecasts for wafer size distribution are presented.

Silicon Wafer Revenue Forecast

Table 4-9 contains the revenue forecast for silicon wafers worldwide. Our methodology takes the wafer size distribution forecast in Table 4-4 and multiplies this matrix by our view of wafer price trends and test wafer consumption trends (by wafer size) in the forecast horizon. We do not publish our specific wafer price forecast, but do make comments on trend outlooks from time to time. For the first time, we have broken out the polished and epitaxial wafer components of the revenue forecast, and is consistent with how Dataquest has been collecting revenue information since 1985.

In our analysis, we have concluded that the revenue forecast would resemble the semiconductor industry more closely than the capital spending markets. The concept of semiconductor revenue per square inch is more closely tied to silicon consumption than raw wafer capacity of the industry, although this metric is cyclical. The six-year CAGR of 16.2 percent is slightly higher than the semiconductor forecast of 13.9 percent. This is somewhat contrary to the conventional model that semiconductor manufacturers will attempt to control the costs associated with manufacturing, which includes using silicon more efficiently in the future, which would tend to keep the growth rate of silicon revenue slightly below that of the semiconductor revenue. Yet, our forecast does not reflect this, primarily because the industry is migrating seriously over the next several years to 200mm wafers, which have a silicon wafer revenue per square inch significantly higher than the smaller wafer sizes. Further, the migration toward epitaxial wafer use, however slight, will also tend to favor higher silicon market growth relative to semiconductors. Therefore, the mix shift will tend to increase the growth rates in revenue, bringing the forecast at a slightly higher level to the semiconductor growth rates.

Table 4-1
Forecast of Captive and Merchant Silicon* and Merchant Epitaxial Wafers by Region (Millions of Square Inches)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Worldwide Total Silicon + Epi	2,907.6	3,523.8	3,777.5	4,048.2	4,600.8	5,252.6	6,009.0	6,625.1	11.1
Merchant Prime Polished Silicon	1,869.2	2,271.4	2,307.4	2,348.3	2,631.5	3,025.7	3,428.8	36,64.5	8.3
Merchant Prime Epitaxial Silicon	359.7	477.4	559.6	635.3	754.4	865.1	1,110.7	13,82.7	19.4
Captive Silicon	147.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	0.0
Merchant Virgin Test and Monitor	531.7	701.0	836.5	990.6	1,140.9	1,287.8	1,395.5	15,03.9	13.6
Americas Total Silicon + Epi	829.0	943.1	1,063.5	1,158.2	1,323.5	1,515.9	1,691.4	1,856.4	11.9
Merchant Prime Polished Silicon	440.0	485.0	534.1	573.3	640.0	754.0	845.1	895.0	10.8
Merchant Prime Epitaxial Silicon	172.3	226.5	266.5	297.4	343.7	381.9	449.9	538.2	15.5
Captive Silicon	87.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	0.0
Merchant Virgin Test and Monitor	129.7	182.6	213.9	238.5	290.8	331.0	347.4	374.2	12.7
Japanese Total Silicon + Epi	1,277.9	1,483.4	1,502.2	1,588.4	1,764.5	1,961.8	2,221.3	2,417.9	8.5
Merchant Prime Polished Silicon	878.1	1,036.6	982.9	958.8	1,050.5	1,154.7	1,265.4	1,320.6	4.1
Merchant Prime Epitaxial Silicon	111.8	137.1	159.0	182.1	222.7	268.0	382.5	489.9	23.6
Captive Silicon	42.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	0.0
Merchant Virgin Test and Monitor	246.0	287.7	338.3	425.5	469.3	517.1	551.4	585.4	12.6
European Total Silicon + Epi	353.8	457.7	519.3	562.4	641.1	729.2	841.6	903.1	12.0
Merchant Prime Polished Silicon	222.4	281.4	303.6	317.1	349.3	401.0	449.5	462.0	8.6
Merchant Prime Epitaxial Silicon	57.3	86.1	109.4	123.3	145.3	159.6	197.0	227.9	17.6
Captive Silicon	6.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0
Merchant Virgin Test and Monitor	68.1	87.2	103.3	119.0	143.5	165.6	192.1	210.2	15.8
Asia/Pacific Total Silicon + Epi	446.9	639.6	692.5	739.2	871.7	1,045.7	1,254.7	1,447.7	14.6
Merchant Prime Polished Silicon	328.7	468.4	486.8	499.1	591.7	716.0	868.8	986.9	13.2
Merchant Prime Epitaxial Silicon	18.3	27.7	24.7	32.5	42.7	55.6	81.3	126.7	28.8
Captive Silicon	12.0	0	0	0	0	0	0	0.0	NA
Merchant Virgin Test and Monitor	87.9	143.5	181.0	207.6	237.3	274.1	304.6	334.1	15.1

NA = Not applicable
*Includes prime, test, and monitor wafers
Source: Dataquest (January 1997)

Table 4-2
Forecast Growth Rates of Captive and Merchant Silicon* and Merchant Epitaxial Wafers by Region (Percentage of MSI)

	1994	1995	1996	1997	1998	1999	2000	2001
Worldwide Total Silicon + Epi	18.9	21.2	7.2	7.2	13.7	14.2	14.4	10.3
Merchant Prime Polished Silicon	16.5	21.5	1.6	1.8	12.1	15.0	13.3	6.9
Merchant Prime Epitaxial Silicon	26.0	32.7	17.2	13.5	18.7	14.7	28.4	24.5
Captive Silicon	17.6	-49.7	0	0	0	0	0	0
Merchant Virgin Test and Monitor	23.2	31.8	19.3	18.4	15.2	12.9	8.4	7.8
Americas Total Silicon + Epi	15.6	13.8	12.8	8.9	14.3	14.5	11.6	9.8
Merchant Prime Polished Silicon	9.5	10.2	10.1	7.3	11.6	17.8	12.1	5.9
Merchant Prime Epitaxial Silicon	28.1	31.5	17.7	11.6	15.6	11.1	17.8	19.6
Captive Silicon	17.6	-43.7	0	0	0	0	0	0
Merchant Virgin Test and Monitor	21.6	40.8	17.1	11.5	21.9	13.8	5.0	7.7
Japanese Total Silicon + Epi	12.7	16.1	1.3	5.7	11.1	11.2	13.2	8.9
Merchant Prime Polished Silicon	11.9	18.1	-5.2	-2.5	9.6	9.9	9.6	4.4
Merchant Prime Epitaxial Silicon	16.0	22.6	16.0	14.5	22.3	20.3	42.7	28.1
Captive Silicon	13.5	-47.6	0	0	0	0	0	0
Merchant Virgin Test and Monitor	13.8	17.0	17.6	25.8	10.3	10.2	6.6	6.2
European Total Silicon + Epi	22.2	29.4	13.5	8.3	14.0	13.7	15.4	7.3
Merchant Prime Polished Silicon	14.2	26.5	7.9	4.4	10.2	14.8	12.1	2.8
Merchant Prime Epitaxial Silicon	37.4	50.3	27.1	12.7	17.8	9.8	23.4	15.7
Captive Silicon	20.0	-50.0	0	0	0	0	0	0
Merchant Virgin Test and Monitor	41.3	28.0	18.5	15.2	20.6	15.4	16.0	9.4
Asia/Pacific Total Silicon + Epi	46.3	43.1	8.3	6.7	17.9	20.0	20.0	15.4
Merchant Prime Polished Silicon	47.5	42.5	3.9	2.5	18.6	21.0	21.3	13.6
Merchant Prime Epitaxial Silicon	41.9	51.4	-10.8	31.6	31.4	30.2	46.2	55.8
Captive Silicon	33.3	-100.0	NA	NA	NA	NA	NA	NA
Merchant Virgin Test and Monitor	45.0	63.3	26.1	14.7	14.3	15.5	11.1	9.7

NA = Not applicable
*Includes prime, test, and monitor wafers
Source: Dataquest (January 1997)

Table 4-3
Merchant Epitaxial Silicon Demand by Application, 1994-2001 (Millions of Square Inches)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Worldwide Total Epitaxial Silicon	359.5	477.4	559.5	635.3	754.4	865.1	1,110.7	1,382.8	19.4
CMOS Logic/Bipolar/Flash	241.3	296.0	374.4	404.9	453.9	508.8	576.2	633.0	13.5
Discrete	112.7	171.9	164.7	185.5	227.1	215.2	302.8	343.1	12.2
DRAM	5.5	9.6	20.5	45.0	73.4	141.1	231.7	406.7	86.8
Americas Total Epitaxial Silicon	172.3	226.5	266.5	297.4	343.7	381.9	449.9	538.2	15.5
CMOS Logic/Bipolar/Flash	140.2	177.4	214.4	230.2	256.6	283.9	319.1	349.4	12.0
Discrete	26.6	42.3	40.6	45.6	55.9	52.9	74.5	84.4	12.2
DRAM	5.5	6.8	11.5	21.6	31.3	45.1	56.3	104.4	57.6
Japanese Total Epitaxial Silicon	111.8	137.1	159.0	182.1	222.7	268.0	382.5	489.9	23.6
CMOS Logic/Bipolar/Flash	52.1	51.8	74.9	79.3	86.8	94.7	106.5	118.4	14.8
Discrete	59.6	85.4	81.3	91.2	111.0	104.5	146.1	164.9	11.6
DRAM	-	-	2.8	11.7	24.9	68.8	129.8	206.7	NM
European Total Epitaxial Silicon	57.3	86.1	109.4	123.3	145.3	159.6	197.0	227.9	17.6
CMOS Logic/Bipolar/Flash	34.5	46.0	67.1	71.8	80.2	90.9	103.7	104.0	14.6
Discrete	22.8	37.5	36.7	41.4	51.0	48.5	68.6	78.0	13.0
DRAM		2.5	5.6	10.1	14.1	20.2	24.8	45.8	62.1
Asia/Pacific Total Epitaxial Silicon	18.3	27.7	24.7	32.5	42.7	55.6	81.3	126.7	28.9
CMOS Logic/Bipolar/Flash	14.5	20.7	18.0	23.7	30.3	39.2	46.8	61.1	19.7
Discrete	3.7	6.7	6.1	7.2	9.3	9.3	13.7	15.8	15.4
DRAM	-	0.2	0.6	1.6	3.1	7.1	20.8	49.8	144.1

NM = Not meaningful
Source: Dataquest (January 1997)

Table 4-4
Worldwide Wafer Size Distribution Forecast, 1994-2001 (Percentage Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1994	1995	1996	1997	1998	1999	2000	2001
Percentage Square Inches by Diameter									
2 Inches	3.14	0.1	0.1	0	0	0	0	0	0
3 Inches	7.07	1.4	1.1	0.8	0.6	0.5	0.4	0.3	0.2
100mm	12.17	14.8	13.1	10.5	8.9	7.6	6.6	6.0	5.2
125mm	19.02	24.7	21.2	17.7	15.6	13.6	11.7	10.6	9.4
150mm	27.38	47.0	45.0	41.0	34.5	31.7	30.5	29.9	27.5
200mm	48.67	12.2	19.5	30.1	40.1	46.1	49.7	51.5	54.9
300mm	109.56	0	0	0	0.2	0.4	1.1	1.8	2.8
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		2,908	3,524	3,777	4,048	4,601	5,253	6,009	6,625
Growth (%)		18.9	21.2	7.2	7.2	13.7	14.2	14.4	10.3
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0.9	0.9	0.3	0.2	0.2	0	0	0
3 Inches	7.07	5.6	5.5	4.2	3.6	3.1	2.8	2.5	2.1
100mm	12.17	35.3	37.9	32.5	29.7	28.9	28.6	29.5	28.2
125mm	19.02	37.7	39.3	35.1	33.3	33.0	32.2	33.4	32.8
150mm	27.38	49.9	57.9	56.5	51.0	53.3	58.5	65.6	66.6
200mm	48.67	7.3	14.1	23.4	33.4	43.6	53.6	63.5	74.8
300mm	109.56	0	0	0	0.06	0.16	0.53	0.99	1.67
Total Wafers (M)		136.6	155.6	151.9	151.1	162.2	176.4	195.5	206.0
Average Wafer Diameter (Inches)		5.21	5.37	5.63	5.84	6.01	6.16	6.25	6.40

Source: Dataquest (January 1997)

Table 4-5
The Americas Wafer Size Distribution Forecast, 1994-2001 (Percentage Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1994	1995	1996	1997	1998	1999	2000	2001
Percentage Square Inches by Diameter									
2 Inches	3.14	0.1	0.1	0	0	0	0	0	0
3 Inches	7.07	1.1	1.0	0.8	0.6	0.5	0.4	0.3	0.3
100mm	12.17	20.5	17.7	14.0	12.2	10.7	9.4	8.5	7.6
125mm	19.02	22.3	19.2	16.5	14.6	12.0	10.0	9.2	8.2
150mm	27.38	42.8	40.1	39.4	38.0	34.9	33.6	33.0	33.0
200mm	48.67	13.2	21.9	29.3	34.4	41.5	45.4	47.3	48.3
300mm	109.56	0	0	0	0.2	0.4	1.2	1.7	2.6
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		829	943	1,064	1,158	1,324	1,516	1,691	1,856
Growth (%)		15.6	13.8	12.8	8.9	14.3	14.5	11.6	9.8
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0.3	0.3	0	0	0	0	0	0
3 Inches	7.07	1.3	1.3	1.2	1.0	0.9	0.9	0.7	0.8
100mm	12.17	14.0	13.7	12.2	11.6	11.6	11.7	11.8	11.6
125mm	19.02	9.7	9.5	9.2	8.9	8.4	8.0	8.2	8.0
150mm	27.38	13.0	13.8	15.3	16.1	16.9	18.6	20.4	22.4
200mm	48.67	2.2	4.2	6.4	8.2	11.3	14.1	16.4	18.4
300mm	109.56	0	0	0	0.02	0.05	0.17	0.26	0.44
Total Wafers (M)		40.4	42.9	44.4	45.8	49.1	53.4	57.8	61.6
Average Wafer Diameter (Inches)		5.11	5.29	5.52	5.68	5.86	6.01	6.10	6.19

Source: Dataquest (January 1997)

Table 4-6
Japan Wafer Size Distribution Forecast, 1994-2001 (Percentage Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1994	1995	1996	1997	1998	1999	2000	2001
Percentage Square Inches by Diameter									
2 Inches	3.14	0	0	0	0	0	0	0	0
3 Inches	7.07	1.4	1.1	0.8	0.7	0.5	0.4	0.3	0.2
100mm	12.17	10.4	9.5	8.2	7.2	6.4	5.6	5.1	4.5
125mm	19.02	29.4	26.4	22.0	20.4	18.8	16.9	15.4	14.0
150mm	27.38	49.8	49.7	46.5	35.6	33.8	33.9	34.9	31.9
200mm	48.67	9.0	13.3	22.5	35.8	39.9	41.6	41.8	45.5
300mm	109.56	0	0	0	0.3	0.6	1.6	2.5	3.9
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		1,278	1,483	1,502	1,588	1,765	1,962	2,221	2,418
Growth (%)		12.7	16.1	1.3	5.7	11.1	11.2	13.2	8.9
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0	0	0	0	0	0	0	0
3 Inches	7.07	2.5	2.3	1.7	1.6	1.2	1.1	0.9	0.7
100mm	12.17	10.9	11.6	10.1	9.4	9.3	9.0	9.3	8.9
125mm	19.02	19.8	20.6	17.4	17.0	17.4	17.4	18.0	17.8
150mm	27.38	23.2	26.9	25.5	20.7	21.8	24.3	28.3	28.2
200mm	48.67	2.4	4.1	6.9	11.7	14.5	16.8	19.1	22.6
300mm	109.56	0	0	0	0.04	0.10	0.29	0.51	0.86
Total Wafers (M)		58.8	65.5	61.7	60.4	64.3	68.9	76.1	79.1
Average Wafer Diameter (Inches)		5.26	5.37	5.57	5.79	5.91	6.02	6.09	6.24

Source: Dataquest (January 1997)

Table 4-7
European Wafer Size Distribution Forecast, 1994-2001 (Percentage Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1994	1995	1996	1997	1998	1999	2000	2001
Percentage Square Inches by Diameter									
2 Inches	3.14	0.1	0.1	0	0	0	0	0	0
3 Inches	7.07	0.7	0.6	0.4	0.2	0.2	0.1	0.1	0
100mm	12.17	20.5	20.0	15.4	11.8	9.3	8.0	7.4	6.3
125mm	19.02	21.7	18.7	14.2	11.3	9.8	7.6	7.0	6.3
150mm	27.38	43.0	41.3	39.7	37.2	32.7	30.8	27.1	24.0
200mm	48.67	14.0	19.3	30.3	39.5	47.8	52.7	57.0	61.2
300mm	109.56	0	0	0	0	0.2	0.8	1.4	2.2
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		354	458	519	562	641	729	842	903
Growth (%)		22.2	29.4	13.5	8.3	14.0	13.7	15.4	7.3
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0.1	0.1	0	0	0	0	0	0
3 Inches	7.07	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0
100mm	12.17	6.0	7.5	6.6	5.5	4.9	4.8	5.1	4.7
125mm	19.02	4.0	4.5	3.9	3.3	3.3	2.9	3.1	3.0
150mm	27.38	5.6	6.9	7.5	7.6	7.7	8.2	8.3	7.9
200mm	48.67	1.0	1.8	3.2	4.6	6.3	7.9	9.9	11.4
300mm	109.56	0	0	0	0	0.01	0.05	0.11	0.18
Total Wafers (M)		17.0	21.3	21.5	21.2	22.3	24.0	26.6	27.1
Average Wafer Diameter (Inches)		5.14	5.23	5.54	5.82	6.04	6.22	6.34	6.51

Source: Dataquest (January 1997)

Table 4-8
Asia/Pacific Wafer Size Distribution Forecast, 1994-2001 (Percentage Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1994	1995	1996	1997	1998	1999	2000	2001
Percentage Square Inches by Diameter									
2 Inches	3.14	0.4	0.2	0.1	0.1	0.1	0	0	0
3 Inches	7.07	2.2	1.6	1.0	0.8	0.6	0.5	0.4	0.3
100mm	12.17	12.0	9.7	6.2	5.3	4.3	3.6	3.2	2.5
125mm	19.02	17.8	14.0	12.7	10.3	8.5	7.1	6.3	5.2
150mm	27.38	49.7	44.0	32.3	24.5	22.0	19.5	18.6	15.4
200mm	48.67	17.9	30.5	47.7	59.0	64.5	69.0	70.5	75.2
300mm	109.56	0	0	0	0	0	0.3	1.0	1.4
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		447	640	693	739	872	1,046	1,255	1,448
Growth (%)		46.3	43.1	8.3	6.7	17.9	20.0	20.0	15.4
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0.6	0.4	0.3	0.2	0.2	0	0	0
3 Inches	7.07	1.4	1.4	1.0	0.8	0.7	0.7	0.7	0.6
100mm	12.17	4.4	5.1	3.5	3.2	3.1	3.1	3.3	3.0
125mm	19.02	4.2	4.7	4.6	4.0	3.9	3.9	4.2	4.0
150mm	27.38	8.1	10.3	8.2	6.6	7.0	7.4	8.5	8.1
200mm	48.67	1.6	4.01	6.8	9.0	11.6	14.8	18.2	22.4
300mm	109.56	0	0	0	0	0	0.03	0.11	0.18
Total Wafers (M)		20.3	25.9	24.4	23.8	26.4	30.0	35.0	38.2
Average Wafer Diameter (Inches)		5.29	5.60	6.01	6.29	6.48	6.66	6.76	6.94

Source: Dataquest (January 1997)

Table 4-9
Worldwide Merchant Silicon Wafer Revenue Forecast, 1994-2001 Includes Polished, Virgin Test, and Epitaxial Silicon (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Polished Silicon*	3,252	4,483	5,217	5,421	6,259	7,439	8,665	9,860	14.0
Percentage Growth	26.2	37.9	16.4	3.9	15.5	18.8	16.5	13.8	
Epitaxial Wafers	1,331	1,815	2,188	2,397	2,836	3,352	4,438	5,680	20.9
Percentage Growth	35.0	36.4	20.5	9.6	18.3	18.2	32.4	28.0	
Worldwide	4,583	6,298	7,405	7,818	9,095	10,790	13,103	15,540	16.2
Percentage Growth	28.6	37.4	17.6	5.6	16.3	18.6	21.4	18.6	

*Includes prime and virgin test/monitor wafers
Source: Dataquest (January 1997)

Our revenue forecast has factored an 8 to 10 percent price decline for wafers starting in 1997. However, product migration to 200mm wafers and a higher epitaxial wafer mix will mostly offset this price decline on a per-square-inch basis. These same mix issues will continue to move toward higher silicon manufacturer revenue per square inch, resulting in a CAGR for revenue five points higher than the area CAGR.

Silicon Unit Forecast Overview

We anticipated that the second half of 1996 would be weaker in silicon demand, based on the migration from 4Mb to 16Mb DRAMs mentioned in earlier forecasts. However, starting about August, the silicon market flat out collapsed, with run rates by the end of 1996 about 20 percent below those of just six months earlier. These dynamics can mostly be explained by the activities in the DRAM market and inventory trends. As a result, the long-term absolute MSI shipment level was reduced about 5 percent compared to our last forecast, with the six-year CAGR at 11.1 percent.

As we have noted in prior publications, the industry migration from 4Mb to 16Mb DRAMs would cause a dramatic reduction in the amount of silicon required per bit. Die size relationships mean that the average 16Mb DRAM has two to three times more bits per square inch than the 4Mb generation. Even in the face of high bit demand growth, the industry does typically see a short period of time in which square inch requirement actually decreases.

This means that wafer starts should actually decline for a period of two to three quarters as a result of this silicon efficiency. Indeed, this can be shown to be true, as we have performed a quarterly analysis of the relative square inch consumption by the DRAM market. These normalized figures are shown in Table 4-10.

As Table 4-10 illustrates, 14 percent less silicon is required in third quarter 1996 compared with fourth quarter 1995 to support a higher DRAM bit demand. Also, not taking inventories into consideration, wafer starts should have declined into the DRAM sector during first quarter 1996. Naturally, this did not happen.

Table 4-10
Relative Silicon Area Consumed by DRAM, Fourth Quarter 1995 through 1997

	Q4/95	Q1/96	Q2/96	Q3/96	Q4/96	Q1/97	Q2/97	Q3/97	Q4/97
Percentage of Q4/95 Wafer Area Consumption Rate	100.0	89.1	86.1	86.0	97.5	99.2	106.0	120.9	132.8
Ratio of 16Mb versus 4Mb (Units)	0.30	0.50	0.63	0.87	1.15	1.55	2.09	2.76	3.37

Source: Dataquest (January 1997)

Optimism about demand for DRAM and fear of a silicon shortage meant DRAM manufacturers continued to produce in the first half, expanding DRAM chip and wafer bank inventories as well as keeping inventories of raw silicon wafers high. This corrected during third quarter 1996. Silicon area growth for 1996 will end up at about 7 percent growth, in terms of MSI.

Theoretically, silicon consumption into the DRAM sector should be recovering now. However, actual shipments from wafer manufacturers will lag by four to six months as inventories are worked down. We do expect recovery in silicon MSI shipment growth by the middle of 1997. Our quarterly model into the DRAM sector suggests run rates by fourth quarter 1997 should be 20 to 30 percent higher than current depressed levels. Our MSI growth forecast overall for 1997 is just over 7 percent. With end-use semiconductor and electronic equipment demand strengthening, we would expect accelerated growth in silicon consumption starting in the middle of 1997 and returning to double-digit MSI growth rates in 1998.

The 200mm Wafer Ramps Up—Suppliers Have Responded with Capacity

Dataquest has been studying the subject of 200mm wafers and their ramp rate closely over the last three years, particularly in light of the massive announcements in fab capacity and requirement through the rest of the decade. We are expecting more than 200 fabs will be online by the year 2000 processing 200mm wafers. Future demand for 200mm product wafers has been affected positively by the semiconductor industry's excess capacity, and have not been reduced significantly since our last forecast in mid-1996. Why? Semiconductor companies now have some time to convert 150mm fabs to the more cost-effective 200mm wafers. This has added incremental product wafer demand to the industry at 200mm wafers. A large factor in 200mm demand, the consumption of test wafers, has remained essentially unchanged since our last update. The industry average is about one test wafer per seven product wafers for sizes below 200mm. By the year 2000, we now expect this ratio to be one test wafer for per over three product wafers at 200mm.

Wafer suppliers have answered the need with several new wafer plants and billions of dollars of committed investment during 1996. We continue to believe that the ramp of 200mm wafers will be supply constrained from time to time through the decade, although the faster-than-anticipated conversion to the 16Mb DRAM will mean adequate supply to meet demand in 1997 and 1998. While we are stopping short of calling a shortage of 200mm wafers to the point of restricting ramp-up plans, we would expect buyers of wafers will experience firm to rising prices again by 1999, and may be placed on allocation from time to time.

What about 300mm Wafers?

There has been a significant amount of activity in 300mm wafer development recently. A new consortium of Japanese companies, Selete (Semiconductor Leading Edge Technologies Inc.), has been formed to spearhead the 300mm technology development. We understand equipment began shipping into the clean room setup at a facility made available by Hitachi during the second half of 1996. SEMATECH has also coordinated an effort that has companies participating from other regions outside of Japan, called the International 300mm Initiative (I300I). I300I recently completed a survey that concluded that there would be as many as 11 pilot facilities on line running 300mm wafers by the year 2000, the majority starting during 1999. Although we believe that many companies have committed internally to build such pilot plants, it was only very late in 1996 where the first public announcement took place. Surprisingly the plant is to be located in Europe, a Texas Instruments facility in Italy, to be specific. We believe that during the first half of 1997, many more such announcements will be made, with most of the activity centered in Japan.

Silicon wafer manufacturers have noticeably ramped commitment, as at least five different companies have announced or have committed to dedicated pilot lines for 300mm wafer production. Sample volumes have been available for a couple of years already. The earliest of these starts production in late 1997, with the latest coming on during 1999.

We believe the first commercially productive plant will be started in the 2001 through 2003 time frame (after the feasibility noted above), with serious volume ramp up in the years 2003 through 2005. This would be consistent with shrink 0.25-micron technology being primarily produced on 300mm wafers. This means that 200mm wafers represent at least a two technology generation wafer size, and fabs being built today may have longer lives than history would indicate.

Our current forecast reflects the increased activity at the R&D and pilot facility level, and is likely somewhat conservative. Prices are still being quoted in the $1,000 to $1,300 per wafer area for mechanical test samples with prime quality wafers still significantly higher. This market is expected to be supply constrained for quite some time.

Further details and issues regarding the move toward 300mm wafers will be included in a Dataquest Perspective newsletter in the next couple of months.

Epitaxial Wafer Trends: Are DRAMs in the Future?

Sales of merchant epitaxial wafers by the wafer suppliers accounted for 477 MSI in 1995. About 62 percent of these wafers were used for CMOS logic applications while only 2 percent were used for DRAM products. The remainder were shipped into the power/discrete device segments. By the year 2000, Dataquest expects that fully 21 percent of merchant epitaxial silicon will be used for DRAMs, primarily driven by two factors. The CMOS logic application remains dominant at 52 percent. The overall epitaxial wafer market will experience a 19.4 CAGR from 1995 through 2001.

First, trench capacitor designs benefit from the use of epitaxial silicon. It is believed that both IBM and Siemens are currently using epitaxial silicon while Toshiba has been using hi-wafers (wafers that include a hydrogen bake surface treatment to reduce surface contamination) to improve the performance of their trench capacitor design. We believe that, for late-generation shrink versions of 16Mb and for 64Mb DRAMs, companies that employ the trench design (which include the companies noted plus Texas Instruments and affiliated fabs, perhaps including Hitachi) will need to use epitaxial silicon.

Second, even in the stacked capacitor design, some companies (primarily in Japan) are finding that epitaxial silicon can be used to enhance yield by eliminating the very localized silicon "pit" defect which has recently become important at the 0.25-micron level technology in larger wafers (200mm and 300mm). Fujitsu is believed to be seriously evaluating and nearly committed to the use of epitaxial silicon, and several other Japanese companies, including Matsushita and Oki, also have epitaxial silicon under consideration for DRAMs.

We will watch this area of device construction technology very closely over the next several years, as there is a distinct possibility that this need for epitaxial silicon will be a single-generation need. At the 0.18-micron generation, the use of other capacitor dielectrics and electrode materials may enable companies to return to planar or simple stack structures, perhaps eliminating the driving need for the epitaxial layer.

Our semiconductor manufacturing analyst in Japan is currently preparing a Perspective newsletter that will describe the issues and offer a low-end and high-end forecast for epitaxial wafer use in the DRAM segment.

Update of Historical Merchant Epitaxial Market Estimates

From time to time, Dataquest refines forecast and data collection methodologies in order to provide greater value to our clients. Whenever we implement these changes, we run the risk of the new model adding new information, which requires we restate historical figures. With the implementation of new data collection methods with regard to the power/discrete segment, and an updated forecast model for CMOS logic, Dataquest has restated the merchant epitaxial wafer MSI figures back to 1991. These changes will be reflected fully in the Silicon Market Share publication expected for a June 1997 release.

Highlights of the North American Silicon Wafer Market and Forecast

Silicon consumption in North America is forecast to grow 13 percent in 1996 to 1,064 MSI, and we expect a more mild 9 percent growth in 1997. Microprocessor and other logic chip demand have been and will continue to be key drivers behind increased silicon demand in North America, and epitaxial wafer demand will be focused on CMOS logic.

Merchant epi wafer consumption increased 17 percent in 1996 to 267 MSI, driven in large part by microprocessor manufacturers, such as Intel and AMD, which build their microprocessors on epi wafers. Weakness in the automotive and discrete segments of the chip market significantly slowed the market compared to 1995 growth levels. By 2000, epitaxial silicon will account for 27 percent of the square inches consumed in North America—the highest concentration in any region.

Dataquest's longer-term forecast for North American silicon consumption remains firm, primarily because we believe that the United States will attract a larger share of foreign multinational fabs, such as those currently being built by Hyundai, TSMC, Samsung, and others expected to be announced over the next couple of years. We are projecting that total silicon MSI will grow at an 11.9 percent CAGR for the time period 1995 through 2001.

Highlights of the Japanese Silicon Wafer Market and Forecast

Our Japan silicon consumption forecast calls for growth of just over 1 percent to 1,503 MSI in 1996 as the bottom fell out of the DRAM-sensitive region. We expect moderate growth of 6 percent in 1997, recovering to double-digit expansion again in 1998 as the industry completes its migration to 16Mb DRAMs.

Unlike North America, with its sizable CMOS epi wafer market, Japan's merchant epitaxial wafer market is more focused on discrete and bipolar applications today. However, future growth prospects may be more closely linked to the application in the DRAM device. Because we believe that a number of suppliers will migrate toward epitaxial silicon for shrink 64Mb DRAMs, Japan is among the fastest-growing epitaxial markets with a CAGR of over 23 percent. Near-term economic weakness, however, may put a lid on this growth, but we are still calling for an above average 14 percent growth for epitaxial demand in 1997, after a 16 percent growth in 1996, and a 23 percent increase in 1995.

Dataquest remains moderately conservative with its longer-term growth scenario for silicon wafer demand in general in Japan, as the country continues to work through the evolution of its semiconductor production infrastructure (seen as being too heavily dependent on the DRAM). Investment patterns during 1995 suggested that Japanese semiconductor manufacturers were willing to come to the table and invest, preserving their stake in the memory business against the Koreans; yet Japanese companies were among the first to pull back during 1996. Also, through the use of joint ventures and other alliances, we expect that Japanese company production will gradually depend less on domestic production. We are estimating that silicon demand will grow 8.5 percent CAGR for the years 1995 through 2001, the slowest growth of all regions.

Highlights of the European Silicon Wafer Market and Forecast

Demand for silicon wafers in Europe, as well as wafer fabrication equipment, remains heavily dependent on the fab activities of foreign semiconductor firms. With increased presence from European and Korean companies, the outlook for silicon consumption has brightened.

The European market grew 14 percent in 1995 to 519 MSI. European silicon demand will moderate significantly in 1997, to the 8 percent growth level. Siemens Dresden and other DRAM production, and multinationals

Intel, Motorola, Hyundai, LG Semicon, and Texas Instruments will continue to ramp to answer the demand in Europe, helping silicon consumption grow at healthy double-digit levels from 1998 through 2000. The long-term picture for Europe, with a 12 percent CAGR through the year 2001, places this region as the second fastest growing, narrowly outpacing North America.

Epitaxial wafer demand in the region increased dramatically in 1996 to 109 MSI, growing 50 percent. This has been a direct result of Intel in Ireland, Philips, IBM in France, and Siemens ramping DRAM production in Germany. In the near term, epitaxial wafer demand increases will come from predominantly European producers, primarily from the power/discrete. Later in the decade, the DRAM capacity ramps and the migration to epitaxial silicon in DRAMs from multinationals with fabs in Europe will drive the epitaxial market to a CAGR over nine percentage points above polished bare wafer consumption through the decade.

Highlights of the Asia/Pacific Silicon Wafer Market and Forecast

Silicon consumption grew at an 8 percent pace in 1996, as the DRAM cutbacks affected the region in the second half. This growth is somewhat misleading as about 70 percent of the growth came from test and monitor wafer consumption because of the larger mix of 200mm wafer consumption. DRAM overcapacity will continue to put a significant drag on demand in early 1997, with growth expected to be under 7 percent (with over half of the growth again in the test and monitor wafer). Past 1997, the trend will resume that Asia/Pacific will represent the fastest-growing region as DRAM driven consumption will return by 1998 and new fab projects will be revitalized beginning in 1999. The six-year CAGR forecast of 14.6 percent is 3.5 points over the worldwide market rate.

Epitaxial wafer consumption will grow at the fastest rate in the Asia/Pacific region as well with a CAGR of 29 percent. However, this comes from, and will remain, a low base of consumption. While the foundries will require a significant portion of their capacity to consume epitaxial wafers and remain the primary growth driver for epitaxial wafers in the region, the DRAM fabs in the region do not use epi wafers. With the exception of a few joint venture fabs, the epi consumption in Asia/Pacific DRAM capacity will remain quite low compared to other regions. Epitaxial wafer consumption will remain below 9 percent of total Asia/Pacific MSI by the year 2000 (compared to 18 percent worldwide).

Dataquest Perspective

We anticipated that the second half of 1996 would be weaker in silicon demand, based on the migration from 4Mb to 16Mb DRAMs mentioned in earlier forecasts. However, starting about August, the silicon market flat out collapsed, with run rates by the end of 1996 about 20 percent below those of just six months earlier. These dynamics can mostly be explained by the activities in the DRAM market and inventory trends. As a result, the long-term absolute MSI shipment level was reduced about 5 percent compared to our last forecast, with the six-year CAGR at 11.1 percent.

Theoretically, silicon consumption into the DRAM sector should be recovering now. However, actual shipments from wafer manufacturers will lag by four to six months as inventories are worked down. We do expect recovery in silicon MSI shipments by the middle of 1997. Our quarterly model into the DRAM sector suggests run rates by fourth quarter 1997 should be 20 to 30 percent higher than current depressed levels. Our MSI growth forecast overall for 1997 is just over 7 percent. With end-use semiconductor and electronic equipment demand strengthening, we would expect accelerated growth in silicon consumption starting in the middle of 1997 and returning to double-digit MSI growth rates in 1998.

The silicon market, driven by a strong long-term picture for semiconductor unit demand in general, will grow faster over the next six years than the last six years. As the industry transforms into a 200mm baseline, the outlook for silicon wafer manufacturers becomes brighter. Silicon manufacturers have answered the call for 200mm capacity, with significantly increased capital outlays. Activity in 300mm wafer development has accelerated, particularly in Japan with the Selete consortium. Increased visibility of I300I has also contributed to the first 300mm pilot fab announcement. We still expect only pilot volume activity in 300mm wafers through the year 2000.

Sales of merchant epitaxial wafers by the wafer suppliers accounted for 477 MSI in 1995. About 62 percent of these wafers were used for CMOS logic applications while only 2 percent were used for DRAM products. The remainder was shipped into the power/discrete device segments. By the year 2000, Dataquest expects that fully 21 percent of merchant epitaxial silicon will be used for DRAMs, primarily driven by two factors. The CMOS logic application remains dominant at 52 percent. The overall epitaxial wafer market will experience a 19.4 CAGR from 1995 through 2001.

The silicon market has become recognized again as being strategic in the semiconductor manufacturing infrastructure. Will this continue? We believe it will, as long as silicon suppliers continue to concentrate on value-add processes and techniques as the equipment manufacturers have done, as well as adequately and smartly plan capacity additions.

Chapter 5
Semiconductor Consumption Forecast

This chapter presents data on the worldwide semiconductor market by region. The regional semiconductor market, or regional semiconductor consumption, deals with where chips are consumed; this contrasts with regional semiconductor production, which deals with where chips are manufactured. The data presented here is for the merchant market and does not include the value of chips made by captive semiconductor manufacturers for internal use.

This is an excerpt from the Semiconductor Five-Year Forecast, published by Dataquest in October 1996 (SEMM-WW-MT-9603). Further details regarding this forecast can be found in that publication.

Yearly exchange rate variations can have a significant effect on the 1989 through 1996 data in the following tables. For more information about the exchange rates used and their effects, refer to Appendix B.

Semiconductor Consumption

Table 5-1 shows revenue and growth from semiconductor shipments for the years 1989 through 1995 broken down by region. Table 5-2 shows revenue and growth from semiconductor shipments for the years 1995 through 2001 broken down by region of consumption.

Table 5-1
Worldwide Semiconductor Consumption by Region—Historical; Includes Merchant Semiconductor Companies Only (Millions of Dollars)

	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Americas	17,070	16,540	16,990	20,430	27,926	35,939	48,349	18.9
Percentage Growth	7.7	-3.1	2.7	20.2	36.7	28.7	34.5	
Japan	21,491	20,257	22,496	20,579	24,645	31,010	42,164	11.9
Percentage Growth	3.5	-5.7	11.1	-8.5	19.8	25.8	36.0	
Europe, Middle East, and Africa	9,498	10,415	11,014	12,218	15,461	20,819	28,341	20.0
Percentage Growth	11.9	9.7	5.8	10.9	26.5	34.7	36.1	
Asia/Pacific	6,280	7,333	9,194	12,034	17,486	22,812	32,417	31.5
Percentage Growth	9.2	16.8	25.4	30.9	45.3	30.5	42.1	
Worldwide	54,339	54,545	59,694	65,261	85,518	110,580	151,271	18.6
Percentage Growth	6.8	0.4	9.4	9.3	31.0	29.3	36.8	

Source: Dataquest (January 1997)

Table 5-2
Worldwide Semiconductor Consumption by Region, Merchant Semiconductor Sales Only—Forecast (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Americas	48,349	44,177	50,440	62,330	79,222	97,714	112,469	15.1
Percentage Growth	34.5	-8.6	14.2	23.6	27.1	23.3	15.1	
Japan	42,164	36,574	40,476	48,368	58,842	70,483	78,095	10.8
Percentage Growth	36.0	-13.3	10.7	19.5	21.7	19.8	10.8	
Europe, Middle East, and Africa	28,341	27,136	29,642	34,951	42,225	53,099	60,214	13.4
Percentage Growth	36.1	-4.3	9.2	17.9	20.8	25.8	13.4	
Asia/Pacific	32,417	29,090	34,047	43,273	54,627	68,923	80,157	16.3
Percentage Growth	42.1	-10.3	17.0	27.1	26.2	26.2	16.3	
Worldwide	151,271	136,977	154,605	188,922	234,916	290,219	330,936	13.9
Percentage Growth	36.8	-9.4	12.9	22.2	24.3	23.5	14.0	

Source: Dataquest (January 1997)

Chapter 6
Semiconductor Production Forecast

This chapter presents data on the worldwide semiconductor production by region. Semiconductor production is defined by the place where the wafers are fabricated, and regional semiconductor production includes all production in the region, including merchant and captive producers, and all foreign producers. For instance, American semiconductor production includes Digital Equipment and Delco fabs as well as Japanese company and European company fabs in America.

Yearly exchange rate variations can have a significant effect on the data up to 1996 in the following tables. For more information about the exchange rates used and their effects, refer to Appendix B.

The semiconductor industry has a global manufacturing infrastructure. Production of semiconductors is constantly shifting among regions, as new capital money is flowing toward areas of relative lower capital cost, and higher growth areas of consumption. Dataquest reviews some of the trends, and potential impacts, for the future.

Historical Semiconductor Production

Table 6-1 shows the historical semiconductor production for the years 1989 through 1995 broken down by region. Dataquest follows a methodology that employs the use of our fab database, estimating the memory, microcomponent, logic, and analog/power/discrete production components separately, and estimating net production among regions for foundry activity. This approach provides insight in observing and forecasting production trends for front-end manufacturing.

Because of the reclassification of the MOS portion of IBM Microelectronics' business as merchant, the captive production figures changed dramatically in 1993. However IBM's bipolar production, which is consumed internally, is still classified as captive by Dataquest.

Captive Semiconductor Production

Semiconductor production from captive manufacturers is estimated to be $1.81 billion in 1995, down from just under $2 billion in 1994. IBM has restructured and entered the merchant semiconductor market as of 1993. Dataquest has reclassified IBM's MOS semiconductor production to merchant, but the bipolar products (exclusively used internally) are still reported as captive. This part of IBM's business will be converted to MOS over the next three to five years, and had resulted in a lower figure for captive production in 1995 and future years.

Many captive producers may consider the move to merchant to better take advantage of the worldwide growth of semiconductors, leveraging their sunk costs in plant and equipment for higher return in a larger end-user base. Still others may elect to take advantage of the now evolving and maturing foundry business, electing to contract out their manufacturing rather than invest in expensive new facilities for their relatively small production base. We have not, however, included any such movement to merchant or fabless in our captive production forecast. The four largest captive producers accounted for nearly 70 percent of the $1.81 billion in 1995. These producers are IBM (bipolar only), Delco Electronics, Digital Equipment, and Northern Telecom.

Clearly, the foundry industry is real and represents a key change in the semiconductor industry manufacturing infrastructure. We continue to expect U.S. companies in particular, both fabless and IDM companies, to continue to expand their use of foundries in Asia/Pacific and Japan for semiconductor manufacturing.

Table 6-1
Worldwide Semiconductor Production by Region—Historical; Merchant and Captive Semiconductor Company Sales (Millions of U.S. Dollars)

	1989	1990	1991	1992	1993	1994	1995	CAGR (%) 1989-1995
Total Americas	22,232	24,202	26,039	29,207	32,643	39,617	49,535	14.3
Merchant	18,464	20,453	22,275	24,998	30,942	37,887	47,882	17.2
Captive	3,768	3,749	3,764	4,209	1,701	1,730	1,653	-12.8
Percentage Growth	8.3	8.9	7.6	12.2	11.8	21.4	25.0	
Percentage Worldwide	37.6	40.8	40.4	41.5	37.3	35.2	32.4	
Total Japan	28,527	26,384	28,338	28,273	35,515	45,289	61,106	13.5
Merchant	28,119	25,977	27,925	27,914	35,515	45,289	61,106	13.8
Captive	408	407	413	359	0	0	0	-100.0
Percentage Growth	6.7	-7.5	7.4	-0.2	25.6	27.5	34.9	
Percentage Worldwide	48.2	44.5	44.0	40.1	40.6	40.3	39.9	
Total Europe, Middle East, and Africa	6,451	6,350	6,979	8,589	11,741	15,463	20,711	21.5
Merchant	5,782	5,723	6,396	7,957	11,421	15,243	20,551	23.5
Captive	669	627	583	632	320	220	160	-21.2
Percentage Growth	10.2	-1.6	9.9	23.1	36.7	31.7	33.9	
Percentage Worldwide	10.9	10.7	10.8	12.2	13.4	13.7	13.5	
Total Asia/Pacific	1,974	2,392	3,097	4,391	7,636	12,095	21,732	49.2
Merchant	1,974	2,392	3,097	4,391	7,636	12,095	21,732	49.2
Captive	NA	NA	NA	NA	NA	NA	NA	
Percentage Growth	5.7	21.2	29.5	41.8	73.9	58.4	79.7	
Percentage Worldwide	3.3	4.0	4.8	6.2	8.7	10.8	14.2	
Worldwide	59,184	59,328	64,453	70,460	87,535	112,464	153,084	17.2
Percentage Growth	7.6	0.2	8.6	9.3	24.2	28.5	36.1	
Merchant	54,339	54,545	59,693	65,260	85,514	110,514	151,271	18.6
Percentage Growth	6.8	0.4	9.4	9.3	31.0	29.2	36.9	
Captive	4,845	4,783	4,760	5,200	2,021	1,950	1,813	-15.1
Percentage Growth	17.4	-1.3	-0.5	9.2	-61.1	-3.5	-7.0	

NA = Not applicable
Source: Dataquest (January 1997)

The Move toward Asia Continues after a Pause, European Growth Rests

The production trends of the last three years may contain two or three surprises to some. Of no surprise is the strong growth in Asia/Pacific production, breaking over 14 percent of worldwide production in 1995. The strength in Asian DRAM producers and the emergence of the foundry market have been, and will continue to be, in the long term the key drivers in that growth. Expected regional capital spending and electronic equipment production will certainly keep this long-term production trend in place, however the dramatic price collapse in DRAM as well as foundry wafer pricing pressures have meant a temporary pause in the trend today.

European production has expanded from just under 11 percent of the semiconductors produced in 1991 to 13.5 percent in 1995. This is additionally remarkable in that the last four years have been good overall growth years, resulting in near tripling of the region's production in four years. Why the move to Europe? With the region's economies recovering and with the PC boom in the early 1990s, Europe has attracted PC production, particularly in the United Kingdom. Semiconductor production has moved along with the PC, with Intel and DRAM producers worldwide taking part. Also the acceleration of telecommunications related semiconductor production benefits the European companies. Dataquest believes that while multinationals will continue to invest heavily in Europe, the trend is currently in a holding pattern in part because of the concentration of current strategic spending growth in America, and the recent pause in growth of electronic equipment production.

There has been a significant relative decline in the percentage of the world's production being done in the United States. Over the last three years, North American production decreased from about 42 to 32 percent of the world's production overall. This is despite the fact that U.S. companies have increased their share of the worldwide semiconductor market in the same time period. Several factors are at work here. First, North American multinational companies have been investing heavily overseas. North America has been a net exporter of capital for several years now, as foreign companies have yet to balance the scales with investments inside the United States. This trend should stabilize over the next several years, as Japanese, Taiwanese, and Korean companies have started to accelerate their investment in the United States.

Second, while U.S. companies are recognized as technology leaders, they have recently begun calling upon foreign producers to manufacture their products in the foundry market. While fabless companies have been the key driver of the market to this point, starting in 1994 we saw a major shift in the "integrated device manufacturer," or IDM (a merchant supplier of semiconductors that has a fab), to increase use of foundries. This imbalance in the concentration of foundry capacity is starting to make U.S. semiconductor companies a little nervous, and have actually impressed upon key foundry suppliers to begin building production in the United States. In fact, TSMC announced plans to build a major fab in the United States, and we believe that other foundry companies are likely to follow. Clearly, users of foundry have stated a preference for close access to the fab. Any foundry provider who has capacity in the United States is likely to have a more stable customer base than those that do not.

And third, while Japanese and European companies have invested somewhat outside their own country, these companies have remained "patriots of the domestic economy" and have kept the vast majority of investment within the region, with perhaps the exceptions of NEC and SGS-Thomson. This, along with the strong DRAM market over the last three years, has stabilized the Japanese production proportion over the last two years, keeping the same approximate 40 percent share of the production market. However, as we now fully realize, the DRAM market is cyclical and Japanese foundries will feel pressure from Asian producers, so we expect a resumption of the gradual decay in the base of production in Japan through the rest of the decade.

Semiconductor Production Trends: Accelerating Shift to Asia/Pacific

Table 6-2 shows forecast semiconductor production by region for the period from 1995 through 2001. The major trend is the growth of the Asia/Pacific region at mostly the expense of Japan. By 2001, Dataquest believes that Asia/Pacific-ROW will expand to about 18 percent on a revenue basis.

North America will remain steady on a percentage basis, as lower cost of capital and clear leadership in technology and innovative design motivate companies to invest in the United States. Also, Asian companies have begun a regional production diversification program, with several major fabs earmarked for the United States. Europe production share is expected to expand slightly with a product mix shifting to contain a higher memory component, driven by the need for proximity to PC production, as more DRAM capacity is added by large internationals very late in the decade. Japan's share of production is likely to continue to erode, as the cost of capital remains high and as Japanese companies increasingly invest in capacity overseas.

Dataquest Perspective

Where the PC and telecommunications production goes, so goes semiconductors. This is true from the perspective of the business forecast, as well as the production line. Europe and Asia/Pacific, with very large capital spending upticks over the last several years, and expected to continue that trend, will continue to gain share in world production over the next several years.

The shifts and currents in semiconductor production trends mean that equipment and material suppliers will absolutely need a global presence in every sense of the word to remain competitive in the market. Product supply can no longer depend on local trends, as all major semiconductor companies have made it clear they are investing on a worldwide basis. However, local service and support is a requirement to maintain customer satisfaction.

Table 6-2
Worldwide Semiconductor Production by Region—Forecast; Merchant and Captive Semiconductor Company Sales (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Total Americas	49,535	47,701	54,549	67,072	81,432	97,674	109,880	14.2
Merchant	47,882	46,161	53,030	65,556	79,871	96,062	108,216	14.6
Captive	1,653	1,540	1,519	1,516	1,561	1,612	1,664	0.1
Percentage Growth	25.0	-3.7	14.4	23.0	21.4	19.9	12.5	
Percentage Worldwide	32.4	34.4	34.9	35.2	34.4	33.5	33.0	
Total Japan	61,106	52,599	58,286	68,957	84,335	103,608	116,158	11.3
Merchant	61,106	52,599	58,286	68,957	84,335	103,608	116,158	11.3
Captive	0	NA	NA	NA	NA	NA	NA	
Percentage Growth	34.9	-13.9	10.8	18.3	22.3	22.9	12.1	
Percentage Worldwide	39.9	37.9	37.3	36.2	35.7	35.5	34.9	
Total Europe, Middle East, and Africa	20,711	19,152	21,570	26,308	32,918	40,651	46,674	14.5
Merchant	20,551	19,040	21,490	26,260	32,888	40,631	46,662	14.6
Captive	160	112	80	48	30	20	12	-35.1
Percentage Growth	33.9	-7.5	12.6	22.0	25.1	23.5	14.8	
Percentage Worldwide	13.5	13.8	13.8	13.8	13.9	13.9	14.0	
Total Asia/Pacific	21,732	19,177	21,799	28,149	37,821	49,918	59,899	18.4
Merchant	21,732	19,177	21,799	28,149	37,821	49,918	59,899	18.4
Captive	NA	NA	NA	NA	NA	NA	NA	NA
Percentage Growth	79.7	-11.8	13.7	29.1	34.4	32.0	20.0	
Percentage World-wide	14.2	13.8	14.0	14.8	16.0	17.1	18.0	
Worldwide	153,084	138,629	156,204	190,486	236,507	291,851	332,612	13.8
Percentage Growth	36.1	-9.4	12.7	21.9	24.2	23.4	14.0	
Merchant	151,271	136,977	154,605	188,922	234,916	290,219	330,936	13.9
Percentage Growth	36.9	-9.4	12.9	22.2	24.3	23.5	14.0	
Captive	1,813	1,652	1,599	1,564	1,591	1,632	1,676	-1.3
Percentage Growth	-7.0	-8.9	-3.2	-2.2	1.7	2.6	2.7	

NA = Not applicable
Source: Dataquest (January 1997)

Taiwan is clearly the new major production growth area. We would expect Malaysia and Thailand to be the next major growth countries in three to five years. Evidence of this includes recent joint venture fab announcements by Texas Instruments and others. Silicon plants are now being strategically placed, such as SEH's Malaysian plant and announced joint venture in Taiwan, Komatsu's joint venture with Formosa Plastics in Taiwan, and MEMC's joint ventures in both Korea (Posco-Hüls), Taiwan (Taisil), and Malaysia (MEMC-Kulim).

Further, the concept of contract manufacturing in semiconductors is clearly here to stay. Equipment and material suppliers could find themselves selling their technical products to an international team from several companies, including the manufacturer and the designer. However, the emergence of the dedicated foundry company, taking ownership of the process and manufacturing flow, will tend to centralize this activity. Dataquest has started the Semiconductor Contract Manufacturing research program and will continue to explore the key trends in contract manufacturing and foundries, including technology trends and supply/demand balance through the decade.

Appendix A

Macroeconomic Outlook: Fourth Quarter 1996

World Outlook: Global Economy at Dawn of New Era

The world economy appears to be witnessing the dawn of a new era as it enters the final quarter of 1996 and drives headlong into 1997. The makings of this new era have been in the works for some time now. The collapse of communism, the spread of digital technology, the ideology of smaller, more efficient, and fiscally responsible government, the global integration of economic activity, and the aging of populations in the world's developed economies—all these have contributed to forces that are changing the trajectory of the world economy and its individual constituents. There is still considerable uncertainty about the path the world's economies will ultimately find themselves following. Moreover, there is still substantial room for debate about what can and should be done to enhance the positive impact of economic change and minimize its negative side effects. Nonetheless, it increasingly appears the world's economies are entering a new age characterized by limited inflation and significantly greater reliance on private initiative. To this point, the forces responsible for these traits have also produced low GDP growth, rising income inequality, and relatively high unemployment in the world's leading economies. One would hope that these maladies prove to be no more than passing side effects accompanying the world economy's transition to a new era. If not, chronic persistence of these maladies would almost surely unleash additional forces that could dramatically alter the future course of the global economy.

The most recent forecast for the world economy from the WEFA Group indicates global real GDP growth will conclude 1996 on a positive note. Although global real GDP growth is now expected to be somewhat slower in 1996 than previously anticipated, growth is still forecast to be above the rate experienced in 1995. WEFA anticipates continued acceleration of world real GDP growth through 1998, at which time growth is expected to level off and remain near 4 percent for several following years. Aggregate real GDP growth for the world's developed economies is likewise expected to conclude 1996 on an upbeat note. Real GDP growth for the world's developed economies as a group in 1996 is anticipated to just better the rate posted in 1995. WEFA now expects real GDP growth in 1997 to match 1996 growth. Beyond 1997, growth is forecast to accelerate somewhat and remain around 2.5 percent through 2001. As for inflation, WEFA continues to expect lower price growth among the world's developed economies in 1996 as compared to 1995 when measured by an aggregate Consumer Price Index (CPI) for all developed economies. WEFA forecasts a very gradual acceleration of inflation through 1999, at which point CPI growth will run about 2.5 percent. Still, this figure is below the average posted over 1990 to 1995. However, this rosy picture for developed economies as a group masks marked variation in the experiences anticipated for individual developed economies.

The world's developing or emerging economies are expected to continue experiencing real GDP growth rates about two to three times better than their developed counterparts. Emerging Asia/Pacific economies, spearheaded by China, remain forecast to lead the list of fastest-growing economies. Growth rates among Asia/Pacific economies, however, are slowing. And as we shall see later, several of the region's heretofore star performers actually find themselves struggling. Developing Latin American economies are still anticipated to experience real GDP growth rates that lag their Asia/Pacific rivals. Nonetheless, boosted by Mexico's continued recovery and continued economic progress throughout South America, Latin America should experience growth rates about twice those experienced by developed economies. Prospects remain bright for many emerging eastern European economies. Several eastern European economies are already posting rates of real GDP growth that rival those experienced by emerging Asia/Pacific economies. Overall, WEFA forecasts this region to experience about 4.5 annual real GDP growth to the end of the decade. Although the potential for growth remains strong among the economies of the former Soviet Union, WEFA continues to expect a contraction of aggregate real GDP for these economies in 1996. Growth is anticipated to commence in 1997 and eventually move to rates that rival eastern Europe and Latin America by decade's end.

Americas: U.S. Economy ... Too Hot? Too Cold? Just Right?

The current circumstances of the U.S. economy remind us somewhat of the children's story about Goldilocks and the Three Bears. In the case of the U.S. economy, economists are Goldilocks and the (dreaded) three bears are falling real GDP, rising unemployment, and (most ferocious of all!) runaway inflation. Month after month throughout 1996, economists have been sampling the porridge of U.S. economic data available to them. Each time they sample the data, they hope the bears will remain away for yet another month. Sometimes the porridge of statistics they sample has been too hot, meaning runaway inflation could be back anytime. Sometimes the porridge has been too cold, meaning falling real GDP and rising unemployment may be just outside the front door. And sometimes the porridge has been just right, meaning all three bears are off hibernating (thank you very much!) The upshot of this analogy about the U.S. economy is that economists generally have very mixed views about the current state of U.S. economy activity. They also have varying degrees of fear about just how soon one of those dreaded bears is going to show up and cause trouble. There seems to be general agreement that the economy is very close to being just right. Inflation and unemployment are unbelievably low. And real GDP growth is proceeding, albeit in quarterly fits and starts and at slow average annual rates. Just how long the U.S. economy can maintain the delicate balance between low inflation, low unemployment, and real GDP growth remains to be seen. Economists know there are bears out in the woods somewhere. The only question is: When will they return and how ravenous will they be?

Elsewhere in the Americas, Canada's near-term prospects remain poor. Although recent economic data indicates a sustained recovery may be just about to begin, Canada continues to struggle. Canadian fiscal policy remains tight even in the face of falling budget deficits. And recent appreciation of the Canadian dollar, despite accommodative money policy by the Bank of Canada, could delay Canada's recovery. Longer term, Canada's prospects appear much better. WEFA expects Canada to experience robust real GDP growth accompanied by low consumer price inflation within two years.

Mexico continues to show signs of recovery from the crisis that nearly crushed it two years ago. Real GDP is growing, inflation declining, and the peso now reasonably stable. International investors remain somewhat gun shy. But Mexico's success in reducing inflation together with the steps it has taken toward fighting corruption should help attract vital foreign investment. As for the rest of Latin America, the outlook also appears bright. Brazil and Argentina look to be recovering from recent economic setbacks. There is a growing spirit of cooperation among the region's economies that should encourage economic specialization, foster economic integration, and so buoy economic growth. As in Mexico, the pace of economic development critically depends on the progress of government-initiated economic and social reforms. It also very much depends on prudent management of exchange rates. Latin America's emerging economies would do well to always keep in mind the lessons of Mexico's experience.

WEFA's real GDP growth forecasts for the Americas region are reported in Table A-1.

Europe, Middle East, and Africa: Resurgent Germany Shepherding EU toward Common Currency

Recent economic data from western Europe suggests circumstances are improving for many of the region's economies. Prospects for Germany in particular now appear much better. Economic statistics for Germany indicate that real GDP jumped sharply in spring and that industrial production has now sustained increases over several consecutive months. To this point, Germany's recovery appears rooted in the economy's export sector. Germany's domestic sector remains stagnant and must improve if economic recovery is to continue.

The United Kingdom continues to exhibit robust economic health. Economic data for the United Kingdom indicates that real GDP is continuing to grow and that consumer spending growth, buoyed in part by tax cuts, is especially strong. There is mounting concern that the United Kingdom economy may be on the verge of overheating. This has prompted debate on the advisability of further tax cuts. Britain's Conservative government may find the temptation to cut taxes too hard to resist with general elections scheduled for next spring.

Economic data indicates France's economy remains very unsettled. Although the economy's export sector has recently shown some improvement, the domestic sector remains stymied. Business confidence is low and households are struggling with the impact of double-digit unemployment. Given France's strong commitment to the Masstricht process, it appears unlikely that government policymakers will intervene on behalf of the economy anytime soon.

Finally, economic statistics for Italy indicate that economy remains mired in the doldrums. Real GDP and private consumption growth remains very weak. Inflation is sharply down but unemployment is high and looks likely to remain so. The possibility of government policy relief seems very remote at this point. Italy is under intense pressure both at home and abroad to meet Masstricht requirements for entry into the European Monetary Union. Italy's efforts to meet these requirements are likely to hold economic recovery back for sometime.

The long-term outlook for western Europe largely depends on the outcome of the Masstricht Treaty process. Championed by Germany and France, the treaty calls for the establishment of a European Monetary Union in 1999 and the institution of a common currency for Union members in 2002. Entry into the proposed Monetary Union will be granted based on economic and fiscal criteria evaluated in 1997. In order to meet these criteria, many treaty signatories are finding it necessary to impose tight fiscal and monetary policies on their economies. While these policies are proving successful in pushing economies toward meeting Masstricht criteria, they are taking their toll on employment and economic growth. There are strong currency-related incentives for treaty signatories not to be left out of the treaty's proposed Monetary Union. At the same time, countries must balance these concerns against the welfare of their populations. Only time will tell how the Masstricht process plays out. One thing is for sure, however—strong commitment to the process on the part of all treaty parties will hold economic growth back in most of western Europe.

Elsewhere in the region, prospects for eastern Europe remain good. As in Latin America, economic success for former Warsaw Pact economies has largely been linked to the progress of necessary economic and social reforms. Although carrying out reforms has not been easy, leading economies of the region like the Czech Republic, Slovakia, Poland, and Slovenia are now beginning to reap the rewards of their efforts. These economies are attracting foreign capital and have found markets for their products. Others in the region have not been so successful and still find themselves struggling. Likewise, many economies of the former Soviet Union continue to struggle. Many thought, or at least hoped, that Yeltsin's victory in Russia's July presidential elections would herald the dawning of a new era for the Russian economy. Sadly, Yeltsin's failing health combined with infighting among his subordinates seem to have delayed a new economic era for Russia. Still, economic progress is being made. Privatization continues and inflation has been reduced. Nonetheless, basic structural reforms in the Russian economy are badly needed. Foremost among necessary reforms is a tax system that can regularly and reliably collect all the taxes owed the government. Also needed are commercial laws that establish contracts and provide recourse to damaged contract parties.

WEFA's real GDP growth forecasts for the Europe, Middle East, and Africa region are reported in Table A-1.

Japan and Asia/Pacific: Japan's Recovery Slowing, Four Tigers Struggling

Japan's economy continues to recover, but progress appears to be slowing. Not surprisingly, real GDP growth decelerated to a more sustainable level in spring following very rapid growth over the winter. To this point, Japan's recovery appears primarily fueled by robust business investment in plant and equipment as well as by strong housing demand. Contrary to expectations, public spending remains an important component of real GDP growth. Unfortunately, consumer spending remains sluggish and exports apparently have yet to respond to the yen's sharp retreat from historically high levels in 1995. There is justifiable concern about the near-term course of Japan's economy. Funds available for government priming of the economy through public investment are dwindling and likely to be exhausted soon. Moreover, Japanese tax policy is about to assume a decidedly contractionary stance. Over the next few months, social security taxes are slated to increase, an income tax rebate scheduled to end, and the value-added tax expected to increase. Although consumer confidence appears to be rising as unemployment falls, the impact of these taxes on spendable income could well override any increased willingness to spend as a result of improving confidence.

Relative to the rest of the world, the outlook for Asia/Pacific remains bright. However, the luster is definitely beginning to fade from the gold, especially for the Four Tigers. A combination of short-term upheavals and long-term developments is adversely impacting the region's economy and altering its dynamics. This year's sharp decline in semiconductor prices has exacted a tremendous toll on economies heavily devoted to semiconductor production. Korea has been especially impacted on this account. Sluggish export demand for electronics, especially from Japan and western Europe, has also exacted a toll on the region's electronics component and product industries. These short-term upheavals have coincided with a number of long-term developments that have served to heighten their impact. A number of economies in the region have undertaken fiscal austerity programs in recent years designed to reduce inflation and trim government deficits. The contractionary force of these programs has only served to amplify the impact of this year's export-related downturn. More significantly, a number of emerging economies, such as Vietnam and India, have come "on line" in recent years. These economies have positioned themselves as highly competitive producers of lower value-added products. Just as the Emerging Tigers (Indonesia, Malaysia, the Philippines, and Thailand) drew lower value-added production away from the Four Tigers earlier in the decade, these newly emerging Asia/Pacific economies are drawing production away from the Emerging Tigers, thereby exacerbating their economic difficulties.

Several economists have questioned the foundations of Asia/Pacific's economic success on the grounds that the region has been all too eager to invest in physical capital (plant and equipment) but seemingly disinclined to invest in human capital (worker skills). Events in recent years appear to be bearing out the bottom line of this argument. As production has shifted from the Four Tigers to the Emerging Tigers, and now from the Emerging Tigers to the region's newly emerging economies, large numbers of unemployed workers have been left in the wake of the production shifts. Sadly, these workers apparently lack the skills necessary to produce higher value-added product. In a region where production is continually shifted on the basis of cost, sustained national economic development depends on workers continually acquiring the increasing skills necessary to produce ever higher-valued products.

It would seem China has benefited the greatest from producer efforts to capitalize on the emergence of new economies in Asia/Pacific. Cost-driven shifts of production to China no doubt have contributed significantly to China's prodigious real GDP growth over the last decade or so. Based on official statistics, China's real GDP has grown at annual rates above 10 percent for over a decade. These growth rates, however, must be taken with grain of salt. There are strong reasons to believe that China's official statistics are biased and that actual real GDP growth in China has been somewhat less. Still, there is general agreement among economists that China's economic progress has been remarkable and that its rates of real GDP growth are certainly noteworthy. But for all of China's success as an emerging producer, its potential as a consumer remains subdued. China's economic development is concentrated in isolated enclaves along its eastern seaboard. An overwhelming majority of Chinese still live off the land in the interior of the country. Here, economic progress and, more importantly, income growth, remain stagnant. Moreover, although population growth has been dramatically reduced through a variety of government programs, China's population continues to grow. All this means the level of per capita income for China as a whole remains low by developed standards. Even if we grant China its official rates of real GDP growth and assume these rates, diluted by population growth, translate into prodigious rates of per capita income growth, Chinese per capita income will not even begin to approach the levels sustained by developed economies for quite some time. This is not to deny that significant consumption demand will be generated and grown in those areas experiencing economic development. It is to point out, however, that only a fraction of China's more than 1 billion potential consumers will actually express significant demand by 2000.

WEFA's real GDP growth forecasts for the Japan and Asia/Pacific regions are reported in Table A-1.

Reported real GDP and CPI growth rates are taken from the most recently available quarterly world forecast of the WEFA Group as contained in Table 1.0, "World Forecast Summary," *World Outlook, Executive Summary,* October 18, 1996, page 3. Economic commentary is based on independent research by Dataquest.

Table A-1
Forecast Real GDP Growth, 1996-2001 (Percent)

	1996	1997	1998	1999	2000	2001
Americas						
United States	2.2	2.2	2.3	2.3	2.2	2.2
Canada	1.4	2.5	3.2	3.9	3.8	3.8
Mexico	4.2	4.7	5.3	4.9	3.9	4.7
Latin America (Excluding Mexico)	3.0	4.6	4.8	4.2	4.3	4.6
Europe, Middle East, and Africa						
Germany	1.2	2.2	2.5	2.4	2.6	2.6
France	1.0	2.3	2.3	2.1	2.2	2.1
Italy	0.8	0.9	2.2	2.2	2.1	1.9
United Kingdom	2.1	3.1	3.3	2.4	2.2	2.5
Eastern Europe	4.6	4.4	4.5	4.5	4.6	4.6
Former Soviet Union	-2.6	2.9	5.6	5.7	5.0	5.0
Middle East	2.6	3.9	3.7	3.6	3.4	3.5
Africa	4.4	4.4	4.5	4.6	4.8	4.9
Japan and Asia/Pacific						
Japan	3.8	2.1	3.2	2.9	2.6	2.5
China	9.5	9.6	9.2	8.9	8.6	8.6
Pacific Basin	6.8	6.8	6.8	6.6	6.5	6.4

Source: The WEFA Group (November 1996)

Appendix B
Exchange Rates

Dataquest does not forecast exchange rates per se; however, we do forecast semiconductor-related markets in several regions of the world, and we use the U.S. dollar as a common currency for intermarket comparisons and aggregation. In general, in the forecast period Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. For the forecasts presented here:

- Actual monthly exchange rates were used for all months in the historical interval up to October 1996.
- The October 1996 exchange rate was then assumed to hold for the months of November and December 1996 and throughout all future years 1997 to 2001.

Dataquest uses an average annual exchange rate to convert annual revenue from local currency values to U.S. dollar values. Table B-1 outlines the rates used in the forecasts presented here.

Table B-1
Exchange Rates per U.S. Dollar

Country	1995	1996*	U.S. Dollar Appreciation (%) 1995-1996*
Australia (Dollar)	1.35	1.28	-5.18
Austria (Schilling)	10.06	10.58	5.17
Belgium (Franc)	29.42	30.95	5.19
Canada (Dollar)	NA	1.36	NM
China (Renminbi)	NA	8.34	NM
Denmark (Krone)	5.59	5.81	3.87
European Union (ECU)	0.77	0.80	3.28
Finland (Markka)	4.37	4.59	5.02
France (Franc)	4.97	5.11	2.87
Germany (Mark)	1.43	1.50	5.12
Greece (Drachma)	231.34	240.44	3.93
Hong Kong (Dollar)	7.74	7.73	-0.02
India (Rupee)	32.38	35.51	9.66
Ireland (Punt)	0.62	0.63	0.99
Italy (Lira)	1,628.21	1,543.18	-5.22
Japan (Yen)	93.90	107.81	14.81
Malaysia (Ringgit)	2.51	2.51	0.15
Mexico (Peso)	6.41	7.58	18.23
Netherlands (Guilder)	1.60	1.69	5.16
New Zealand (Dollar)	1.52	1.46	-4.42
Norway (Krone)	6.33	6.47	2.26
Portugal (Escudo)	149.77	154.20	2.96
Singapore (Dollar)	1.43	1.41	-0.99
South Africa (Rand)	NA	4.29	NM
South Korea (Won)	770.57	803.83	4.32
Spain (Peseta)	124.40	126.61	1.78
Sri Lanka (Rupee)	NA	55.32	NM
Sweden (Krona)	7.14	6.69	-6.28
Switzerland (Franc)	1.18	1.23	4.17
Taiwan (Dollar)	26.48	27.47	3.76
Thailand (Baht)	24.91	25.35	1.75
United Kingdom (Pound)	0.63	0.65	2.03

*Estimated
NA = Not tracked until 1996
NM = Not meaningful
Source: Dataquest (October 1996)

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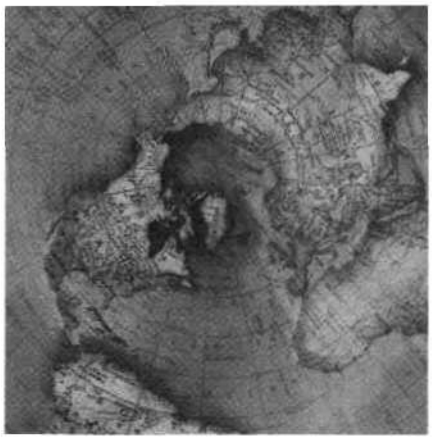

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Market Definitions—Semiconductor Equipment

Dataquest Guide

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
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Chapter 1
Market Share Survey Overview

Each year, Dataquest surveys semiconductor equipment vendors to estimate their annual revenue derived from front-end semiconductor equipment sales. The survey covers 126 semiconductor equipment vendors worldwide (this varies according to mergers, acquisitions, liquidations, and start-ups, among others) by 52 individual semiconductor equipment product categories (excluding subtotals), in four world regions. This exercise helps Dataquest maintain its dynamic database of semiconductor equipment supply by company and semiconductor equipment shipment by world region and product. The information gained is supplemented and cross-checked with Dataquest's various other information sources. Dataquest conducts this research on an annual basis. The categories for which semiconductor equipment revenue is reported are comprehensively defined for the purpose of clarity and guidance to survey participants. These definitions may occasionally be revised, altered, or expanded to reflect changes in semiconductor manufacturing technology. To support these definitions, Dataquest will issue an annual survey guide to all participants in its semiconductor equipment market share survey program. This comprises the 1996 survey guide.

Chapter 2
Semiconductor Equipment Companies Surveyed Worldwide for 1995

European Companies

AET Thermal

ASM International

ASM Lithography

AST Electronic

Centrotherm GmbH

Convac

E.T. Electrotech

Jenoptik

Jipelec

Leica

LPE

Orbot

Presi

Sapi Equipment

Steag Microtech

Karl Suss

Carl Zeiss

Japanese Companies

Amaya

Anelva

Canon

Dainippon Screen

Dan Science

Ebara

Enya

ETS Company

Fujikoshi

Hitachi

Holon

Japan Production Engineering

JEOL

Kaijo Denki

Kokusai Electric

Koyo Lindberg

Kuwano Electric

Lasertec

Maruwa

Matsushita Electric

MC Electronics

Materials Research Corp.

Musashi

Nidek

Nikon

Nissin Electric

Plasma Systems

Ryokosha

Samco

Sankyo Engineering

Shibaura Engineering

Shimada

Shinko Electric

Shinko Seiki

Sugai

Sumitomo Metals

Tazmo

Toho Kasei

Tokyo Aircraft Instruments

Tokyo Electron Ltd.

Tokyo Ohka Kogyo

Topcon

Toray Industries

Toshiba Machine

Toyoko Kagaku

Ulvac

Yuasa

Joint Venture Companies (Cross-Region)

Alcan Technology

Bruce Technologies

Sumitomo/Eaton Nova

North American Companies

ADE Corp.

Advanced Crystal Sciences

AG Associates

Amray

Applied Materials

Biorad Micromeasurements

CFM Technology

CHA Industries

Concept Systems Design

CVC Products

Cybeq Systems

Denton Vacuum

Eaton

Etec Systems

FSI International

Fusion Semiconductor Systems

Gasonics

Genus

High Temperature Engineering

Inspex

Integrated Solutions

IPEC/Westech Systems

IVS

KLA Instruments

Lam Research

Lepton

Kurt J. Lesker

Matrix Integrated Systems

Mattson Technologies

Moore

Nanometrics

Novellus Systems

OnTrak Systems

Opal

Optical Specialties

Pacific Western

Phoenix Process Automation

Plasma & Materials Technologies

Process Technology Ltd.

Rudolph Research

Santa Clara Plastics

SCI Manufacturing

Semiconductor Systems

Semitherm

Semitool

Silicon Valley Group

Speedfam

Sputtered Films

Strasbaugh

SubMicron Systems

Tegal

Tencor Instruments

Thermawave

Tystar

Ultrapointe

Ultratech Stepper

Varian

Verteq

Watkins-Johnson

Summary

17 European companies

47 Japanese companies

3 joint venture companies

59 North American companies

Chapter 3
General Sales Definitions

All sales are reported according to customer location, that is, shipping destination. These destinations are defined regionally. The regions are Americas; Japan; Europe, Middle East, and Africa; and Asia/Pacific. Asia/Pacific is further subdivided into two subregions: Korea and Rest of Asia/Pacific. Please note that these definitions represent a change from previous surveys.

Sales do not include spare parts or service, but do include retrofits and upgrades. Also, our market estimates include only equipment used in the front-end wafer fabrication process. We do not include equipment used in other market applications such as flat panel display manufacturing, thin-film head manufacturing, or multichip modules. Finally, as part of our convention to report end-user revenue, the revenue associated with equipment kits sent from one company to be fabricated and assembled by another company is valued at the full system shipment price paid by the semiconductor manufacturer. This revenue is assigned to the company that originated the kit, with the exception of implant joint ventures. Thus, for public companies, the sales reported here may differ from the sales reported in annual reports.

Research Metrics

The following metrics apply to how Dataquest views and analyzes the semiconductor equipment market.

End user. The final purchaser of the equipment.

End-user spending. End-user average purchase price times shipments to end users.

End-user average purchase price. The average price paid for a branded, finished product by the final purchaser of the product.

Shipments to end users. The sum of branded finished products delivered to the final purchaser.

Chapter 4

Exchange Rate Definitions

When converting a company's local currency sales into U.S. dollars, or vice versa, it is important to use the 1995 exchange rates provided in Table 4-1. These rates will prevent inconsistencies in the conversion of offshore sales between companies. These exchange rates will be used in the 1995 market share survey. Exchange rates for historical years are available on request.

Table 4-1
Average 1995 Exchange Rates per U.S. Dollar

	1995 Rate	1994 Rate	U.S. $ Appreciation (%)
Austria (Schilling)	10.06	11.40	-11.77
Belgium (Franc)	29.42	33.36	-11.82
China (Yuan)	8.35	8.54	-2.17
Denmark (Krone)	5.59	6.35	-11.94
ECU	0.77	0.84	-8.30
Finland (Markka)	4.37	5.21	-16.05
France (Franc)	4.97	5.54	-10.22
Germany (Mark)	1.43	1.62	-11.69
Greece (Drachma)	231.34	242.06	-4.43
Hong Kong (Dollar)	7.74	7.73	0.10
India (Rupee)	32.38	31.15	3.94
Ireland (Punt)	0.62	0.67	-6.69
Italy (Lira)	1,628.21	1,609.34	1.17
Japan (Yen)	93.90	101.81	-7.77
Malaysia (Ringgit)	2.51	2.62	-4.32
Netherlands (Guilder)	1.60	1.82	-11.80
Norway (Krone)	6.33	7.04	-10.18
Portugal (Escudo)	149.77	165.63	-9.58
Singapore (Dollar)	1.43	1.53	-6.58
South Korea (Won)	770.57	802.84	-4.02
Spain (Peseta)	124.40	133.48	-6.80
Sweden (Krona)	7.14	7.70	-7.28
Switzerland (Franc)	1.18	1.37	-13.62
Taiwan (Dollar)	26.48	26.45	0.09
Thailand (Baht)	24.91	25.36	-1.77
United Kingdom (Pound)	0.63	0.65	-3.16

Source: Dataquest (January 1996)

Chapter 5
Semiconductor Equipment Product Category Hierarchy

The following semiconductor equipment product category hierarchy begins with total semiconductor equipment and indents each subcategory in the left-hand column according to its position in the hierarchy. At each level in the hierarchy, all subcategories that contribute to this level are indicated as a subcategory summation in the right-hand column. Any level in the hierarchy that does not depend on any subcategories is marked as "Data Point."

Total Wafer Fab Equipment	Total Lithography + Resist Processing Equipment + Total Clean Process + Dry Strip + Total Dry Etch + Chemical Mechanical Polishing + Total Deposition + Thermal Nondeposition + Total Ion Implantation + Total Process Control + Other Equipment
Patterning	
Total Lithography	Contact/Proximity[1] + Projection Aligners + Total Steppers + Total Direct-Write + Total Maskmaking + X-Ray
Contact/Proximity[1]	Data Point
Projection Aligners	Data Point
Steppers	Data Point
Total Direct-Write	Direct-Write E-Beam + Direct-Write Optical
Direct-Write E-Beam	Data Point
Direct-Write Optical	Data Point
Total Maskmaking	Maskmaking E-Beam + Maskmaking Optical
Maskmaking E-Beam	Data Point
Maskmaking Optical	Data Point
X-Ray	Data Point
Resist Processing Equipment (Track)	Data Point
Etching/Cleaning	
Total Clean Process (Formerly Total Wet Process)	Auto Wet (Immersion) Stations + Spray Processors[2] + Vapor Phase Clean[2] + Scrubbers[2] + Post-CMP Clean[2] + Other Clean Process[1]
Auto Wet (Immersion) Stations	Data Point
Spray Processors[2]	Batch Spray Processor[2] + Single-Wafer Spray Processor[2]
Batch Spray Processor[2]	Data Point
Single Wafer Spray Processor[2]	Data Point
Vapor Phase Clean[2]	Data Point
Scrubber[2]	Data Point
Post-CMP Clean[2]	Data Point

(Continued)

Other Clean Process[1]	Manual Wet Benches[1] + Rinsers/Dryers[1] + Megasonics[1]
Manual Wet Benches[1]	Data Point
Rinser/Dryers[1]	Data Point
Megasonics[1]	Data Point
Dry Strip	Data Point
Total Dry Etch	Low-Density Etch + High-Density Etch
Low-Density Etch	Data Point
High-Density Etch	Data Point
Chemical Mechanical Polishing[3]	Data Point
Deposition	
Total Deposition	Total CVD + Sputtering + Silicon Epitaxy + Other Deposition[1]
Total CVD	Tube CVD + Nontube CVD
Tube CVD	Horizontal LPCVD + Vertical LPCVD + Horizontal PECVD
Nontube CVD	LPCVD Reactors + PECVD Reactors + Atmospheric Pressure CVD/Subatmospheric Pressure CVD + High-Density Plasma CVD
Total LPCVD	LPCVD Reactors + Horizontal LPCVD + Vertical LPCVD
LPCVD Reactors	Data Point
Horizontal LPCVD	Data Point
Vertical LPCVD	Data Point
Total PECVD	PECVD Reactors + Horizontal PECVD Reactors + High-Density Plasma CVD
PECVD Reactors	Data Point
Horizontal PECVD Reactors	Data Point
High-Density Plasma CVD	Data Point
Atmospheric Pressure CVD/Subatmospheric Pressure CVD	Data Point
Sputtering	Data Point
Silicon Epitaxy	Data Point
Other Deposition[1]	Molecular Beam Epitaxy[1] + Metalorganic CVD[1] + Evaporation[1]
Molecular Beam Epitaxy[1]	Data Point
Metalorganic CVD[1]	Data Point
Evaporation[1]	Data Point
Modification	
Thermal Nondeposition	Diffusion + Rapid Thermal Processing
Diffusion	Vertical Diffusion + Horizontal Diffusion
Vertical Diffusion	Data Point
Horizontal Diffusion	Data Point
Rapid Thermal Processing	Data Point

(Continued)

Total Ion Implantation	Medium-Current Implanter + High-Current Implanter + High-Voltage Implanter
Medium-Current Implanter	Data Point
High-Current Implanter	Data Point
High-Voltage Implanter	Data Point
Verification	
Total Process Control	Optical Metrology + CD SEM + Thin-Film Measurement[2] + Wafer Defect Inspection and Review + Other Process Control[1]
Optical Metrology (Overlay)	Data Point
CD SEM	Data Point
Thin-Film Measurement[2]	Data Point
Wafer Defect Inspection and Review	Unpatterned Wafer Inspection + Patterned Wafer Inspection + Wafer Review + Other Inspection
Unpatterned Wafer Inspection (Monitor)	Data Point
Patterned Wafer Inspection	Data Point
Wafer Review	Automated Review + Manual Review and Inspection
Automated Review	Data Point
Manual Review and Inspection	Data Point
Other Inspection	Data Point
Other Process Control[1]	Data Point
Other Categories	
Other Equipment[1]	Factory Automation[1] + Ion Milling[1] + Other[1]
Factory Automation[1]	Data Point
Ion Milling[1]	Data Point
Other[1]	Data Point

[1]Not surveyed since 1991
[2]Starting from 1994
[3]Starting from 1993
Source: Dataquest (January 1996)

Chapter 6

Semiconductor Equipment Product Category Definitions

The following semiconductor equipment product category definitions begin with total wafer fab equipment and continue through each subcategory in the same order as shown in the preceding semiconductor equipment hierarchy. At each level in the hierarchy, all subcategories that continue to this level are shown as a subcategory summation in the right-hand column. Comprehensive definitions are furnished at every level. Dataquest has organized the wafer fab equipment market into five major categories of front-end processing equipment. The equipment is defined on the basis of the function it performs in the manufacturing process.

Total Wafer Fab Equipment	Total Lithography + Resist Processing Equipment + Total Clean Process + Dry Strip + Total Dry Etch + Chemical Mechanical Polishing + Total Deposition + Thermal Nondeposition + Total Ion Implantation + Total Process Control + Other Equipment
Patterning of a thin film (lithography and track)	
Total Lithography	Contact/Proximity[1] + Projection Aligners + Total Steppers + Total Direct-Write + Total Maskmaking + X-Ray
Contact/Proximity[1]	Defined as an optical patterning system in which a wafer-size photomask is manually aligned over or directly on top of a wafer and then exposed to collimated light to create an image.
Projection Aligners	Defined as an optical exposure system in which an image on the mask is projected onto the wafer to create an image.
Stepper	Defined as an optical exposure system that projects a reticle image directly onto the wafer, stepping to cover the wafer with the reticle image. The advantage of stepper technology over projection aligners and contact/proximity methods is that a reticle can be produced to a lower defect level and with tighter dimensions than an entire wafer mask. Alignment of the reticle to the wafer is accomplished by transmitting a laser beam through an alignment target on the reticle and reflecting it off a corresponding pattern on the wafer.
Total Direct-Write	Direct-Write E-Beam + Direct-Write Optical
Direct-Write E-Beam	Defined as an electron beam lithographic process used in semiconductor manufacturing to transfer the circuit pattern directly to the integrated circuit being fabricated. This equipment uses no photomask or reticle to generate the pattern.
Direct-Write Optical	Defined as a lithographic process, similar to direct-write e-beam, that uses a laser to transfer the circuit pattern directly to the wafer.
Total Maskmaking	Maskmaking E-Beam + Maskmaking Optical
Maskmaking E-Beam	Defined as lithographic equipment used in semiconductor manufacturing to generate patterns on photomasks. An electron beam is used to transfer the circuit pattern to a photoresist-coated photoblank.

(Continued)

Maskmaking Optical	Defined as a lithographic process similar to maskmaking e-beam, but using a laser to transfer the circuit pattern to a photoresist-coated photoblank.
X-Ray	Defined as an imaging system using X-rays as the exposure source. The main advantages of this system over conventional exposure systems is that X-ray systems provide depth of focus superior to optical lithographic techniques and produce a much shorter wavelength than UV light, thus resolving smaller feature sizes.
Resist Processing Equipment (Track)	Defined as equipment used to coat, bake, and develop photoresist material on wafer surfaces.
Etching and cleaning of thin films and/or substrate surfaces (clean process, dry strip, and dry etch equipment)	
Clean Process (Formerly Wet Process)	Refers to a wide range of liquid and gaseous cleaning process equipment used throughout semiconductor manufacturing whereby photoresist, organic residue, trace metal and/or dielectric, or particles are removed from the wafer surface.
Total Clean Process (Formerly Total Wet Process)	Auto Wet (Immersion) Stations + Spray Processors[2] + Vapor Phase Clean[2] + Scrubbers[2] + Post-CMP Clean[2] + Other Clean Process[1]
Auto Wet (Immersion) Stations	Defined as a cleaning station whereby the wafer and/or the wafer carriers are automatically transported through the equipment and the various immersion cleaning steps.
Spray Processors[2]	Batch Spray Processor[2] + Single-Wafer Spray Processor[2]
Batch Spray Processor[2]	A standalone piece of equipment, manual or automated, that uses nozzles inside of a chamber to spray liquid process chemicals as the reagent over a carrier of wafers. This is a cleaning/ etching application on the wafer surface and does not include chemical reprocessors that reclaim spent chemicals from the manufacturing process.
Single-Wafer Spray Processor[2]	A standalone piece of equipment (manual or automated) that uses nozzles inside of a chamber to spray liquid process chemical as the reagent over a single wafer, used as a cleaning application.
Vapor Phase Clean[2]	Defined as a piece of equipment that introduces cleaning reagents to the surface of the wafer in a gaseous or vapor form and where by-products are pumped away using a vacuum-type pump.
Scrubber[2]	Defined as an equipment set using a brush (or similar physical structure) to remove particles from wafers. This cleaning technique may be augmented with an ultrasonic energy source.
Post-CMP Clean[2]	Refers specifically to equipment that removes from the wafer surface the slurry residue from a chemical mechanical polishing (CMP) process.
Other Clean Process[1]	This category includes equipment that is not included as part of the equipment specifically addressed in Total Clean Process and that is used as standalone wafer processing equipment. Examples include manual wet benches, wet etch, rinser/ dryers, and megasonic cleaners.

(Continued)

Manual Wet Bench[1]	Defined as a cleaning station whereby the wafer carriers must be manually transported through the equipment.
Rinser/Dryers[1]	Defined as a technique for removing wet chemicals from the surface of a wafer and/or drying the wafer.
Megasonics[1]	Defined as equipment that uses acoustical energy in the 700-to-1,200-kHz frequency range that augments standard cleaning chemicals.
Dry Strip	Defined as a process that removes a material (usually photoresist) from a wafer surface after etching using an oxygen plasma or ozone.
Total Dry Etch	Low-Density Etch + High-Density Etch
Low-Density Etch	Defined as a process that selectively removes unwanted material from a wafer by using a radio frequency (RF) plasma as the primary etch medium whereby the wafers are etched without wet chemicals. Dry etch includes both plasma etching (barrel and planer) and reactive ion etching (RIE).
High-Density Etch	Defined as a dry etch process in which the plasma is generated using a source designed to generate a high-density plasma ($>=10^{11}$ ions/cm^3) in a low-pressure environment. Sources in this category include inductively coupled plasma (ICP), transformer-coupled plasma (TCP), helicon wave, HRe-, and microwave-based sources (for example, ECR and microwave).
Chemical Mechanical Polishing[3]	Defined as a process that removes unwanted material from a wafer by using a corrosive liquid/solid slurry inside equipment designed to apply pressure on the active surface. This segment is specifically limited to removal of significant amounts of dielectric or metal material and does not include the process of contamination removal by chemical "scrubbing." This latter type of equipment is considered under wet processing.
Deposition of a thin film (chemical vapor deposition, physical vapor deposition, molecular beam epitaxy, and metalorganic CVD equipment)	
Total Deposition	Total CVD + Sputtering + Silicon Epitaxy + Other Deposition[1]
Chemical Vapor Deposition	Defined as a method for depositing thin films of materials that function as dielectrics, conductors, or semiconductors. A chemical containing atoms of the material to be deposited reacts with another chemical, either at an elevated temperature or in a plasma, producing the desired material, which is deposited on the wafer surface while by-products of the reaction are removed from the process chamber.
Atmospheric Pressure CVD/ Subatmospheric Pressure CVD	Defined as a chemical vapor deposition process in which both the reaction and deposition occur at atmospheric or subatmospheric pressure.
LPCVD Reactors	Defined as a reactor in which the reaction and deposition occur at an elevated temperature and low pressure. Reactors in this category include W, WSi_X, CVDTiN, and other metal CVD systems.

(Continued)

PECVD Reactors	Defined as a reactor in which the reaction and deposition occur in an RF plasma, usually at reduced pressure.
High-Density Plasma CVD	Defined as a reactor in which the reaction and deposition occur in a high-density plasma (for example, ECR, ICP, and helicon), usually at reduced pressure.
Horizontal LPCVD	Defined as a CVD process in which both the reaction and the deposition take place at an elevated temperature and reduced pressure, in a horizontally oriented furnace tube.
Vertical LPCVD	Defined as a CVD process in which both the reaction and deposition take place at an elevated temperature and reduced pressure, in a vertically oriented furnace tube.
Horizontal PECVD	Defined as a system based on a standard horizontal tube furnace design in which reaction and deposition occur in an RF plasma, usually at reduced pressure.
Sputtering	A method of depositing a thin film of material on wafer surfaces. A given material (target) is bombarded with ions generated in an RF plasma, which dislodge atoms of the target material. The displaced target material atoms are deposited on the wafer surface.
Silicon Epitaxy	Defined as a process for depositing single-crystal silicon on a substrate by decomposition of a silicon precursor gas such as silane, silicon tetrachloride, or dichlorosilane.
Other Deposition[1]	Metalorganic CVD[1] + Molecular Beam Epitaxy[1] + Evaporation[1]
Metalorganic CVD[1]	Defined as a CVD technique using metalorganic precursors such as trimethylgallium that react at elevated temperatures to deposit thin films of compound semiconductor materials such as GaAs.
Molecular Beam Epitaxy[1]	Defined as a process for depositing thin films of elemental or compound materials by direct transport of the film materials from a heated source to the wafer surface, carried out in a high vacuum. This process is similar to evaporation.
Evaporation[1]	A process that uses heat to change a material (usually a metal or metal alloy) from a solid to a gaseous state, with the atoms in the resulting vapor being deposited on the wafer as a solid thin film.
Modification properties of a thin film or substrate (diffusion, RTP, and ion implantation)	
Thermal Nondeposition	Diffusion + Rapid Thermal Processing
Diffusion	Horizontal Diffusion + Vertical Diffusion
Horizontal Diffusion	Diffusion is a high-temperature annealing process that allows impurities (dopants) introduced into substrate material to spread or diffuse into the substrate. Horizontal diffusion equipment employs horizontally oriented tubes.
Vertical Diffusion	Vertical diffusion equipment employs vertically oriented tubes.
Rapid Thermal Processing	A process that performs a high-temperature diffusion, CVD, or epitaxial process in a short period.

(Continued)

Ion Implantation	Medium-Current Implanter + High-Current Implanter + High-Voltage Implanter
Medium-Current Implanter	Ion implantation is a process that introduces impurities into a substrate by means of ion bombardment to achieve the desired electrical properties in defined areas of a wafer. Medium-current implanters generate singly charged ion energies of less than 750 keV and deliver implant doses less than or equal 1 E14 ions per cm^2.
High-Current Implanter	High-current implanters generate singly charged ion energies of less than 750 keV and deliver implant doses greater than 1 E14 ions per cm^2, but typically between 1 E15 ions to 1 E18 ions per cm^2.
High-Voltage Implanter	High-voltage implanters generate singly charged ion energies greater than 750 keV.
Verification that process steps in fabrication have been performed within specifications (process control equipment including optical metrology, CD-SEM, thin film measurement, wafer defect inspection and review, and other process control)	
Optical Metrology (Overlay)	Defined as equipment that measures wafers after lithographic exposure to check for layer-to-layer overlap.
CD-SEM	A critical dimension of a semiconductor device refers to a line, element, or feature that must be manufactured and controlled to tight specifications. CD-SEM equipment checks the widths of the line, elements, or features of critical circuit patterns as well as contact areas.
Thin-Film Measurement[2]	Defined as a measurement tool used to ascertain the composition, thickness, and quality of the thin-film layer deposited on the wafer. The tool may use some assumptions on the physical parameters of the film to measure its reflectivity, thickness, and refractive index. Semiconductor manufacturing processes such as planarization, PVD, CVD, diffusion, etch, and lithography are among the segments that may use these tools.
Wafer Defect Inspection and Review	Unpatterned Wafer Inspection + Patterned Wafer Inspection + Wafer Review + Other Inspection.
Unpatterned Wafer Inspection (Monitor)	Defined as measurement equipment used to locate defects and contaminants in bare (unprocessed) wafers.
Patterned Wafer Inspection	Defined as equipment used to inspect patterned (processed) wafers for defects and contaminants.
Wafer Review	Automated Review + Manual Review and Inspection
Automated Review	Defined as automated equipment that identifies and classifies defects and contaminants in patterned wafers. This equipment is usually attached to patterned wafer inspection stations.
Manual Review and Inspection	Defined as operator-assisted equipment used to identify and classify defects and contaminants in patterned wafers. This equipment includes sophisticated microscope stations.
Other Inspection	Defined as other inspection and review equipment.

(Continued)

Other Process Control[1]	Other process control represents a broad market that includes mask, metrology, inspection, and repair equipment, as well as other categories of process monitoring equipment, and analytical instrumentation. This is a highly fragmented market with dozens of companies selling into a multitude of noncompetitive market niches.
Other Categories	
Other Equipment[1]	Factory Automation[1] + Ion Milling[1] + Other[1]
Factory Automation[1]	Includes CIM software for shop floor control, factory host computer systems, cell controllers and interface hardware, and wafer transport systems, including automatic guided vehicles and rail transport systems.
Ion Milling[1]	Defined as a process that uses a beam of charged particles to remove material from a wafer. Also known as sputter etching or ion beam etching.
Other[1]	A general catchall category that includes the other capital equipment used throughout the fab but not classified within the other five major types of wafer processing equipment. Included in this segment are decontamination systems, wafer markers, gas analyzers, storage stations, and other types of equipment.

[1]Not surveyed since 1991
[2]Starting from 1994
[3]Starting from 1993
Source: Dataquest (January 1996)

Chapter 7
Worldwide Geographic Region Definitions

Dataquest has revised its regional definitions effective this year. The region formerly known as "Rest of World" has been eliminated and its components have been redistributed across the remaining regions. The remaining regions, in turn, have been redefined to accommodate this change. Central America, South America, and the Caribbean have been combined with North America to define the new region "Americas." The Middle East (including Israel) and Africa have been combined with Europe in the new region "Europe, Middle East, and Africa." The Pacific Island nations of Oceania have been combined with Asia/Pacific in the new region "Asia/Pacific." Note that Asia/Pacific is further divided into two mutually exclusive subregions, "Korea" and "Rest of Asia/Pacific."

Americas

North America

Includes Canada, Mexico, and the United States (50 states).

Central America

South America

Caribbean

Japan

Japan is the only single-country region.

Europe, Middle East, and Africa

Europe

Western Europe

Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including the former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).

Eastern Europe

Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).

Middle East (Includes Israel)

Africa

Asia/Pacific

Korea

Korea is a single-country subregion.

Rest of Asia/Pacific

Includes Asia/Pacific's other Newly Industrialized Economies (NIEs) and the remainder of Asia/Pacific, including Oceania. Asia/Pacific's other NIEs include Hong Kong, Singapore, and Taiwan. The remainder of Asia/Pacific includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam, as well as the Pacific Island nations that make up Oceania.

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SEMICONDUCTOR EQUIPMENT, MANUFACTURING AND MATERIALS WORLDWIDE 1996

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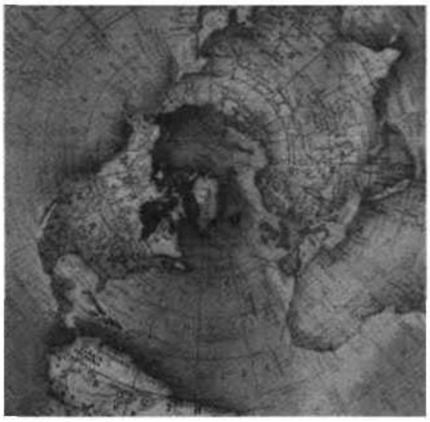

Dataquest

Asia/Pacific Fab Database

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-MS-9606
Publication Date: January 6, 1997
Filing: Market Statistics

Asia/Pacific Fab Database

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-MS-9606
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Filing: Market Statistics

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Asia/Pacific Fab Database

Background and Methodology

This report contains the Asia/Pacific portion of Dataquest's wafer fab database. These tables cover fabs located in the Asia/Pacific region. The Semiconductor Equipment, Materials, and Manufacturing Worldwide (SEMM) program conducts extensive annual surveys complemented with quarterly secondary research to maintain this database. Published once a year, this document represents Dataquest's best insights and estimates into the end market of semiconductor equipment.

The tables in this report cover planned and existing merchant, captive, and foundry fab lines. A fab line consists of a series of equipment that does front-end semiconductor manufacturing (from initial oxide through wafer probe). Occasionally, two or more separate product-specific fab lines or wafer sizes operate in a single clean room or physical plant. In this situation, Dataquest considers the clean room to be separate fab lines if the company dedicates equipment to each wafer size or product line. If a company installs substantially different equipment during an expansion (for example, equipment to increase the maximum wafer diameter), again Dataquest divides the clean room and creates two entries in the database. Therefore, a company may operate many fab lines at one location.

Worldwide Geographic Region Definitions and Regional Roll-Ups

Americas

Includes Central America (all nations), Canada, Mexico, United States, Puerto Rico, and South America (all nations)

Japan

Japan is the only single-country region.

Europe, Africa, and Middle East

Includes Africa (all nations), Albania, Andorra, Armenia, Azerbaijan, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Gibraltar, Hungary, Iceland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Middle East (all nations), Moldova, Monaco, Netherlands, Norway, Poland, Romania, Russia, San Marino, Scandinavia, Slovakia, Spain, Sweden, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan, Vatican City, and all nations within the former Yugoslavia

Asia/Pacific

Includes Australia, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam

Table Column Definitions

The Company column indicates the operator of the fab line. For contract manufacturers that trade capacity for capital investment in the fab, Dataquest lists the contract manufacturer. For incorporated joint ventures, Dataquest will either list the incorporated entity or the major investors, separated with slashes.

The Fab Name column provides a reference to a particular fab or fab line to distinguish it from other fabs or lines owned by that company. Although Dataquest makes every attempt to match the nomenclature used by the company, occasionally some additional qualifiers (for example, Phase 1) appear to provide insight into the facility's history or organization.

The City column displays the most detailed location information. This reference is usually a city or town, but could be an often-used district name (for example, Science Park in the city of Hsinchu, Taiwan). If this column lists a district, Dataquest will list the city in the State or Province column. In some cases, a reference to a state or province will be included in the city or district column to create a unique identifier for this location.

The State, Province, or Prefecture columns denote the second most detailed location. This reference is usually a state (for the United States), province (for Canada and many European and Asian countries), or a prefecture (for Japan). For countries within the United Kingdom, Dataquest will list the country name (for example, Scotland) in this column so Dataquest can list the descriptor "U.K." in the Country column.

The Country column indicates the broadest location identifier in this report. This reference is usually a country, except in the case of the United Kingdom (see above). As Japan is a single-country region, a regional qualifier does not exist for fabs in Japan.

The Devices Produced column lists the products manufactured at this site. The listings generally fall into five product groups, with the following nomenclature and definitions (when warranted):

- MOS memory
  - DRAM: Dynamic RAM
  - EEPROM or E2: Electrically erasable PROM
  - EPROM: Ultraviolet erasable PROM
  - FERRAM: Ferroelectric RAM
  - FIFO: First-in/first-out memory
  - Flash: Flash memory
  - MEM: Memory
  - NvMem: Nonvolatile memory (ROM, PROM, EPROM, EEPROM, FERRAM)
  - PROM: Programmable ROM

- RAM: Random-access memory
- ROM: Read-only memory
- SpMem: Other specialty memory (such as dual-port, shift-register, color lookup)
- SRAM: Static RAM
- VRAM: Video RAM

■ MOS microcomponent/digital logic

- Arrays: Gate array
- ASIC: Application-specific IC
- ASSP: Application-specific standard product
- Bit: Bit slice (subset of MPU functions)
- CBIC: Cell-based IC
- Custom: Full-custom IC (single user)
- DSP: Digital signal processor
- FPGA: Field-programmable gate array
- LISP: 32-bit list instruction set processor for AI
- Log or Logic: Standard logic
- MCU: Microcontroller unit
- Mixsig ASIC: Mixed-signal ASIC
- MPR: Microperipheral
- MPRCom: MPR digital communications (ISDN, LAN, UART, modem)
- MPU: Microprocessor unit
- PLD: Programmable logic device
- RISC: Reduced-instruction-set computation 32-bit MPU
- Telecom: Telecommunications chip

■ Power/discrete/analog (including bipolar power)

- A/D D/A: Analog-to-digital, digital-to-analog converter
- Automotive: Dedicated to automobile applications
- Codec: Coder/decoder
- Diode
- Dis or Discrete: Discrete
- FET: Field-effect transistor
- GTO: Gate turn-off thyristor
- HEMT: High-electron-mobility transistor
- IGBT: Insulated gate bipolar transistor
- Interface: Interface IC

- Lin: Linear/analog device
- MDiode: Microwave diode
- MESFET: Metal semiconductor field-effect transistor
- MFET: Microwave field-effect transistor
- Modem: Modulator/demodulator
- MMIC: Monolithic microwave IC
- MOSFET: MOS-based field-effect transistor
- Op Amp: Operational amplifier
- Pwr IC: Power IC
- Pwr Tran: Power transistor
- Rectifier
- Reg: Voltage regulator
- RF: Radio frequency
- SCR: Schottky rectifier
- Sensor
- Smart Pwr: Smart power
- SST: Small-signal transistor
- Switch: Switching device
- Thyristor
- Tran: Transistor
- Zener Diode

- Optoelectronic
  - CCD: Charge-coupled device (imaging)
  - Coupler: Photocoupler
  - IED: Infrared-emitting diode
  - Image Sensor
  - Laser: Semiconductor laser or laser IC
  - LED: Light-emitting diode
  - Opto: Optoelectronic
  - PDiode: Photodiode
  - PTran: Photo transistor
  - SAW: Surface acoustic wave device
  - SIT Image Sensor: Static induction transistor image sensor
- Bipolar digital
  - Includes all digital ICs using a bipolar process

The Activities column shows the types of semiconductor manufacturing performed at this location. The activities include:

- "Frnt" means this location performs front-end wafer processing. Front-end wafer processing includes the manufacturing steps from initial oxide through wafer probe test.
- "Rsrch" means the location performs product or process research. Research differs from pilot manufacturing in that research wafers are nonsalable.
- "Dsgn" means this location has a design center.
- "Pilot" means this location performs pilot production. Pilot production means the location produces in small volumes while "debugging" new products or process technologies. The main difference between research and pilot is that, unlike research, pilot wafers are salable product.
- "Fndry" means this location performs contract manufacturing. Contract manufacturing is the production, under contract, of another company's branded product. This is also known as foundry production.
- "Assy/tst" means this location performs assembly and/or testing. Assembly and testing includes the manufacturing steps from E-test through final assembly into a package and final test.

The Processes column indicates each fab's use of five major types of processes. The process groupings are:

- P/CMOS: P-channel metal-oxide semiconductor (PMOS) and/or complementary metal-oxide semiconductor (CMOS)
- NMOS: N-channel metal-oxide semiconductor (NMOS)
- BiCMOS: Bipolar and CMOS combined on a chip
- BIPOLAR: Bipolar
- III-V: Gallium arsenide and other compound semiconductor processes

The Year and Quarter of Initial Production column displays the year (and quarter, if available) in which this line, having completed all qualifications, began manufacturing in production volumes. The format for this reference is "year.quarter" (for example, 1994.3 translates to the third calendar quarter of 1994).

The Initial Monthly Wafer Starts column indicates the initial monthly volume of production wafer throughput.

The column Estimated Maximum Monthly Wafer Starts contains the equipment-limited wafer start capacity per four-week period. Only the throughput of the installed equipment and the process complexity limits the maximum starts. Dataquest does not consider current staffing or the number of shifts operating in determining this metric.

Maximum (Wafer) Diameter represents the maximum wafer size that the fab or fab line can process. Wafer diameters, although expressed colloquially in inches, conform to metric specifications. For wafers greater than 3 inches in diameter, expression in inches becomes inaccurate. When calculating square inches, Dataquest uses the following approximations:

- Stated diameter of 4 inches (100mm) = Approximate diameter of 3.938 inches
- Stated diameter of 5 inches (125mm) = Approximate diameter of 4.922 inches
- Stated diameter of 6 inches (150mm) = Approximate diameter of 5.906 inches
- Stated diameter of 8 inches (200mm) = Approximate diameter of 7.87 inches

Minimum Linewidth is the smallest feature size, measured in microns, attainable in production volumes.

Table 1
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year & Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Advanced Semiconductor Manuf. Corp. of Shanghai	Fab 1	Shanghai	Suzhou	China	Lin Digital IC for TV EPROM	Frnt	P/CMOS	1992		10,000	6	0.8
Advanced Semiconductor Manuf. Corp. of Shanghai		Shanghai	Suzhou	China	EPROM Linear Digital ICs for TV	Frnt Fndry	P/CMOS Bipolar	1992		13,000	5	2
Advanced Semiconductor Manuf. Corp. of Shanghai		Shanghai	Suzhou	China	Lin Digital IC for TV EPROM	Frnt Fndry	P/CMOS	1996		10,000	6	0.8
Advanced Semiconductor Manuf. Corp. of Shanghai		Shanghai	Suzhou	China	Foundry	Frnt Fndry	P/CMOS				8	0.5
Amalgamated Wireless		Sydney		Australia	ASIC	Frnt	P/CMOS	1989.2		7,000	6	1.5
Arcus Technology Ltd.		Bangalore		India	MixSig ASIC 16-Bit 32-Bit RISC MPU	Frnt						
Beijing Industrial Complex		Beijing		China	Regulators Telecom	Frnt	P/CMOS	1988		10,000	3	5
Chartered Semiconductor	Fab I	Singapore		Singapore	Logic MixSig ASIC ROM EEPROM	Frnt Fndry	P/CMOS	1989.2	500	26,000	6	0.6
Chartered Semiconductor	Fab II	Singapore		Singapore	Logic MixSig ASIC SRAM ROM	Frnt Fndry Assy/Tst	P/CMOS	1995.3	500	40,000	8	0.18
Daewoo	Bipolar		Kyungki-Do	Korea	Diode Rectifier	Frnt	Bipolar	1983		30,000	4	5
Daewoo	Bipolar	Guro-Dong	Seoul	Korea	Analog	Frnt Assy/Tst	Bipolar	1986.3		10,000	4	2
Daewoo	MOS	Guro-Dong	Seoul	Korea	Custom ASIC	Frnt Assy/Tst	P/CMOS NMOS	1988.3		10,000	4	1
Dongsung	Bipolar	Umsung		Korea	Diode Rectifier	Frnt Assy/Tst	Bipolar	1996		30,000	4	5
Episil Technologies Inc.	Fab 2	Science Park	Hsinchu	Taiwan	Bipolar IC Power Tran	Frnt Fndry	BiCMOS Bipolar	1991		6,000	5	5
Government of China		Shanghai	Suzhou	China	Memory	Frnt						
Hitachi/LG		Kulim		Malaysia	64Mb 256Mb DRAM	Frnt	P/CMOS	1988	30,000	30,000	8	0.35
Holtek	Fab 1	Science Park	Hsinchu	Taiwan	MCU ASIC NuMem	Frnt Dsgn	P/CMOS	1990.4		30,000	5	0.8
Hua Ko Electronics		Tai Po		Hong Kong	MPU Lin ASIC Log SRAM ROM	Frnt Pilot Assy/Tst	P/CMOS	1982		8,000	4	2.5
Hua Yue Microelectronics Company Ltd.	Fab 1	Shaoxing		China	Consumer ICs ASIC	Frnt	Bipolar	1991		20,000	3	5
Hua Yue Microelectronics Company Ltd.	Fab 2	Shaoxing		China	Consumer ICs ASIC	Frnt	P/CMOS Bipolar	1992	7,000	10,000	5	3
Huajing Electronics Group	Fab 1-A	Wuxi		China	Telecom Consumer Lin ASIC	Frnt	Bipolar	1992		10,000	4	2
Huajing Electronics Group	Fab 1-B	Wuxi		China	Consumer ICs Audio Visual	Frnt	P/CMOS	1994		10,000	5	2
Huajing Electronics Group	Fab 1-C	Wuxi		China		Frnt	P/CMOS	1994		20,000	5	1
Hualon Microelectronics	Fab 1A	Science Park	Hsinchu	Taiwan	Logic ASIC MPU	Frnt Dsgn Fndry Assy/Tst	P/CMOS	1988.4		27,000	6	0.6
Hualon Microelectronics	Fab 1B	Science Park	Hsinchu	Taiwan	Logic ASIC MPU	Frnt Dsgn Fndry Assy/Tst	P/CMOS NMOS BiCMOS GaAs/III-V Other	1995.4	7,000	26,000	5	0.6
Hyundai	MOS Fab 1-B	Ichon	Kyungki-Do	Korea	64Kb 256Kb 1Mb SRAM	Frnt Rsrch	P/CMOS	1985		23,000	5	0.8

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year & Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Hyundai	MOS Fab 1-A	Ichon	Kyungki-Do	Korea	256K DRAM SRAM	Frnt	P/CMOS	1985		15,000	5	1
Hyundai	MOS Fab 2-A	Ichon	Kyungki-Do	Korea	1Mb 4Mb DRAM	Frnt Rsrch	P/CMOS	1986		15,000	6	0.65
Hyundai	MOS Fab 3	Ichon	Kyungki-Do	Korea	4Mb DRAM	Frnt Rsrch Fndry	P/CMOS	1989	16,000	20,000	6	0.5
Hyundai	MOS R&D	Ichon	Kyungki-Do	Korea	DRAM	Frnt Rsrch Pilot	P/CMOS	1989		3,000	6	0.25
Hyundai	MOS Fab 2-B	Ichon	Kyungki-Do	Korea	4Mb DRAM	Frnt Rsrch	P/CMOS	1992	10,000	20,000	6	0.5
Hyundai	Fab 4	Ichon	Kyungki-Do	Korea	4Mb 16Mb DRAM	Frnt Rsrch Fndry	P/CMOS	1993	8,000	10,000	8	0.35
Hyundai	Fab 5	Ichon	Kyungki-Do	Korea	16Mb 64Mb DRAM	Frnt Rsrch Fndry	P/CMOS	1994	18,000	25,000	8	0.35
Hyundai	Fab 6	Ichon	Kyungki-Do	Korea	64Mb DRAM	Frnt Rsrch	P/CMOS	1996	21,000	30,000	8	0.35
Jinan	No. 1	Jinan		China	Log Op Amp	Frnt Pilot		1985		10,000	3	5
Jinan	No. 2	Jinan		China	1Kb SRAM 4Kb DRAM	Frnt Pilot	NMOS	1989		8,000	3	5
Korea Diode Company Ltd.	Bip Line 1	Buchon		Korea	Analog Trans	Frnt Assy/Tst	Bipolar	1975		20,000	4	1.5
Korean Electronic Company	Bip Line 2	Gumi-City	Kyungbuk	Korea	Analog ICs ASIC	Frnt Assy/Tst	Bipolar	1986		15,000	5	1.2
Kukje		Shihung		Korea	Optoelectronics	Frnt Assy/Tst	GaAs/III-V	1992		4,000	3	5
LG Semicon	C1, Phase 1	Chongju-City	Chungche-ongbuk-do	Korea	1Mb 4Mb DRAM	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS	1990	24,000	30,000	6	0.5
LG Semicon	C1, Phase 2	Chongju-City	Chungche-ongbuk-do	Korea	4Mb DRAM	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS	1991	24,000	30,000	6	0.5
LG Semicon	C2, Phase 1	Chongju-City	Chungche-ongbuk-do	Korea	16Mb DRAM	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS	1993	11,000	15,000	8	0.35
LG Semicon	C2, Phase 2	Chongju-City	Chungche-ongbuk-do	Korea	16Mb DRAM	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS	1995	20,000	25,000	8	0.35
LG Semicon	Gumi Bipolar	Gumi-City	Kyeong-sansbuk-do	Korea	Analog Logic	Frnt Dsgn Assy/Tst	Bipolar	1980.2	18,000	25,000	5	1.2
LG Semicon	Gumi MOS	Gumi-City	Kyeong-sansbuk-do	Korea	SRAM ROM Logic	Frnt Dsgn Assy/Tst	P/CMOS	1984.4	11,000	15,000	6	0.8
LG Semicon	G1	Gumi-City	Kyeong-sansbuk-do	Korea	SRAM ROM ASIC	Frnt Dsgn Assy/Tst	P/CMOS	1995	16,000	20,000	8	0.5
Macronix Inc.	Fab 1	Science Park	Hsinchu	Taiwan	ROM EPROM 1Mb 4Mb Flash	Frnt Dsgn	P/CMOS	1992.2		35,000	6	0.45
Macronix Inc.	Fab 1-A	Science Park	Hsinchu	Taiwan	Foundry	Frnt Dsgn	P/CMOS	1994		25,000	6	0.45
Malaysian Institute of Microelectronic Systems	Phase 1	Johor Baru		Malaysia	ASIC	Frnt Rsrch Pilot		1996.4		7,000	6	0.5
Mitsubishi			Hsinchu	Taiwan	16Mb DRAM	Frnt Assy/Tst	P/CMOS	1996		12,000	8	0.35
Mosel Vitelic	Fab 1A	Science Park	Hsinchu	Taiwan	DRAM VRAM	Frnt Dsgn Fndry	P/CMOS	1995.1	2,000	15,000	6	0.45
Mosel Vitelic	Fab 1B	Science Park	Hsinchu	Taiwan	DRAM VRAM	Frnt Fndry	P/CMOS	1995.4	2,000	15,000	6	0.34

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year & Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Motorola	ISMP	Seremban		Malaysia	Pwr Tran Dis SST Small Signal	Frnt Rsrch Assy/Tst	Bipolar	1988.2		4,000	4	3
Nan Ya Technology	Fab 1	Tao Yuan		Taiwan	16Mb 64Mb DRAM	Frnt Dsgn	P/CMOS	1996.2	2,000	30,000	8	0.45
NEC		Beijing		China	MCU Logic	Frnt Assy/Tst	P/CMOS	1994		5,000	6	1.2
Photronics				Taiwan	Opto	Frnt Assy/Tst				10,000	3	
Powerchip (Elitegroup)	Fab 1	Science Park	Hsinchu	Taiwan	16Mb DRAM	Frnt	P/CMOS	1996.2	5,000	25,000	8	0.4
Quality Semiconductor				Australia	16-Bit 32-Bit MCU FIFO Foundry	Frnt Fndry	P/CMOS	1988		2500	6	0.6
Ramax		Melbourne		Australia	FerRAM	Frnt	P/CMOS GaAs/III-V	1990				
RCL Semiconducors		Tai Po		Hong Kong	Memory MPU Log Lin Tran	Frnt Pilot Assy/Tst	P/CMOS	1982		4,000	4	2.5
RCL Semiconducors		Tai Po		Hong Kong		Frnt Assy/Tst	P/CMOS	1993		6,000	5	2.5
Sammi	III-V	Yongin	Kyungki-Do	Korea	LED Ld HEMT	Frnt Assy/Tst	GaAs/III-V	1992		4,000	3	5
Samsung	Bipolar	Buchon-City	Kyungki-Do	Korea	Analog	Frnt Dsgn	Bipolar	1974	23,000	40,000	4	3
Samsung	MOS	Buchon-City	Kyungki-Do	Korea	MCRO Logic	Frnt Dsgn	P/CMOS NMOS	1974	15,000	30,000	5	2
Samsung	Fab 1	Kiheung-Up	Kyungki-Do	Korea	MOS ICs	Frnt Dsgn	P/CMOS	1984.1	21,000	35,000	4	1
Samsung	Fab 2	Kiheung-Up	Kyungki-Do	Korea	SRAM Mask ROM	Frnt Dsgn	P/CMOS	1985.1	25,000	35,000	6	1
Samsung	Fab 3	Kiheung-Up	Kyungki-Do	Korea	1Mb DRAM SRAM	Frnt Dsgn	P/CMOS	1988.3	24,000	35,000	6	0.8
Samsung	R&D	Kiheung-Up	Kyungki-Do	Korea	R&D	Frnt Dsgn Pilot	P/CMOS	1989.2		3,000	6	0.3
Samsung	Fab 4	Kiheung-Up	Kyungki-Do	Korea	4Mb DRAM SRAM	Frnt Dsgn	P/CMOS	1990	25,000	35,000	6	0.5
Samsung	Fab 5	Kiheung-Up	Kyungki-Do	Korea	16Mb DRAM	Frnt Dsgn	P/CMOS	1993	19,000	25,000	8	0.5
Samsung	Fab 6	Kiheung-Up	Kyungki-Do	Korea	16Mb 64Mb DRAM	Frnt Dsgn	P/CMOS	1995.1	23,000	30,000	8	0.35
Samsung	Fab 7	Kiheung-Up	Kyungki-Do	Korea	16Mb 64Mb DRAM	Frnt Dsgn	P/CMOS	1996	15,000	20,000	8	0.35
Semiconductor Complex		Nagar -Chandigarh		India	LSI	Frnt Pilot	BiCMOS	1993			6	3
SGS-Thomson	Fab 2	Singapore		Singapore	Analog Discrete	Frnt Rsrch Pilot	BiCMOS Bipolar	1984		42,000	5	2.5
SGS-Thomson	Fab 3	Singapore		Singapore	Lin Pwr Tran SST Pwr ICs	Frnt	Bipolar	1984	16,000	37,000	5	2.5
SGS-Thomson	Fab 1	Singapore		Singapore	MPR ASIC Analog	Frnt Rsrch	P/CMOS NMOS	1988	12,000	28,000	5	2
SGS-Thomson	Fab 4	Singapore		Singapore	Telecom IC Disk Drive IC Special Consumer IC	Frnt Rsrch	P/CMOS	1996	8,000	23,000	5	1.5
Shanghai Belling Microelectronics		Shanghai	Suzhou	China	Telecom Consumer IC Dis	Frnt	P/CMOS	1989		10,000	4	1.1
Shanghai Belling Microelectronics		Shanghai	Suzhou	China		Frnt	P/CMOS				8	0.5
Shanghai Industrial Complex	Fab 1	Shanghai	Suzhou	China		Frnt	P/CMOS Bipolar	1991		10,000	5	3
Shanghai Industrial Complex	Fab No. 1	Shanghai	Suzhou	China	Tran Lin Log Mem	Frnt Rsrch Pilot	NMOS			1,200	4	3
Shanghai Industrial Complex	Fab No. 2	Shanghai	Suzhou	China	ASIC	Frnt	P/CMOS BiCMOS					1
SubMicron Technology	Fab 1	Bangkok	Chachaersao	Thailand	Foundry	Frnt Fndry	P/CMOS	1996		20,000	8	0.5

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year & Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Suzhou Complex		Suzhou		China	Log Opto Consumer	Frnt Assy/Tst	P/CMOS Bipolar	1990			3	
Taijin No. 1		Taijin		China	Audio IC	Frnt	P/CMOS			10,000	3	5
Taiwan Semiconductor Manufacturing Co.	Fab 1	Science Park	Hsinchu	Taiwan	Mem Micro Logic Analog	Frnt Fndry	P/CMOS BiCMOS	1988		19,000	6	0.8
Taiwan Semiconductor Manufacturing Co.	Fab 2-A	Science Park	Hsinchu	Taiwan	Logic	Frnt Fndry	P/CMOS	1990.3		37,500	6	0.6
Taiwan Semiconductor Manufacturing Co.	Fab 2-B	Science Park	Hsinchu	Taiwan	SRAM	Frnt Fndry	P/CMOS	1992.4		37,500	6	0.5
Taiwan Semiconductor Manufacturing Co.	Fab 3	Science Park	Hsinchu	Taiwan	DRAM SRAM ROM Log Custom	Frnt Fndry	P/CMOS BiCMOS	1995	17,000	30,000	8	0.35
Taiwan Semiconductor Manufacturing Co.	Fab 4	Science Park	Hsinchu	Taiwan	Log Custom MPU Mem 64Mb DRAM	Frnt Fndry Assy/Tst	P/CMOS BiCMOS	1996.4	5,000	25,000	8	0.35
Tech Semiconductor	Fab 1	Singapore		Singapore	16Mb DRAM	Frnt Fndry	P/CMOS	1993.2	6,000	12,000	8	0.5
Tech Semiconductor	Fab 2	Singapore		Singapore	16Mb DRAM	Frnt Fndry	P/CMOS	1996.3	10,000	25,000	8	0.35
Texas Instruments/Acer	Fab 1A	Science Park	Hsinchu	Taiwan	4Mb DRAM	Frnt Fndry	P/CMOS	1991.4	5,000	22,000	6	0.5
Texas Instruments/Acer	Fab 1B	Science Park	Hsinchu	Taiwan	4Mb 16Mb DRAM	Frnt Fndry	P/CMOS	1995.3	5,000	25,000	8	0.35
United Microelectronics Corp.	Fab 1	Science Park	Hsinchu	Taiwan	Consumer IC Logic Tft-Lcds	Frnt Fndry	P/CMOS NMOS	1982.2		50,000	4	0.8
United Microelectronics Corp.	Fab 2	Science Park	Hsinchu	Taiwan	MPR MPU SRAM ROM I/O	Frnt Fndry	P/CMOS	1989		45,000	6	0.5
United Microelectronics Corp.	Fab 3-A	Science Park	Hsinchu	Taiwan	Foundry SRAM ROM Logic MPU MPR	Frnt Fndry	P/CMOS	1995	5,000	25,000	8	0.35
United Microelectronics Corp.	United Semi-conductor Corporation	Science Park	Hsinchu	Taiwan	Foundry SRAM ROM Logic MPU MPR	Frnt Fndry	P/CMOS	1996.3	4,000	25,000	8	0.35
Vanguard International	Fab 1	Science Park	Hsinchu	Taiwan	4Mb DRAM	Frnt Rsrch Pilot	P/CMOS	1991		4,000	6	0.5
Vanguard International	Fab 1A	Science Park	Hsinchu	Taiwan	4Mb 16Mb DRAM	Frnt Rsrch Fndry Assy/Tst	P/CMOS	1995.2	5,000	16,000	8	0.35
Winbond	Fab 1	Science Park	Hsinchu	Taiwan	Telecom ICs	Frnt Dsgn	P/CMOS	1988.3		22,000	5	0.8
Winbond	Fab 2	Science Park	Hsinchu	Taiwan	DRAM	Frnt Dsgn	P/CMOS BiCMOS	1992.4		35,000	6	0.5

Source: Dataquest (December 1996)

Table 2
Front-End Production Lines Beginning Operation 1997 and After

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Alphatec/TI Semiconductor	Phase 1	Bangkok	Chachaersao	Thailand	16Mb 64Mb DRAM	Frnt	P/CMOS	1997.3	10,000	20,000	8	0.35
Anam/Amkor			Seoul	Korea	Foundry pDSPs Logic	Frnt Fndry Assy/Tst		1998		20,000	8	0.5
Chartered Semiconductor	Fab III	Singapore		Singapore	Logic SRAM	Frnt Fndry	P/CMOS	1997.2		47,000	8	0.18
Hitachi/Nippon Steel Semiconductor	Tampins	Singapore		Singapore	64Mb DRAM	Frnt	P/CMOS	1998		20,000	8	0.3
Holtek	Fab 2	Science Park	Hsinchu	Taiwan	MCU ASIC NvMem	Frnt Dsgn Fndry	P/CMOS	1997.3	2,000	20,000	8	0.6
Hua Yue Microelectronics Company Ltd.	Fab 3	Shaoxing		China	Consumer ICs ASIC	Frnt	P/CMOS	1998		20,000	6	0.8
Huajing Electronics Group	Fab 2	Wuxi		China	Telecom Consumer Auto ICs ASIC Dis	Frnt	P/CMOS	1997		10,000	6	0.8
Hyundai	Fab 7	Ichon	Kyungki-Do	Korea	16Mb 64Mb DRAM	Frnt Rsrch	P/CMOS	1997		30,000	8	0.35
InterConnect Technology		Sama Jaya Trade Zone	Sarawak	Malaysia		Frnt		1997		25,000	8	0.25
LG Semicon	C1 Phase 3	Chongju-City	Chungcheongbuk-do	Korea	16Mb 64Mb DRAM	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS	1997		30,000	8	0.35
LG Semicon	G2	Gumi-City	Kyeongsansbuk-do	Korea	64Mb DRAM	Frnt Dsgn Assy/Tst	P/CMOS	1997	3,000	30,000	8	0.35
Macronix Inc.	Fab 2	Science Park	Hsinchu	Taiwan	ROM EPROM Logic	Frnt Dsgn	P/CMOS	1997.2	5,000	30,000	8	0.35
Macronix Inc.	Fab 3	Science Park	Hsinchu	Taiwan	ROM EPROM Logic	Frnt Dsgn	P/CMOS	2000		40,000	8	0.25
Mosel Vitelic	Fab 2	Science Park	Hsinchu	Taiwan	16Mb 64Mb DRAM SRAM	Frnt Dsgn Fndry	P/CMOS	1997.2	5,000	20,000	8	0.35
Motorola	MOS-17	Tianjin		China	Telecom ASIC RF SmartMOS	Frnt Assy/Tst	P/CMOS	1997.4		12,000	8	0.5
NEC		Beijing		China	MCU Logic 4Mb DRAM ASIC	Frnt Assy/Tst	P/CMOS	2000		5,000	6	0.7
Samsung	Fab 8	Kiheung-Up	Kyungki-Do	Korea	64Mb DRAM	Frnt Dsgn	P/CMOS	1997		25,000	8	0.3
SGS-Thomson	Fab 5	Singapore		Singapore	Logic	Frnt Rsrch	P/CMOS	1998.2	4,000	20,000	8	0.5
Shanghai Hua Hong Microelectronics		Poudong	Shanghai	China		Frnt	P/CMOS	1997			8	0.5
Taiwan Semiconductor Manufacturing Co.	Fab 5	Science Park	Hsinchu	Taiwan	Log Custom MPU Memory Foundry	Frnt Fndry Assy/Tst	P/CMOS BiCMOS	1997.4	5,000	25,000	8	0.35
Texas Instruments/Acer	Fab 2	Science Park	Hsinchu	Taiwan	16Mb 64Mb DRAM	Frnt Fndry	P/CMOS	1997.3	5,000	50,000	8	0.35
United Microelectronics	United Silicon Inc.	Science Park	Hsinchu	Taiwan	Foundry	Frnt Fndry	P/CMOS	1997		25,000	8	0.25
United Microelectronics	United IC Corp.	Science Park	Hsinchu	Taiwan	Foundry Memory ASIC MPU Logic	Frnt Fndry	P/CMOS	1997.2	1,000	17,000	8	0.35

Table 2 (Continued)
Front-End Production Lines Beginning Operation 1997 and After

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Vanguard International	Fab 1B	Science Park	Hsinchu	Taiwan	16Mb DRAM	Frnt Rsrch Fndry Assy/ Tst	P/CMOS	1997.1	5,000	16,000	8	0.35
Vanguard International	Fab 2	Science Park	Hsinchu	Taiwan	4Mb DRAM 16Mb DRAM 1Mb Sync SRAM	Frnt	P/CMOS	1998		40,000	8	0.18
Winbond	Fab 3	Science Park	Hsinchu	Taiwan	SRAM Logic	Frnt	P/CMOS	1997.1	5,000	25,000	8	0.35
Winbond	Fab 4	Science Park	Hsinchu	Taiwan	DRAM	Frnt	P/CMOS	1997.3	1,000	15,000	8	0.35

Source:Dataquest (December 1996)

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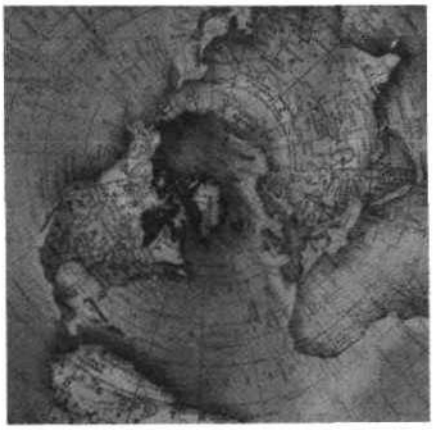

Dataquest

Japan Fab Database

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
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Filing: Market Statistics

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Japan Fab Database

Background and Methodology

This report contains the Japan portion of Dataquest's wafer fab database. These tables cover fabs located in the Japan region. The Semiconductor Equipment, Materials, and Manufacturing Worldwide (SEMM) program conducts extensive annual surveys complemented with quarterly secondary research to maintain this database. Published once a year, this document represents Dataquest's best insights and estimates into the end market of semiconductor equipment.

The tables in this report cover planned and existing merchant, captive, and foundry fab lines. A fab line consists of a series of equipment that does front-end semiconductor manufacturing (from initial oxide through wafer probe). Occasionally, two or more separate product-specific fab lines or wafer sizes operate in a single clean room or physical plant. In this situation, Dataquest considers the clean room to be separate fab lines if the company dedicates equipment to each wafer size or product line. If a company installs substantially different equipment during an expansion (for example, equipment to increase the maximum wafer diameter), again Dataquest divides the clean room and creates two entries in the database. Therefore, a company may operate many fab lines at one location.

Worldwide Geographic Region Definitions and Regional Roll-Ups

Americas

Includes Central America (all nations), Canada, Mexico, United States, Puerto Rico, and South America (all nations)

Japan

Japan is the only single-country region.

Europe, Africa, and Middle East

Includes Africa (all nations), Albania, Andorra, Armenia, Azerbaijan, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Gibraltar, Hungary, Iceland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Middle East (all nations), Moldova, Monaco, Netherlands, Norway, Poland, Romania, Russia, San Marino, Scandinavia, Slovakia, Spain, Sweden, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan, Vatican City, and all nations within the former Yugoslavia

Asia/Pacific

Includes Australia, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam

Table Column Definitions

The Company column indicates the operator of the fab line. For contract manufacturers that trade capacity for capital investment in the fab, Dataquest lists the contract manufacturer. For incorporated joint ventures, Dataquest will either list the incorporated entity or the major investors, separated with slashes.

The Fab Name column provides a reference to a particular fab or fab line to distinguish it from other fabs or lines owned by that company. Although Dataquest makes every attempt to match the nomenclature used by the company, occasionally some additional qualifiers (for example, Phase 1) appear to provide insight into the facility's history or organization.

The City column displays the most detailed location information. This reference is usually a city or town, but could be an often-used district name (for example, Science Park in the city of Hsinchu, Taiwan). If this column lists a district, Dataquest will list the city in the State or Province column. In some cases, a reference to a state or province will be included in the city or district column to create a unique identifier for this location.

The State, Province, or Prefecture columns denote the second most detailed location. This reference is usually a state (for the United States), province (for Canada and many European and Asian countries), or a prefecture (for Japan). For countries within the United Kingdom, Dataquest will list the country name (for example, Scotland) in this column so Dataquest can list the descriptor "U.K." in the Country column.

The Country column indicates the broadest location identifier in this report. This reference is usually a country, except in the case of the United Kingdom (see above). As Japan is a single-country region, a regional qualifier does not exist for fabs in Japan.

The Devices Produced column lists the products manufactured at this site. The listings generally fall into five product groups, with the following nomenclature and definitions (when warranted):

- MOS memory
  - DRAM: Dynamic RAM
  - EEPROM or E2: Electrically erasable PROM
  - EPROM: Ultraviolet erasable PROM
  - FERRAM: Ferroelectric RAM
  - FIFO: First-in/first-out memory
  - Flash: Flash memory
  - MEM: Memory
  - NvMem: Nonvolatile memory (ROM, PROM, EPROM, EEPROM, FERRAM)
  - PROM: Programmable ROM

- RAM: Random-access memory
- ROM: Read-only memory
- SpMem: Other specialty memory (such as dual-port, shift-register, color lookup)
- SRAM: Static RAM
- VRAM: Video RAM

■ MOS microcomponent/digital logic

- Arrays: Gate array
- ASIC: Application-specific IC
- ASSP: Application-specific standard product
- Bit: Bit slice (subset of MPU functions)
- CBIC: Cell-based IC
- Custom: Full-custom IC (single user)
- DSP: Digital signal processor
- FPGA: Field-programmable gate array
- LISP: 32-bit list instruction set processor for AI
- Log or Logic: Standard logic
- MCU: Microcontroller unit
- Mixsig ASIC: Mixed-signal ASIC
- MPR: Microperipheral
- MPRCom: MPR digital communications (ISDN, LAN, UART, modem)
- MPU: Microprocessor unit
- PLD: Programmable logic device
- RISC: Reduced-instruction-set computation 32-bit MPU
- Telecom: Telecommunications chip

■ Power/discrete/analog (including bipolar power)

- A/D D/A: Analog-to-digital, digital-to-analog converter
- Automotive: Dedicated to automobile applications
- Codec: Coder/decoder
- Diode
- Dis or Discrete: Discrete
- FET: Field-effect transistor
- GTO: Gate turn-off thyristor
- HEMT: High-electron-mobility transistor
- IGBT: Insulated gate bipolar transistor
- Interface: Interface IC

- Lin: Linear/analog device
- MDiode: Microwave diode
- MESFET: Metal semiconductor field-effect transistor
- MFET: Microwave field-effect transistor
- Modem: Modulator/demodulator
- MMIC: Monolithic microwave IC
- MOSFET: MOS-based field-effect transistor
- Op Amp: Operational amplifier
- Pwr IC: Power IC
- Pwr Tran: Power transistor
- Rectifier
- Reg: Voltage regulator
- RF: Radio frequency
- SCR: Schottky rectifier
- Sensor
- Smart Pwr: Smart power
- SST: Small-signal transistor
- Switch: Switching device
- Thyristor
- Tran: Transistor
- Zener Diode

- Optoelectronic
  - CCD: Charge-coupled device (imaging)
  - Coupler: Photocoupler
  - IED: Infrared-emitting diode
  - Image Sensor
  - Laser: Semiconductor laser or laser IC
  - LED: Light-emitting diode
  - Opto: Optoelectronic
  - PDiode: Photodiode
  - PTran: Photo transistor
  - SAW: Surface acoustic wave device
  - SIT Image Sensor: Static induction transistor image sensor
- Bipolar digital
  - Includes all digital ICs using a bipolar process

The Activities column shows the types of semiconductor manufacturing performed at this location. The activities include:

- "Frnt" means this location performs front-end wafer processing. Front-end wafer processing includes the manufacturing steps from initial oxide through wafer probe test.
- "Rsrch" means the location performs product or process research. Research differs from pilot manufacturing in that research wafers are nonsalable.
- "Dsgn" means this location has a design center.
- "Pilot" means this location performs pilot production. Pilot production means the location produces in small volumes while "debugging" new products or process technologies. The main difference between research and pilot is that, unlike research, pilot wafers are salable product.
- "Fndry" means this location performs contract manufacturing. Contract manufacturing is the production, under contract, of another company's branded product. This is also known as foundry production.
- "Assy/tst" means this location performs assembly and/or testing. Assembly and testing includes the manufacturing steps from E-test through final assembly into a package and final test.

The Processes column indicates each fab's use of five major types of processes. The process groupings are:

- P/CMOS: P-channel metal-oxide semiconductor (PMOS) and/or complementary metal-oxide semiconductor (CMOS)
- NMOS: N-channel metal-oxide semiconductor (NMOS)
- BiCMOS: Bipolar and CMOS combined on a chip
- BIPOLAR: Bipolar
- III-V: Gallium arsenide and other compound semiconductor processes

The Year and Quarter of Initial Production column displays the year (and quarter, if available) in which this line, having completed all qualifications, began manufacturing in production volumes. The format for this reference is "year.quarter" (for example, 1994.3 translates to the third calendar quarter of 1994).

The Initial Monthly Wafer Starts column indicates the initial monthly volume of production wafer throughput.

The column Estimated Maximum Monthly Wafer Starts contains the equipment-limited wafer start capacity per four-week period. Only the throughput of the installed equipment and the process complexity limits the maximum starts. Dataquest does not consider current staffing or the number of shifts operating in determining this metric.

Maximum (Wafer) Diameter represents the maximum wafer size that the fab or fab line can process. Wafer diameters, although expressed colloquially in inches, conform to metric specifications. For wafers greater than 3 inches in diameter, expression in inches becomes inaccurate. When calculating square inches, Dataquest uses the following approximations:

- Stated diameter of 4 inches (100mm) = Approximate diameter of 3.938 inches
- Stated diameter of 5 inches (125mm) = Approximate diameter of 4.922 inches
- Stated diameter of 6 inches (150mm) = Approximate diameter of 5.906 inches
- Stated diameter of 8 inches (200mm) = Approximate diameter of 7.87 inches

Minimum Linewidth is the smallest feature size, measured in microns, attainable in production volumes.

Table 1
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Prefecture	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Start	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Aishin Seiki	Handa	Handa-Shi	Aichi	Automotive	Frnt		1991			6	
Aishin Seiki	Shinkawa	Hekinan-Shi	Aichi	Automotive	Frnt Pilot		1990			3	
Asahi Kasei Micro Systems		Atsugi-Shi	Kanagawa	Tran Custom	Frnt Rsrch Pilot	NMOS	1987		4,000	5	
Asahi Kasei Micro Systems		Nobeoka-Shi	Miyazaki	SRAM Full Custom Other MOS Logic	Frnt Assy/Tst	P/CMOS	1993.3		6,000	6	0.8
Canon		Hiratsuka-Shi	Kanagawa	Amorphous Image Sensors	Frnt Pilot	GaAs/III-V				3	
Canon		Hiratsuka-Shi	Kanagawa	ASIC	Frnt Pilot	P/CMOS			3,000	6	
Canon Denshi		Chichibu-Shi	Saitama	CCD	Frnt Pilot	NMOS	1984		5,000	5	3
Casio		Hachioji-Shi	Tokyo	ASIC	Frnt Pilot Assy/Tst				11,000	4	
Fuji Electric		Matsumoto-Shi	Nagano	Diode Pwr Tran MOSFET	Frnt	Bipolar	1985		50,000	4	6
Fuji Electric		Matsumoto-Shi	Nagano	Custom ASSP	Frnt	P/CMOS BiC-MOS Bipolar	1990		3,000	6	0.8
Fuji Electric		Matsumoto-Shi	Nagano	MOSFET IGBT High-Voltage Diode	Frnt	NMOS Bipolar	1995		30,000	5	3
Fuji Electric		Matsumoto-Shi	Nagano	Custom ASSP	Frnt	BiCMOS Bipolar			15,000	4	2
Fuji Film Microdevice		Kurokawa-Gun	Miyagi	CCD Converter Full Custom	Frnt	P/CMOS	1992		3,000	6	1
Fuji Xerox		Suzuka-Shi	Mie	Pwr ICs Image Sensor Log	Frnt Pilot	P/CMOS	1986		3,000	5	3
Fujitsu	VLSI 1	Aizu Wakamatsu-Shi	Fukushima	Dis A/D D/A	Frnt Assy/Tst	Bipolar	1983		30,000	5	1.5
Fujitsu	VLSI 2	Aizu Wakamatsu-Shi	Fukushima	MPU	Frnt Assy/Tst	P/CMOS NMOS	1984		40,000	5	1
Fujitsu	Bldg. No. 1	Aizu Wakamatsu-Shi	Fukushima	Arrays Logic	Frnt	P/CMOS Bipolar	1985		10,000	5	1.2
Fujitsu	VLSI 3	Aizu Wakamatsu-Shi	Fukushima	Logic	Frnt	P/CMOS NMOS	1988		20,000	6	1
Fujitsu	Bldg. No. 2	Aizu Wakamatsu-Shi	Fukushima	Arrays CBIC 32-Bit MCU	Frnt	P/CMOS	1990.2		20,000	6	0.7
Fujitsu	Bldg. No. 2-2	Aizu Wakamatsu-Shi	Fukushima	Arrays Logic CBIC MPU	Frnt	P/CMOS	1995		35,000	6	0.35
Fujitsu	Bldg. No. 2-3	Aizu Wakamatsu-Shi	Fukushima	Arrays Logic CBIC MPU	Frnt	P/CMOS	1996		10,000	8	0.35
Fujitsu	No. 2	Isawa-Gun	Iwate	ROM EPROM	Frnt Assy/Tst	NMOS	1984		32,000	5	1.5
Fujitsu	No. 3	Isawa-Gun	Iwate	4Mb DRAM SRAM ROM MPU	Frnt	P/CMOS NMOS	1987		50,000	6	0.8
Fujitsu	No. 4-1	Isawa-Gun	Iwate	16Mb DRAM SGRAM	Frnt	P/CMOS NMOS	1990.4		20,000	6	0.42
Fujitsu	No. 4-2	Isawa-Gun	Iwate	16Mb DRAM	Frnt	P/CMOS	1996	10,000	25,000	8	0.3
Fujitsu		Kawasaki-Shi	Kanagawa	3D ICs Josephson Junction	Frnt Pilot		1988		5,000	5	0.35
Fujitsu	No. 1	Kuwana-Gun	Mie	Arrays	Frnt Pilot Assy/Tst	P/CMOS NMOS	1984		10,000	6	1
Fujitsu	No. 2	Kuwana-Gun	Mie	Log Arrays 4Mb DRAM	Frnt Pilot Assy/Tst	P/CMOS Bipolar	1987		10,000	6	0.8
Fujitsu	No. 3 Phase 1	Kuwana-Gun	Mie	4Mb 16Mb DRAM SRAM MPU	Frnt	P/CMOS	1992		15,000	6	0.5
Fujitsu	No. 3 Phase 2	Kuwana-Gun	Mie	16Mb 64Mb DRAM	Frnt Pilot	P/CMOS	1994		500	8	0.25
Fujitsu-AMD Semiconductor	Fab 1 Phase 1	Aizu Wakamatsu Shi	Fukushima	4Mb 16Mb 32Mb Flash EPROM	Frnt	P/CMOS	1994.4	10,000	12,500	8	0.5
Fujitsu-Quantum Device	No.1	Nakakoma-Gun	Yamanashi	Fet Lin Opto HEMT	Frnt	GaAs/III-V	1984		13,000	4	1.5

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Prefecture	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Start	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Fujitsu-Quantum Device	No.2	Nakakoma-Gun	Yamanashi	HEMT ASIC	Frnt	GaAs/III-V	1992		13,000	4	1.5
Genesys Technology		Nishiwaki-shi			Frnt		1992				
Hamamatsu Photronics		Hamamatsu-Shi	Shizuoka	Opto	Frnt Rsrch				15,000	3	
Hitachi	Chitose 1-1F	Chitose-Shi	Hokkaido	4M DRAM MCU	Frnt	P/CMOS	1988		15,000	6	0.8
Hitachi	Chitose 1-2F	Chitose-Shi	Hokkaido	4M DRAM MCU	Frnt	P/CMOS	1990		15,000	6	0.8
Hitachi		Hitachi-Shi	Ibaraki	Pwr GTO Thyristors TTL	Frnt	Bipolar	1983		15,000	5	3
Hitachi	N1-1	Hitachinaka-Shi	Ibaraki	1Mb 4Mb DRAM	Frnt	P/CMOS	1983		15,000	6	0.8
Hitachi	N2-1	Hitachinaka-Shi	Ibaraki	16Mb DRAM	Frnt	P/CMOS	1994.4	10,000	10,000	8	0.35
Hitachi	N2/3F	Hitachinaka-Shi	Ibaraki	16Mb 64Mb DRAM	Frnt	P/CMOS	1996	10,000	15,000	8	0.35
Hitachi	N2-2	Hitachinaka-Shi	Ibaraki	16Mb 64Mb DRAM	Frnt	P/CMOS	1996	10,000	10,000	8	0.35
Hitachi	R&D 2	Kodaira-Shi	Tokyo	MPU SRAM DRAM Arrays CBIC	Frnt Pilot	P/CMOS	1985		3,000	6	0.5
Hitachi	R&D 1	Kodaira-Shi	Tokyo	MPU Memory CBIC	Frnt Pilot	P/CMOS	1987		5,000	5	0.8
Hitachi	Komoro	Komoro-Shi	Nagano	Laser	Frnt	P/CMOS BiC-MOS GaAs/III-V	1980		15,000	3	1.5
Hitachi	D1	Mobara-Shi	Chiba	1Mb 4Mb DRAM LCD Driver	Frnt	P/CMOS BiC-MOS	1982		25,000	5	1.3
Hitachi	D3	Mobara-Shi	Chiba	4Mb DRAM	Frnt	P/CMOS	1990		15,000	6	0.8
Hitachi	K4-1F	Nakakoma-Gun	Yamanashi	MPU Logic	Frnt	P/CMOS	1983		30,000	5	1.3
Hitachi	K4-2F	Nakakoma-Gun	Yamanashi	MPU Logic	Frnt	P/CMOS	1988		20,000	6	1
Hitachi	K4-3F	Nakakoma-Gun	Yamanashi	4Mb DRAM 1Mb SRAM EPROM	Frnt	P/CMOS	1989		10,000	6	0.8
Hitachi	K2-1F	Nakakoma-Gun	Yamanashi	4Mb DRAM SRAM MCU	Frnt	P/CMOS	1990		25,000	6	2
Hitachi	K2-2F	Nakakoma-Gun	Yamanashi	16Mb DRAM	Frnt	P/CMOS	1995		10,000	8	0.5
Hitachi	D4/D5	Ome-Shi	Tokyo	64Mb DRAM 64Mb Flash ASIC	Frnt Rsrch Pilot	P/CMOS	1994		5,000	8	0.35
Hitachi	T1	Takasaki-Shi	Gunma	Discrete Bip Analog Opto	Frnt	P/CMOS BiC-MOS Bipolar	1986		15,000	5	2
Hitachi	T2	Takasaki-Shi	Gunma	Mem Bip Lin	Frnt	P/CMOS BiC-MOS Bipolar	1988		15,000	6	1.2
Hitachi	T4	Takasaki-Shi	Gunma	256Kb 1Mb SRAM	Frnt	P/CMOS BiC-MOS	1992		20,000	6	0.5
Hitachi	T3	Takasaki-Shi	Gunma	16Mb DRAM	Frnt	P/CMOS	1995		10,000	8	0.5
Hitachi Tobu Semiconductor	Fab 1-2F	Goshogawara Shi	Aomori	MCU	Frnt	P/CMOS	1995		17,000	6	0.8
Honda	Tochigi Lab	Haga-Gun	Tochigi	Eng. Control Sensors MMIC	Frnt Pilot	P/CMOS GaAs/III-V	1990			3	
IBM Microelectronics		Yasu-Gun	Shiga	64Mb DRAM pDSP	Frnt	P/CMOS	1990	6,000	15,000	8	0.35
IBM Microelectronics		Yasu-Gun	Shiga	Array MPU ROM	Frnt	P/CMOS			30,000	5	1
Iwatsu		Hachioji-Shi	Tokyo		Frnt Pilot	P/CMOS	1986		6,000	5	1.5
JVC		Yokosuka-Shi	Kanagawa	1Kb Arrays DSP Custom	Frnt Pilot	P/CMOS			9,000	3	3

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Prefecture	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Start	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Kawasaki Steel		Utsunomiya-Shi	Tochigi	256Kb SRAM CBIC Arrays	Frnt Pilot Fndry	P/CMOS	1991		9,000	6	0.5
Kodenshi	Plant 3	Uji-Shi		Opto Discrete	Frnt Assy/Tst	Bipolar GaAs/III-V	1995.2		7,000	5	
Konica	Lab	Nishi-Shinjuku	Tokyo	Opto	Frnt Rsrch Pilot		1984		7,000	3	
KTI Semiconductor	Fab 1	Nishiwaki-Shi	Hyogo	16Mb DRAM ASIC	Frnt Assy/Tst	P/CMOS	1992.4		10,000	8	0.5
Kyocera		Kansai-Shi	Kyoto		Frnt Rsrch Pilot		1992.2				
Kyoto Semiconductor		Kyoto-Shi	Niigata	LED Tran Image Sensor	Frnt	GaAs/III-V					
LSI Logic	Fab 1	Tsukuba-Shi	Ibaraki	ASIC CBIC MPU MPR SRAM	Frnt Fndry	P/CMOS BiC-MOS	1989		20,000	6	1
LSI Logic	Fab 2	Tsukuba-Shi	Ibaraki	ASIC CBIC MPU MPR SRAM	Frnt	P/CMOS BiC-MOS	1993		8,000	6	0.6
Matsushita	Fab A	Arai-Shi	Niigata	Analog Discrete	Frnt	Bipolar	1967	15,000	30,000	4	6
Matsushita	Fab B	Arai-Shi	Niigata	MCU Logic ASSP	Frnt	P/CMOS BiC-MOS Bipolar	1982		14,000	5	1.5
Matsushita	Fab C-1	Arai-Shi	Niigata	Analog	Frnt Assy/Tst	P/CMOS Bipolar	1984		7,000	5	2
Matsushita	Fab C-2	Arai-Shi	Niigata	CCD Mixsig ICs	Frnt Assy/Tst	P/CMOS	1984		7,000	5	0.8
Matsushita	Fab D-1	Arai-Shi	Niigata	Analog	Frnt	Bipolar	1985		22,000	4	1.8
Matsushita	Fab D-2	Arai-Shi	Niigata	Analog	Frnt	Bipolar	1985		18,000	5	1.5
Matsushita		Hioki-Gun	Kagoshima	Opto LED Laser	Frnt	NMOS GaAs/III-V	1974		1,000	2	3
Matsushita	Fab A	Hioki-Gun	Kagoshima	Analog	Frnt	BiCMOS Bipolar	1980		28,000	4	2
Matsushita	S/C R6	Kadoma-Shi	Osaka	16Mb DRAM 64-Bit MPU 64Mb DRAM	Frnt Rsrch Pilot Assy/Tst	P/CMOS	1991.1		500	6	0.35
Matsushita	Kyoto R&D	Kyoto-Shi	Niigata	DRAM	Frnt Rsrch Pilot Assy/Tst	P/CMOS	1991		500	8	0.25
Matsushita	C	Nagaokakyo-Shi	Kyoto	Discrete (Power)	Frnt	Bipolar	1980		18,000	4	3
Matsushita	V	Nagaokakyo-Shi	Kyoto	Discrete	Frnt	P/CMOS NMOS	1982		19,000	4	2
Matsushita	Fab A	Tonami-Shi	Toyama	MCU ASIC	Frnt	P/CMOS	1994	8,000	12,000	6	0.5
Matsushita	Fab C	Tonami-Shi	Toyama	16Mb DRAM	Frnt	P/CMOS	1996		10,000	8	0.35
Matsushita	Fab B	Tonami-Shi	Toyama	16Mb DRAM 16-Bit MCU	Frnt	P/CMOS	1996.1	10,000	20,000	6	0.35
Matsushita	Fab A-1	Uozu-Shi	Toyama	MCU	Frnt	P/CMOS	1985		34,000	5	1.2
Matsushita	Fab C-1	Uozu-Shi	Toyama	MPU MCU Logic ASSP	Frnt	P/CMOS	1987		27,000	6	1
Matsushita	Fab C-2	Uozu-Shi	Toyama	MCU	Frnt	P/CMOS	1990		24,000	6	0.6
Matsushita	Fab B	Uozu-Shi	Toyama	MCU DSP Logic ASSP	Frnt	P/CMOS	1991		20,000	6	0.8
Matsushita		Utsunomiya-Shi	Tochigi	Discrete (Ss Tr Varicap)	Frnt Pilot Assy/Tst	NMOS Bipolar	1983		10,000	4	5
Meidensha		Numazu-Shi	Shizuoka	GTO Thyristor	Frnt Pilot		1985		7,000	5	
Mitsubishi	No. 1	Fukuoka-Shi	Fukuoka	Pwr Tran Diode Bip	Frnt Assy/Tst	NMOS Bipolar	1976		34,000	4	3
Mitsubishi	No. 2	Fukuoka-Shi	Fukuoka	Bip Lin A/D D/A Dis Micro	Frnt	NMOS Bipolar	1984		42,000	5	1.5

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Prefecture	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Start	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Mitsubishi	ULSI	Itami-Shi	Hyogo	16Mb 64Mb 256Mb DRAM ASIC Flash	Frnt Rsrch Pilot	P/CMOS	1993		10,000	8	0.2
Mitsubishi	TA2	Kami-Gun	Kochi	8-bit 16-bit 32-bit MCU ASIC	Frnt Pilot Assy/Tst	P/CMOS	1988		30,000	6	0.5
Mitsubishi	TA1	Kami-Gun	Kochi	4Mb DRAM 1Mb SRAM ASSP	Frnt	P/CMOS	1990		30,000	6	0.7
Mitsubishi	B-1F	Kikuchi-Gun	Kumamoto	EPROM	Frnt	P/CMOS	1970		30,000	5	1.3
Mitsubishi	B-2F	Kikuchi-Gun	Kumamoto	Arrays MCU	Frnt	P/CMOS	1975		30,000	4	1
Mitsubishi	C-1F	Kikuchi-Gun	Kumamoto	1Mb SRAM 1Mb ROM MCU Flash	Frnt	P/CMOS NMOS	1981		25,000	5	0.8
Mitsubishi	C-2F	Kikuchi-Gun	Kumamoto	EPROM MCU MPU	Frnt	P/CMOS	1981		28,000	5	1.3
Mitsubishi	D-1F	Kikuchi-Gun	Kumamoto	16Mb DRAM	Frnt	P/CMOS	1994		10,000	8	0.35
Mitsubishi	D-1F-2	Kikuchi-Gun	Kumamoto	16Mb DRAM	Frnt	P/CMOS	1996	1,000	15,000	8	0.35
Mitsubishi	B	Saijo-Shi	Ehime	DRAM MCU	Frnt	P/CMOS	1984		39,000	5	0.9
Mitsubishi	C	Saijo-Shi	Ehime	8-bit MCU ASIC	Frnt	P/CMOS	1968	10,000	50,000	5	0.8
Mitsubishi	Sa2A	Saijo-Shi	Ehime	Flash MCU 4Mb SRAM	Frnt	P/CMOS	1991		20,000	6	0.5
Mitsubishi	Sa2B	Saijo-Shi	Ehime	64Mb DRAM EDRAM	Frnt	P/CMOS	1993		16,000	8	0.4
Mitsubishi		Saijo-Shi	Ehime	ASIC	Frnt	P/CMOS					
Mitsumi		Atsugi-Shi	Kanagawa	Log Dis	Frnt Assy/Tst	Bipolar	1984		30,000	4	
Moririca Electronics		Yokohama-Shi	Kanagawa	Opto	Frnt	GaAs/III-V					
Motorola	MOS 7	Aizu	Fukushima	Discrete Logic Analog	Frnt Assy/Tst	P/CMOS NMOS	1972		50,000	4	1.8
Motorola	MOS 7A	Yama-Gun	Fukushima	Logic Analog	Frnt Rsrch Assy/Tst	P/CMOS BiC-MOS Bipolar	1994		50,000	6	0.8
Murata Manufacturing	Yasu	Yasu-Gun	Shiga	Fet MMIC	Frnt Rsrch Pilot	GaAs/III-V	1993				0.8
NEC	Dif-1	Asa-Gun	Yamaguchi	4Mb DRAM 1Mb SRAM MPU FLASH	Frnt Assy/Tst	P/CMOS BiC-MOS	1988		45,000	6	0.8
NEC	Dif-2 (Bldg.C)	Asa-Gun	Yamaguchi	4Mb 16Mb DRAM ASIC	Frnt Assy/Tst	P/CMOS	1993		45,000	6	0.5
NEC	Dif-1	Higashi Hiroshima-Shi	Hiroshima	4Mb DRAM SRAM MPU 4Mb ROM	Frnt Assy/Tst	P/CMOS	1990.4		30,000	6	0.6
NEC	Dif-2	Higashi Hiroshima-Shi	Hiroshima	16Mb 64Mb DRAM ASIC RISC	Frnt	P/CMOS	1996		33,000	8	0.25
NEC	Dif-5	Kumamoto-Shi	Kumamoto	Logic DRAM MCU	Frnt	P/CMOS NMOS	1978		20,000	5	1.2
NEC	Dif-4	Kumamoto-Shi	Kumamoto	Bip Lin Memory ASIC	Frnt	P/CMOS	1983		25,000	5	1.4
NEC	Dif-6	Kumamoto-Shi	Kumamoto	1Mb DRAM MPU MCU Arrays	Frnt	P/CMOS NMOS	1987		30,000	6	1
NEC	Dif-7	Kumamoto-Shi	Kumamoto	MCU 4Mb DRAM ASIC	Frnt	P/CMOS BiC-MOS	1988		30,000	6	0.8
NEC	Dif-8-1	Kumamoto-Shi	Kumamoto	16Mb DRAM 4Mb SRAM RISC ASIC	Frnt	P/CMOS	1994	15,000	60,000	8	0.35
NEC	Dif-1	Otsu-Shi	Shiga	Pwr Tran Linear	Frnt Assy/Tst	Bipolar	1978		25,000	4	2
NEC	Dif-2	Otsu-Shi	Shiga	MCU LCD Driver	Frnt	P/CMOS NMOS	1981		16,000	6	1

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Prefecture	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Start	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
NEC	Dif-3	Otsu-Shi	Shiga	SRAM 4Mb DRAM Micro ASIC	Frnt	P/CMOS NMOS	1983		17,000	6	1
NEC	GaAs	Otsu-Shi	Shiga	Diode Opto FET	Frnt Pilot	GaAs/III-V	1988		2,000	4	3
NEC	Dif-4	Otsu-Shi	Shiga	16 Bit MCU Lcd Driver ASIC	Frnt Assy/Tst	P/CMOS	1989		20,000	6	0.8
NEC	G-1	Sagamihara-Shi	Kanagawa	16Mb DRAM ASIC MPU 4Mb ROM	Frnt Rsrch Pilot Assy/Tst	P/CMOS BiC-MOS	1988		10,000	6	0.8
NEC	C	Sagamihara-Shi	Kanagawa		Frnt				5,000	8	
NEC	Tsuruoka Works 1	Tsuruoka-Shi	Yamagata	Bip Log Lin Dis	Frnt Assy/Tst	Bipolar	1976		20,000	4	1
NEC	Tsuruoka Works 2	Tsuruoka-Shi	Yamagata	Log Lin MPU ASIC	Frnt	P/CMOS Bipolar	1993		20,000	6	0.7
NEC		Tsuruoka-Shi	Yamagata	ASIC LOG MCU	Frnt				10,000	8	Less than 0.8
New Japan Radio	Fab 1	Kamifukuoka-Shi	Saitama	Analog Op Amp Opto	Frnt	Bipolar	1977		21,000	3	4
New Japan Radio	Fab 2	Kamifukuoka-Shi	Saitama	Analog A/D D/A	Frnt Fndry	P/CMOS BiC-MOS Bipolar	1981		35,000	4	2.5
New Japan Radio	GaAS	Kamifukuoka-Shi	Saitama	Analog Discrete Opto	Frnt	GaAs/III-V	1984		200	3	0.5
New Japan Radio	Fab 3	Kamifukuoka-Shi	Saitama	Logic Analog MCU	Frnt Fndry Assy/Tst	P/CMOS BiC-MOS Bipolar	1986		19,000	5	0.8
New Japan Radio	Fab 1	Kamifukuoka-Shi	Saitama	Analog Op Amp Opto	Frnt Rsrch Assy/Tst	Bipolar	1996.4		21,000	4	4
Nippon Precision Circuits	Bldg. S	Nasu-Gun	Tochigi	Log Lin A/D D/A Modem	Frnt	P/CMOS	1984		15,000	4	
Nippon Precision Circuits	Bldg. H	Nasu-Gun	Tochigi	A/D D/A DSP Log ASSP	Frnt	P/CMOS	1990	6,000	10,000	6	
Nippon Silicon			Tochigi	16Mb DRAM	Frnt Rsrch		1990				0.6
Nippon Steel Corporation	Electronics Lab	Sagamihara-Shi	Kanagawa	ASIC 16Mb 64Mb DRAM	Frnt Dsgn Pilot	P/CMOS	1991.4		500	6	0.35
Nippon Steel Corporation		Tateyama-Shi	Chiba	16Mb DRAM	Frnt	P/CMOS	1996.3		15,000	8	
Nippon Steel Semiconductor	M1	Tateyama-Shi	Chiba	MCU Logic LCD Driver	Frnt Assy/Tst	P/CMOS	1985			5	1.2
Nippon Steel Semiconductor	M2	Tateyama-Shi	Chiba	1Mb 4Mb DRAM Flash Logic	Frnt Assy/Tst	P/CMOS	1988		12,000	6	0.6
Nippon Steel Semiconductor	M3	Tateyama-Shi	Chiba	4Mb 16Mb DRAM	Frnt Assy/Tst	P/CMOS	1990		20,000	6	0.5
Nippondenso	Bldg. 1	Kariya-Shi	Aichi	Log Custom MCU Opto	Frnt Pilot		1987		2,000	5	1.5
Nippondenso	705	Nukata-Gun	Aichi	MCU Custom	Frnt Assy/Tst		1993.4		10,000	6	1.5
Nissan	R&D Center	Yokosuka-Shi	Kanagawa	MCU Custom	Frnt Pilot Assy/Tst	P/CMOS	1987		500	5	2
NKK	Phase 1	Ayase-Shi	Kanagawa	256K 1Mb 4Mb SRAM ROM RISC MPU ASIC	Frnt Pilot	P/CMOS	1992		6,000	8	0.5
Oki	H1	Hachioji-Shi	Tokyo	Micro Logic Analog	Frnt Fndry Assy/Tst	P/CMOS BiC-MOS Bipolar	1988		60,000	2	3
Oki	V3	Hachioji-Shi	Tokyo	16Mb 64Mb DRAM Micro Gate Array	Frnt	P/CMOS BiC-MOS GaAs/III-V	1989		2,000	6	0.5
Oki	U1	Hachioji-Shi	Tokyo	64Mb 256Mb DRAM Micro Logic	Frnt	P/CMOS BiC-MOS GaAs/III-V	1992		1,000	6	0.3

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Prefecture	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Start	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Oki	S1	Kurokawa-Gun	Miyagi	4Mb DRAM VRAM 1Mb SRAM 16M MROM	Frnt Assy/Tst	P/CMOS	1981		30,000	6	0.5
Oki	S2	Kurokawa-Gun	Miyagi	16Mb 64Mb DRAM	Frnt Fndry Assy/Tst	P/CMOS	1996.1	5,000	15,000	8	0.3
Oki	S3	Kurokawa-Gun	Miyagi		Frnt Assy/Tst	P/CMOS					
Oki	M3	Miyazaki-Gun	Miyazaki	4Mb 16Mb DRAM	Frnt Assy/Tst	P/CMOS	1967		30,000	6	0.4
Oki	M1	Miyazaki-Gun	Miyazaki	Micro Logic	Frnt Fndry Assy/Tst	P/CMOS BiC-MOS	1984		50,000	4	2
Oki	M2	Miyazaki-Gun	Miyazaki	1Mb DRAM 256Kb SRAM 4M MROM	Frnt Fndry Assy/Tst	P/CMOS	1991		60,000	5	0.8
Olympus		Hachioji-Shi	Tokyo	IC	Frnt Pilot	P/CMOS					
Olympus	S/C Technology Cente	Kamiina-Gun	Nagano	SIT Image Sensor	Frnt Pilot	P/CMOS	1986		5,000	5	3
Omron		Kouka-Gun	Shiga	Opto Image Sensor	Frnt	Bipolar	1975		20,000	4	
Omron		Kouka-Gun	Shiga	Opto Image Sensor	Frnt Pilot Assy/Tst	Bipolar	1987		1,000	4	3
Origin Electric		Oyama-Shi	Tochigi	Tran Diode Dis	Frnt Assy/Tst	Bipolar			17,000	4	
Pioneer Video		Kofu-Shi	Yamanashi	MPR ASIC Analog	Frnt Pilot Assy/Tst	P/CMOS	1985		8,000	5	0.8
Ricoh	Fab 1	Ikeda-Shi	Osaka	256Kb ROM Arrays CBIC Vol.Reg.	Frnt Dsgn Fndry	P/CMOS Bipolar	1982		5,000	6	1.5
Ricoh	Fab 2	Ikeda-Shi	Osaka	1Mb ROM 8-bit MCU Arrays CBIC	Frnt Dsgn Fndry	P/CMOS	1986		5,000	4	0.8
Ricoh	Fab 3	Kato-Gun	Hyogo	4Mb 8Mb ROM 16-bit MCU Arrays CBIC	Frnt Dsgn Fndry	P/CMOS	1990		12,000	6	1.5
Rohm	Apollo Electronics	Chikugo-Shi	Fukuoka	Tran Dis	Frnt Assy/Tst	Bipolar	1981		20,000	4	3
Rohm	Wako	Kasaoka-Shi	Okayama	Linear Epi	Frnt Assy/Tst	Bipolar	1968		20,000	4	1.2
Rohm	LSI R&D 1	Kyoto-Shi	Niigata	MPU Laser Modem Tran LED	Frnt Dsgn Pilot Assy/Tst	P/CMOS	1989		13,000	6	0.8
Rohm		Kyoto-Shi	Niigata	MCU Arrays SRAM EEPROM	Frnt Dsgn Assy/Tst	P/CMOS BiC-MOS	1989		15,000	6	0.8
Rohm	LSI R&D 2	Kyoto-Shi	Niigata	MCU GaAs	Frnt Dsgn Pilot Assy/Tst	P/CMOS BiC-MOS	1994		3,000	6	0.5
Rohm		Kyoto-Shi	Niigata	Laser Opto	Frnt Assy/Tst	Bipolar GaAs/III-V			25,000	4	3
Rohm		Kyoto-Shi	Niigata	Discrete Opto	Frnt Dsgn Assy/Tst	Bipolar GaAs/III-V			15,000	4	3
Sanken	Yamagata Sanken	Higashine-Shi	Yamagata	Pwr Tran Diode IC	Frnt	Bipolar	1981.4	10,000	90,000	5	
Sanken	Fukushima Sanken	Nihonmatsu-Shi	Fukushima	LED	Frnt	GaAs/III-V	1991		2,000	3	
Sanken	Niiza	Niiza-Shi	Saitama	Diode	Frnt	Bipolar	1970	15,000	22,0000	4	
Sanyo	C 3	Anpachi-Gun	Gifu	SRAM EEPROM Disk Drive IC CCD ASIC	Frnt Rsrch Fndry	P/CMOS	1986		30,000	5	0.8
Sanyo	Microelectronics	Anpachi-Gun	Gifu	SRAM Custom CCD	Frnt Rsrch Pilot	P/CMOS	1990		1,000	6	0.4
Sanyo	A 1	Ojiya-Shi	Niigata	1Mb 4Mb DRAM 4-bit 8-bit MCU DSP	Frnt Fndry Assy/Tst	P/CMOS	1985		35,000	5	0.8

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

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Sanyo	B 2	Ojiya-Shi	Niigata	Analog	Frnt Fndry Assy/Tst	BiCMOS Bipolar	1987	30,000	44,000	5	1.2
Sanyo	B 1	Ojiya-Shi	Niigata	EEPROM Flash Logic ASSP	Frnt Fndry Assy/Tst	P/CMOS	1989		28,000	6	0.5
Sanyo	C 2	Ojiya-Shi	Niigata	DRAM	Frnt Fndry Assy/Tst	P/CMOS	1994		25,000	6	0.85
Sanyo	Bip 1	Oura-Gun	Gunma	Analog	Frnt Fndry	Bipolar	1967	20,000	55,000	2	2
Sanyo	Tr	Oura-Gun	Gunma	Trans (SST Pwr. Trans)	Frnt Fndry	Bipolar	1972		30,000	4	1
Sanyo	Tr 2	Oura-Gun	Gunma	Trans SST Power	Frnt Fndry	NMOS Bipolar	1980		60,000	4	2
Sanyo	Bip 2	Oura-Gun	Gunma	Analog	Frnt Fndry	Bipolar	1981		45,000	3	1.6
Sanyo	MOS 2	Oura-Gun	Gunma	Logic ASSP MCU	Frnt Rsrch Fndry	P/CMOS NMOS	1984		22,000	5	1.2
Sanyo	R&D	Oura-Gun	Gunma	Memory Logic	Frnt Rsrch Pilot	Bipolar	1984		3,000	5	1.2
Sanyo	R&D 2	Oura-Gun	Gunma	Memory Logic	Frnt Rsrch Pilot	P/CMOS	1984		3,000	6	0.5
Sanyo	Bip 3	Oura-Gun	Gunma	Analog	Frnt Fndry	Bipolar	1991		40,000	4	1.2
Sanyo	Tr-G	Oura-Gun	Gunma	MOSFET	Frnt Fndry	P/CMOS NMOS	1991		20,000	5	0.8
Sanyo	Tottori	Tottori Shi	Tottori	LED Laser Diode	Frnt Fndry	GaAs/III-V			40,000	3	2
Seiko Epson	Bldg. 3	Sakata-Shi	Yamagata	FPGA PLD CBIC	Frnt Fndry	P/CMOS BiC-MOS	1991		20,000	6	0.65
Seiko Epson	Bldg. B	Suwa-Gun	Nagano	Arrays CBIC SRAM EEPROM	Frnt Fndry	P/CMOS NMOS	1981		50,000	4	2.5
Seiko Epson	Bldg. A	Suwa-Gun	Nagano	Arrays 256Kb SRAM EPROM	Frnt Fndry	P/CMOS	1985		35,000	5	1.5
Seiko Epson	Bldg. D	Suwa-Gun	Nagano	1Mb SRAM ASIC	Frnt	P/CMOS BiC-MOS	1989	5,000	25,000	6	0.8
Seiko Instruments		Matsudo-Shi	Chiba	SRAM Arrays CBIC EEPROM	Frnt Fndry	P/CMOS	1987		3,000	6	0.8
Sharp	Factory 1A	Fukuyama-Shi	Hiroshima	MROM 8-Bit MCU Arrays CBIC LCD Driver	Frnt Fndry	P/CMOS	1985		30,000	6	1
Sharp	Factory 1B	Fukuyama-Shi	Hiroshima	MROM 8-Bit MCU Arrays CBIC LCD Driver	Frnt Fndry	P/CMOS	1985		30,000	6	0.8
Sharp	Factory 2	Fukuyama-Shi	Hiroshima	16Mb MROM, DRAM, SRAM	Frnt Fndry Assy/Tst	P/CMOS	1989		40,000	6	0.6
Sharp	Factory 3	Fukuyama-Shi	Hiroshima	Flash, 32Mb MROM, SRAM	Frnt	P/CMOS	1993	15,000	25,000	8	0.35
Sharp		Kita Katsuragi-Gun	Nara	Optocoupler	Frnt Fndry Assy/Tst	GaAs/III-V	1981		25,000	3	
Sharp	Factory 2	Tenri-Shi	Nara	SRAM MROM MCU LCD Driver	Frnt Fndry	P/CMOS Bipolar	1977		25,000	5	1.2
Sharp	Factory 3	Tenri-Shi	Nara	SRAM MROM MCU ASIC LCD Driver	Frnt Fndry Assy/Tst	P/CMOS Bipolar	1980		22,000	5	0.8
Sharp		Yamato Koriyama-Shi	Nara	Laser LED Opto	Frnt Assy/Tst	GaAs/III-V			22,000	3	
Shimadzu	Atsugi	Atsugi-Shi	Kanagawa	Laser Diode	Frnt Assy/Tst	GaAs/III-V				4	
Shindengen	R&D Center	Hanno-Shi	Saitama	Pwr MOSFET Hybrid	Frnt Dsgn Assy/Tst	NMOS Bipolar	1989		1,000	4	5
Shindengen	Trial	Hanno-Shi	Saitama	Pwr MOSFET Hybrid	Frnt Pilot Assy/Tst	NMOS Bipolar	1991		1,000	4	5

Table 1 (Continued)
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Shindengen	Bldg. 1	Higashine-Shi	Yamagata	Translstor	Frnt	NMOS Bipolar	1985	10,000	15,000	3	10
Shindengen	Bldg. 2	Higashine-Shi	Yamagata	MOSFET	Frnt	NMOS Bipolar	1987		25,000	3	10
Shindengen	Bldg. 3	Higashine-Shi	Yamagata	Power Tran	Frnt	NMOS Bipolar	1993	5,000	7,000	4	10
Shindengen	Ohura -1	Honjo-Shi	Akita	Diode Thyristor	Frnt	Bipolar	1972		100,000	2	10
Shindengen	Ohura -2	Honjo-Shi	Akita	Diode Thyristor	Frnt Assy/Tst	Bipolar	1983		60,000	2	10
Sony		Atsugi-Shi	Kanagawa	FET Laser CCD HEMT	Frnt Pilot Assy/Tst	GaAs/III-V	1988		500	3	
Sony		Atsugi-Shi	Kanagawa	Lin	Frnt Assy/Tst	Bipolar			400	4	2
Sony	2G	Isahaya-Shi	Nagasaki	CCD 256Kb SRAM 1Mb SRAM	Frnt	P/CMOS	1989.4		17,000	6	0.8
Sony	3G	Isahaya-Shi	Nagasaki	1Mb SRAM 4Mb VRAM CCD LOGIC	Frnt	P/CMOS	1991.1		25,000	6	0.5
Sony		Kokubu-Shi	Kagoshima	CCD	Frnt	P/CMOS NMOS	1973		20,000	5	0.6
Sony	No. 2, Phase 1	Kokubu-Shi	Kagoshima	Dis	Frnt	Bipolar	1975	30,000	200,000	4	3
Sony	No. 2, Phase 2	Kokubu-Shi	Kagoshima	Lin A/D D/A	Frnt	Bipolar	1976	25,000	200,000	5	2
Sony	No. 4	Kokubu-Shi	Kagoshima	SRAM MCU	Frnt Assy/Tst	P/CMOS BiC-MOS	1978		28,000	5	1.3
Sony	No. 6	Kokubu-Shi	Kagoshima	Log Memory MCU Lin	Frnt Assy/Tst	P/CMOS NMOS BiCMOS	1992		15,000	6	0.8
Stanley		Hadano-Shi	Kanagawa	Laser LED	Frnt	GaAs/III-V	1986		10,000	4	
Stanley		Yamagata		LED	Frnt	GaAs/III-V	1993				
Sumitomo Metal Industries		Amagasaki-Shi	Hyogo	4Mb DRAM Arrays	Frnt Pilot		1991		300	6	0.8
Texas Instruments	Hato	Hatogaya-Shi	Saitama	Analog LCD Driver ASSP	Frnt Assy/Tst	P/CMOS NMOS	1982		17,700	5	1
Texas Instruments	Hiji 1	Hayami-Gun	Oita	Logic Linear Arrays	Frnt	Bipolar	1974		8000	5	1
Texas Instruments	Hiji 8	Hayami-Gun	Oita	Logic	Frnt	P/CMOS NMOS BiCMOS			10,000	6	0.8
Texas Instruments	Miho 5	Inashiki-Gun	Ibaragi	ASSP ASIC MPU DSP CBIC	Frnt Assy/Tst	NMOS	1982		29,000	5	1
Texas Instruments	Miho 6	Inashiki-Gun	Ibaragi	1Mb 4Mb DRAM ASSP MPU	Frnt Assy/Tst	P/CMOS NMOS BiCMOS			15,000	6	0.8
Tohoku Semiconductor	Step 1	Sendai-Shi	Miyagi	1Mb DRAM MCU MPU	Frnt Assy/Tst	P/CMOS	1988		7,500	6	1
Tohoku Semiconductor	Step 2	Sendai-Shi	Miyagi	4Mb DRAM MPU MCU	Frnt	P/CMOS BiC-MOS	1991		10,000	6	0.8
Tohoku Semiconductor	Step 3	Sendai-Shi	Miyagi	16Mb 64Mb DRAM	Frnt	P/CMOS	1995.2		15,000	8	0.35
Tokin		Sendai-Shi	Miyagi	Power SIT	Frnt Pilot	Bipolar			10,000	3	
Toko		Iruma-Gun	Saitama		Frnt	NMOS	1990		15,000	5	3
Toko		Iruma-Gun	Saitama	A/D D/A Telecom Diode	Frnt Assy/Tst	Bipolar	1990		20,000	5	3.5
Toshiba	No. 2	Himeji-Shi	Hyogo	Tran Diode	Frnt Assy/Tst	NMOS Bipolar	1982		30,000	5	2
Toshiba	No. 1	Himeji-Shi	Hyogo	Pwr FET Tran Diode	Frnt Assy/Tst	NMOS Bipolar	1990		45,000	4	2
Toshiba	Bldg.108 D-1	Kawasaki-Shi	Kanagawa	Pwr Tran Lin	Frnt	P/CMOS BiC-MOS Bipolar	1970		15,000	5	2
Toshiba	Bldg.108 D-2	Kawasaki-Shi	Kanagawa	16Mb 64Mb DRAM Flash	Frnt Pilot	P/CMOS	1990		1,300	8	0.35

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Prefecture	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Start	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Toshiba	Phase 1 & 2	Kimitsu-Shi	Chiba	Diode Rectifier Thyristor	Frnt Assy/Tst	Bipolar	1970		44,000	4	4
Toshiba	Kubik 1	Kita Kyushu-Shi	Fukuoka	Bip Analog Opto	Frnt	Bipolar GaAs/III-V	1986		36,000	4	1.5
Toshiba	Kubik 2	Kita Kyushu-Shi	Fukuoka	Bip Analog	Frnt Fndry	P/CMOS BiC-MOS Bipolar	1988		30,000	5	1.2
Toshiba	Kubik 3	Kita Kyushu-Shi	Fukuoka	Analog	Frnt	P/CMOS BiC-MOS Bipolar	1993		30,000	6	1
Toshiba	Bldg.101, D-1	Kitakami-Shi	Iwate	CCD ASIC MPU MCU MROM	Frnt Assy/Tst	P/CMOS	1984		40,000	5	1
Toshiba	Bldg.101, D-2	Kitakami-Shi	Iwate	CCD ASIC MPU MCU MROM	Frnt	P/CMOS	1986		40,000	5	1
Toshiba	Bldg.102, D-3	Kitakami-Shi	Iwate	ASIC	Frnt	P/CMOS	1989		15,000	6	1
Toshiba	Bldg.102, D-4	Kitakami-Shi	Iwate	EPROM MROM MPU ASIC	Frnt	P/CMOS	1991		15,000	6	0.8
Toshiba	Bldg.106, D-5	Kitakami-Shi	Iwate	EPROM MROM MPU ASIC	Frnt	P/CMOS BiC-MOS	1993		24,000	6	0.8
Toshiba		Nomi-Gun	Ishikawa	Pwr Tran	Frnt Assy/Tst	Bipolar	1992		30,000	4	2
Toshiba	C-Cubed 1	Oita-Shi	Oita	MCU SRAM Logic	Frnt	P/CMOS NMOS	1986		33,000	4	1.2
Toshiba	C-Cubed 2	Oita-Shi	Oita	MCU SRAM Logic	Frnt	P/CMOS	1987		32,000	5	1.2
Toshiba	C-Cubed 3	Oita-Shi	Oita	MCU ASIC DRAM SRAM	Frnt	P/CMOS	1989		32,000	5	1
Toshiba	C-Cubed 4	Oita-Shi	Oita	4Mb 16Mb DRAM	Frnt	P/CMOS	1991		40,000	6	0.5
Toshiba	Y-Cubed, No. 1-Mod 1	Yokkaichi-Shi	Mie	4Mb 16Mb DRAM	Frnt	P/CMOS	1993		10,000	8	0.5
Toshiba	Y-Cubed, No. 1-Mod 2	Yokkaichi-Shi	Mie	4Mb 16Mb DRAM	Frnt	P/CMOS	1994	10,000	25,000	8	0.35
Toshiba	Y-Cubed, No. 2	Yokkaichi-Shi	Mie	16Mb DRAM 64Mb DRAM 256Mb DRAM	Frnt	P/CMOS	1996.3		28,000	8	0.35
Toyoda Group	Technology Center	Inazawa Shi	Aichi	LED	Frnt Pilot	GaAs/III-V	1993			2	25
Toyoda Group	Higashi Kariya	Kariya-Shi	Aichi	ASIC	Frnt	P/CMOS	1990			5	
Toyoda Group	Kyowa	Obu-Shi	Aichi	Pwr Tran	Frnt Assy/Tst	Bipolar	1990.2			4	
Toyota Motor	Me	Toyota-Shi	Aichi	MCU Pwr ICs Custom	Frnt Pilot Assy/Tst	P/CMOS Bipolar	1990		500	5	2
Unizon		Itami-Shi	Hyogo	Zener Diode Reg Arrays	Frnt	Bipolar			10,000	5	
Yamaha	Fab 2	Aira-Gun	Kagoshima	ROM CBIC ASSP	Frnt Fndry	P/CMOS	1995		10,000	6	0.65
Yamaha	Building 11-2	Toyooka-Mura	Shizuoka	ASIC MPR	Frnt	P/CMOS	1996	5,000	15,000	6	0.5
Yokogawa Lmt		Kamiina-Gun	Nagano	Tran Diode Opto Analog	Frnt Assy/Tst	P/CMOS Bipolar	1988		7,000	4	3

Source: Dataquest (December 1996)

Table 2
Front-End Production Lines Beginning Operation 1997 and After

Company	Fab Name	City	Prefecture	Devices Produced	Activities	Processes	Year & Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Fujitsu-AMD Semiconductor	Fab 1, Phase 2	Aizu Wakamatsu-Shi	Fukushima	16Mb 32Mb 4Mb 8Mb Flash	Frnt	P/CMOS	1997.2	10,000	12,500	8	0.35
Fujitsu-AMD Semiconductor	Fab 2, Phase 1	Aizu Wakamatsu-Shi	Fukushima	16Mb 32Mb 64Mb Flash	Frnt	P/CMOS	1997.4		12,500	8	0.35
Fujitsu-AMD Semiconductor	Fab 2, Phase 2	Aizu Wakamatsu-Shi	Fukushima	16Mb 32Mb 64Mb Flash	Frnt	P/CMOS	1998		12,500	8	0.25
Hitachi	Chitose 2	Chitose-Shi	Hokkaido	64Mb DRAM	Frnt	P/CMOS	1998		10,000	8	0.35
Hitachi	N3/2F	Hitachinaka-Shi	Ibaraki	64Mb DRAM	Frnt		1998		10,000	8	0.35
Kawasaki Steel	Phase 2	Utsunomiya-Shi	Tochigi	SRAM Arrays	Frnt	P/CMOS	1997		4,000	6	0.5
KTI Semiconductor	Fab 2	Nishiwaki-Shi	Hyogo	16Mb 64Mb DRAM ASIC	Frnt	P/CMOS	1997.1		5,500	8	0.35
Matsushita	Fab D	Tonami-Shi	Toyama	16Mb 64Mb DRAM	Frnt	P/CMOS	1997		10,000	8	0.35
Mitsubishi				4K 16K 64K FRAM	Frnt	P/CMOS	1997		10,000	6	
Mitsubishi	SA1F	Saijo-Shi	Ehime	64Mb DRAM EDRAM	Frnt Assy/Tst	P/CMOS	1997	10,000	15,000	8	0.3
Mitsumi		Atsugi-Shi	Kanagawa	Logic Power	Frnt Assy/Tst		1997.3				
NEC		Kamigori	Hyogo		Frnt		1997.1				
Nippon Steel Semiconductor	N1	Tateyama-Shi	Chiba	16Mb DRAM	Frnt Assy/Tst	P/CMOS	1997		10,000	8	0.35
Seiko Epson		Sakata-Shi	Yamagata	ICs SRAM Telecom ICs PLDs FPGAs	Frnt		1997.4		20,000	8	0.25
Sharp	Factory 4	Fukuyama-Shi	Hiroshima	Flash 64Mb DRAM	Frnt Assy/Tst	P/CMOS	1998.1	10,000	16000	8	0.25
Sony	4G	Isahaya-Shi	Nagasaki	Logic	Frnt	P/CMOS Bipolar	1997		10,000	6	0.35
Sony		Kokubu-Shi	Kagoshima	Logic	Frnt	P/CMOS	1997		10,000	8	0.35
Toshiba	Advanced Micro-electronic Center	Isogo	Yokohama	256Mb 1Gb DRAM Flash ASIC	Frnt Rsrch Pilot	P/CMOS	1997		1,800	8	0.15
Toshiba	Step 5	Kitakami-Shi	Iwate	16Mb 64Mb DRAM Logic	Frnt Assy/Tst	P/CMOS	1997		30,000	8	0.35
Yamaha	NA	Toyooka-Mura	Shizuoka	ASIC ASSP	Frnt	P/CMOS	1998.3		7,000	8	0.35

Source: Dataquest (December 1996)

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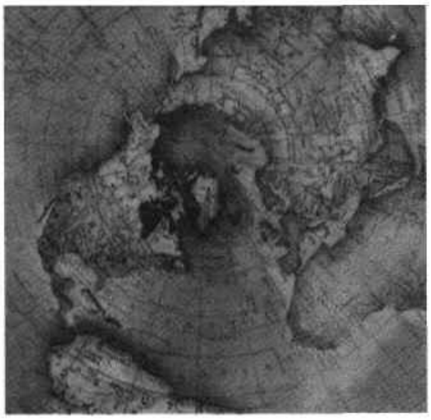

Dataquest

Americas Fab Database

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-MS-9603
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Americas Fab Database

Background and Methodology

This report contains the Americas portion of Dataquest's wafer fab database. These tables cover fabs located in the Americas region. The Semiconductor Equipment, Materials, and Manufacturing Worldwide (SEMM) program conducts extensive annual surveys complemented with quarterly secondary research to maintain this database. Published once a year, this document represents Dataquest's best insights and estimates into the end market of semiconductor equipment.

The tables in this report cover planned and existing merchant, captive, and foundry fab lines. A fab line consists of a series of equipment that does front-end semiconductor manufacturing (from initial oxide through wafer probe). Occasionally, two or more separate product-specific fab lines or wafer sizes operate in a single clean room or physical plant. In this situation, Dataquest considers the clean room to be separate fab lines if the company dedicates equipment to each wafer size or product line. If a company installs substantially different equipment during an expansion (for example, equipment to increase the maximum wafer diameter), again Dataquest divides the clean room and creates two entries in the database. Therefore, a company may operate many fab lines at one location.

Worldwide Geographic Region Definitions and Regional Roll-Ups

Americas

Includes Central America (all nations), Canada, Mexico, United States, Puerto Rico, and South America (all nations)

Japan

Japan is the only single-country region.

Europe, Africa, and Middle East

Includes Africa (all nations), Albania, Andorra, Armenia, Azerbaijan, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Gibraltar, Hungary, Iceland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Middle East (all nations), Moldova, Monaco, Netherlands, Norway, Poland, Romania, Russia, San Marino, Scandinavia, Slovakia, Spain, Sweden, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan, Vatican City, and all nations within the former Yugoslavia

Asia/Pacific

Includes Australia, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam

Table Column Definitions

The Company column indicates the operator of the fab line. For contract manufacturers that trade capacity for capital investment in the fab, Dataquest lists the contract manufacturer. For incorporated joint ventures, Dataquest will either list the incorporated entity or the major investors, separated with slashes.

The Fab Name column provides a reference to a particular fab or fab line to distinguish it from other fabs or lines owned by that company. Although Dataquest makes every attempt to match the nomenclature used by the company, occasionally some additional qualifiers (for example, Phase 1) appear to provide insight into the facility's history or organization.

The City column displays the most detailed location information. This reference is usually a city or town, but could be an often-used district name (for example, Science Park in the city of Hsinchu, Taiwan). If this column lists a district, Dataquest will list the city in the State or Province column. In some cases, a reference to a state or province will be included in the city or district column to create a unique identifier for this location.

The State, Province, or Prefecture columns denote the second most detailed location. This reference is usually a state (for the United States), province (for Canada and many European and Asian countries), or a prefecture (for Japan). For countries within the United Kingdom, Dataquest will list the country name (for example, Scotland) in this column so Dataquest can list the descriptor "U.K." in the Country column.

The Country column indicates the broadest location identifier in this report. This reference is usually a country, except in the case of the United Kingdom (see above). As Japan is a single-country region, a regional qualifier does not exist for fabs in Japan.

The Devices Produced column lists the products manufactured at this site. The listings generally fall into five product groups, with the following nomenclature and definitions (when warranted):

- MOS memory
  - DRAM: Dynamic RAM
  - EEPROM or E2: Electrically erasable PROM
  - EPROM: Ultraviolet erasable PROM
  - FERRAM: Ferroelectric RAM
  - FIFO: First-in/first-out memory
  - Flash: Flash memory
  - MEM: Memory
  - NvMem: Nonvolatile memory (ROM, PROM, EPROM, EEPROM, FERRAM)
  - PROM: Programmable ROM

- RAM: Random-access memory
- ROM: Read-only memory
- SpMem: Other specialty memory (such as dual-port, shift-register, color lookup)
- SRAM: Static RAM
- VRAM: Video RAM

- MOS microcomponent/digital logic
  - Arrays: Gate array
  - ASIC: Application-specific IC
  - ASSP: Application-specific standard product
  - Bit: Bit slice (subset of MPU functions)
  - CBIC: Cell-based IC
  - Custom: Full-custom IC (single user)
  - DSP: Digital signal processor
  - FPGA: Field-programmable gate array
  - LISP: 32-bit list instruction set processor for AI
  - Log or Logic: Standard logic
  - MCU: Microcontroller unit
  - Mixsig ASIC: Mixed-signal ASIC
  - MPR: Microperipheral
  - MPRCom: MPR digital communications (ISDN, LAN, UART, modem)
  - MPU: Microprocessor unit
  - PLD: Programmable logic device
  - RISC: Reduced-instruction-set computation 32-bit MPU
  - Telecom: Telecommunications chip
- Power/discrete/analog (including bipolar power)
  - A/D D/A: Analog-to-digital, digital-to-analog converter
  - Automotive: Dedicated to automobile applications
  - Codec: Coder/decoder
  - Diode
  - Dis or Discrete: Discrete
  - FET: Field-effect transistor
  - GTO: Gate turn-off thyristor
  - HEMT: High-electron-mobility transistor
  - IGBT: Insulated gate bipolar transistor
  - Interface: Interface IC

- Lin: Linear/analog device
- MDiode: Microwave diode
- MESFET: Metal semiconductor field-effect transistor
- MFET: Microwave field-effect transistor
- Modem: Modulator/demodulator
- MMIC: Monolithic microwave IC
- MOSFET: MOS-based field-effect transistor
- Op Amp: Operational amplifier
- Pwr IC: Power IC
- Pwr Tran: Power transistor
- Rectifier
- Reg: Voltage regulator
- RF: Radio frequency
- SCR: Schottky rectifier
- Sensor
- Smart Pwr: Smart power
- SST: Small-signal transistor
- Switch: Switching device
- Thyristor
- Tran: Transistor
- Zener Diode

- Optoelectronic
  - CCD: Charge-coupled device (imaging)
  - Coupler: Photocoupler
  - IED: Infrared-emitting diode
  - Image Sensor
  - Laser: Semiconductor laser or laser IC
  - LED: Light-emitting diode
  - Opto: Optoelectronic
  - PDiode: Photodiode
  - PTran: Photo transistor
  - SAW: Surface acoustic wave device
  - SIT Image Sensor: Static induction transistor image sensor
- Bipolar digital
  - Includes all digital ICs using a bipolar process

The Activities column shows the types of semiconductor manufacturing performed at this location. The activities include:

- "Frnt" means this location performs front-end wafer processing. Front-end wafer processing includes the manufacturing steps from initial oxide through wafer probe test.
- "Rsrch" means the location performs product or process research. Research differs from pilot manufacturing in that research wafers are nonsalable.
- "Dsgn" means this location has a design center.
- "Pilot" means this location performs pilot production. Pilot production means the location produces in small volumes while "debugging" new products or process technologies. The main difference between research and pilot is that, unlike research, pilot wafers are salable product.
- "Fndry" means this location performs contract manufacturing. Contract manufacturing is the production, under contract, of another company's branded product. This is also known as foundry production.
- "Assy/tst" means this location performs assembly and/or testing. Assembly and testing includes the manufacturing steps from E-test through final assembly into a package and final test.

The Processes column indicates each fab's use of five major types of processes. The process groupings are:

- P/CMOS: P-channel metal-oxide semiconductor (PMOS) and/or complementary metal-oxide semiconductor (CMOS)
- NMOS: N-channel metal-oxide semiconductor (NMOS)
- BiCMOS: Bipolar and CMOS combined on a chip
- BIPOLAR: Bipolar
- III-V: Gallium arsenide and other compound semiconductor processes

The Year and Quarter of Initial Production column displays the year (and quarter, if available) in which this line, having completed all qualifications, began manufacturing in production volumes. The format for this reference is "year.quarter" (for example, 1994.3 translates to the third calendar quarter of 1994).

The Initial Monthly Wafer Starts column indicates the initial monthly volume of production wafer throughput.

The column Estimated Maximum Monthly Wafer Starts contains the equipment-limited wafer start capacity per four-week period. Only the throughput of the installed equipment and the process complexity limits the maximum starts. Dataquest does not consider current staffing or the number of shifts operating in determining this metric.

Maximum (Wafer) Diameter represents the maximum wafer size that the fab or fab line can process. Wafer diameters, although expressed colloquially in inches, conform to metric specifications. For wafers greater than 3 inches in diameter, expression in inches becomes inaccurate. When calculating square inches, Dataquest uses the following approximations:

- Stated diameter of 4 inches (100mm) = Approximate diameter of 3.938 inches
- Stated diameter of 5 inches (125mm) = Approximate diameter of 4.922 inches
- Stated diameter of 6 inches (150mm) = Approximate diameter of 5.906 inches
- Stated diameter of 8 inches (200mm) = Approximate diameter of 7.87 inches

Minimum Linewidth is the smallest feature size, measured in microns, attainable in production volumes.

Table 1
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	State	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Advanced Micro Devices	Fab 10	Austin	TX	U.S.	PLD ASIC	Frnt Rsrch	P/CMOS NMOS	1983	4,000	18,000	6	0.9
Advanced Micro Devices	Fab 14	Austin	TX	U.S.	1Mb 2Mb Flash	Frnt Rsrch	P/CMOS	1984	3,000	14,000	6	0.8
Advanced Micro Devices	Fab 15	Austin	TX	U.S.	Am486 MPU MCU MPR DSPs	Frnt Rsrch	P/CMOS	1984	2,000	14,000	8	0.7
Advanced Micro Devices	Fab 25	Austin	TX	U.S.	K5 MPU	Frnt Rsrch	P/CMOS	1995.4	1,200	24,000	8	0.25
Advanced Micro Devices	Fab 17	Sunnyvale	CA	U.S.	2Mb Flash 4Mb Flash 4Mb EPROM 1Mb EPROM	Frnt Rsrch Dsgn Assy/Tst	P/CMOS	1991.1	500	6,000	8	0.18
Advanced Power Technology	Fab 1	Bend	OR	U.S.	Power MOSFET IGBT	Frnt Dsgn Assy/Tst	NMOS	1989	200	1,200	4	2
Allegro MicroSystems		Willow Grove	PA	U.S.	SRAM ROM Analog	Frnt Fndry Assy/Tst	P/CMOS	1982		13,000	4	2.2
Allegro MicroSystems		Worcester	MA	U.S.	Custom Dis	Frnt	P/CMOS BiCMOS Bipolar	1987		19,000	4	4
Allied Signal Aerospace	Microelectronics Ctr.	Columbia	MD	U.S.	SRAM MPU Mixsig ASIC Custom	Frnt Rsrch Dsgn Pilot Fndry Assy/Tst	P/CMOS BiCMOS	1985	1,400	1,400	4	1.2
Alpha Industries		Woburn	MA	U.S.	RF Tran Lin	Frnt Fndry	GaAs/III-V	1987	160	160	3	0.25
American Microsystems Inc.	Fab 9	Pocatello	ID	U.S.	Arrays PLD CBIC Custom Mixsig ASIC EEPROM	Frnt Rsrch	P/CMOS NMOS	1984.2	200	26,000	5	0.5
Anadigics	35 Technology	Warren	NJ	U.S.	GaAs IC	Frnt Rsrch Dsgn Pilot	GaAs/III-V	1986	100	2,800	4	0.5
Analog Devices		Santa Clara	CA	U.S.	Analog Mixed Signal	Frnt Fndry	P/CMOS BiCMOS Bipolar	1970		7,000	4	3
Analog Devices		Santa Clara	CA	U.S.	Analog Mixed Signal	Frnt Fndry	P/CMOS BiCMOS	1983		2,000	4	1.5
Analog Devices		Sunnyvale	CA	U.S.	Analog Mixed Signal	Frnt	P/CMOS BiCMOS	1996		5,000	6	1
Analog Devices	Wilmington Fab	Wilmington	MA	U.S.	Analog Lin Amp A/D D/A	Frnt Rsrch	P/CMOS BiCMOS Bipolar	1979		16,000	4	0.8
Applied Microcircuits Corp.	Fab 1	San Diego	CA	U.S.	Bipolar and BiCMOS ASIC and ASSP Bipolar Foundry	Frnt Fndry Assy/Tst	BiCMOS Bipolar	1983.2	400	3,000	4	1
Atmel Corporation	Fab 3	Colorado Springs	CO	U.S.	EPROM EPLD Flash EEPROM Digital Logic/Analog Serial	Frnt Rsrch Fndry	P/CMOS BiCMOS	1990.1	1,000	26,000	6	0.35
Atmel Corporation	Fab 5	Colorado Springs	CO	U.S.	EPROM EEPROM Flash	Frnt Rsrch	P/CMOS	1994.4	2,500	29,000	6	0.35
Ball Aerospace		Boulder	CO	U.S.	Military/Aerospace	Frnt Pilot		1989		5,000	6	1.2
Bell Northern Research		Ottawa	Ontario	Canada		Frnt Rsrch Pilot	GaAs/III-V					
Bipolar ICs Inc.		Los Gatos	CA	U.S.	Discrete Microwave Transistors	Frnt Rsrch	Bipolar	1988		3,000	4	0.5
Burr-Brown Corporation	Microtech	Tucson	AZ	U.S.	Hybrid Analog	Frnt Rsrch Dsgn Assy/Tst	Bipolar	1984		10,000	4	3

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	State	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
California Microdevices	Thin Films	Milpitas	CA	U.S.	Discrete	Frnt Rsrch Dsgn Assy/Tst	Bipolar	1985		6,200	4	3
California Microdevices	Micro Div.	Tempe	AZ	U.S.	Mixsig ASIC Custom MPU MCU MPR NvMEM	Frnt Rsrch Fndry Assy/Tst	P/CMOS BiCMOS	1978		6,500	6	1
Calogic		Fremont	CA	U.S.	A/D D/A	Frnt Pilot Fndry	P/CMOS Bipolar	1985		3,600	4	3
Celeritek Inc.		San Jose	CA	U.S.	FET Amp	Frnt Pilot	GaAs/III-V	1985			3	
Cherry Semiconductor	Bipolar	East Greenwich	RI	U.S.	Discrete	Frnt Rsrch Assy/Tst	P/CMOS BiCMOS Bipolar	1981.1		22,000	6	1.5
Commodore Semiconductors	Fab 1	Norristown	PA	U.S.	ASIC	Frnt Rsrch Fndry	P/CMOS BiCMOS Other	1986.4		20,000	5	0.8
Compensated Devices		Melrose	MA	U.S.	Discrete Diode Zener Diode	Frnt Rsrch Dsgn	Bipolar	1974	800	1,500	3	3
Cray Research		Chippewa Falls	WI	U.S.	Arrays	Frnt Rsrch Pilot	P/CMOS BiCMOS	1993		5,000	8	0.8
Cray Research		Chippewa Falls	WI	U.S.	Arrays	Frnt Rsrch Pilot					4	1.5
Crystalonics		Cambridge	MA	U.S.	Cap Reg Diode Hybrid	Frnt Pilot	P/CMOS Bipolar	1970		2,000	4	3
Cypress Semiconductor	Fab 3	Bloomington	MN	U.S.	SRAM	Frnt Rsrch	P/CMOS	1991.2		34,000	6	0.65
Cypress Semiconductor	Fab 4	Bloomington	MN	U.S.	SRAM EPROM FPGA	Frnt Rsrch	P/CMOS	1995.2		20,000	8	0.5
Cypress Semiconductor	Fab 2	Round Rock	TX	U.S.	SRAM EEPROM EPROM	Frnt Rsrch	P/CMOS BiCMOS	1987.3		36,000	6	0.65
Cypress Semiconductor	Fab 1	San Jose	CA	U.S.	SRAM Logic MPU MPR	Frnt Rsrch Pilot	P/CMOS BiCMOS	1984.1		9,450	6	0.5
Dallas Semiconductor	Fab 10	Dallas	TX	U.S.	SRAM Random Logic	Frnt Rsrch Dsgn Assy/Tst	P/CMOS	1986.4		7,000	6	0.8
Dallas Semiconductor	Fab 11	Dallas	TX	U.S.	SRAMs Random Logic	Frnt Rsrch Dsgn Assy/Tst	P/CMOS	1994.4	2,000	10,000	6	0.4
David Sarnoff Labs	Silicon IC Center	Princeton	NJ	U.S.	MEM Bip Microcomponents MOS MPR Custom Power ICs	Frnt Rsrch Dsgn Pilot Assy/Tst	P/CMOS BiCMOS Bipolar	1983		1,000	4	0.5
Delco Electronics Corporation	Fab 1	Kokomo	IN	U.S.	Pressure Sensors Accelerometers Darlingtons	Frnt Dsgn Assy/Tst	Bipolar Other	1962		15,000	5	5
Delco Electronics Corporation	Fab 2	Kokomo	IN	U.S.	Power Discretes ASIC	Frnt Dsgn Fndry Assy/Tst	P/CMOS NMOS BiCMOS Bipolar Other	1978.2	4,000	14,000	5	2
Delco Electronics Corporation	Fab 3	Kokomo	IN	U.S.	ASIC MPU Linear Power	Frnt Dsgn Assy/Tst	P/CMOS Bipolar	1985.4	5,000	23,000	6	1
Digital Equipment Corporation	Fab 4	Hudson	MA	U.S.	MCU Alpha	Frnt Pilot	P/CMOS	1988	200	5,000	6	0.5
Digital Equipment Corporation	Pilot	Hudson	MA	U.S.	MPU MCU MPR CBIC Custom	Frnt Pilot	P/CMOS	1989.2		1,600	6	1.5
Digital Equipment Corporation	Fab 6	Hudson	MA	U.S.	MPU Alpha	Frnt	P/CMOS	1995.2		20,000	8	0.18

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	State	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Dionics Inc.	Rushmore Fab	Westbury	NY	U.S.	Bipolar Discrete CKTS and Opto	Frnt Pilot Fndry	Bipolar	1969.1	1,000	5,000	3	2.5
ECI Semiconductor		Santa Clara	CA	U.S.	Analog ASIC Discrete Opto Power	Frnt Fndry	P/CMOS Bipolar	1974		17,000	5	3
EG&G	4-Inch Fab	Sunnyvale	CA	U.S.	Analog Drivers Opto CCD	Frnt Rsrch Dsgn Pilot Fndry Assy/Tst	P/CMOS NMOS	1981		2,000	4	2.5
Elantec	Fab 1	Milpitas	CA	U.S.	Analog Monolithic ICs	Frnt Pilot	Bipolar	1984.2	250	2,500	5	2
Exel		Livermore	CA	U.S.	ASIC	Frnt Fndry		1996.4	6,000	20,000	6	0.35
Exel		San Jose	CA	U.S.	64Kb EEPROM PLD SRAM MCU	Frnt Rsrch	P/CMOS Bipolar	1987		10,000	3	1.3
Fab Tech	Fab Tech 1	Lee's Summit	MO	U.S.	Power Discrete Wafers	Frnt Fndry	Bipolar	1996.1		20,000	5	1.5
Fluke Corporation	FMO	Everett	WA	U.S.	ASIC	Frnt Rsrch Assy/Tst	P/CMOS BiCMOS	1981		8,000	4	1.8
Foxboro ICT		San Jose	CA	U.S.	Dis Pressure Sensors	Frnt Assy/Tst	Bipolar	1982		24,000	3	3
Frequency Sources		Lowell	MA	U.S.	Dis ASIC	Frnt Rsrch Dsgn Assy/Tst	P/CMOS	1986		1,000	4	1
Fujitsu	No. 1	Gresham	OR	U.S.	4Mb DRAM	Frnt	P/CMOS	1982.1	1,000	17,000	6	0.65
General Electric	PSF	Schenectady	NY	U.S.	Smart Pwr	Frnt Rsrch Pilot	P/CMOS BiCMOS Bipolar	1985		1,600	4	2
General Electric	MMIC Fab	Syracuse	NY	U.S.	MMIC	Frnt Pilot Assy/Tst	GaAs/III-V	1986		2,000	4	0.5
Gennum Corporation	Landmark	Burlington	Ontario	Canada	Signal Processors	Frnt Rsrch Pilot	Bipolar	1974	200	1,500	4	1.2
Germanium Power Devices		Andover	MA	U.S.	Opto Dis	Frnt		1974		10,000	3	
GMT Microelectronics	Fab No. 1	Norristown	PA	U.S.	Foundry	Frnt	P/CMOS BiCMOS Other	1995.3		20,000	5	1
GMT Microelectronics	Fab No. 2	Norristown	PA	U.S.	Foundry	Frnt				18,000	6	0.6
Government of the United States	Lawrence Berkeley Microsystems Lab	Berkeley	CA	U.S.	Radiation Detectors	Frnt Rsrch Fndry	P/CMOS NMOS	1991			4	1
Government of the United States	Lawrence Berkeley Instrument Lab	Berkeley	CA	U.S.	Radiation Detectors	Frnt Rsrch Fndry	P/CMOS GaAs/III-V	1993			3	5
Government of the United States	National Security Administration	Fort Meade	MD	U.S.	Custom Mil Std	Frnt	P/CMOS Bipolar	1988		10,000	6	1
Government of the United States	National Security Administration	Fort Meade	MD	U.S.	Mil Std	Frnt Pilot	P/CMOS	1990.4		5,000	6	0.8
Government of the United States	Army ETDL	Fort Monmouth	NJ	U.S.		Frnt Pilot		1987		5,000	5	
Government of the United States	Hanscom Air Force Base	Lexington	MA	U.S.	Custom Mil Std	Frnt Assy/Tst	P/CMOS Bipolar	1986		8,000	4	
Government of the United States	Lawrence Livermore Lab	Livermore	CA	U.S.	Wafer-Scale CoMPUter	Frnt Rsrch Pilot	P/CMOS NMOS	1987		2,000	6	0.25
Government of the United States	Naval Ocean Systems Ctr.	San Diego	CA	U.S.		Frnt Pilot		1988		5,000	4	
Harris Semiconductor	Fab 2	Findlay	OH	U.S.	MPU MCU MPR ASIC	Frnt Rsrch	P/CMOS BiCMOS	1973.2		20,000	4	2

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	State	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Harris Semiconductor	Fab 3	Findlay	OH	U.S.	Analog Mixed Signal Power Drivers MPR	Frnt Rsrch	P/CMOS BiCMOS Bipolar	1973.2	12,000	18,000	4	3
Harris Semiconductor	Fab 5	Findlay	OH	U.S.	MCU DSP Power ICs MPR	Frnt Rsrch	P/CMOS BiCMOS	1993.3	35,000	110,000	5	1.2
Harris Semiconductor	Fab 4	Mountaintop	PA	U.S.	Rectifiers	Frnt	P/CMOS NMOS Bipolar	1990.1		27,000	4	2
Harris Semiconductor	Fab 5	Mountaintop	PA	U.S.	Pwr IGBT Rectifiers	Frnt	P/CMOS NMOS Bipolar	1990.1		17,000	5	2
Harris Semiconductor	Fab 6	Mountaintop	PA	U.S.	Power MOS IGBTS	Frnt	P/CMOS NMOS	1990.1	1,500	19,500	6	2
Harris Semiconductor	Fab 8	Mountaintop	PA	U.S.	Power MOS IGBTS	Frnt	NMOS	1991.3	4,000	19,500	6	1
Harris Semiconductor	Fab 54	Palm Bay	FL	U.S.	4-Inch	Frnt Fndry	P/CMOS BiCMOS	1979.1	3,000	10,000	4	1.5
Harris Semiconductor	Fab 59	Palm Bay	FL	U.S.	6-Inch	Frnt	P/CMOS NMOS BiCMOS Other	1984.2	1,000	6,250	6	0.6
Hewlett-Packard	4-Inch	Corvallis	OR	U.S.	CBIC	Frnt Assy/Tst	P/CMOS	1979		10,000	4	1
Hewlett-Packard	6-Inch	Corvallis	OR	U.S.	ASIC MPR DSP RISC	Frnt Fndry	P/CMOS	1990.4		12,500	6	0.8
Hewlett-Packard		Corvallis	OR	U.S.	Analog	Frnt Pilot Assy/Tst	GaAs/III-V	1994	300	500	3	0.25
Hewlett-Packard	FTC	Fort Collins	CO	U.S.	MPU ASIC	Frnt Rsrch Dsgn Assy/Tst	P/CMOS NMOS Bipolar	1978		10,000	6	0.4
Hewlett-Packard		Newark	CA	U.S.	MMIC FET Dis	Frnt	GaAs/III-V	1988.4		900	3	
Hewlett-Packard	Bipolar	San Jose	CA	U.S.	Tran	Frnt Pilot Assy/Tst	GaAs/III-V	1981		200	2	0.5
Hewlett-Packard	Diode	San Jose	CA	U.S.	Diode	Frnt Pilot Assy/Tst	Bipolar	1981		2,400	2	3
Hewlett-Packard	Oed	San Jose	CA	U.S.	Opto	Frnt Pilot Assy/Tst	GaAs/III-V	1984		2,050	3	5
Hewlett-Packard	Gaas	Santa Clara	CA	U.S.	Discrete Power	Frnt Rsrch Pilot	GaAs/III-V			600	3	0.15
Hewlett-Packard		Santa Clara	CA	U.S.	Logic ASIC	Frnt Pilot	Bipolar			1,600	3	1.5
Hewlett-Packard	2 inch	Santa Rosa	CA	U.S.	GaAs IC Analog	Frnt Pilot	GaAs/III-V	1976		75	2	0.25
Hewlett-Packard	3 Inch	Santa Rosa	CA	U.S.	GaAs IC Analog	Frnt	GaAs/III-V	1994.1		300	3	0.25
Hitachi	U2	Irving	TX	U.S.	1Mb 4Mb DRAM 256Kb SRAM MPU	Frnt	P/CMOS	1990		16,500	6	0.8
Holt Integrated Circuits		Irvine	CA	U.S.	Op Amp EEPROM Log ASIC	Frnt Fndry Assy/Tst	P/CMOS			10,000	4	2.5
Honeywell Electronics	VHSIC	Plymouth	MN	U.S.	SRAM ASIC Analog Discrete	Frnt Rsrch Pilot	P/CMOS Bipolar	1974		1,800	4	0.65
Honeywell Electronics	Opto Fab	Richardson	TX	U.S.	Optoelectronics	Frnt Rsrch Pilot	GaAs/III-V	1973.4		400	2	10
Honeywell Electronics	Sensor Fab	Richardson	TX	U.S.	Sensors	Frnt	Bipolar GaAs/III-V	1985	100	5,000	4	2
Hughes	HTC	Carlsbad	CA	U.S.	Mil Std Opto ASIC Lin	Frnt Pilot	P/CMOS BiCMOS	1987		8,800	4	1.5
Hughes	Fab 2	Newport Beach	CA	U.S.	ASIC Lin	Frnt Rsrch Pilot Fndry Assy/Tst	P/CMOS	1973		4,000	4	3
Hughes	SPC-Fab 3	Newport Beach	CA	U.S.	Arrays Custom Mix ASIC	Frnt Rsrch	P/CMOS	1983		6,000	4	0.6

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	State	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Hughes		Sylmar	CA	U.S.	Solar Cell Arrays	Frnt Rsrch Assy/Tst		1982		24,000	4	
Hughes	GaAs	Torrance	CA	U.S.	MMIC	Frnt Rsrch Pilot Assy/Tst	GaAs/III-V	1977		240	3	0.25
IBM Microelectronics	Bldg. 970	Essex Junction	VT	U.S.	64Mb DRAM MPU Multimedia ICs	Frnt	P/CMOS	1988		24,000	8	0.35
IBM Microelectronics	Bldg. 963	Essex Junction	VT	U.S.	4Mb DRAM, MPU	Frnt Fndry	P/CMOS	1989.4		16,000	5	0.5
IBM Microelectronics	Bldg. 973	Essex Junction	VT	U.S.	16Mb DRAM	Frnt	P/CMOS	1989.4		20,000	8	0.5
IBM Microelectronics	ASTC	Hopewell Junction	NY	U.S.	64Mb 256Mb	Frnt	P/CMOS	1989		10,000	8	0.35
IBM/Cirrus	Bldg. 322	Hopewell Junction	NY	U.S.	Logic	Frnt	P/CMOS BiCMOS	1995.3		20,000	8	0.25
IC Sensors		Milpitas	CA	U.S.	MCU MPU DSP MPR	Frnt Rsrch	P/CMOS Bipolar	1988		17,600	4	0.5
IMP	Building 1	San Jose	CA	U.S.	ASIC Analog MPR	Frnt Fndry	P/CMOS NMOS BiCMOS	1982.4	1,200	3,000	5	0.8
Integrated Circuit Works		San Jose	CA	U.S.	Foundry	Frnt Fndry	P/CMOS BiCMOS	1984		7,000	6	0.6
Integrated Device Technology	Fab 4	Hillsboro	OR	U.S.	Logic SRAM	Frnt	P/CMOS	1996.1		10,000	8	0.5
Integrated Device Technology	Fab 2	Salinas	CA	U.S.	Fast 16Kb 64Kb 256Kb SRAM	Frnt	P/CMOS	1987		13,500	6	1
Integrated Device Technology	Fab 3	San Jose	CA	U.S.	SRAM MPU RISC Logic	Frnt	P/CMOS BiCMOS	1991		15,000	6	0.8
Intel	Fab 5	Aloha	OR	U.S.	x86 MPU	Frnt Dsgn	P/CMOS BiCMOS	1980		15,000	6	0.5
Intel	D1B	Aloha	OR	U.S.	x86 MPU	Frnt Rsrch Dsgn Pilot	BiCMOS	1993		10,000	8	0.18
Intel	Fab 15	Aloha	OR	U.S.	x86 MPU	Frnt	BiCMOS	1996		20,000	8	0.35
Intel	Fab 6	Chandler	AZ	U.S.	MCU	Frnt	P/CMOS BiCMOS	1984		24,000	6	1
Intel	Fab 12	Chandler	AZ	U.S.	x86 MPU	Frnt	BiCMOS	1996		24,000	8	0.35
Intel	Fab 7	Rio Rancho	NM	U.S.	Flash Memory	Frnt	P/CMOS	1984		23,000	6	0.5
Intel	Fab 9	Rio Rancho	NM	U.S.	x86 MPU	Frnt	P/CMOS BiCMOS	1988		48,000	6	0.8
Intel	Fab 11	Rio Rancho	NM	U.S.	x86 MPU	Frnt	BiCMOS	1995	19,000	33,000	8	0.35
Intel	D2	Santa Clara	CA	U.S.	x86 MPU	Frnt Rsrch Dsgn	BiCMOS	1991		11,000	8	0.25
International Microcircuits Inc.		Milpitas	CA	U.S.	ASIC	Frnt Pilot	P/CMOS	1991		800	5	1
International Rectifier	Ppd4	El Segundo	CA	U.S.	Pwr Trans MOSFET	Frnt Rsrch Dsgn Assy/Tst	P/CMOS NMOS	1983		13,000	4	5
International Rectifier	Hexfet	Temecula	CA	U.S.	Pwr Trans MOSFET	Frnt Assy/Tst	P/CMOS	1986.4		42,000	5	5
International Rectifier	Hexfet-2	Temecula	CA	U.S.	Pwr Trans MOSFET	Frnt Assy/Tst	P/CMOS	1995.3		10,000	6	2
Kodak		Rochester	NY	U.S.	Imaging Arrays CBIC CCD	Frnt Rsrch Pilot	P/CMOS Bipolar	1984		5,000	4	1.5
Konica Technology		Silicon Valley	CA	U.S.	Opto Log ASIC	Frnt Rsrch		1985				
Kulite		Leonia	NJ	U.S.	Discrete	Frnt	Bipolar			24,000	4	3
Linear Technology	Fab 3	Camas	WA	U.S.	Linear	Frnt	P/CMOS BiCMOS Bipolar	1996		10,000	6	1.5
Linear Technology	Fab 1	Milpitas	CA	U.S.	Linear Interface A/D D/A	Frnt Dsgn Assy/Tst	P/CMOS BiCMOS Bipolar	1982		9,000	4	3

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

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Linear Technology	Fab 2	Milpitas	CA	U.S.	Linear	Frnt Dsgn Assy/Tst	P/CMOS BiCMOS Bipolar	1992.4		8,000	4	2
Linfinity Microelectronics	Markon Bldg.	Garden Grove	CA	U.S.	Linear Bipolar Analog	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS BiCMOS Bipolar	1982	200	9,000	4	3
Litton		San Jose	CA	U.S.	Fet Amp	Frnt	GaAs/III-V				3	
Litton		Santa Clara	CA	U.S.	Microwave Diodes FETs TTMICs	Frnt Fndry	GaAs/III-V	1991.4	15	200	3	
Lockheed Martin		Fort Worth	TX	U.S.		Frnt	NMOS			5,000	4	0.8
Lockheed Martin	Sanders Nashua	Sanders Nashua	NH	U.S.	Analog MMICs	Frnt Rsrch Pilot	GaAs/III-V	1985		19,200	3	0.15
Lockheed Martin	113	Sunnyvale	CA	U.S.	ASIC Mil Std Rad-Hard	Frnt Pilot	P/CMOS	1988.3		640	5	1.5
Lockheed Martin	E Lab	Syracuse	NY	U.S.	Analog Discrete Phemts	Frnt Rsrch Pilot	GaAs/III-V	1983		3,600	3	0.1
Loral Electronics	S/C	Lowell	MA	U.S.	RF and Microwave Diodes	Frnt Rsrch Dsgn Pilot Assy/Tst	Bipolar	1985		2,000	3	
LSI Logic	Fremont Fab	Fremont	CA	U.S.	ASIC	Frnt Rsrch Pilot	P/CMOS			6,000,000	6	1.5
LSI Logic	Milpitas Fab	Milpitas	CA	U.S.	Arrays Custom	Frnt Rsrch Pilot	P/CMOS	1982		6,000	6	0.5
LSI Logic	R&D Pilot	Santa Clara	CA	U.S.	ASIC MPU	Frnt Rsrch Pilot	P/CMOS	1989		5,000	6	0.5
Lucas Novasensor	LCSP	Fremont	CA	U.S.	Processing Pressure Sensors	Frnt	Other			2,500	4	4.5
Lucent Technologies	MOS 2	Allentown	PA	U.S.	Network Communication ASIC DSP	Frnt Dsgn Fndry Assy/Tst	P/CMOS NMOS	1979.2		16,000	5	1.25
Lucent Technologies	BIC 2	Allentown	PA	U.S.	ASIC DSPs Network Communication Wireless	Frnt Dsgn Fndry Assy/Tst	Bipolar	1980.2		7,400	5	1
Lucent Technologies	MOS 5	Allentown	PA	U.S.	DSP Fpga CBIC ASSP Mixsig ASIC Lin	Frnt Dsgn Fndry Assy/Tst	P/CMOS	1984.1		38,400	5	0.55
Lucent Technologies		Lee's Summit	MO	U.S.	Diodes Tran Dis Mod ASIC	Frnt Rsrch Fndry	Bipolar	1967		10,000	5	1.5
Lucent Technologies	VLSI Research Lab	Murray Hill	NJ	U.S.	SRAM ASIC Opto	Frnt Rsrch Pilot	P/CMOS BiCMOS Bipolar	1975		4,000	5	
Lucent Technologies	OR 1	Orlando	FL	U.S.	ASIC DSP PLD FP	Frnt Fndry	P/CMOS BiCMOS	1985	5,400	16,000	6	0.35
Lucent Technologies	Linear I	Reading	PA	U.S.	Linear Analog	Frnt Rsrch	Bipolar	1981.4		16,000	5	1.5
Lucent Technologies	High Voltage II	Reading	PA	U.S.	Power	Frnt Rsrch	P/CMOS	1982.3		15,000	5	3
M/A-Com		Burlington	MA	U.S.	Discretes	Frnt	P/CMOS Bipolar GaAs/III-V	1960	1,800	15,000	4	0.2
M/A-Com	Adv. S/C	Lowell	MA	U.S.	MMIC	Frnt Pilot Fndry Assy/Tst	GaAs/III-V	1985		800	3	0.25
Magnovox		Fort Wayne	IN	U.S.	Arrays CBIC Hybrid	Frnt Dsgn Pilot Assy/Tst	P/CMOS	1976		400	3	5

Table 1 (Continued)
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Mass. Microelectronics Center (M2C)	Jeff	Westborough	MA	U.S.	ASIC	Frnt Dsgn Pilot Fndry Assy/Tst	P/CMOS BiCMOS	1989		1,200	5	2
Matsushita	Fab C	Puyallup	WA	U.S.	1Mb 4Mb DRAM 4-Bit 8-Bit MCU	Frnt Fndry Assy/Tst	P/CMOS	1992.1	3,000	21,000	6	0.6
Maxim Integrated Products	Bipolar	Beaverton	OR	U.S.	Linear	Frnt Pilot Fndry Assy/Tst	Bipolar	1994		4,000	6	0.8
Maxim Integrated Products		Sunnyvale	CA	U.S.	Op Amps A/D D/A	Frnt Pilot	P/CMOS	1990.2		4,000	6	3
McDonnell Douglas	3-Inch Pilot	Huntington Beach	CA	U.S.	4Kb 16Kb SRAM 6Kb Array MPU	Frnt Rsrch Pilot Fndry Assy/Tst	GaAs/III-V	1985		400	3	1
McDonnell Douglas	Dvlpmnt	Huntington Beach	CA	U.S.	MPU Log ASIC Dis	Frnt Rsrch Pilot Assy/Tst	GaAs/III-V	1988.1			3	1
Medtronic/ Micro-Rel	Wafer Fab	Tempe	AZ	U.S.	CMOS Bipolar ASIC	Frnt Fndry	P/CMOS BiCMOS Bipolar	1984.3	500	5,000	6	0.3
Micrel Semiconductor	Fab 1	San Jose	CA	U.S.	MixSig Lin	Frnt	P/CMOS BiCMOS Bipolar	1992		4,000	4	1.2
Micro-Circuit Eng.		West Palm Beach	FL	U.S.	Custom	Frnt Dsgn Fndry	NMOS	1979		12,000	4	4
Micro Power Systems		Santa Clara	CA	U.S.	Lin Custom	Frnt Assy/Tst	P/CMOS BiCMOS Bipolar	1975		15,000	3	4
Micro Quality Semiconductor		Garland	TX	U.S.	Rectifier Multiplier	Frnt	Bipolar			10,000	4	
Microchip Technology	Fab 4	(United States)		U.S.		Frnt	P/CMOS				8	
Microchip Technology	Fab 1	Chandler	AZ	U.S.	EEPROM MCU ASIC	Frnt	P/CMOS	1989	9,000	20,500	6	0.9
Microchip Technology	TI	Tempe	AZ	U.S.	EEPROM MCU ASIC	Frnt	P/CMOS	1994.3	1,500	12,000	8	0.35
Micron Technology	Fab 3	Boise	ID	U.S.	1Mb 4Mb 16Mb DRAM	Frnt Rsrch Assy/Tst	P/CMOS	1991.1		20,000	8	0.35
Micron Technology	Fab 1	Boise	ID	U.S.	4Mb 16Mb DRAM, VRAM, SRAM	Frnt Rsrch Pilot Assy/Tst	P/CMOS	1996.4		18,000	8	0.35
Micron Technology	Fab 2	Boise	ID	U.S.	4Mb 16Mb DRAM, VRAM, SRAM	Frnt Rsrch Assy/Tst	P/CMOS	1996.4		10,000	8	0.35
Micropac Industries		Garland	TX	U.S.	Mil Std Opto Hybrid	Frnt Pilot Assy/Tst				3,000	4	
Microsemi Corporation		Broomfield	CO	U.S.	Schottky Diode Rectifer	Frnt Assy/Tst	NMOS	1981		8,800	4	5
Microsemi Corporation		Torrance	CA	U.S.	Mil Std Dis	Frnt Pilot	Bipolar			4,800	3	12
Microwave Technology		Fremont	CA	U.S.	MMIC Amp FET	Frnt Assy/Tst	GaAs/III-V	1983			3	0.25
Mitel Semiconductor	Fab 1	Bromont	Quebec	Canada	Telecom A/D D/A	Frnt Fndry	P/CMOS	1976	4,000	12,000	6	0.8
Mitsubishi		North Durham	NC	U.S.	1Mb 4Mb DRAM	Frnt	P/CMOS	1990.4	3,400	9,000	6	0.5
Motorola	MOS 2	Austin	TX	U.S.	Log A/D MCU	Frnt Rsrch	P/CMOS	1983		50,000	4	1
Motorola	MOS 3	Austin	TX	U.S.	MCU	Frnt Rsrch Fndry	P/CMOS	1983		50,000	4	1
Motorola	STL	Austin	TX	U.S.	MCU Flash	Frnt Rsrch	P/CMOS	1984		36,550	5	1
Motorola	MOS 8	Austin	TX	U.S.	MCU FSRAM DSP Lin Risc	Frnt Rsrch	P/CMOS	1988.4		20,800	5	0.65
Motorola	MOS 13/14	Austin	TX	U.S.	MPU MCU RISC	Frnt Rsrch	P/CMOS BiCMOS	1995		7,200	8	0.25

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	State	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Motorola	MOS 12	Chandler	AZ	U.S.	MCU MPU	Frnt Rsrch	P/CMOS BiCMOS	1994.2		16,800	8	0.35
Motorola	Guad Power	Guadalajara		Mexico	Thyristor	Frnt				36,000	3	
Motorola	MOS 10	Irvine	CA	U.S.	DSP D/A A/D, MCU	Frnt Dsgn Assy/ Tst	P/CMOS BiCMOS	1982		12,000	6	0.55
Motorola	Bipolar 1	Mesa	AZ	U.S.	Telecom Op Amp Automotive Analog	Frnt Fndry	P/CMOS BiCMOS Bipolar	1983		40,000	4	3
Motorola	Bipolar 2	Mesa	AZ	U.S.	Logic	Frnt	Bipolar	1983		36,000	4	2.5
Motorola	Bipolar 3	Mesa	AZ	U.S.	Analog Gate Arrays	Frnt	P/CMOS BiCMOS Bipolar	1983		16,000	4	1.25
Motorola	MOS 5	Mesa	AZ	U.S.	MCU	Frnt	Bipolar	1988		22,000	5	0.8
Motorola	MOS 6	Mesa	AZ	U.S.	ASIC Analog Log	Frnt	P/CMOS BiCMOS	1988.4	8,000	12,000	6	0.5
Motorola	MOS 21	Mesa	AZ	U.S.	Logic ASIC Analog Discrete	Frnt	P/CMOS BiCMOS	1995		9,200	8	0.6
Motorola	MOS 11	Oakhill	TX	U.S.	SRAM DSP MCU MPU Risc	Frnt	P/CMOS BiCMOS	1992	3,140	15,700	8	0.35
Motorola	Bipolar 5	Phoenix	AZ	U.S.	RF Pwr Small Signal Opto	Frnt	Bipolar	1983		26,000	5	1.25
Motorola	MOS 4	Phoenix	AZ	U.S.	MOSFET Smart Pwr Discrete	Frnt	Bipolar	1986		18,000	6	3
Motorola	Com 1	Phoenix	AZ	U.S.	RF Power	Frnt Pilot	P/CMOS	1995		2,400	6	1.5
Motorola	Dfs	Phoenix	AZ	U.S.	Rectifiers	Frnt				14,400	3	
Motorola	Opto	Phoenix	AZ	U.S.	Opto	Frnt Pilot	GaAs/III-V			8,000	2	
Motorola	Phoenix Power	Phoenix	AZ	U.S.	Pwr Tran	Frnt	Bipolar			30,000	5	10
Motorola	Zener/Rectifier	Phoenix	AZ	U.S.	Zener Diode Rectifier	Frnt	Bipolar			56,000	4	10
Motorola	MOS 15	Research Triangle Park	NC	U.S.	8-Bit MCU Logic	Frnt Rsrch	P/CMOS	1984		12,000	6	0.8
Motorola	CS-1 Phase 1	Tempe	AZ	U.S.	Analog RF	Frnt Pilot	GaAs/III-V	1991.3		1,600	4	0.35
N-Chip		San Jose	CA	U.S.	MCM	Frnt Pilot	P/CMOS	1986		1,000	5	3
National Semiconductor	Fab 1	Arlington	TX	U.S.	Telecom Controllers ASICs	Frnt	P/CMOS BiCMOS	1985		17	6	1.25
National Semiconductor	Fab 2	Arlington	TX	U.S.	L.A.N. Audio PC Products	Frnt	P/CMOS BiCMOS	1992		14.5	6	0.5
National Semiconductor	Fab 2A	Arlington	TX	U.S.	LAN Audio PC Products	Frnt	P/CMOS BiCMOS	1996		15.5	6	0.5
National Semiconductor	5-Inch	Santa Clara	CA	U.S.	Bipolar Linear	Frnt	GaAs/III-V	1982.4	2,000	12,000	5	0.5
National Semiconductor	6-Inch	Santa Clara	CA	U.S.	EPROM MPR MCU DSP ASIC	Frnt	P/CMOS BiCMOS Bipolar	1992.1		2,000	6	0.5
National Semiconductor	8-Inch	Santa Clara	CA	U.S.	MPR MCU MPR DSP ASIC	Frnt		1995.4		15,000	8	0.35
National Semiconductor	Bipolar	South Portland	ME	U.S.	Log	Frnt Dsgn Assy/ Tst	P/CMOS BiCMOS Bipolar	1967		43,520	4	2.5
National Semiconductor	CMOS	South Portland	ME	U.S.	Log Array	Frnt Dsgn Assy/ Tst	P/CMOS BiCMOS	1985		5,500	5	1

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	State	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
National Semiconductor	MOS 3	West Jordan	UT	U.S.	EPROM EEPROM Embedded Controllers Analog Discrete	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS NMOS	1985		15,000	6	0.6
NEC	K-Line	Roseville	CA	U.S.	DRAM ASIC MCU	Frnt Assy/Tst	P/CMOS NMOS	1984		25,000	5	1
NEC	M-Line	Roseville	CA	U.S.	16Mb DRAM	Frnt Assy/Tst	P/CMOS	1991		35,000	6	0.5
Northern Telecom	Mod 4	Nepean	Ontario	Canada	CBIC Custom	Frnt Rsrch Dsgn Assy/Tst	P/CMOS	1990.1		6,000	6	
Northrop Grumman		Baltimore	MD	U.S.	Si/ Bipolar, MOS	Frnt	P/CMOS BiCMOS Bipolar	1985.1		1,000	6	0.15
Northrop Grumman		Baltimore	MD	U.S.	GaAs-RF	Frnt	GaAs/III-V	1995.1		500	4	0.15
Optek Technology Inc.	Fab 1	Carrollton	TX	U.S.	Mil Std Pwr ICs	Frnt	NMOS	1987		15,000	4	
Optek Technology Inc.	Fab 2	Carrollton	TX	U.S.	Mil Std Pwr ICs	Frnt	NMOS	1987		15,000	5	
Opto Diode		Newbury Park	CA	U.S.	Opto Diode	Frnt	GaAs/III-V	1981				
Orbit Semiconductor Inc.	Fab 1	Sunnyvale	CA	U.S.	Arrays Custom Mixsig ASIC ASIC	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS NMOS BiCMOS	1991		9,600	4	1.2
Orbit Semiconductor Inc.	Fab 1	Sunnyvale	CA	U.S.	Foundry	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS	1995		2,000	6	0.8
Orbit Semiconductor Inc.	Fab 2	Sunnyvale	CA	U.S.	Arrays Custom Mixsig ASIC	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS	1996		1,000	6	0.8
Paradigm Technology Inc.	SRAM Fab	San Jose	CA	U.S.	256Kb 1Mb 4Mb SRAM	Frnt Rsrch	P/CMOS	1990.1		6,000	6	0.55
Performance Semiconductor	Fab 1	Sunnyvale	CA	U.S.	SRAM Arrays MIPS RISC MPU	Frnt Pilot	P/CMOS	1986		5600	6	1
Performance Semiconductor	Fab 2	Sunnyvale	CA	U.S.	SRAM MPU ASIC	Frnt Pilot	P/CMOS BiCMOS	1990.4		7,000	6	0.7
Philips	Fab 22	Albuquerque	NM	U.S.	EPROM MCU MPR DSP Analog	Frnt Rsrch	P/CMOS NMOS BiCMOS Bipolar	1980		25,000	4	1.2
Philips	Fab 23	Albuquerque	NM	U.S.	MCU MPR ASIC Analog Discrete Opto Power ICs	Frnt Rsrch	P/CMOS BiCMOS	1988.4		17,000	6	0.8
Philips	Fab 1	Sunnyvale	CA	U.S.	Amplifiers Converters Timers	Frnt Dsgn Fndry	Bipolar	1964.1	50	22,500	4	1.8
Powerex		Youngwood	PA	U.S.	High-Pwr Discrete Diodes SCRS Transistors	Frnt Rsrch	Bipolar	1980.1	20,000	40,000	4	5
Powerex	Planar Transistor	Youngwood	PA	U.S.	Discrete Diode Pwr Tran Thyristor	Frnt Rsrch Pilot	Bipolar	1988		5,000	4	5
Precision Mono.	Fab 1	Santa Clara	CA	U.S.	ASIC	Frnt Pilot Assy/Tst	P/CMOS	1985		1,600	4	3
Precision Mono.	Fab 2	Santa Clara	CA	U.S.	Custom	Frnt Pilot Assy/Tst	Bipolar			3,200	4	2.5
Protect Devices		Tempe	AZ	U.S.	Diode	Frnt Assy/Tst	Bipolar	1968		19,200	3	25

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	State	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Ramtron International Corporation	Northgate	Colorado Springs	CO	U.S.	4Kb/16Kb/64kb FRAM	Frnt Rsrch Dsgn Pilot Fndry Assy/Tst	P/CMOS	1993		1,200	6	1
Raytheon	GaAs Fab	Andover	MA	U.S.	GaAs MMIC	Frnt Fndry	GaAs/III-V	1985.3	150	200	4	0.15
Raytheon	Research Fab	Andover	MA	U.S.	GaAs MMIC	Frnt	GaAs/III-V	1989.3			3	0.15
Raytheon	Linear	Mountain View	CA	U.S.	Lin ASIC Dis Tran SST	Frnt	Bipolar	1979		6,400	4	5
Raytheon	LSI Arrays	Mountain View	CA	U.S.	20Kb Arrays	Frnt	P/CMOS Bipolar	1987		10,000	4	1
Rockwell Semiconductor System	Fab VII	Colorado Springs	CO	U.S.	DSP Analog Mixed Signal Controllers	Frnt Assy/Tst	P/CMOS	1986		800	5	1
Rockwell Semiconductor System	GaAs Wafer Fab	Newbury Park	CA	U.S.	DACs Power Amplifiers Front-End Receivers	Frnt Rsrch Dsgn Pilot Assy/Tst	GaAs/III-V	1985		250	4	0.9
Rockwell Semiconductor System	Fab 1	Newport Beach	CA	U.S.	Modem Telecom	Frnt Rsrch Dsgn Pilot Assy/Tst	P/CMOS	1979		25,000	4	2
Rockwell Semiconductor System	Fab IV	Newport Beach	CA	U.S.	DSP Analog Mixed Signal Controllers	Frnt Rsrch Dsgn Pilot Assy/Tst	P/CMOS	1987.4		2,100	5	0.8
Rockwell Semiconductor System	Fab VI	Newport Beach	CA	U.S.	DSP Analog Mixed Signal Controllers RF	Frnt Rsrch Dsgn Pilot Assy/Tst	P/CMOS			1,100	8	0.25
Rockwell Semiconductor System	Fav V	Newport Beach	CA	U.S.	DSP Analog Mixed Signal Controllers	Frnt Rsrch Dsgn Pilot Assy/Tst	P/CMOS			2,500	8	0.5
Rohm	Kifer Plant	Sunnyvale	CA	U.S.	Custom Mixed Signal ASIC	Frnt	Bipolar	1989		15,000	5	3
S-MOS Sysyems		Vancouver		Canada		Frnt Dsgn		1991				
Samsung	GaAs	Milpitas	CA	U.S.	GaAs Fet MMIC	Frnt Dsgn Pilot Fndry Assy/Tst	GaAs/III-V	1982		3500	4	0.25
Sanders Associates	GaAs	Nashua	NH	U.S.	Lin MMIC	Frnt Pilot Assy/Tst	GaAs/III-V	1985		400	3	0.5
Sandia National Labs	MDL	Albuquerque	NM	U.S.	R&D	Frnt Fndry	P/CMOS Other	1989		1,200	8	0.5
Santa Barbara Rsch.	SBRC	Goleta	CA	U.S.	Mil Std Infrared Detector	Frnt Pilot		1987		1,000	4	
Sematech	ATDF	Austin	TX	U.S.	R&D	Frnt Rsrch Pilot	P/CMOS	1988.3		5,000	8	0.25
Semicoa		Costa Mesa	CA	U.S.	Custom Hi-Rel Pwr Photo	Frnt	Bipolar	1969		12,000	3	7
Semiconductor Laser International		Endicott	NY	U.S.	High Pwrd Diode Lasers (HPDL)	Frnt	GaAs/III-V	1996				
Semtech Corporation	Corpus Christi	Corpus Christi	TX	U.S.	Bipolar ACS Y Vortage Supressors	Frnt	Bipolar	1974	1,000	8,000	4	2
Semtech Corporation	Newbury Park	Newbury Park	CA	U.S.	Discrete Rectifier Zener Diode	Frnt Rsrch Assy/Tst	Bipolar	1968		10,000	2	
Semtech Corporation		Santa Clara	CA	U.S.	Linear products	Frnt	P/CMOS GaAs/III-V	1974		12,000	4	4
Semtech Corporation		Santa Clara	CA	U.S.	Bipolar CMOS	Frnt Fndry	P/CMOS BiCMOS Bipolar	1975	1,500	10,000	5	2
Sensor Solid State		Quakertown	PA	U.S.	Custom Dis Sensors	Frnt Pilot	P/CMOS NMOS	1969		500	4	3

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	State	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Sensym Inc.	Fab 1	Milpitas	CA	U.S.	Pressure Transducers	Frnt Fndry	Bipolar	1993	600	2,000	4	3.5
SGS-Thomson	Fab 4	Carrollton	TX	U.S.	SRAM ASIC EPROM EEPROM	Frnt Rsrch Dsgn Fndry	P/CMOS NMOS BiCMOS	1979.2		9,000	6	1.2
SGS-Thomson	Fab 6	Carrollton	TX	U.S.	1Mb SRAM Arrays	Frnt Rsrch Dsgn	P/CMOS NMOS BiCMOS	1989		6,000	6	1
SGS-Thomson		Philadelphia	PA	U.S.	Dis RF	Frnt	Bipolar			12,000	4	5
SGS-Thomson	Phoenix Fab	Phoenix	AZ	U.S.	x86 MPEG Logic	Frnt Dsgn	P/CMOS	1995		15,000	8	0.35
SGS-Thomson		San Diego	CA	U.S.	ASIC Log	Frnt Rsrch	P/CMOS BiCMOS	1981		14,000	4	2
Sid Microelectronics		Contagoem		Brazil	Lin Pwr Tran SST Pwr ICs	Frnt	P/CMOS Bipolar	1984		12,000	3	30
Sid Microelectronics		Contagoem		Brazil	Pwr ICs	Frnt	P/CMOS	1990		13,000	4	2
Silicon Transistor Corporation	STC	Chelmsford	MA	U.S.	Pwr Bipolar Discrete	Frnt Fndry	Bipolar	1971	200	2,000	4	4
Sipex Corporation	Fab 1	Milpitas	CA	U.S.	ASIC Mixed Signal	Frnt Rsrch Pilot	P/CMOS BiCMOS Bipolar	1987		4,000	4	3
Solid Power Company		Farmingdale	NY	U.S.	Pwr Tran	Frnt Assy/Tst	Bipolar	1967		24,000	2	20
Solid State Devices		La Mirada	CA	U.S.	Hi-Rel Custom	Frnt Pilot	Bipolar			4,000	4	
Solitron Devices		West Palm Beach	FL	U.S.	Pwr Transistors Diodes Hybrid FETs Precision Resistors	Frnt Fndry	P/CMOS Bipolar Others	1992		500	3	2
Sony	Fab 12	San Antonio	TX	U.S.	ASIC PLD	Frnt	Bipolar	1982		12,800	6	1.25
Sony	Fab 11	San Antonio	TX	U.S.	SRAM	Frnt	P/CMOS	1991		16,000	6	0.45
Standard Microsystems		Hauppauge	NY	U.S.	Custom CBIC	Frnt Fndry Assy/Tst	P/CMOS	1984		19,200	4	1.25
Supertex		Sunnyvale	CA	U.S.	Analog Power	Frnt Rsrch	P/CMOS NMOS	1976		9,0000	4	4
Symbios Logic	Colorado Springs (CS 3)	Colorado Springs	CO	U.S.	CBIC ASIC MPB Analog Mixed Signal	Frnt Rsrch Pilot	P/CMOS	1994		8,400	8	0.5
Symbios Logic	Ft. Collins 6	Fort Collins	CO	U.S.	CBIC ASIC MPB Analog Mixed Signal	Frnt Dsgn Pilot Assy/Tst	P/CMOS	1986		6,000	6	0.75
Synergy Semiconductor	Scott	Santa Clara	CA	U.S.	Fast-SRAM MPR ASIC	Frnt Pilot Assy/Tst	P/CMOS BiCMOS Bipolar	1996.3	300	1,200	6	1
Sypex	Fab 1	Milpitas	CA	U.S.	Op Amp CBIC Custom	Frnt Pilot Fndry Assy/Tst	P/CMOS	1986		1,600	4	4
Teccor Electronics	Sideator	Irving	TX	U.S.	ASIC Analog	Frnt Rsrch Dsgn Assy/Tst	Bipolar	1969		10,000	3	0.24
Teccor Electronics	Triacs Stand	Irving	TX	U.S.	Discrete Thyristor	Frnt Rsrch Dsgn Assy/Tst	Bipolar	1986		16,000	3	0.35
Telcom Devices		Camarillo	CA	U.S.	Photodiode LED	Frnt Rsrch Dsgn Assy/Tst	GaAs/III-V	1993		800	2	
Teledyne		Los Angeles	CA	U.S.	Hi-Rel Hybrid and A/D D/A	Frnt Pilot	Bipolar			5,000	4	
Teledyne		Mountain View	CA	U.S.	Pwr ICs Pwr MOSFET Hybrids	Frnt Pilot Assy/Tst	P/CMOS BiCMOS Bipolar	1972		5,000	4	

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	State	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Teledyne	GaAs	Mountain View	CA	U.S.	FET	Frnt Pilot Assy/Tst	GaAs/III-V			80	3	0.5
TEMIC	Fab 3	Santa Clara	CA	U.S.	Pwr Smart Pwr	Frnt Dsgn Pilot Assy/Tst	P/CMOS BiCMOS	1986	100	18,000	6	0.6
TEMIC	Fab 2	Santa Clara	CA	U.S.	Smart Pwr A/D D/A	Frnt Dsgn Assy/Tst	P/CMOS BiCMOS		100	6,000	4	2
Texas Instruments	DMOS	Dallas	TX	U.S.	Log MPU	Frnt	P/CMOS	1985.2		29,200	6	0.6
Texas Instruments	Dlin	Dallas	TX	U.S.	Lin	Frnt Rsrch	P/CMOS BiCMOS Bipolar	1989		27,000	6	1
Texas Instruments	Dlog	Dallas	TX	U.S.	Lin ASSP	Frnt Rsrch	P/CMOS	1989		16,000	6	0.8
Texas Instruments	DMOS 5 Phase 1	Dallas	TX	U.S.	16Mb DRAM	Frnt Rsrch	P/CMOS	1995		16,000	8	0.5
Texas Instruments	H-Fab	Houston	TX	U.S.	Adv Bip ASSP ASIC	Frnt	P/CMOS Bipolar	1984		25,466	5	1
Texas Instruments	LMOS	Lubbock	TX	U.S.	EPROM Flash DSP Speech	Frnt	P/CMOS	1978.2	15,000	28,000	6	0.6
Texas Instruments	Fab III	Santa Cruz	CA	U.S.	Mixed Signal ASIC DSP	Frnt Rsrch	P/CMOS BiCMOS Bipolar	1992.2		3,400	6	0.8
Texas Instruments	S-Fab	Sherman	TX	U.S.	Log MPR	Frnt	Bipolar	1980		51600	5	1
TriQuint Semiconductor	Building 59	Beaverton	OR	U.S.	MMIC Lin Opto CBIC Arrays	Frnt	GaAs/III-V	1981		2300	4	0.7
TRW		La Jolla	CA	U.S.	A/D D/A Multipliers	Frnt Rsrch Pilot	P/CMOS NMOS Bipolar	1987		5,000	4	
TRW		Manhattan Beach	CA	U.S.	Lin Tran Pwr Tran Hybrd	Frnt Pilot	NMOS	1982		5,000	4	
TRW		Redondo Beach	CA	U.S.	RF Pwr	Frnt Pilot Assy/Tst	GaAs/III-V	1971		500	3	0.1
TRW	D1	Redondo Beach	CA	U.S.	Lin Tran Pwr Tran Hybrd	Frnt Pilot Assy/Tst	P/CMOS Bipolar	1985		1,600	4	1.5
TRW	D1	Redondo Beach	CA	U.S.	VHSIC Mil Std Fer-RAM	Frnt Assy/Tst	P/CMOS	1986		6,400	4	0.5
Twinstar Semiconductor	Twinstar	Richardson	TX	U.S.	16Mb 64Mb DRAM	Frnt	P/CMOS	1996.2	10,000	15,000	8	0.3
Unitrode		Merrimack	NH	U.S.	Lin Smart Pwr Custom	Frnt Pilot Assy/Tst	Bipolar	1987		4,000	4	5
Unitrode		Watertown	MA	U.S.	Hybrid Dis	Frnt	Bipolar			10,000	4	
Universal Semiconductor		San Jose	CA	U.S.	Linear Arrays ASIC Power ICs	Frnt Rsrch Dsgn Pilot Fndry Assy/Tst	P/CMOS BiCMOS Bipolar	1980		10,000	4	2
Vitesse Semiconductor	Camarillo Fab	Camrillo	CA	U.S.	GaAs ICs	Frnt	GaAs/III-V	1986.1	100	3,000	4	0.3
VLSI Technology	Module A	San Antonio	TX	U.S.	Arrays CBIC MPU Telecom ICs	Frnt Rsrch Fndry	P/CMOS	1988.4	1,250	8,000	6	0.35
VLSI Technology	Module B	San Antonio	TX	U.S.	Arrays CBIC MPU Telecom ICs	Frnt Rsrch Fndry	P/CMOS	1991.4		3,500	6	0.35
VLSI Technology	Module C	San Antonio	TX	U.S.	Arrays CBIC MPU Telecom ICs	Frnt Rsrch Fndry	P/CMOS	1994		4,250	6	0.35
VLSI Technology	Module D	San Antonio	TX	U.S.	Arrays CBIC MPU Telecom ICs	Frnt Rsrch Fndry	P/CMOS	1996		4,250	6	0.35

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

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VLSI Technology	McKay 1	San Jose	CA	U.S.	CBICs	Frnt Fndry	P/CMOS	1982.4	1,000	11,000	6	0.5
Xicor	Phase 2	Milpitas	CA	U.S.	EEPROM	Frnt	P/CMOS	1981	1,000	8,000	6	0.5
Zenith Microcircuits	Hvsr	Elk Grove	IL	U.S.	High-Volt Diode Tri-ode	Frnt Assy/Tst	Bipolar	1981		16,000	2	20
Zilog	Module 1	Nampa	ID	U.S.	MPU MCU Custom	Frnt Rsrch Fndry Assy/Tst	NMOS	1988		15,000	5	1.2
Zilog	Module 2	Nampa	ID	U.S.	Z8XXX MPU MCU Custom	Frnt Rsrch Fndry Assy/Tst	P/CMOS NMOS BiCMOS	1988		10,200	5	0.65
Zilog	Module 3	Nampa	ID	U.S.	MPU MCU Custom	Frnt Rsrch Assy/Tst	P/CMOS	1994		8,000	8	0.6

Source: Dataquest (December 1996)

Table 2
Front-End Production Lines Begining Operation 1997 and After

Company	Fab Name	City	State	Country	Devices Produced	Activities	Processes	Year & Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line width (Microns)
American Microsystems Inc.	Fab 10	Pocatello	ID	U.S.	Arrays PLD CBIC Custom Mixsig ASIC	Frnt Rsrch	P/CMOS	1997.3	6,500	25,000	8	0.35
Cypress Semiconductor	Fab 5 Phase 1	Round Rock	TX	U.S.		Frnt		1997.4		15,000	8	0.25
Cypress Semiconductor	Fab 5 Phase 2	Round Rock	TX	U.S.		Frnt		1999		15,000	8	0.25
Fujitsu	No. 2	Gresham	OR	U.S.	64Mb DRAM	Frnt	P/CMOS	1998	5,000	10,000	8	0.25
Harris	Power MOS 8-Inch	Mountaintop	PA	U.S.	MOSFET IGBT Thyristor	Front	NMOS	1997	2,000	15,000	8	1.0
Hitachi	U3	Irving	TX	U.S.	MCU	Frnt	P/CMOS	1997		10,000	8	0.3
Hyundai	Oregon Fab	Eugene	OR	U.S.	16Mb 64Mb DRAM	Frnt Rsrch	P/CMOS	1998	3,000	30,000	8	0.25
IBM/Toshiba		Manassas	VA	U.S.	64Mb DRAM	Frnt	P/CMOS	1997.4	15,000	28,000	8	0.25
Intel	Fab 16	Fort Worth	TX	U.S.	x86 MPU	Frnt	BiCMOS	1998		24,000	8	0.25
Intel	D1C	Ronler Acres	OR	U.S.	x86 MPU	Frnt Rsrch Dsgn Pilot	P/CMOS BiCMOS	1997		15,000	8	0.1
LSI Logic	Fab 1	Gresham	OR	U.S.	ASIC CBIC MPU MPR SRAM	Frnt	P/CMOS BiCMOS	1997		15,000	8	0.35
Lucent Technologies/ Cirrus	OR 2	Orlando	FL	U.S.	ASIC	Frnt Fndry	P/CMOS	1997.1	200	20,000	8	0.25
Matsushita	Fab D	Puyallup	WA	U.S.	DRAM Logic	Frnt Dsgn Assy/ Tst	P/CMOS	1998.2		20,000	8	0.25
Microchip Technology	Fab 3	(United States)		U.S.		Frnt	P/CMOS	1998.2			8	
Micron Technology		Lehi	UT	U.S.		Frnt		1999			8	0.25
Motorola	Power Rect	Phoenix	AZ	U.S.	Rectifiers	Frnt		1998		6,000	6	1.5
Motorola	MOS 19	Research Triangle Park	NC	U.S.	MPU MCU Logic	Frnt Rsrch Pilot	P/CMOS BiCMOS	1999	480	4,800	8	0.35
Motorola	MOS 19 Phase 2	Research Triangle Park	NC	U.S.	PowerPC MPU	Frnt Rsrch	P/CMOS	1999.4	4,800	25,000	8	0.35
National Semiconductor	New 8-Inch Fab	South Portland	ME	U.S.	Log Array	Frnt Dsgn Assy/ Tst	P/CMOS BiCMOS	1997	1,000	8,000	8	0.25
NEC	G-Line	Roseville	CA	U.S.	64Mb 256Mb DRAM	Frnt Assy/Tst	P/CMOS	1996		20,000	8	0.25
Rockwell Semiconductor Systems	Fab VIII	Colorado Springs	CO	U.S.	DSP Analog Mixed Signal Controllers	Frnt Assy/Tst	P/CMOS	1997.3		4,000	8	0.18
Rockwell Semiconductor Systems	Fab IX	Colorado Springs	CO	U.S.	DSP Analog Mixed Signal Controllers	Frnt Assy/Tst	P/CMOS	1999		4,000	8	0.12
Samsung		Austin	TX	U.S.	64Mb DRAM	Frnt Rsrch Dsgn	P/CMOS	1998.1	10,000	25,000	8	0.3
Siemens/Motorola	MOS 18	Richmond	VA	U.S.	64Mb 256Mb DRAM	Frnt Pilot	P/CMOS	1998.3	1,000	25,000	8	0.18
Taiwan Semiconductor Manufacturing Co.	Fab 6	Camas	WA	U.S.	DRAM SRAM Mixed Signal ASIC	Frnt Fndry	P/CMOS	1998	3,000	30,000	8	0.25
Texas Instruments	DMOS 5 Phase 2	Dallas	TX	U.S.	64Mb 256Mb DRAM	Frnt Rsrch	P/CMOS	1997		16,000	8	0.35
Texas Instruments	DMOS 6	Dallas	TX	U.S.	DSP	Frnt Rsrch	P/CMOS	1997.4	10,000	30,000	8	0.25
TriQuint Semiconductor	Building 2	Hillsboro	OR	U.S.	RF Mixed Signal	Frnt Fndry	GaAs/III-V	1997.3				

Source: Dataquest (December 1996)

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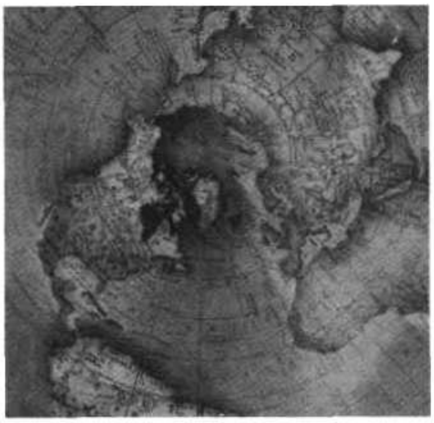

Dataquest

Europe, Africa, and Middle East Fab Database

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
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Europe, Africa, and Middle East Fab Database

Background and Methodology

This report contains the Europe, Africa, and Middle East portion of Dataquest's wafer fab database. These tables cover fabs located in the Europe, Africa, and Middle East region. The Semiconductor Equipment, Materials, and Manufacturing Worldwide (SEMM) program conducts extensive annual surveys complemented with quarterly secondary research to maintain this database. Published once a year, this document represents Dataquest's best insights and estimates into the end market of semiconductor equipment.

The tables in this report cover planned and existing merchant, captive, and foundry fab lines. A fab line consists of a series of equipment that does front-end semiconductor manufacturing (from initial oxide through wafer probe). Occasionally, two or more separate product-specific fab lines or wafer sizes operate in a single clean room or physical plant. In this situation, Dataquest considers the clean room to be separate fab lines if the company dedicates equipment to each wafer size or product line. If a company installs substantially different equipment during an expansion (for example, equipment to increase the maximum wafer diameter), again Dataquest divides the clean room and creates two entries in the database. Therefore, a company may operate many fab lines at one location.

Worldwide Geographic Region Definitions and Regional Roll-Ups

Americas

Includes Central America (all nations), Canada, Mexico, United States, Puerto Rico, and South America (all nations)

Japan

Japan is the only single-country region.

Europe, Africa, and Middle East

Includes Africa (all nations), Albania, Andorra, Armenia, Azerbaijan, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Gibraltar, Hungary, Iceland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Middle East (all nations), Moldova, Monaco, Netherlands, Norway, Poland, Romania, Russia, San Marino, Scandinavia, Slovakia, Spain, Sweden, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan, Vatican City, and all nations within the former Yugoslavia

Asia/Pacific

Includes Australia, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam

Table Column Definitions

The Company column indicates the operator of the fab line. For contract manufacturers that trade capacity for capital investment in the fab, Dataquest lists the contract manufacturer. For incorporated joint ventures, Dataquest will either list the incorporated entity or the major investors, separated with slashes.

The Fab Name column provides a reference to a particular fab or fab line to distinguish it from other fabs or lines owned by that company. Although Dataquest makes every attempt to match the nomenclature used by the company, occasionally some additional qualifiers (for example, Phase 1) appear to provide insight into the facility's history or organization.

The City column displays the most detailed location information. This reference is usually a city or town, but could be an often-used district name (for example, Science Park in the city of Hsinchu, Taiwan). If this column lists a district, Dataquest will list the city in the State or Province column. In some cases, a reference to a state or province will be included in the city or district column to create a unique identifier for this location.

The State, Province, or Prefecture columns denote the second most detailed location. This reference is usually a state (for the United States), province (for Canada and many European and Asian countries), or a prefecture (for Japan). For countries within the United Kingdom, Dataquest will list the country name (for example, Scotland) in this column so Dataquest can list the descriptor "U.K." in the Country column.

The Country column indicates the broadest location identifier in this report. This reference is usually a country, except in the case of the United Kingdom (see above). As Japan is a single-country region, a regional qualifier does not exist for fabs in Japan.

The Devices Produced column lists the products manufactured at this site. The listings generally fall into five product groups, with the following nomenclature and definitions (when warranted):

- MOS memory
  - DRAM: Dynamic RAM
  - EEPROM or E2: Electrically erasable PROM
  - EPROM: Ultraviolet erasable PROM
  - FERRAM: Ferroelectric RAM
  - FIFO: First-in/first-out memory
  - Flash: Flash memory
  - MEM: Memory
  - NvMem: Nonvolatile memory (ROM, PROM, EPROM, EEPROM, FERRAM)
  - PROM: Programmable ROM

  - RAM: Random-access memory
  - ROM: Read-only memory
  - SpMem: Other specialty memory (such as dual-port, shift-register, color lookup)
  - SRAM: Static RAM
  - VRAM: Video RAM
- MOS microcomponent/digital logic
  - Arrays: Gate array
  - ASIC: Application-specific IC
  - ASSP: Application-specific standard product
  - Bit: Bit slice (subset of MPU functions)
  - CBIC: Cell-based IC
  - Custom: Full-custom IC (single user)
  - DSP: Digital signal processor
  - FPGA: Field-programmable gate array
  - LISP: 32-bit list instruction set processor for AI
  - Log or Logic: Standard logic
  - MCU: Microcontroller unit
  - Mixsig ASIC: Mixed-signal ASIC
  - MPR: Microperipheral
  - MPRCom: MPR digital communications (ISDN, LAN, UART, modem)
  - MPU: Microprocessor unit
  - PLD: Programmable logic device
  - RISC: Reduced-instruction-set computation 32-bit MPU
  - Telecom: Telecommunications chip
- Power/discrete/analog (including bipolar power)
  - A/D D/A: Analog-to-digital, digital-to-analog converter
  - Automotive: Dedicated to automobile applications
  - Codec: Coder/decoder
  - Diode
  - Dis or Discrete: Discrete
  - FET: Field-effect transistor
  - GTO: Gate turn-off thyristor
  - HEMT: High-electron-mobility transistor
  - IGBT: Insulated gate bipolar transistor
  - Interface: Interface IC

- Lin: Linear/analog device
- MDiode: Microwave diode
- MESFET: Metal semiconductor field-effect transistor
- MFET: Microwave field-effect transistor
- Modem: Modulator/demodulator
- MMIC: Monolithic microwave IC
- MOSFET: MOS-based field-effect transistor
- Op Amp: Operational amplifier
- Pwr IC: Power IC
- Pwr Tran: Power transistor
- Rectifier
- Reg: Voltage regulator
- RF: Radio frequency
- SCR: Schottky rectifier
- Sensor
- Smart Pwr: Smart power
- SST: Small-signal transistor
- Switch: Switching device
- Thyristor
- Tran: Transistor
- Zener Diode

- Optoelectronic
  - CCD: Charge-coupled device (imaging)
  - Coupler: Photocoupler
  - IED: Infrared-emitting diode
  - Image Sensor
  - Laser: Semiconductor laser or laser IC
  - LED: Light-emitting diode
  - Opto: Optoelectronic
  - PDiode: Photodiode
  - PTran: Photo transistor
  - SAW: Surface acoustic wave device
  - SIT Image Sensor: Static induction transistor image sensor
- Bipolar digital
  - Includes all digital ICs using a bipolar process

The Activities column shows the types of semiconductor manufacturing performed at this location. The activities include:

- "Frnt" means this location performs front-end wafer processing. Front-end wafer processing includes the manufacturing steps from initial oxide through wafer probe test.
- "Rsrch" means the location performs product or process research. Research differs from pilot manufacturing in that research wafers are nonsalable.
- "Dsgn" means this location has a design center.
- "Pilot" means this location performs pilot production. Pilot production means the location produces in small volumes while "debugging" new products or process technologies. The main difference between research and pilot is that, unlike research, pilot wafers are salable product.
- "Fndry" means this location performs contract manufacturing. Contract manufacturing is the production, under contract, of another company's branded product. This is also known as foundry production.
- "Assy/tst" means this location performs assembly and/or testing. Assembly and testing includes the manufacturing steps from E-test through final assembly into a package and final test.

The Processes column indicates each fab's use of five major types of processes. The process groupings are:

- P/CMOS: P-channel metal-oxide semiconductor (PMOS) and/or complementary metal-oxide semiconductor (CMOS)
- NMOS: N-channel metal-oxide semiconductor (NMOS)
- BiCMOS: Bipolar and CMOS combined on a chip
- BIPOLAR: Bipolar
- III-V: Gallium arsenide and other compound semiconductor processes

The Year and Quarter of Initial Production column displays the year (and quarter, if available) in which this line, having completed all qualifications, began manufacturing in production volumes. The format for this reference is "year.quarter" (for example, 1994.3 translates to the third calendar quarter of 1994).

The Initial Monthly Wafer Starts column indicates the initial monthly volume of production wafer throughput.

The column Estimated Maximum Monthly Wafer Starts contains the equipment-limited wafer start capacity per four-week period. Only the throughput of the installed equipment and the process complexity limits the maximum starts. Dataquest does not consider current staffing or the number of shifts operating in determining this metric.

Maximum (Wafer) Diameter represents the maximum wafer size that the fab or fab line can process. Wafer diameters, although expressed colloquially in inches, conform to metric specifications. For wafers greater than 3 inches in diameter, expression in inches becomes inaccurate. When calculating square inches, Dataquest uses the following approximations:

- Stated diameter of 4 inches (100mm) = Approximate diameter of 3.938 inches
- Stated diameter of 5 inches (125mm) = Approximate diameter of 4.922 inches
- Stated diameter of 6 inches (150mm) = Approximate diameter of 5.906 inches
- Stated diameter of 8 inches (200mm) = Approximate diameter of 7.87 inches

Minimum Linewidth is the smallest feature size, measured in microns, attainable in production volumes.

Table 1
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
ABB Semiconductor	Waferfab & Assembly	Lensburg	Aargun	Switzerland	HighPwr Disc	Frnt Dsgn Assy/ Tst	Bipolar	1981.4	3,000	16,000	4	3
AEG AG (Daimler Benz)	Ulm Rsch	Ulm		Germany	3-D ICs Mm-Wave Opto	Frnt Rsrch Dsgn Fndry		1991				
Alcatel Mietec	Fab 1	Oudenaarde	O-VL	Belgium	Custom Mixsig ASIC	Frnt Dsgn Assy/ Tst	P/CMOS NMOS BiCMOS	1985	6,000	15,000	4	0.6
Alcatel Mietec	Fab 2	Oudenaarde	O-VL	Belgium	Custom Mixsig ASIC ASSP	Frnt Dsgn Fndry Assy/ Tst	P/CMOS BiCMOS	1993.2	2,000	10,000	6	0.3
Analog Devices		Limerick	Ireland	U.K.	Analog Lin AD/DA DSPs	Frnt Rsrch	P/CMOS BiCMOS	1986		20,000	4	2
Analog Devices		Limerick	Ireland	U.K.	DSPs Analog	Frnt Rsrch Pilot	P/CMOS BiCMOS	1995		4,400	6	0.6
Ansaldo Trasporti	Linita	Genoa		Italy	Power Disc	Frnt	Bipolar	1970		6,000	4	2
Atmel Corporation	Fab 6	Rousset Cedex		France	Std. Cell Dig. Logic	Frnt Rsrch Pilot Fndry Assy/ Tst	P/CMOS BiCMOS	1985	800	8,000	6	0.5
Atmel Corporation	Fab 7	Rousset Cedex		France	Custom Mixsig ASICs	Frnt Rsrch Dsgn Assy/Tst	P/CMOS BiCMOS	1996.3		20,000	8	0.35
Atmos/Elpol		Warsaw		Poland	ASIC	Frnt Pilot					4	2
Austria Mikro Systeme International	Unterpremstatten	Unterpremstatten		Austria	ASIC Analog	Frnt Rsrch Dsgn Pilot Assy/Tst	P/CMOS NMOS BiCMOS	1983		16,000	4	0.8
Baneasa S.A. (Ipra)		Bucharest		Romania	Thyristor Diode Lin	Frnt	Bipolar					
BT&D Technologies		Ipswich	England	U.K.	Opto Laser LED	Frnt Rsrch Dsgn Pilot Assy/Tst		1987		320	2	1
Elex	X-Fab	Erfurt		Germany	CMOS Sensors Power	Frnt Fndry	P/CMOS Other	1987.4	10,000	14,000	6	0.65
ElMOS GmbH	Fab 2	Dortmund		Germany	EEPROM ASICs 8-Bit MCU-Cores	Frnt	P/CMOS	1995	2,000	15,000	8	0.65
EM Microelectronics Marin S.A.	Marin	Marin		Switzerland	Hybrid ICs	Frnt Rsrch Dsgn Fndry Assy/ Tst	P/CMOS BiCMOS	1992		6,000	6	0.5
Ericsson		Kalmar		Sweden	Pwr Disc	Frnt Dsgn Assy/ Tst	Bipolar	1972		25,000	4	
Ericsson		Kista		Sweden	ASIC (Telecom Chips)	Frnt Pilot	P/CMOS BiCMOS	1994		1,000	6	0.5
Fraunhofer Institute	Itzhoe	Itzhoe		Germany	ASIC	Frnt Rsrch Pilot	P/CMOS	1996			6	0.8
Fujitsu	Phase 1	Newton Aycliffe	England	U.K.	4Mb 16Mb DRAM	Frnt Assy/Tst	P/CMOS	1991		5,600	6	0.5
Fujitsu	Phase 2	Newton Aycliffe	England	U.K.	4Mb DRAM	Frnt	P/CMOS	1995		14,000	6	0.5
GEC Plessey		Caswell	England	U.K.		Frnt Rsrch Pilot	GaAs/III-V				3	
GEC Plessey		Lincoln	England	U.K.	Power ICs, IGBTs	Frnt Rsrch Dsgn Pilot Assy/Tst	P/CMOS Bipolar	1981		12,000	4	1
GEC Plessey		Lincoln	England	U.K.	MPR ASIC Discrete	Frnt Rsrch Dsgn Assy/Tst	Bipolar	1984		12,000	4	1
GEC Plessey		Plymouth	England	U.K.	MPU DSPs ASIC Analog	Frnt Rsrch Dsgn	P/CMOS	1987		3,000	6	0.7

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
GEC Plessey		Plymouth	England	U.K.	ASIC	Frnt Rsrch Dsgn	P/CMOS Bipolar	1995.4	330	3,000	8	0.25
GEC Plessey		Roborough	England	U.K.	ASIC DSP Telecom	Frnt Dsgn Assy/Tst	P/CMOS NMOS	1987		6,000	6	0.7
GEC Plessey		Roborough	England	U.K.	MPU DSP ASIC Analog	Frnt Dsgn Assy/Tst	P/CMOS	1995	330	3,000	8	0.7
GEC Plessey		Roborough	England	U.K.	ASIC	Frnt Dsgn Assy/Tst	P/CMOS	1996	2,000	24,000	8	0.5
GEC Plessey	Cheney Manor	Swindon, Wiltshire	England	U.K.	Analog	Frnt Rsrch Dsgn Assy/Tst	Bipolar	1961		8,000	4	0.5
General Instrument		Cricklade	England	U.K.	Dis	Frnt Dsgn Assy/Tst	Bipolar			10,000	4	
Hamamatsu Photonics		Oldham		U.K.		Frnt						
Hitachi	E2	Landshut	Bavaria	Germany	16Mb DRAM	Frnt Assy/Tst	P/CMOS	1993.1	1,500	16,000	8	0.35
HMT		Brugg		Switzerland	Consumer ICs	Frnt Dsgn Assy/Tst	NMOS			15,000	3	
Hughes	Semiconductor Products	Glenrothes, Fife	Scotland	U.K.	EPROM Mixsig ASIC	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS NMOS	1971		2,800	4	2
IBM Microelectronics		Corbeil-Essonnes		France	1Mb DRAM	Frnt Pilot	P/CMOS	1989		7,000	8	0.8
IBM Microelectronics		Corbeil-Essonnes		France	Arrays Lin Custom	Frnt	Bipolar			40,000	5	2
IBM Microelectronics		Corbeil-Essonnes		France	DRAM SRAM	Frnt	P/CMOS			25,000	5	1
IBM Microelectronics		Hannover		Germany	Dis	Frnt	Bipolar			20,000	4	3
IBM Microelectronics		Sindelfingen		Germany	Pwr Dis Hybrid	Frnt	Bipolar			20,000	4	3
IBM Microelectronics		Sindelfingen		Germany	Arrays	Frnt	Bipolar			15,000	5	2
IBM Microelectronics		Sindelfingen		Germany	DRAM SRAM DSP MPU Custom	Frnt	NMOS			25,000	5	1.5
IBM Microelectronics		Zurich		Switzerland		Frnt Rsrch Pilot	P/CMOS GaAs/III-V				3	
IBM/Philips		Boeblingen		Germany	4Mb DRAM	Frnt	P/CMOS	1989.1		20,000	8	0.8
IBM/Siemens	ACL	Corbeil-Essonnes		France	16Mb 64Mb DRAM	Frnt Assy/Tst	P/CMOS	1991	16,100	30,000	8	0.35
ICCE		Baneasa		Romania	Opto Lin	Frnt Rsrch	Bipolar					
ICM Praha		Praha		Czech Republic	Foundry Sensors Detection	Frnt Dsgn Fndry Assy/Tst	P/CMOS NMOS Other	1989.1	200	400	3	3
IMEC	P Line	Leuven	Brabant	Belgium	R&D Prototyping	Frnt Rsrch Dsgn Pilot Assy/Tst	P/CMOS NMOS BiCMOS	1987		500	6	0.18
Institute of Electron Technology	R&D Silicon	Warsaw		Poland	ASIC MCU DSP Opto	Frnt Rsrch Dsgn	P/CMOS	1978		25,000	4	3
Integral		Minsk City		Russia		Frnt	P/CMOS Bipolar			75,000	6	
Intel	Fab 18	Kiryat Gat		Israel	Flash Memory	Frnt	BiCMOS	1996		30,000	8	0.25
Intel	Fab 10	Leixlip	Ireland	U.K.	x86 MPU	Frnt	BiCMOS	1994		20,000	8	0.5
Intel	Fab 14	Leixlip	Ireland	U.K.	x86 MPU	Frnt	BiCMOS	1996		24,000	8	0.25

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Intel	Fab 8	Migdal Ha'emek		Israel	x86 MPU MCU MPR	Frnt	P/CMOS	1985		28,000	6	0.8
International Rectifier	Borgaro	Turin		Italy	Rectifier Thyristor	Frnt Dsgn Assy/ Tst		1960		15,000	4	
International Rectifier	Venaria	Turin		Italy	Rectifier Thyristor	Frnt Dsgn Assy/ Tst				10,000	4	
Iskra		Trbovlje		Slovenia	Dis	Frnt Dsgn Pilot Assy/Tst	Bipolar			5,000	3	
Isocom		Hartlepool	England	U.K.	Opto	Frnt Assy/Tst	GaAs/III-V					
Italtel		Rome		Italy		Frnt	GaAs/III-V	1988				
ITT				Germany		Frnt						
ITT	IC-Waferfab	Freiburg		Germany	MCU Hybrid Mixsig ASIC	Frnt Rsrch Dsgn Assy/Tst	P/CMOS NMOS Bipolar	1992		15,500	5	0.5
ITT		Freiburg		Germany	Dis Custom	Frnt Rsrch Dsgn Assy/Tst	Bipolar			16,800	4	5
IXYS Semiconductor	Edisonstrasse 16	Lampertheim		Germany	MOSFET Bipolar	Frnt Dsgn Assy/ Tst	Bipolar Other	1971			5	2
Lucas Novasensor		Sutton Coldfield	England	U.K.	Pwr Dis	Frnt Dsgn Assy/ Tst	GaAs/III-V					
Lucent Technologies	MD-1	Tres Cantos	Madrid	Spain	CBIC Custom DSP	Frnt Dsgn Fndry Assy/ Tst	P/CMOS	1988.1	3,000	21,000	6	0.32
Microelectronica	Wafer Processing	Bucharest		Romania	Memory Logic	Frnt Dsgn Fndry Assy/ Tst	P/CMOS NMOS Other	1983.2	1,000		4	
Microelectronics—Ime Ltd.		Sofia		Bulgaria	Lin	Frnt Dsgn Pilot Assy/Tst	P/CMOS BiCMOS			2,000	1	2
Microelectronics—Ime Ltd.		Sofia		Bulgaria	Lin	Frnt Dsgn Pilot Assy/Tst	P/CMOS BiCMOS			9,000	5	2
Micronas SA	Fab 2	Bevaix	Neuchatel	Switzerland	Arrays Custom Sensors	Frnt Rsrch Pilot	P/CMOS Other	1990.1	1,000	7,000	6	1
Micronas SA		Espoo		Finland	Lin CBIC Custom	Frnt Dsgn Pilot Fndry Assy/ Tst	P/CMOS	1986		4,000	4	2
Mikroelektronik & Technologie Ges.	Smd	Dresden		Germany	ASIC SRAM DSP	Frnt Rsrch Pilot	P/CMOS					
Mitel Semiconductor	AB	Jarfalla		Sweden	Custom Mixsig ASIC SOS, Opto	Frnt Fndry	P/CMOS GaAs/III-V	1972	2,500	5,000	4	0.8
Mitel Semiconductor	Bruttou 1	Jarfalla		Sweden	Custom Mixsig ASIC	Frnt Dsgn Fndry Assy/ Tst	P/CMOS BiCMOS	1991.1	1,500	3,500	6	1
Motorola	MOS 1	East Kilbride	Scotland	U.K.	MCU Logic	Frnt Assy/Tst	P/CMOS	1969		56,000	4	0.8
Motorola	MOS 9	East Kilbride	Scotland	U.K.	FSRAM DSP MCU	Frnt Fndry Assy/Tst	P/CMOS	1990		24,000	6	0.35
Motorola	MOS 16	South Queensferry	Scotland	U.K.	MPU Alpha Analog	Frnt	P/CMOS BiCMOS	1990.1		7,200	6	0.5

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Motorola	Bipolar 4	Toulouse		France	Analog Op. Amp / Telecom Automotive	Frnt	P/CMOS Bipolar	1979		28,000	4	2.5
Motorola	BP 6	Toulouse		France	Low-Frequency Power	Frnt	P/CMOS Bipolar			18,000	5	1.5
Motorola	MOS 20	Toulouse		France	Analog Automotive	Frnt	P/CMOS			20,000	6	1.2
Motorola	Rectifier Fab	Toulouse		France	High Voltage Discrete Pwr Diodes	Frnt	Bipolar			7,000	3	2.5
National Semiconductor		Furstenfeldbruch		Germany	Lin	Frnt Rsrch Pilot	P/CMOS Bipolar					
National Semiconductor	Linear 4 Inch	Greenock	Scotland	U.K.	Lin	Frnt	Bipolar	1977		37,000	4	5
National Semiconductor	Fab 1	Greenock	Scotland	U.K.	Lin	Frnt Dsgn Assy/Tst	P/CMOS Bipolar	1977.4	1,000	48,000	4	2
National Semiconductor	Fab 2	Greenock	Scotland	U.K.	Lin	Frnt Dsgn Assy/Tst	P/CMOS Bipolar	1982.3		26,000	4	1
National Semiconductor	Fab 3	Greenock	Scotland	U.K.	Lin	Frnt	P/CMOS Bipolar	1986.4	1,000	10,000	6	0.8
NEC	1 Phase	Livingston	Scotland	U.K.	DRAM SRAM MPU	Frnt	P/CMOS	1987		25,000	6	0.5
NEC	2 Phase	Livingston	Scotland	U.K.	16Mb 64Mb DRAM	Frnt	P/CMOS	1996.4		20,000	8	0.35
Newmarket Microsystems		Newmarket	England	U.K.	Lin Dis	Frnt	Bipolar			10,000	4	
Newport Wafer Fab		Newport	Wales	U.K.	Foundry	Frnt Fndry Assy/Tst	P/CMOS	1982		20,000	6	0.7
Newport Wafer Fab	F21	Newport	Wales	U.K.	Foundry	Frnt Fndry Assy/Tst	P/CMOS	1996.4		5,000	6	0.25
Nuova Mistral S.p.A.		Sermoneta (Latina)		Italy	Zener Diode Diodes SST	Frnt Dsgn Assy/Tst	Bipolar	1983		15,000	4	3
Orbit Semiconductor Inc		Eilat		Israel	Arrays Custom Mixsig ASIC	Frnt Fndry	P/CMOS	1996		2,000	6	0.8
Philips	Fab 1	Caen		France	Consumer ICs	Frnt Dsgn Assy/Tst	P/CMOS BiCMOS Bipolar	1989	2,200	25,000	6	1.2
Philips	Fab 2	Caen		France	Analog	Frnt Dsgn Assy/Tst	BiCMOS	1995	2,000	10,000	8	0.8
Philips	I & A Wafer Fab	Hamburg		Germany	MOS BiCMOS Logic	Frnt Dsgn Assy/Tst	P/CMOS NMOS BiCMOS	1981	2,500	24,000	6	0.6
Philips	CIC Wafer Fab	Hamburg		Germany	Consumer ICs	Frnt Dsgn Assy/Tst	Bipolar	1987	11,000	25,700	6	1
Philips	DS Wafer Fab	Hamburg		Germany	Discr	Frnt Dsgn Assy/Tst	Bipolar	1991	6,000	24,000	4	2
Philips	Consumer ICs	Nijmegen		Netherlands	Bipolar/BiCMOS ICs	Frnt Dsgn	P/CMOS BiCMOS Bipolar	1971	2,000	30,000	5	1.2
Philips		Nijmegen		Netherlands	Log	Frnt Assy/Tst	P/CMOS	1984		26,000	4	3
Philips		Nijmegen		Netherlands	SRAM Consumer ICs	Frnt Assy/Tst	P/CMOS NMOS	1988.4		8,400	6	0.8
Philips	MOS 3	Nijmegen		Netherlands	Consumer ICs Disc	Frnt Assy/Tst	P/CMOS	1993	15,000	25,000	6	0.6
Philips	MOS 4	Nijmegen		Netherlands	Consumer ICs	Frnt Assy/Tst	P/CMOS	1996	10,000	20,000	8	0.35
Philips		Paris		France	Tran	Frnt Dsgn Assy/Tst	GaAs/III-V	1970		12,000	5	5

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Philips		Redhill	England	U.K.		Frnt Rsrch Pilot	GaAs/III-V				3	
Philips		Silford	England	U.K.		Frnt Rsrch Pilot	GaAs/III-V				2	
Philips	Diffusion Centre	Stadskanaal		Netherlands	Power Rectifiers Diodes	Frnt Dsgn Assy/Tst	Bipolar	1970		70,000	4	
Philips	PowerMOS	Stockport, Cheshire	England	U.K.	Power MOSFET	Frnt Dsgn	NMOS	1988	10,000	16000	5	0.8
Philips	Bipolar 1	Stockport, Cheshire	England	U.K.	Power Transistors	Frnt Dsgn	Bipolar	1996	24,000	40,000	6	3
Robert Bosch GmbH	4 Inch Fab	Reutlingen		Germany	ASIC Automotive ICs	Frnt Dsgn Assy/Tst	P/CMOS NMOS BiCMOS Bipolar Other	1978		20,000	4	2.5
Robert Bosch GmbH	Fab 2	Reutlingen		Germany	ASIC Automotive ICs	Frnt Dsgn Fndry Assy/Tst	P/CMOS BiCMOS Bipolar Other	1995		18,000	6	0.8
Seagate Microelectronics		Livingston	Scotland	U.K.	Lin	Frnt Dsgn Assy/Tst	Bipolar	1986.1		5,000	4	3
SEMEFAB	Fab	Glenrothes, Fife	Scotland	U.K.	CMOS Linear Discrete MOSFET Bipolar	Frnt Dsgn Pilot Fndry Assy/Tst	P/CMOS NMOS BiCMOS Bipolar	1987	150	6,000	4	1.5
Semikron		Nurnberg		Germany	Dis	Frnt Assy/Tst	Bipolar			10,000	5	
SGS-Thomson	R1, Phase 1	Agrate		Italy	Flash EPROM	Frnt Rsrch Pilot	P/CMOS	1991			6	0.6
SGS-Thomson	Fab 3	Agrate		Italy	EPROM Arrays Mixslg ASIC	Frnt Rsrch Dsgn Pilot	P/CMOS	1995		25,000	6	0.6
SGS-Thomson	M5, Phase 2	Catania	Sicily	Italy	Log Lin Custom Smart Pwr	Frnt Rsrch	P/CMOS	1996		25,000	6	1.5
SGS-Thomson	M5, Phase 3	Catania	Sicily	Italy	EPROM Flash Memory	Frnt Rsrch	P/CMOS	1996		20,000	8	0.5
SGS-Thomson	M5, Phase 1	Catania	Sicily	Italy	Log Lin Custom Smart Pwr	Frnt Rsrch	P/CMOS			25,000	5	1.5
SGS-Thomson	Grenoble	Grenoble	Isere	France	Lin Smart Pwr Custom	Frnt Dsgn Assy/Tst	P/CMOS Bipolar	1980		25,000	4	1.5
SGS-Thomson	Rennes Fab	Rennes		France	Linear Telecom	Frnt Fndry	P/CMOS BiCMOS Bipolar	1986	500	20,000	5	1.8
SGS-Thomson	Module 5, Phase 1	Rousset		France	EPROM EEPROM MPU MCU Telecom	Frnt Dsgn Assy/Tst	P/CMOS NMOS	1987		26,000	5	1.2
SGS-Thomson	Module 5, Phase 2	Rousset		France	EPROM EEPROM MPU MCU Telecom	Frnt Dsgn Assy/Tst	P/CMOS NMOS	1996		26,000	6	1.2
SGS-Thomson	Planar	Tours		France	Disc	Frnt Dsgn		1996		15,000	5	5
SGS-Thomson	Mesa	Tours		France	Dis	Frnt Dsgn				60,000	4	10
SGS-Thomson	Planar	Tours		France	Dis	Frnt Dsgn				15,000	4	5
SGS Thomson	Crolles 1	Grenoble	Isère	France	CMOS BICMOS ICs	Frnt Dsgn	P/CMOS BiCMOS			22,000	8	0.25
Siemens	SIMEC (Lines 1 and 2)	Dresden	Saxonia	Germany	16Mb 64Mb DRAM	Frnt Rsrch	P/CMOS	1996.2	5,000	30,000	8	0.25
Siemens	B	Munich		Germany	MOS Logic Bip Logic	Frnt Dsgn Assy/Tst		1964		2,500	5	0.5
Siemens	P (B402)	Munich		Germany	MOS Logic Bip Logic	Frnt		1987	1,000	14,000	6	0.35

Table 1 (Continued)
Front-End Production Lines in Operation before 1997

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Siemens	Materials and Wafer Fab	Regensburg	Bavaria	Germany	LED/IRED MR Sensors Laser Photo PIN Diodes	Frnt Dsgn	GaAs/III-V	1986	2,300	16,500	4	1
Siemens	H15, H16, H17	Regensburg	Bavaria	Germany	4Mb DRAM ASIC ASSP 1Mb DRAM-ASIC	Frnt Assy/Tst	P/CMOS	1986.3	1,200	46,600	6	0.35
Siemens	H14, H15	Villach Carinthia		Austria	Logic Power	Frnt Rsrch Dsgn	Bipolar	1981	2,000	61,000	5	1
SMST	Building 31	Boblingen		Germany		Frnt	P/CMOS	1989	9,000	16,000	8	0.4
South African Microelectronic Systems		Pretoria		South Africa	CBIC ASIC	Frnt Rsrch Pilot	P/CMOS	1992		5,000	6	1.5
TAG		Zurich		Switzerland	Dis	Frnt Dsgn Assy/Tst				10,000	3	
TEMIC	Fab 4, Phase 1	Heilbronn		Germany	Analog	Frnt Dsgn Assy/Tst	P/CMOS BiCMOS Bipolar GaAs/III-V	1979	200	15,000	6	0.7
TEMIC	Fab 4, Phase 2	Heilbronn		Germany	Analog Disc	Frnt Dsgn Assy/Tst	Bipolar	1994.4	200		6	0.7
TEMIC	Fab 150, Phase 1	Nantes		France	256K SRAM MCU ASIC Lin	Frnt Dsgn Fndry Assy/Tst	P/CMOS BiCMOS	1986	500	10,500	6	0.5
TEMIC	Fab 150, Phase 2	Nantes		France	SRAM MCU ASIC	Frnt Dsgn Fndry Assy/Tst	P/CMOS BiCMOS	1994.4	500	15,000	6	0.35
Texas Instruments	AMOS, Phase 1	Avezzano	AQ	Italy	4Mb 16Mb DRAM 4Mb Flash	Frnt Dsgn	P/CMOS	1990	8,000	22,000	8	0.25
Texas Instruments	AMOS, Phase 2	Avezzano	AQ	Italy	16Mb DRAM	Frnt Dsgn	P/CMOS	1996	8,000	20,000	8	0.25
Texas Instruments	Fris	Freising		Germany	MPR	Frnt	P/CMOS BiCMOS	1977		22,300	6	0.6
Texet		Nice		France	Dis	Frnt Dsgn Assy/Tst				10,000	4	
Thesys GmbH		Erfurt		Germany	ASIC	Frnt	P/CMOS BiCMOS				6	1.5
Tower Semiconductor		Migdal Ha'emek		Israel	MPU MCU MPR DSP Arrays Custom	Frnt Fndry Assy/Tst	P/CMOS	1986.3		14,000	6	0.8
Vaisala		Vantaa		Finland	Lin	Frnt Dsgn Pilot Assy/Tst	P/CMOS			200	3	5
Westcode Semiconductor		Chippenham	England	U.K.	Dis	Frnt Dsgn Assy/Tst	Bipolar	1977		10,000	2	
Zentrum Mikroelektronik Dresden	ZVEZ	Dresden	0 1127	Germany	ASIC Mem Foundries	Frnt Rsrch Dsgn Fndry Assy/Tst	P/CMOS NMOS BiCMOS	1987.1	5,000	17,000	5	0.6
Zetex		Chadderton Lancashire	England	U.K.	Discrete Analog	Frnt Rsrch	P/CMOS NMOS Bipolar	1970		9,000	4	2

Source: Dataquest (December 1996)

Table 2
Front-End Production Lines Beginning Operation 1997 and After

Company	Fab Name	City	Province	Country	Devices Produced	Activities	Processes	Year and Quarter of Initial Production	Initial Monthly Wafer Starts	Estimated Maximum Monthly Wafer Starts	Maximum Wafer Diameter (Inches)	Estimated Minimum Line Width (Microns)
Advanced Micro Devices	Fab 30	Dresden		Germany	K5	Frnt	P/CMOS	1999.2	1,000	24,000	8	0.18
Fujitsu	Fab 2	Newton Aycliffe	England	U.K.	16Mb 64Mb DRAM	Frnt	P/CMOS	1999	10,000	15,000	8	0.25
IBM Microelectronics	AMF	Corbeil-Essonnes		France	64Mb DRAM	Frnt Assy/Tst	P/CMOS	1997		15,000	8	0.2
Mitsubishi		Alsdorf		Germany	4MB 16MBDRAM	Frnt Assy/Tst	P/CMOS	1997.2		7,000	8	0.35
Newport Wafer Fab		Newport	Wales	U.K.	Foundry	Frnt Fndry Assy/ Tst	P/CMOS	1997.4		10,000	8	0.25
SGS-Thomson	R1 Phase 2	Agrate		Italy	Flash EPROM	Frnt Rsrch Pilot	P/CMOS	1998			8	0.35
SGS-Thomson	M5 Phase 4	Catania	Sicily	Italy	EPROM & Flash memory	Frnt Rsrch	P/CMOS	1997.1		15,000	8	0.3
SGS-Thomson	Rennes Fab	Rennes		France	Linear Telecom	Frnt	P/CMOS BiCMOS Bipolar	1998		20,000	6	1.8
SGS-Thomson	Rousset 2000	Rousset		France	MCU EEPROM NvMEM	Frnt Dsgn Assy/Tst	P/CMOS	1998		20,000	8	0.25
Siemens		Newcastle-upon-Tyne	England	U.K.	DRAM	Frnt Pilot	P/CMOS	1997.3	1,200	18,000	8	0.25
Siemens		North Tyneside	England	U.K.	ASIC	Frnt	P/CMOS	1997		25,000	8	0.35

Source: Dataquest (December 1996)

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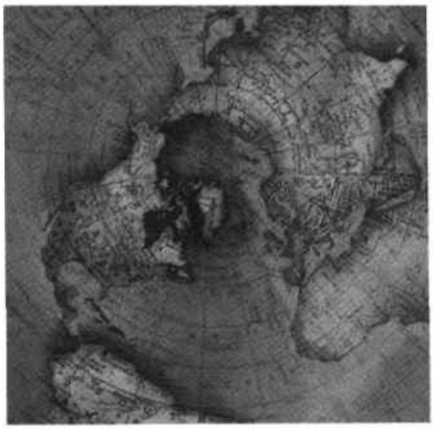

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1995 Silicon Wafer Market Share Estimates

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-MS-9602
Publication Date: June 24, 1996
Filing: Market Statistics

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Note: All tables show estimated data.

1995 Silicon Wafer Market Share Estimates

Section 1: Introduction and Definitions

Dataquest's Semiconductor Equipment, Manufacturing, and Materials Worldwide service tracks the silicon wafer industry by examining the merchant silicon and epitaxial wafer market, captive silicon production, wafer price trends, and silicon square-inch consumption.

The information in this document is focused on the silicon and silicon epitaxial wafers used in the manufacturing of semiconductor devices.

Definitions and Conventions

The calendar-year sales of merchant silicon and silicon epitaxial wafer suppliers are estimated in U.S. dollars and converted to millions of square inches using an average selling price and wafer size distribution analysis for each region. Currency fluctuations over the last several years affect the dollar value of wafer sales of Japanese and European companies. Dataquest uses average exchange rates supplied by the International Monetary Fund (IMF) to convert local currency to U.S. dollars. The average exchange rates for the Japanese yen and German deutsche mark for 1991 through 1995 are shown in Table 1-1.

Table 1-1
Japanese and German Exchange Rates

	1991	1992	1993	1994	1995
Japanese Yen/U.S.$1	135.00	126.00	111.00	101.81	93.90
German Deutsche Mark/U.S.$1	1.66	1.55	1.65	1.62	1.43

Source: Dataquest (June 1996)

Silicon Products

The merchant silicon wafer market is categorized into two product segments—silicon wafers and silicon epitaxial wafers. Silicon wafers include polished prime, test, and monitor wafers grown by both Czochralski and float zone methods. In the silicon database, Dataquest does not include sales of polysilicon, single-crystal silicon ingots (unless noted), silicon materials used in solar applications, or compound semiconductor material substrates such as gallium arsenide.

In this report, "polished wafers" are finished wafers that do not have an epitaxial silicon layer deposited on them, and this includes both prime and test wafers in terms of revenue reporting. Epitaxial wafers are polished wafers with an epitaxial layer deposited by the silicon manufacturer. The wafer is sold to the customer with the epitaxial layer already supplied. Prime wafers are used for the actual production of semiconductors and tend to have very tight specifications and are dependent on the application. Test/monitor wafers are used to test the process with, typically, destructive testing methods and do not produce semiconductor devices. The specifications for these wafers are much less stringent, although a minimum set of specifications is required for durability, reliability, and cleanliness.

Silicon Producers

Companies that produce silicon and epitaxial wafers are defined as either merchant silicon companies or captive silicon producers. Merchant silicon companies are suppliers such as Shin-Etsu Handotai of Japan and Wacker Siltronic AG of Germany.

Silicon also is produced, to a lesser extent, by both merchant and captive semiconductor manufacturers. These semiconductor manufacturers collectively are referred to as captive silicon producers because they grow single-crystal silicon to produce wafers for their own internal consumption. Examples of captive producers with significant internal silicon production include AT&T and Motorola in the United States and Hitachi in Japan.

Merchant or Captive

Some captive silicon producers have sold small amounts of material on the merchant silicon market. These producers have sold wafers to ensure that internal production methods continue to produce material of competitive quality and cost. Dataquest estimates that merchant sales for these companies historically have represented a small percentage of their total captive silicon production, and thus these companies are identified as captive rather than as merchant silicon producers.

Dataquest identifies Toshiba Ceramics, a subsidiary of Toshiba Corporation, as a merchant silicon company even though a substantial amount of its silicon production is consumed by its semiconductor parent. However, because Toshiba Ceramics is actively marketing its material on the merchant market, Toshiba Ceramics is considered a merchant rather than a captive silicon producer. Toshiba Corporation is considered a customer of Toshiba Ceramics.

In 1995, Texas Instruments' captive silicon manufacturing operation was substantially acquired by MEMC Electronic Materials. The new operation, called MEMC Southwest, is a joint venture of MEMC and Texas Instruments where MEMC has 80 percent ownership. MEMC Southwest is now reclassified as merchant, and its sales are now reported as sales for MEMC Electronic Materials.

Merchant Silicon and Epitaxial Wafer Suppliers

Table 1-2 contains a list of merchant silicon manufacturers that were active in the worldwide market in 1995 by base of company. This table, organized by region of corporate ownership, summarizes whether a company offers silicon and/or epitaxial wafers.

MEMC Electronic Materials has been reclassified as a U.S. company after a successful initial public offering on the New York Stock Exchange in July 1995. Hüls AG (a German company) still owns about 53 percent of the stock of MEMC Electronic Materials; however, the Securities Exchange Commission filing classifies MEMC as a Delaware company. In this report, all years from 1991 through 1995 have been reported as if MEMC were a U.S. company.

Table 1-2
Worldwide Merchant Silicon and Epitaxial Companies, 1995

Companies	Silicon Wafers	Epitaxial Wafers
U.S. Companies		
Crysteco Inc.	X	
General Instrument Power Semiconductor Division		X
Lawrence Semiconductor Labs		X
M/A-COM Semiconductor Products		X
MEMC Electronic Materials	X	X
Moore Technologies		X
Pure Sil (Formerly Pensilco)	X	
Unisil	X	
Virginia Semiconductor	X	
Japanese Companies		
Komatsu Electronic Metals	X	X
Mitsubishi Materials Silicon		
Mitsubishi Materials Silicon	X	X
Siltec Corporation	X	X
NSC Electron Corporation (Nittetsu Denshi)	X	
Shin-Etsu Handotai	X	X
Sumitomo Sitix (formerly Osaka Titanium Company)	X	X
Showa Denko	X	X
Toshiba Ceramics	X	X
European Companies		
Epitech		X
Okmetic	X	
Siltronix SA	X	
Topsil Semiconductor Materials A/S	X	
Wacker	X	X
Rest of World Companies		
Korean Companies		
Posco-Hüls (included in MEMC Electronic Materials summary)	X	
LG-Siltron	X	X
Rest of Asia/Pacific Companies		
Taiwanese Companies		
Episil Technologies Inc. (Hermes Epitaxy affiliate)		X
Sino-America	X	
Tatung Company	X	

Source: Dataquest (June 1996)

Section 2: Historical Millions of Square Inches by Region and by Product, 1991 through 1995

Table 2-1
Shipments of Merchant and Captive Silicon Wafers* and Merchant Epitaxial Wafers to Each Region, 1991-1995 (Millions of Square Inches)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas	605.2	650.9	716.9	829.0	943.1	11.7
Growth (%)	-5.5	7.6	10.1	15.6	13.8	
Japan	1,038.5	972.8	1,134.3	1,277.9	1,483.4	9.3
Growth (%)	4.7	-6.3	16.6	12.7	16.1	
Europe	212.2	235.0	289.6	353.8	457.7	21.2
Growth (%)	-9.9	10.7	23.2	22.2	29.4	
Asia/Pacific	189.8	238.0	305.4	446.9	639.6	35.5
Growth (%)	5.0	25.4	28.3	46.3	43.1	
Worldwide	2,045.7	2,096.7	2,446.2	2,907.6	3,523.8	14.6
Growth (%)	-0.1	2.5	16.7	18.9	21.2	

Includes prime, virgin test, and monitor wafers
Source: Dataquest (June 1996)

Table 2-2
Shipments of Merchant Epitaxial Wafers to Each Region, 1991-1995 (Millions of Square Inches)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas	84.2	128.1	156.2	194.8	246.7	30.8
Growth (%)	-4.4	52.1	21.9	24.7	26.6	
Japan	104.0	87.0	89.1	118.4	163.7	12.0
Growth (%)	11.9	-16.3	2.4	32.9	38.3	
Europe	23.0	23.9	36.2	56.1	84.1	38.3
Growth (%)	21.7	3.9	51.5	55.0	49.9	
Asia/Pacific	8.3	9.5	13.0	18.0	25.5	32.4
Growth (%)	80.4	14.5	36.8	38.5	41.7	
Worldwide	219.5	248.5	294.5	387.3	520.0	24.1
Growth (%)	7.3	13.2	18.5	31.5	34.3	

Source: Dataquest (June 1996)

Table 2-3
Shipments of Merchant and Captive Silicon* Wafers to Each Region, 1991-1995 (Millions of Square Inches)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas	521.0	522.8	560.7	634.2	696.4	7.5
Growth (%)	-5.6	0.3	7.2	13.1	9.8	
Japan	934.5	885.8	1,045.2	1,159.5	1,319.7	9.0
Growth (%)	3.9	-5.2	18.0	10.9	13.8	
Europe	189.2	211.1	253.4	297.7	373.6	18.5
Growth (%)	-12.6	11.6	20.0	17.5	25.5	
Asia/Pacific	181.5	228.5	292.4	428.9	614.1	35.6
Growth (%)	3.0	25.9	28.0	46.7	43.2	
Worldwide	1,826.2	1,848.2	2,151.7	2,520.3	3,003.8	13.2
Growth (%)	-1.0	1.2	16.4	17.1	19.2	

*Includes prime, virgin test, and monitor wafers

Source: Dataquest (June 1996)

Table 2-4
Shipments of Captive Silicon* Wafers to Each Region, 1991-1995 (Millions of Square Inches)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas	70.0	72.0	74.0	87.0	49.0	-8.5
Growth (%)	-12.5	2.9	2.8	17.6	-43.7	
Japan	40.0	37.0	37.0	42.0	22.0	-13.9
Growth (%)	-13.0	-7.5	0	13.5	-47.6	
Europe	5.0	5.0	5.0	6.0	3.0	-12.0
Growth (%)	-37.5	0	0	20.0	-50.0	
Asia/Pacific	0	6.0	9.0	12.0	0	N/M
Growth (%)	N/M	N/M	50.0	33.3	-100.0	
Worldwide	115.0	120.0	125.0	147.0	74.0	-10.4
Growth (%)	-14.2	4.3	4.2	17.6	-49.7	

*Includes prime, virgin test, and monitor wafers

N/M = Not meaningful

Source: Dataquest (June 1996)

Table 2-5
Shipments of Merchant Silicon* Wafers to Each Region, 1991-1995
(Millions of Square Inches)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas	451.0	450.8	486.7	547.2	647.4	9.5
Growth (%)	-4.5	0	8.0	12.4	18.3	
Japan	894.5	848.8	1,008.2	1,117.5	1,297.7	9.7
Growth (%)	4.9	-5.1	18.8	10.8	16.1	
Europe	184.2	206.1	248.4	291.7	370.6	19.1
Growth (%)	-11.7	11.9	20.5	17.4	27.0	
Asia/Pacific	181.5	222.5	283.4	416.9	614.1	35.6
Growth (%)	3.0	22.6	27.4	47.1	47.3	
Worldwide	1,711.2	1,728.2	2,026.7	2,373.3	2,929.8	14.4
Growth (%)	0.1	1.0	17.3	17.1	23.4	

*Includes prime, virgin test, and monitor wafers

Source: Dataquest (June 1996)

Table 2-6
Shipments of Merchant Test and Monitor Wafers to Each Region, 1991-1995
(Millions of Square Inches)

	1991	1992	1993	1994	1995
Americas	90.2	90.2	106.7	129.7	182.6
Japan	178.9	169.8	216.1	246.0	287.7
Europe	36.8	41.2	48.2	68.1	87.2
Asia/Pacific	36.3	44.5	60.6	87.9	143.5
Worldwide	342.2	345.6	431.6	531.7	701.0
Growth (%)	0.1	1.0	24.9	53.8	62.4

Source: Dataquest (June 1996)

Table 3-1
Worldwide Wafer Size Distribution, 1988-1995
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1988	1989	1990	1991	1992	1993	1994	1995
Percent Square Inches by Diameter									
2 Inches	3.14	0.4	0.3	0.3	0.2	0.2	0.1	0.1	0.1
3 Inches	7.07	3.0	3.7	3.0	2.5	2.1	1.6	1.4	1.1
100mm	12.17	28.0	26.1	23.4	20.3	18.7	16.0	14.8	13.1
125mm	19.02	43.4	40.0	37.4	34.8	33.0	28.8	24.7	21.2
150mm	27.38	24.4	29.1	34.2	39.7	43.3	47.0	47.0	45.1
200mm	48.67	0.8	0.9	1.7	2.4	2.7	6.4	12.2	19.4
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		1,603	1,856	2,048	2,046	2,097	2,446	2,908	3,524
Growth (%)		18.5	15.7	10.4	-0.1	2.5	16.7	18.9	21.2
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	2.3	1.6	1.7	1.5	1.0	1.0	0.9	0.7
3 Inches	7.07	6.9	9.8	8.8	7.3	6.3	5.6	5.6	5.5
100mm	12.17	36.9	39.8	39.3	34.1	32.3	32.2	35.3	37.9
125mm	19.02	36.5	39.0	40.3	37.5	36.3	37.0	37.7	39.3
150mm	27.38	14.3	19.7	25.6	29.7	33.2	42.0	49.9	58.1
200mm	48.67	0.3	0.3	0.7	1.0	1.2	3.2	7.3	14.0
Total Wafers (M)		97.1	110.2	116.4	111.1	110.3	121.0	136.6	155.7
Average Wafer Diameter (Inches)		4.58	4.63	4.73	4.84	4.92	5.07	5.21	5.37

Source: Dataquest (June 1996)

Table 3-2
North American Wafer Size Distribution, 1988-1995
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1988	1989	1990	1991	1992	1993	1994	1995
Percent Square Inches by Diameter									
2 Inches	3.14	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3 Inches	7.07	2.2	3.2	1.8	1.5	1.3	1.2	1.1	1.0
100mm	12.17	33.4	31.6	28.8	26.8	26.3	22.0	20.5	17.7
125mm	19.02	41.9	36.7	35.4	32.5	31.9	26.5	22.3	19.2
150mm	27.38	20.7	26.9	30.5	35.6	36.5	41.7	42.8	40.1
200mm	48.67	1.7	1.5	3.4	3.5	3.9	8.5	13.2	21.9
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		546	582	640	605	651	717	829	943
Growth (%)		23.7	6.5	10.0	-5.5	7.6	10.1	15.6	13.8
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2
3 Inches	7.07	1.7	2.6	1.6	1.3	1.2	1.2	1.3	1.4
100mm	12.17	15.0	15.1	15.2	13.3	14.1	13.0	14.0	13.7
125mm	19.02	12.0	11.2	11.9	10.3	10.9	10.0	9.7	9.5
150mm	27.38	4.1	5.7	7.1	7.9	8.7	10.9	13.0	13.8
200mm	48.67	0.2	0.2	0.4	0.4	0.5	1.3	2.2	4.2
Total Wafers (M)		33.2	35.1	36.5	33.4	35.6	36.6	40.4	42.9
Average Wafer Diameter (Inches)		4.58	4.6	4.73	4.8	4.83	5	5.11	5.29

Source: Dataquest (June 1996)

Table 3-3
Japan Wafer Size Distribution, 1988-1995
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1988	1989	1990	1991	1992	1993	1994	1995
Percent Square Inches by Diameter									
2 Inches	3.14	0.1	0.1	0.1	0.1	0	0	0	0
3 Inches	7.07	2.8	2.6	2.3	2.0	1.7	1.5	1.4	1.1
100mm	12.17	21.4	20.2	17.9	15.6	13.2	11.5	10.4	9.5
125mm	19.02	48.1	46.5	42.9	39.3	36.7	32.2	29.4	26.4
150mm	27.38	27.4	30.3	36.4	41.6	46.9	50.2	49.8	49.7
200mm	48.67	0.2	0.3	0.5	1.5	1.5	4.6	9.0	13.3
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		777	913	992	1,039	973	1,134	1,278	1,483
Growth (%)		16.0	17.5	8.7	4.7	-6.3	16.6	12.7	16.1
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0.2	0.3	0.3	0.3	0	0	0	0
3 Inches	7.07	3.1	3.4	3.2	2.9	2.3	2.4	2.5	2.3
100mm	12.17	13.7	15.2	14.6	13.3	10.6	10.7	10.9	11.6
125mm	19.02	19.6	22.3	22.4	21.5	18.8	19.2	19.8	20.6
150mm	27.38	7.8	10.1	13.2	15.8	16.7	20.8	23.2	26.9
200mm	48.67	0	0.1	0.1	0.3	0.3	1.1	2.4	4.1
Total Wafers (M)		44.4	51.3	53.8	54.1	48.6	54.2	58.8	65.5
Average Wafer Diameter (Inches)		4.72	4.76	4.85	4.94	5.05	5.16	5.26	5.37

Source: Dataquest (June 1996)

Table 3-4
European Wafer Size Distribution, 1988-1995
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1988	1989	1990	1991	1992	1993	1994	1995
Percent Square Inches by Diameter									
2 Inches	3.14	0.4	0.4	0.3	0.3	0.3	0.2	0.1	0.1
3 Inches	7.07	5.0	4.3	3.7	3.1	2.5	1.7	0.7	0.6
100mm	12.17	40.1	35.9	32.5	29.1	25.9	22.0	20.5	20.0
125mm	19.02	34.3	33.0	31.9	30.8	30.5	29.5	21.7	18.7
150mm	27.38	19.5	24.4	28.3	32.3	36.7	42.3	43.0	40.8
200mm	48.67	0.7	2.0	3.3	4.4	4.1	4.3	14.0	19.8
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		196	231	235	212	235	290	354	458
Growth (%)		14.0	17.9	1.7	-9.7	10.7	23.2	22.2	29.4
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.1
3 Inches	7.07	1.4	1.4	1.2	0.9	0.8	0.7	0.4	0.4
100mm	12.17	6.5	6.8	6.3	5.1	5.0	5.2	6.0	7.5
125mm	19.02	3.5	4.0	3.9	3.4	3.8	4.5	4.0	4.5
150mm	27.38	1.4	2.1	2.4	2.5	3.1	4.5	5.6	6.8
200mm	48.67	0	0.1	0.2	0.2	0.2	0.3	1.0	1.9
Total Wafers (M)		13.1	14.7	14.3	12.3	13.2	15.3	17.0	21.2
Average Wafer Diameter (Inches)		4.37	4.48	4.58	4.68	4.77	4.9	5.14	5.24

Source: Dataquest (June 1996)

Table 3-5
Asia/Pacific-ROW Wafer Size Distribution, 1988-1995
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (Sq. In.)	1988	1989	1990	1991	1992	1993	1994	1995
Percent Square Inches by Diameter									
2 Inches	3.14	6.0	2.0	1.6	1.2	0.8	0.6	0.4	0.2
3 Inches	7.07	6.0	13.0	10.5	8.1	5.6	2.9	2.2	1.6
100mm	12.17	25.5	25.1	22.1	15.5	13.7	13.0	12.0	9.7
125mm	19.02	30.0	21.2	21.8	22.4	23.1	20.8	17.8	14.0
150mm	27.38	32.5	38.7	43.3	51.0	54.1	52.3	49.7	45.1
200mm	48.67	0	0	0.7	1.8	2.7	10.4	17.9	29.4
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		84	130	181	190	238	305	447	640
Growth (%)		20.0	54.8	39.2	4.9	25.4	28.3	46.3	43.1
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	1.6	0.8	0.9	0.7	0.6	0.6	0.6	0.4
3 Inches	7.07	0.7	2.4	2.7	2.2	1.9	1.3	1.4	1.4
100mm	12.17	1.8	2.7	3.3	2.4	2.7	3.3	4.4	5.1
125mm	19.02	1.3	1.4	2.1	2.2	2.9	3.3	4.2	4.7
150mm	27.38	1.0	1.8	2.9	3.5	4.7	5.8	8.1	10.5
200mm	48.67	0	0	0.0	0.1	0.1	0.7	1.6	3.9
Total Wafers (M)		6.4	9.2	11.9	11.2	12.9	14.9	20.3	26.1
Average Wafer Diameter (Inches)		4.09	4.24	4.41	4.65	4.85	5.10	5.29	5.59

Source: Dataquest (June 1996)

Section 4: Historical Market Share by Company, by Region, and by Product, 1991 through 1995

Table 4-1
Top 15 Merchant Silicon and Epitaxial Wafer Manufacturing Companies
Comparison of 1995 and 1994 Ranking by Worldwide Revenues
(End-User Revenue in Millions of U.S. Dollars)

	1995	1995 Rank	1994	1994 Rank	Percentage Change
All Companies	6,297.8		4,582.8		37
Shin-Etsu Handotai	1,614.4	1	1,174.3	1	37
MEMC Electronic Materials (Consolidated)	1,046.9	2	757.6	2	38
Sumitomo Sitix Silicon	791.1	3	582.4	3	36
Wacker Siltronic AG	678.0	4	500.4	4	35
Mitsubishi Materials Silicon	631.5	5	475.2	5	33
Komatsu Electronic Metals	579.9	6	452.9	6	28
Toshiba Ceramics	366.7	7	242.1	7	51
LG-Siltron	179.8	8	87.4	9	106
Nittetsu Denshi	138.0	9	105.8	8	30
Unisil Corp.	65.1	10	40.0	10	63
Showa Denko	34.6	11	22.1	11	57
Okmetic	25.0	12	19.0	12	32
Episil	24.7	13	16.2	15	53
Crysteco Inc.	20.7	14	17.9	14	16
Topsil	19.4	15	18.8	13	3
All Other Companies	82.0		70.7		16

Source: Dataquest (June 1996)

Table 4-2
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to the World, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	16.8	16.3	14.8	17.9	20.7	
Epitaxy Inc.	10.7	10.6	12.5	14.8	0	
MEMC Electronic Materials[1]	446.6	483.7	552.5	660.8	886.9	
Unisil Corp.	16.6	17.6	22.3	40.0	65.1	
Other U.S. Companies[2]	11.9	13.1	20.7	28.0	38.9	
Total U.S. Companies	502.6	541.3	622.8	761.5	1,011.6	19.1
Japan-Based Companies						
Komatsu Electronic Metals	332.6	317.8	377.3	452.9	579.9	
Mitsubishi Materials Silicon	326.4	306.5	363.6	475.2	631.5	
Nittetsu Denshi	56.4	72.0	84.5	105.8	138.0	
Sumitomo Sitix Silicon	382.1	370.9	443.6	582.4	791.1	
Shin-Etsu Handotai	768.5	780.4	895.7	1,174.3	1,614.4	
Showa Denko	11.9	13.9	16.4	22.1	34.6	
Toshiba Ceramics	148.2	140.7	209.1	242.1	366.7	
NBK Corporation/Kawasaki Steel	11.3	13.9	8.7	0	0	
Total Japanese Companies	2,037.4	2,016.1	2,398.9	3,054.8	4,156.2	19.5
Europe-Based Companies						
Okmetic	4.5	5.9	16.7	19.0	25.0	
Wacker Siltronic AG	295.9	337.3	401.2	500.4	678.0	
Other European Companies[3]	21.5	19.3	25.7	31.4	39.8	
Total European Companies	321.9	362.5	443.6	550.8	742.8	23.2
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	17.3	96.8	160.0	
LG-Siltron[4]	35.4	48.1	61.0	87.4	179.8	
Oriental Electronic Metals	0	4.5	3.4	0	0	
Episil	3.2	11.2	13.1	16.2	24.7	
Sino-America	5.2	7.7	3.3	7.6	12.0	
Tatung Company	7.3	0	0.1	7.7	10.7	
Total Asia/Pacific Companies	51.1	71.5	98.2	215.7	387.2	65.9
All Companies	2,913.0	2,991.4	3,563.5	4,582.8	6,297.8	21.3

*Includes prime, test, and monitor wafers

Note: Numbers may not add to totals shown because of rounding.

[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward

[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.

[3]Other European companies include Topsil and Siltronix SA

[4]Epitaxy Inc. included from 1995 onward

Source: Dataquest (June 1996)

Table 4-3
Each Company's Revenue from Shipments of Merchant Silicon* Wafers to the World, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	16.8	16.3	14.8	17.9	20.7	
Epitaxy Inc.	0	0	0	0	0	
MEMC Electronic Materials[1]	346.5	373.8	403.1	440.5	585.6	
Unisil Corp.	16.6	17.6	22.3	40.0	65.1	
Other U.S. Companies[2]	5.6	4.5	4.9	5.9	7.2	
Total U.S. Companies	385.5	412.2	445.1	504.3	678.6	15.2
Japan-Based Companies						
Komatsu Electronic Metals	261.9	258.5	295.4	343.1	436.5	
Mitsubishi Materials Silicon	233.0	218.9	282.1	342.2	440.0	
Nittetsu Denshi	56.4	72.0	84.5	105.8	138.0	
Sumitomo Sitix Silicon	283.0	265.4	307.5	373.0	493.7	
Shin-Etsu Handotai	554.6	562.3	643.1	882.0	1,265.1	
Showa Denko	11.9	13.9	16.2	20.6	31.9	
Toshiba Ceramics	90.7	91.9	151.2	170.4	260.8	
NBK Corporation/Kawasaki Steel	10.3	11.3	5.5	0	0	
Total Japanese Companies	1,501.8	1,494.2	1,785.5	2,237.1	3,066.0	19.5
Europe-Based Companies						
Okmetic	4.5	5.9	16.7	19.0	25.0	
Wacker Siltronic AG	217.4	214.8	224.1	270.3	347.9	
Other European Companies[3]	21.5	19.3	20.7	21.4	22.8	
Total European Companies	243.4	240.0	261.5	310.7	395.7	12.9
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	17.3	96.8	160.0	
LG-Siltron[4]	35.4	48.1	61.0	87.4	159.7	
Oriental Electronic Metals	0	4.5	3.4	0	0	
Episil	0	0	0	0	0	
Sino-America	5.2	7.7	3.3	7.6	12.0	
Tatung Company	7.3	0	0.1	7.7	10.7	
Total Asia/Pacific Companies	47.9	60.3	85.1	199.5	342.4	63.5
All Companies	2,178.6	2,206.7	2,577.2	3,251.6	4,482.7	19.8

*Includes prime, test, and monitor wafers

Note: Numbers may not add to totals shown because of rounding.

[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward

[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.

[3]Other European companies include Topsil and Siltronix SA

[4]Epitaxy Inc. included from 1995 onward

Source: Dataquest (June 1996)

Table 4-4
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to the World, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	0	0	0	0	0	
Epitaxy Inc.	10.7	10.6	12.5	14.8	0	
MEMC Electronic Materials[1]	100.1	109.9	149.4	220.3	301.3	
Unisil Corp.	0	0	0	0	0	
Other U.S. Companies[2]	6.3	8.6	15.8	22.1	31.7	
Total U.S. Companies	117.1	129.1	177.7	257.2	333.0	29.9
Japan-Based Companies						
Komatsu Electronic Metals	70.7	59.3	81.9	109.8	143.4	
Mitsubishi Materials Silicon	93.4	87.6	81.5	133.0	191.5	
Nittetsu Denshi	0	0	0	0	0	
Sumitomo Sitix Silicon	99.1	105.5	136.1	209.4	297.4	
Shin-Etsu Handotai	213.9	218.1	252.6	292.3	349.3	
Showa Denko	0	0	0.2	1.5	2.7	
Toshiba Ceramics	57.5	48.8	57.9	71.7	105.9	
NBK Corporation/Kawasaki Steel	1.0	2.6	3.2	0	0	
Total Japanese Companies	535.6	521.9	613.4	817.7	1,090.2	19.4
Europe-Based Companies						
Okmetic	0	0	0	0	0	
Wacker Siltronic AG	78.5	122.5	177.1	230.1	330.1	
Other European Companies[3]	0	0	5.0	10.0	17.0	
Total European Companies	78.5	122.5	182.1	240.1	347.1	45.0
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	0	0	0	
LG-Siltron[4]	0	0	0	0	20.1	
Oriental Electronic Metals	0	0	0	0	0	
Episil	3.2	11.2	13.1	16.2	24.7	
Sino-America	0	0	0	0	0	
Tatung Company	0	0	0	0	0	
Total Asia/Pacific Companies	3.2	11.2	13.1	16.2	44.8	93.5
All Companies	734.4	784.7	986.3	1,331.2	1,815.1	25.4

Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-5
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to the Americas, 1991-1995(End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	13.6	11.4	11.3	13.6	12.3	
Epitaxy Inc.	4.7	5.2	5.9	7.0	0	
MEMC Electronic Materials[1]	201.6	202.6	215.8	264.7	407.4	
Unisil Corp.	13.9	14.8	15.6	29.9	47.5	
Other U.S. Companies[2]	10.5	11.8	18.1	24.5	33.8	
Total U.S. Companies	244.3	245.8	266.7	339.7	501.0	19.7
Japan-Based Companies						
Komatsu Electronic Metals	7.5	8.4	20.7	33.7	67.6	
Mitsubishi Materials Silicon	55.7	69.6	81.9	101.2	116.2	
Nittetsu Denshi	0	0	0	0	0	
Sumitomo Sitix Silicon	69.5	96.3	127.4	182.8	262.3	
Shin-Etsu Handotai	161.9	193.0	224.8	280.0	353.9	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	5.7	
NBK Corporation/Kawasaki Steel	5.8	9.8	4.3	0	0	
Total Japanese Companies	300.4	377.1	459.1	597.7	805.7	28.0
Europe-Based Companies						
Okmetic	0	0	0	1.1	6.0	
Wacker Siltronic AG	126.8	143.0	180.0	205.0	281.0	
Other European Companies[3]	2.8	2.2	2.7	3.5	5.1	
Total European Companies	129.6	145.2	182.7	209.6	292.1	22.5
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	1.6	1.6	5.5	
LG-Siltron[4]	0.5	3.0	4.5	8.4	32.5	
Oriental Electronic Metals	0	0	0	0	0	
Episil	0	0	0	0	0.1	
Sino-America	0	0	0	0.1	0	
Tatung Company	0	0	0	0	0	
Total Asia/Pacific Companies	0.5	3.0	6.1	10.1	38.1	195.4
All Companies	674.8	771.1	914.6	1,157.1	1,636.8	24.8

*Includes prime, test, and monitor wafers
Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-6
Each Company's Revenue from Shipments of Merchant Silicon* Wafers to the Americas, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	13.6	11.4	11.3	13.6	12.3	
Epitaxy Inc.	0	0	0	0	0	
MEMC Electronic Materials[1]	135.4	129.8	120.2	126.3	215.4	
Unisil Corp.	13.9	14.8	15.6	29.9	47.5	
Other U.S. Companies[2]	5.2	4.1	4.5	5.4	6.6	
Total U.S. Companies	168.1	160.1	151.6	175.2	281.8	13.8
Japan-Based Companies						
Komatsu Electronic Metals	4.7	5.2	18.5	29.1	55.6	
Mitsubishi Materials Silicon	44.6	49.8	58.5	56.6	48.3	
Nittetsu Denshi	0	0	0	0	0	
Sumitomo Sitix Silicon	19.4	30.8	43.2	69.7	98.4	
Shin-Etsu Handotai	98.8	115.5	134.9	167.0	206.2	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	5.7	
NBK Corporation/Kawasaki Steel	4.8	7.4	1.3	0	0	
Total Japanese Companies	172.3	208.7	256.4	322.4	414.2	24.5
Europe-Based Companies						
Okmetic	0	0	0	1.1	6.0	
Wacker Siltronic AG	88.0	67.0	74.0	82.0	108.0	
Other European Companies[3]	2.8	2.2	2.4	2.5	3.5	
Total European Companies	90.8	69.2	76.4	85.6	117.5	6.7
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	1.6	1.6	5.5	
LG-Siltron[4]	0.5	3.0	4.5	8.4	23.5	
Oriental Electronic Metals	0	0	0	0	0	
Episil	0	0	0	0	0	
Sino-America	0	0	0	0.1	0	
Tatung Company	0	0	0	0	0	
Total Asia/Pacific Companies	0.5	3.0	6.1	10.1	29.0	176.0
All Companies	431.7	441.0	490.5	593.3	842.5	18.2

*Includes prime, test, and monitor wafers

Note: Numbers may not add to totals shown because of rounding.

[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward

[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.

[3]Other European companies include Topsil and Siltronix SA

[4]Epitaxy Inc. included from 1995 onward

Source: Dataquest (June 1996)

Table 4-7
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to the Americas, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	0	0	0	0	0	
Epitaxy Inc.	4.7	5.2	5.9	7.0	0	
MEMC Electronic Materials[1]	66.2	72.8	95.6	138.4	192.0	
Unisil Corp.	0	0	0	0	0	
Other U.S. Companies[2]	5.3	7.7	13.6	19.1	27.2	
Total U.S. Companies	76.2	85.7	115.1	164.5	219.2	30.2
Japan-Based Companies						
Komatsu Electronic Metals	2.8	3.2	2.2	4.6	12.0	
Mitsubishi Materials Silicon	11.1	19.8	23.4	44.6	67.9	
Nittetsu Denshi	0	0	0	0	0	
Sumitomo Sitix Silicon	50.1	65.5	84.2	113.1	163.9	
Shin-Etsu Handotai	63.1	77.5	89.9	113.0	147.7	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	0	
NBK Corporation/Kawasaki Steel	1.0	2.4	3.0	0	0	
Total Japanese Companies	128.1	168.4	202.7	275.3	391.5	32.2
Europe-Based Companies						
Okmetic	0	0	0	0	0	
Wacker Siltronic AG	38.8	76.0	106.0	123.0	173.0	
Other European Companies[3]	0	0	0.3	1.0	1.6	
Total European Companies	38.8	76.0	106.3	124.0	174.6	45.6
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	0	0	0	
LG-Siltron[4]	0	0	0	0	9.0	
Oriental Electronic Metals	0	0	0	0	0	
Episil	0	0	0	0	0.1	
Sino-America	0	0	0	0	0	
Tatung Company	0	0	0	0	0	
Total Asia/Pacific Companies	0	0	0	0	9.1	NM
All Companies	243.1	330.1	424.1	563.8	794.4	34.4

NM = Not meaningful
Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-8
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to Japan, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	0.8	1.0	0.6	0.8	1.4	
Epitaxy Inc.	0	0	0	0	0	
MEMC Electronic Materials[1]	66.2	62.8	87.7	119.1	135.6	
Unisil Corp.	0.1	0.1	0.5	1.2	3.7	
Other U.S. Companies[2]	0	0	1.8	2.0	2.0	
Total U.S. Companies	67.1	63.9	90.6	123.1	142.7	20.8
Japan-Based Companies						
Komatsu Electronic Metals	318.3	302.0	352.5	408.2	483.1	
Mitsubishi Materials Silicon	267.3	233.3	260.8	328.8	417.8	
Nittetsu Denshi	56.4	72.0	84.5	103.1	132.0	
Sumitomo Sitix Silicon	269.6	226.1	260.1	316.5	405.4	
Shin-Etsu Handotai	534.5	499.8	562.1	658.1	803.1	
Showa Denko	11.9	13.9	16.4	22.1	34.6	
Toshiba Ceramics	145.8	138.0	206.0	238.1	347.7	
NBK Corporation/Kawasaki Steel	2.7	2.6	3.0	0	0	
Total Japanese Companies	1,606.5	1,487.7	1,745.4	2,074.9	2,623.7	13.0
Europe-Based Companies						
Okmetic	0	0	0	0	0	
Wacker Siltronic AG	39.7	31.1	31.7	45.2	50.0	
Other European Companies[3]	8.5	7.2	8.1	8.7	9.7	
Total European Companies	48.2	38.3	39.8	53.9	59.7	5.5
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	7.6	10.7	0.2	
LG-Siltron[4]	0	0	0	0.3	4.0	
Oriental Electronic Metals	0	4.0	2.5	0	0	
Episil	0	8.8	10.1	12.0	19.7	
Sino-America	0	0	0	0	0	
Tatung Company	0	0	0.1	3.8	6.2	
Total Asia/Pacific Companies	0	12.8	20.3	26.8	30.1	NM
All Companies	1,721.8	1,602.7	1,896.1	2,278.7	2,856.2	13.5

*Includes prime, test, and monitor wafers
NM = Not meaningful
Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-9
Each Company's Revenue from Shipments of Merchant Silicon* Wafers to Japan, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	0.8	1.0	0.6	0.8	1.4	
Epitaxy Inc.	0	0	0	0	0	
MEMC Electronic Materials[1]	63.3	59.4	76.4	110.2	127.3	
Unisil Corp.	0.1	0.1	0.5	1.2	3.7	
Other U.S. Companies[2]	0	0	0	0	0	
Total U.S. Companies	64.2	60.5	77.5	112.2	132.4	19.8
Japan-Based Companies						
Komatsu Electronic Metals	250.4	245.9	272.9	303.0	353.0	
Mitsubishi Materials Silicon	185.6	166.1	203.5	241.2	301.8	
Nittetsu Denshi	56.4	72.0	84.5	103.1	132.0	
Sumitomo Sitix Silicon	236.1	200.8	224.6	250.9	315.6	
Shin-Etsu Handotai	387.1	363.8	404.7	486.2	612.6	
Showa Denko	11.9	13.9	16.2	20.6	31.9	
Toshiba Ceramics	89.9	89.6	148.2	166.4	242.4	
NBK Corporation/Kawasaki Steel	2.7	2.4	2.8	0	0	
Total Japanese Companies	1,220.1	1,154.5	1,357.4	1,571.4	1,989.3	13.0
Europe-Based Companies						
Okmetic	0	0	0	0	0	
Wacker Siltronic AG	30.4	23.1	23.5	32.4	39.4	
Other European Companies[3]	8.5	7.2	7.5	7.2	7.0	
Total European Companies	38.9	30.3	31.0	39.6	46.4	4.5
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	7.6	10.7	0.2	
LG-Siltron[4]	0	0	0	0.3	4.0	
Oriental Electronic Metals	0	4.0	2.5	0	0	
Episil	0	0	0	0	0	
Sino-America	0	0	0	0	0	
Tatung Company	0	0	0.1	3.8	6.2	
Total Asia/Pacific Companies	0	4.0	10.2	14.8	10.4	NM
All Companies	1,323.2	1,249.3	1,476.1	1,738.0	2,178.5	13.3

*Includes prime, test, and monitor wafers
NM = Not meaningful
Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-10
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to Japan, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	0	0	0	0	0	
Epitaxy Inc.	0	0	0	0	0	
MEMC Electronic Materials[1]	2.9	3.4	11.3	8.9	8.3	
Unisil Corp.	0	0	0	0	0	
Other U.S. Companies[2]	0	0	1.8	2.0	2.0	
Total U.S. Companies	2.9	3.4	13.1	10.9	10.3	37.3
Japan-Based Companies						
Komatsu Electronic Metals	67.9	56.1	79.6	105.2	130.1	
Mitsubishi Materials Silicon	81.7	67.2	57.3	87.6	116.0	
Nittetsu Denshi	0	0	0	0	0	
Sumitomo Sitix Silicon	33.5	25.3	35.5	65.6	89.8	
Shin-Etsu Handotai	147.4	136.0	157.4	171.9	190.5	
Showa Denko	0	0	0.2	1.5	2.7	
Toshiba Ceramics	55.9	48.4	57.8	71.7	105.3	
NBK Corporation/Kawasaki Steel	0	0.2	0.2	0	0	
Total Japanese Companies	386.4	333.2	388.0	503.5	634.4	13.2
Europe-Based Companies						
Okmetic	0	0	0	0	0	
Wacker Siltronic AG	9.3	8.0	8.2	12.8	10.6	
Other European Companies[3]	0	0	0.6	1.5	2.7	
Total European Companies	9.3	8.0	8.8	14.3	13.3	9.4
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	0	0	0	
LG-Siltron[4]	0	0	0	0	0	
Oriental Electronic Metals	0	0	0	0	0	
Episil	0	8.8	10.1	12.0	19.7	
Sino-America	0	0	0	0	0	
Tatung Company	0	0	0	0	0	
Total Asia/Pacific Companies	0	8.8	10.1	12.0	19.7	NM
All Companies	398.6	353.4	420.0	540.7	677.7	14.2

NM = Not meaningful

Note: Numbers may not add to totals shown because of rounding.

[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward

[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.

[3]Other European companies include Topsil and Siltronix SA

[4]Epitaxy Inc. included from 1995 onward

Source: Dataquest (June 1996)

Table 4-11
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to Europe, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	2.4	3.3	1.9	3.3	5.4	
Epitaxy Inc.	0.9	0.7	0.9	1.0	0	
MEMC Electronic Materials[1]	101.8	103.9	116.4	159.8	205.0	
Unisil Corp.	0.1	0.2	2.3	3.6	3.0	
Other U.S. Companies[2]	0.9	0.7	0.6	0.7	1.2	
Total U.S. Companies	106.1	108.8	122.1	168.4	214.6	19.3
Japan-Based Companies						
Komatsu Electronic Metals	6.8	7.4	2.7	3.4	11.4	
Mitsubishi Materials Silicon	1.5	1.6	1.7	2.0	5.4	
Nittetsu Denshi	0	0	0	0	0	
Sumitomo Sitix Silicon	30.5	30.2	31.2	51.6	70.5	
Shin-Etsu Handotai	29.8	43.8	54.5	88.2	144.4	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	4.6	
NBK Corporation/Kawasaki Steel	0	0	0	0	0	
Total Japanese Companies	68.6	83.0	90.1	145.2	236.3	36.2
Europe-Based Companies						
Okmetic	4.0	5.4	11.1	12.9	14.0	
Wacker Siltronic AG	105.7	131.3	150.0	209.2	300.0	
Other European Companies[3]	8.3	7.7	12.3	16.3	20.9	
Total European Companies	118.0	144.4	173.4	238.4	334.9	29.8
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	0	0	0.1	
LG-Siltron[4]	0	0	0	0	1.2	
Oriental Electronic Metals	0	0	0	0	0	
Episil	0	0	0	0.5	0.7	
Sino-America	0	0	0	0	0	
Tatung Company	0	0	0	0	0	
Total Asia/Pacific Companies	0	0	0	0.5	2.0	NM
All Companies	292.7	336.2	385.6	552.5	787.8	28.1

*Includes prime, test, and monitor wafers

Note: Numbers may not add to totals shown because of rounding.

[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward

[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.

[3]Other European companies include Topsil and Siltronix SA

[4]Epitaxy Inc. included from 1995 onward

Source: Dataquest (June 1996)

Table 4-12
Each Company's Revenue from Shipments of Merchant Silicon* Wafers to Europe, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	2.4	3.3	1.9	3.3	5.4	
Epitaxy Inc.	0	0	0	0	0	
MEMC Electronic Materials[1]	75.3	76.4	81.5	98.8	117.5	
Unisil Corp.	0.1	0.2	2.3	3.6	3.0	
Other U.S. Companies[2]	0.2	0.2	0.2	0.2	0.2	
Total U.S. Companies	78.0	80.1	85.9	105.9	126.1	12.8
Japan-Based Companies						
Komatsu Electronic Metals	6.8	7.4	2.7	3.4	10.1	
Mitsubishi Materials Silicon	1.1	1.2	1.3	1.5	1.5	
Nittetsu Denshi	0	0	0	0	0	
Sumitomo Sitix Silicon	20.4	21.7	23.1	33.4	38.6	
Shin-Etsu Handotai	26.7	39.5	49.5	81.5	134.7	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	4.6	
NBK Corporation/Kawasaki Steel	0	0	0	0	0	
Total Japanese Companies	55.0	69.8	76.6	119.8	189.5	36.2
Europe-Based Companies						
Okmetic	4.0	5.4	11.1	12.9	14.0	
Wacker Siltronic AG	78.6	97.2	96.0	125.9	167.5	
Other European Companies[3]	8.3	7.7	8.2	8.9	8.3	
Total European Companies	90.9	110.3	115.3	147.7	189.8	20.2
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	0	0	0.1	
LG-Siltron[4]	0	0	0	0	0	
Oriental Electronic Metals	0	0	0	0	0	
Episil	0	0	0	0	0	
Sino-America	0	0	0	0	0	
Tatung Company	0	0	0	0	0	
Total Asia/Pacific Companies	0	0	0	0	0.1	NM
All Companies	223.9	260.2	277.8	373.4	505.5	22.6

*Includes prime, test, and monitor wafers
NM = Not meaningful
Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-13
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to Europe, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	0	0	0	0	0	
Epitaxy Inc.	0.9	0.7	0.9	1.0	0	
MEMC Electronic Materials[1]	26.5	27.5	34.9	61.0	87.5	
Unisil Corp.	0	0	0	0	0	
Other U.S. Companies[2]	0.7	0.5	0.4	0.5	1.0	
Total U.S. Companies	28.1	28.7	36.2	62.5	88.5	33.2
Japan-Based Companies						
Komatsu Electronic Metals	0	0	0	0	1.3	
Mitsubishi Materials Silicon	0.4	0.4	0.4	0.5	3.9	
Nittetsu Denshi	0	0	0	0	0	
Sumitomo Sitix Silicon	10.1	8.5	8.1	18.2	31.9	
Shin-Etsu Handotai	3.1	4.3	5.0	6.7	9.7	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	0	
NBK Corporation/Kawasaki Steel	0	0	0	0	0	
Total Japanese Companies	13.6	13.2	13.5	25.4	46.8	36.2
Europe-Based Companies						
Okmetic	0	0	0	0	0	
Wacker Siltronic AG	27.1	34.1	54.0	83.3	132.5	
Other European Companies[3]	0	0	4.1	7.4	12.6	
Total European Companies	27.1	34.1	58.1	90.7	145.1	52.1
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	0	0	0	
LG-Siltron[4]	0	0	0	0	1.2	
Oriental Electronic Metals	0	0	0	0	0	
Episil	0	0	0	0.5	0.7	
Sino-America	0	0	0	0	0	
Tatung Company	0	0	0	0	0	
Total Asia/Pacific Companies	0	0	0	0.5	1.9	NM
All Companies	68.8	76.0	107.8	179.1	282.3	42.3

NM = Not meaningful
Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-14
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to Asia/Pacific, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	0	0.6	1.0	0.2	1.6	
Epitaxy Inc.	5.1	4.7	5.7	6.8	0	
MEMC Electronic Materials[1]	77.0	114.4	132.6	117.2	138.9	
Unisil Corp.	2.5	2.5	3.9	5.3	10.9	
Other U.S. Companies[2]	0.5	0.6	0.2	0.8	1.9	
Total U.S. Companies	85.1	122.8	143.4	130.3	153.3	15.9
Japan-Based Companies						
Komatsu Electronic Metals	0	0	1.4	7.6	17.8	
Mitsubishi Materials Silicon	1.9	2.0	19.2	43.2	92.1	
Nittetsu Denshi	0	0	0	2.7	6.0	
Sumitomo Sitix Silicon	12.5	18.3	24.9	31.5	52.9	
Shin-Etsu Handotai	42.3	43.8	54.3	148.0	313.0	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	2.4	2.7	3.1	4.0	8.7	
NBK Corporation/Kawasaki Steel	2.8	1.5	1.4	0	0	
Total Japanese Companies	61.9	68.3	104.3	237.0	490.5	67.8
Europe-Based Companies						
Okmetic	0.5	0.5	5.6	5.0	5.0	
Wacker Siltronic AG	23.7	31.9	39.5	41.0	47.0	
Other European Companies[3]	1.9	2.2	2.6	2.9	4.1	
Total European Companies	26.1	34.6	47.7	48.9	56.1	21.1
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	8.1	84.5	154.2	
LG-Siltron[4]	34.9	45.1	56.5	78.7	142.1	
Oriental Electronic Metals	0	0.5	0.9	0	0	
Episil	3.2	2.4	3.0	3.7	4.3	
Sino-America	5.2	7.7	3.3	7.5	12.0	
Tatung Company	7.3	0	0	3.9	4.5	
Total Asia/Pacific Companies	50.6	55.7	71.8	178.3	317.1	58.2
All Companies	223.7	281.4	367.2	594.6	1,017.0	46.0

*Includes prime, test, and monitor wafers

Note: Numbers may not add to totals shown because of rounding.

[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward

[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.

[3]Other European companies include Topsil and Siltronix SA

[4]Epitaxy Inc. included from 1995 onward

Source: Dataquest (June 1996)

Table 4-15
Each Company's Revenue from Shipments of Merchant Silicon* Wafers to Asia/Pacific, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	0	0.6	1.0	0.2	1.6	
Epitaxy Inc.	0	0	0	0	0	
MEMC Electronic Materials[1]	72.5	108.2	125.0	105.2	125.4	
Unisil Corp.	2.5	2.5	3.9	5.3	10.9	
Other U.S. Companies[2]	0.2	0.2	0.2	0.3	0.4	
Total U.S. Companies	75.2	111.5	130.1	111.0	138.3	16.5
Japan-Based Companies						
Komatsu Electronic Metals	0	0	1.3	7.6	17.8	
Mitsubishi Materials Silicon	1.7	1.8	18.8	42.9	88.4	
Nittetsu Denshi	0	0	0	2.7	6.0	
Sumitomo Sitix Silicon	7.1	12.1	16.6	19.0	41.1	
Shin-Etsu Handotai	42.0	43.5	54.0	147.3	311.6	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0.8	2.3	3.0	4.0	8.1	
NBK Corporation/Kawasaki Steel	2.8	1.5	1.4	0	0	
Total Japanese Companies	54.4	61.2	95.1	223.5	473.0	71.7
Europe-Based Companies						
Okmetic	0.5	0.5	5.6	5.0	5.0	
Wacker Siltronic AG	20.4	27.5	30.6	30.0	33.0	
Other European Companies	1.9	2.2	2.6	2.8	4.0	
Total European Companies	22.8	30.2	38.8	37.8	42.0	16.5
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	8.1	84.5	154.2	
LG-Siltron[4]	34.9	45.1	56.5	78.7	132.2	
Oriental Electronic Metals	0	0.5	0.9	0	0	
Episil	0	0	0	0	0	
Sino-America	5.2	7.7	3.3	7.5	12.0	
Tatung Company	7.3	0	0	3.9	4.5	
Total Asia/Pacific Companies	47.4	53.3	68.8	174.6	302.9	59.0
All Companies	199.8	256.2	332.8	546.9	956.2	47.9

*Includes prime, test, and monitor wafers

Note: Numbers may not add to totals shown because of rounding.

[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward

[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.

[3]Other European companies include Topsil and Siltronix SA

[4]Epitaxy Inc. included from 1995 onward

Source: Dataquest (June 1996)

Table 4-16
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to Asia/Pacific, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	0	0	0	0	0	
Epitaxy Inc.	5.1	4.7	5.7	6.8	0	
MEMC Electronic Materials[1]	4.5	6.2	7.6	12.0	13.5	
Unisil Corp.	0	0	0	0	0	
Other U.S. Companies[2]	0.3	0.4	0	0.5	1.5	
Total U.S. Companies	9.9	11.3	13.3	19.3	15.0	10.9
Japan-Based Companies						
Komatsu Electronic Metals	0	0	0.1	0	0	
Mitsubishi Materials Silicon	0.2	0.2	0.4	0.3	3.7	
Nittetsu Denshi	0	0	0	0	0	
Sumitomo Sitix Silicon	5.4	6.2	8.3	12.5	11.8	
Shin-Etsu Handotai	0.3	0.3	0.3	0.7	1.4	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	1.6	0.4	0.1	0	0.6	
NBK Corporation/Kawasaki Steel	0	0	0	0	0	
Total Japanese Companies	7.5	7.1	9.2	13.5	17.5	23.6
Europe-Based Companies						
Okmetic	0	0	0	0	0	
Wacker Siltronic AG	3.3	4.4	8.9	11.0	14.0	
Other European Companies[3]	0	0	0	0.1	0.1	
Total European Companies	3.3	4.4	8.9	11.1	14.1	43.8
Asia/Pacific-Based Companies						
Posco-Hüls	0	0	0	0	0	
LG-Siltron[4]	0	0	0	0	9.9	
Oriental Electronic Metals	0	0	0	0	0	
Episil	3.2	2.4	3.0	3.7	4.3	
Sino-America	0	0	0	0	0	
Tatung Company	0	0	0	0	0	
Total Asia/Pacific Companies	3.2	2.4	3.0	3.7	14.2	45.1
All Companies	23.9	25.2	34.4	47.7	60.8	26.3

Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-17
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to Korea, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	NS	NS	NS	0	0.1	
Epitaxy Inc.	NS	NS	NS	1.7	0	
MEMC Electronic Materials[1]	NS	NS	NS	60.6	63.0	
Unisil Corp.	NS	NS	NS	4.0	0	
Other U.S. Companies[2]	NS	NS	NS	0.2	0.2	
Total U.S. Companies	NS	NS	NS	66.5	63.3	NM
Japan-Based Companies						
Komatsu Electronic Metals	NS	NS	NS	5.7	2.7	
Mitsubishi Materials Silicon	NS	NS	NS	28.0	54.0	
Nittetsu Denshi	NS	NS	NS	0	0	
Sumitomo Sitix Silicon	NS	NS	NS	13.5	22.8	
Shin-Etsu Handotai	NS	NS	NS	120.8	249.1	
Showa Denko	NS	NS	NS	0	0	
Toshiba Ceramics	NS	NS	NS	0.9	4.8	
NBK Corporation/Kawasaki Steel	NS	NS	NS	0	0	
Total Japanese Companies	NS	NS	NS	168.9	333.4	NM
Europe-Based Companies						
Okmetic	NS	NS	NS	0	0	
Wacker Siltronic AG	NS	NS	NS	14.5	15.7	
Other European Companies[3]	NS	NS	NS	0.1	0.1	
Total European Companies	NS	NS	NS	14.6	15.8	NM
Asia/Pacific-Based Companies						
Posco-Hüls	NS	NS	NS	83.6	142.8	
LG-Siltron[4]	NS	NS	NS	75.0	127.6	
Oriental Electronic Metals	NS	NS	NS	0	0	
Episil	NS	NS	NS	1.3	1.2	
Sino-America	NS	NS	NS	0	0	
Tatung Company	NS	NS	NS	0	0	
Total Asia/Pacific Companies	NS	NS	NS	159.9	271.6	NM
All Companies	NS	NS	NS	409.9	684.1	NM

*Includes prime, test, and monitor wafers
NS = Not surveyed
NM = Not meaningful
Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-18
Each Company's Revenue from Shipments of Merchant Silicon* Wafers to Korea, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	NS	NS	NS	0	0.1	
Epitaxy Inc.	NS	NS	NS	0	0	
MEMC Electronic Materials[1]	NS	NS	NS	59.6	62.0	
Unisil Corp.	NS	NS	NS	4.0	0	
Other U.S. Companies[2]	NS	NS	NS	0.2	0.2	
Total U.S. Companies	NS	NS	NS	63.8	62.3	NM
Japan-Based Companies						
Komatsu Electronic Metals	NS	NS	NS	5.7	2.7	
Mitsubishi Materials Silicon	NS	NS	NS	27.8	51.3	
Nittetsu Denshi	NS	NS	NS	0	0	
Sumitomo Sitix Silicon	NS	NS	NS	10.5	18.7	
Shin-Etsu Handotai	NS	NS	NS	120.8	249.1	
Showa Denko	NS	NS	NS	0	0	
Toshiba Ceramics	NS	NS	NS	0.9	4.2	
NBK Corporation/Kawasaki Steel	NS	NS	NS	0	0	
Total Japanese Companies	NS	NS	NS	165.7	326.0	NM
Europe-Based Companies						
Okmetic	NS	NS	NS	0	0	
Wacker Siltronic AG	NS	NS	NS	12.0	12.5	
Other European Companies[3]	NS	NS	NS	0	0	
Total European Companies	NS	NS	NS	12.0	12.5	NM
Asia/Pacific-Based Companies						
Posco-Hüls	NS	NS	NS	83.6	142.8	
LG-Siltron[4]	NS	NS	NS	75.0	125.7	
Oriental Electronic Metals	NS	NS	NS	0	0	
Episil	NS	NS	NS	0	0	
Sino-America	NS	NS	NS	0	0	
Tatung Company	NS	NS	NS	0	0	
Total Asia/Pacific Companies	NS	NS	NS	158.6	268.5	NM
All Companies	NS	NS	NS	400.1	669.3	NM

*Includes prime, test, and monitor wafers
NS = Not surveyed
NM = Not meaningful
Note: Numbers may not add to totals shown because of rounding.
[1] Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2] Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3] Other European companies include Topsil and Siltronix SA
[4] Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-19
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to Korea, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	NS	NS	NS	0	0	
Epitaxy Inc.	NS	NS	NS	1.7	0	
MEMC Electronic Materials[1]	NS	NS	NS	1.0	1.0	
Unisil Corp.	NS	NS	NS	0	0	
Other U.S. Companies[2]	NS	NS	NS	0	0	
Total U.S. Companies	NS	NS	NS	2.7	1.0	NM
Japan-Based Companies						
Komatsu Electronic Metals	NS	NS	NS	0	0	
Mitsubishi Materials Silicon	NS	NS	NS	0.2	2.7	
Nittetsu Denshi	NS	NS	NS	0	0	
Sumitomo Sitix Silicon	NS	NS	NS	3.0	4.1	
Shin-Etsu Handotai	NS	NS	NS	0	0	
Showa Denko	NS	NS	NS	0	0	
Toshiba Ceramics	NS	NS	NS	0	0.6	
NBK Corporation/Kawasaki Steel	NS	NS	NS	0	0	
Total Japanese Companies	NS	NS	NS	3.2	7.4	NM
Europe-Based Companies						
Okmetic	NS	NS	NS	0	0	
Wacker Siltronic AG	NS	NS	NS	2.5	3.2	
Other European Companies[3]	NS	NS	NS	0.1	0.1	
Total European Companies	NS	NS	NS	2.6	3.3	NM
Asia/Pacific-Based Companies						
Posco-Hüls	NS	NS	NS	0	0	
LG-Siltron[4]	NS	NS	NS	0	1.9	
Oriental Electronic Metals	NS	NS	NS	0	0	
Episil	NS	NS	NS	1.3	1.2	
Sino-America	NS	NS	NS	0	0	
Tatung Company	NS	NS	NS	0	0	
Total Asia/Pacific Companies	NS	NS	NS	1.3	3.1	NM
All Companies	NS	NS	NS	9.8	14.8	NM

NS = Not surveyed
NM = Not meaningful
Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-20
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to the Rest of Asia/Pacific, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	NS	NS	NS	0.2	1.5	
Epitaxy Inc.	NS	NS	NS	5.1	0	
MEMC Electronic Materials[1]	NS	NS	NS	56.6	75.9	
Unisil Corp.	NS	NS	NS	1.3	10.9	
Other U.S. Companies[2]	NS	NS	NS	0.6	1.7	
Total U.S. Companies	NS	NS	NS	63.8	90.0	NM
Japan-Based Companies						
Komatsu Electronic Metals	NS	NS	NS	1.9	15.1	
Mitsubishi Materials Silicon	NS	NS	NS	15.2	38.1	
Nittetsu Denshi	NS	NS	NS	2.7	6.0	
Sumitomo Sitix Silicon	NS	NS	NS	18.0	30.1	
Shin-Etsu Handotai	NS	NS	NS	27.2	63.9	
Showa Denko	NS	NS	NS	0	0	
Toshiba Ceramics	NS	NS	NS	3.1	3.9	
NBK Corporation/Kawasaki Steel	NS	NS	NS	0	0	
Total Japanese Companies	NS	NS	NS	68.1	157.1	NM
Europe-Based Companies						
Okmetic	NS	NS	NS	5.0	5.0	
Wacker Siltronic AG	NS	NS	NS	26.5	31.3	
Other European Companies[3]	NS	NS	NS	2.8	4.0	
Total European Companies	NS	NS	NS	34.3	40.3	NM
Asia/Pacific-Based Companies						
Posco-Hüls	NS	NS	NS	0.9	11.4	
LG-Siltron[4]	NS	NS	NS	3.7	14.5	
Oriental Electronic Metals	NS	NS	NS	0	0	
Episil	NS	NS	NS	2.4	3.1	
Sino-America	NS	NS	NS	7.5	12.0	
Tatung Company	NS	NS	NS	3.9	4.5	
Total Asia/Pacific Companies	NS	NS	NS	18.4	45.5	NM
All Companies	NS	NS	NS	184.6	332.9	NM

*Includes prime, test, and monitor wafers
NS = Not surveyed
NM = Not meaningful
Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-21
Each Company's Revenue from Shipments of Merchant Silicon Wafers* to the Rest of Asia/Pacific, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	NS	NS	NS	0.2	1.5	
Epitaxy Inc.	NS	NS	NS	0	0	
MEMC Electronic Materials[1]	NS	NS	NS	45.6	63.4	
Unisil Corp.	NS	NS	NS	1.3	10.9	
Other U.S. Companies[2]	NS	NS	NS	0.1	0.2	
Total U.S. Companies	NS	NS	NS	47.2	76.0	NM
Japan-Based Companies						
Komatsu Electronic Metals	NS	NS	NS	1.9	15.1	
Mitsubishi Materials Silicon	NS	NS	NS	15.1	37.1	
Nittetsu Denshi	NS	NS	NS	2.7	6.0	
Sumitomo Sitix Silicon	NS	NS	NS	8.5	22.4	
Shin-Etsu Handotai	NS	NS	NS	26.5	62.5	
Showa Denko	NS	NS	NS	0	0	
Toshiba Ceramics	NS	NS	NS	3.1	3.9	
NBK Corporation/Kawasaki Steel	NS	NS	NS	0	0	
Total Japanese Companies	NS	NS	NS	57.8	147.0	NM
Europe-Based Companies						
Okmetic	NS	NS	NS	5.0	5.0	
Wacker Siltronic AG	NS	NS	NS	18.0	20.5	
Other European Companies[3]	NS	NS	NS	2.8	4.0	
Total European Companies	NS	NS	NS	25.8	29.5	NM
Asia/Pacific-Based Companies						
Posco-Hüls	NS	NS	NS	0.9	11.4	
LG-Siltron[4]	NS	NS	NS	3.7	6.5	
Oriental Electronic Metals	NS	NS	NS	0	0	
Episil	NS	NS	NS	0	0	
Sino-America	NS	NS	NS	7.5	12.0	
Tatung Company	NS	NS	NS	3.9	4.5	
Total Asia/Pacific Companies	NS	NS	NS	16.0	34.4	NM
All Companies	NS	NS	NS	146.8	286.9	NM

*Includes prime, test, and monitor wafers
NS = Not surveyed
NM = Not meaningful
Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Table 4-22
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to the Rest of Asia/Pacific, 1991-1995 (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
United States-Based Companies						
Crysteco Inc.	NS	NS	NS	0	0	
Epitaxy Inc.	NS	NS	NS	5.1	0	
MEMC Electronic Materials[1]	NS	NS	NS	11.0	12.5	
Unisil Corp.	NS	NS	NS	0	- 0	
Other U.S. Companies[2]	NS	NS	NS	0.5	1.5	
Total U.S. Companies	NS	NS	NS	16.6	14.0	NM
Japan-Based Companies						
Komatsu Electronic Metals	NS	NS	NS	0	0	
Mitsubishi Materials Silicon	NS	NS	NS	0.1	1.0	
Nittetsu Denshi	NS	NS	NS	0	0	
Sumitomo Sitix Silicon	NS	NS	NS	9.5	7.7	
Shin-Etsu Handotai	NS	NS	NS	0.7	1.4	
Showa Denko	NS	NS	NS	0	0	
Toshiba Ceramics	NS	NS	NS	0	0	
NBK Corporation/Kawasaki Steel	NS	NS	NS	0	0	
Total Japanese Companies	NS	NS	NS	10.3	10.1	NM
Europe-Based Companies						
Okmetic	NS	NS	NS	0	0	
Wacker Siltronic AG	NS	NS	NS	8.5	10.8	
Other European Companies[3]	NS	NS	NS	0	0	
Total European Companies	NS	NS	NS	8.5	10.8	NM
Asia/Pacific-Based Companies						
Posco-Hüls	NS	NS	NS	0	0	
LG-Siltron[4]	NS	NS	NS	0	8.0	
Oriental Electronic Metals	NS	NS	NS	0	0	
Episil	NS	NS	NS	2.4	3.1	
Sino-America	NS	NS	NS	0	0	
Tatung Company	NS	NS	NS	0	0	
Total Asia/Pacific Companies	NS	NS	NS	2.4	11.1	NM
All Companies	NS	NS	NS	37.8	46.0	NM

NS = Not surveyed
NM = Not meaningful
Note: Numbers may not add to totals shown because of rounding.
[1]Kawatec included from 1994 onward; Texas Instruments included from 1995 onward
[2]Other U.S. companies include Epic Semiconductor, General Instrument Power SC Division, Lawrence Semiconductor Laboratories, M/A-COM Semiconductor Products, Moore Technologies, Pure Sil, Spire Corporation, and Virginia Semiconductor.
[3]Other European companies include Topsil and Siltronix SA
[4]Epitaxy Inc. included from 1995 onward
Source: Dataquest (June 1996)

Section 5: Wafer Pricing

Dataquest conducts a survey of the average polished and epitaxial wafer prices during the first calendar quarter of each year. The survey covers pricing trends in the United States, Europe, Japan, Korea, and Taiwan and is a direct survey of wafer suppliers and brokers, both formally and informally. The raw data is averaged by region and provides part of the correlation among silicon wafer revenue, size distribution, and silicon area consumption.

Tables 5-1 and 5-2 represent the average prices used for regional prime, test, and epitaxial wafers for five different wafer sizes, where available. These prices should not be used as a benchmark for price comparisons among suppliers.

Wafer pricing is a complex process involving many specifications and variables. Also, our survey methodology is strict enough only to gauge approximate values and trends for use as a research tool and guideline. In past publications of the market share estimates, Dataquest has published the results of the current year's survey (in this case, the first quarter of 1996). In order to prevent their use as a benchmark for price comparisons, we have decided to delay the publication of these results until next year's database update.

Table 5-1
Regional Average Selling Price of Polished and Epitaxial Wafers, at Start of Year, 1991-1995 Price per Wafer (U.S. Dollars and Japanese Yen)

Wafer Diameter	Area (Sq. In.)	1991	1992	1993	1994	1995
North America: Polished CZ ($)						
3-Inch	7.07	7.10	7.04	7.04	7.04	7.10
100mm	12.17	9.96	10.47	10.91	10.70	12.75
125mm	19.02	18.80	19.05	19.05	18.80	20.25
150mm	27.39	32.44	31.75	32.44	32.00	34.00
200mm	48.70	109.80	104.71	101.93	118.00	123.50
North America: Epitaxial ($)						
3-Inch	7.07	24.39	24.39	NA	NA	NA
100mm	12.17	32.30	32.30	27.90	26.50	27.00
125mm	19.02	51.50	51.50	48.85	47.75	49.10
150mm	27.39	83.25	83.25	81.54	81.00	85.00
200mm	48.70	195.75	181.40	192.50	205.00	217.00
Japan: Polished CZ (¥)						
3-Inch	7.07	1,525.00	1,525.00	1,310.00	1,310.00	1,310.00
100mm	12.17	1,870.00	1,865.00	1,510.00	1,400.00	1,720.00
125mm	19.02	3,320.00	3,300.00	3,100.00	2,740.00	2,570.00
150mm	27.39	6,100.00	5,900.00	5,400.00	4,700.00	4,660.00
200mm	48.70	22,470.00	19,750.00	19,600.00	15,200.00	14,800.00
Japan: Epitaxial (¥)						
3-Inch	7.07	5,127.00	5,127.00	3,700.00	3,700.00	3,700.00
100mm	12.17	5,700.00	5,600.00	4,300.00	4,000.00	4,200.00
125mm	19.02	10,000.00	9,875.00	8,700.00	8,500.00	7,100.00
150mm	27.39	18,754.00	16,750.00	16,500.00	16,500.00	11,600.00
200mm	48.70	NA	NA	38,750.00	28,500.00	23,700.00
Europe: Polished CZ ($)						
3-Inch	7.07	8.05	8.05	8.05	8.05	8.05
100mm	12.17	11.80	11.40	11.66	11.50	12.10
125mm	19.02	21.35	21.30	21.07	20.00	20.40
150mm	27.39	33.09	33.15	33.40	34.30	36.00
200mm	48.70	115.40	115.75	104.71	122.00	127.00
Europe: Epitaxial ($)						
3-Inch	7.07	23.70	24.01	24.10	24.10	24.10
100mm	12.17	34.69	33.40	33.40	33.00	35.00
125mm	19.02	57.09	55.41	55.41	53.50	54.50
150mm	27.39	86.75	87.40	84.50	83.00	87.50
200mm	48.70	NA	NA	NA	213.00	222.00

(Continued)

Table 5-1 (Continued)
Regional Average Selling Price of Polished and Epitaxial Wafers, at Start of Year, 1991-1995 Price per Wafer (U.S. Dollars and Japanese Yen)

Wafer Diameter	Area (Sq. In.)	1991	1992	1993	1994	1995
Asia/Pacific: Polished CZ ($)						
3-Inch	7.07	7.25	7.25	7.25	7.25	7.25
100mm	12.17	10.66	10.47	10.47	10.50	11.75
125mm	19.02	18.63	19.61	19.34	19.22	22.40
150mm	27.39	33.75	34.95	34.54	34.90	36.75
200mm	48.70	NA	NA	101.00	115.00	120.00
Asia/Pacific: Epitaxial ($)						
3-Inch	7.07	25.10	25.10	NA	NA	NA
100mm	12.17	35.05	35.00	35.50	34.50	35.80
125mm	19.02	53.87	51.90	52.00	50.75	52.25
150mm	27.39	85.70	83.20	82.00	81.00	85.00
200mm	48.70	NA	NA	NA	NA	NA

NA = Not applicable or not available
Source: Dataquest (June 1996)

Table 5-2
Regional Average Selling Price of Polished and Epitaxial Wafers, at Start of Year, 1991-1995 Price per Square Inch (U.S. Dollars and Japanese Yen)

Wafer Diameter	Area (Sq. In.)	1991	1992	1993	1994	1995
North America: Polished CZ ($)						
3-Inch	7.07	1.00	1.00	1.00	1.00	1.00
100mm	12.17	0.82	0.86	0.90	0.88	1.05
125mm	19.02	0.99	1.00	1.00	0.99	1.06
150mm	27.39	1.18	1.16	1.18	1.17	1.24
200mm	48.70	2.25	2.15	2.09	2.42	2.54
North America: Epitaxial ($)						
3-Inch	7.07	3.45	3.45	NA	NA	NA
100mm	12.17	2.65	2.65	2.29	2.18	2.22
125mm	19.02	2.71	2.71	2.57	2.51	2.58
150mm	27.39	3.04	3.04	2.98	2.96	3.10
200mm	48.70	4.02	3.72	3.95	4.21	4.46
Japan: Polished CZ (¥)						
3-Inch	7.07	215.70	215.70	185.29	185.29	185.29
100mm	12.17	153.66	153.25	124.08	115.04	141.33
125mm	19.02	174.55	173.50	162.99	144.06	135.12
150mm	27.39	222.71	215.41	197.15	171.60	170.14
200mm	48.70	461.40	405.54	402.46	312.11	303.90
Japan: Epitaxial (¥)						
3-Inch	7.07	725.18	725.18	523.34	523.34	523.34
100mm	12.17	468.36	460.15	353.33	328.68	345.11
125mm	19.02	525.76	519.19	457.41	446.90	373.29
150mm	27.39	684.70	611.54	602.41	602.41	423.51
200mm	48.70	NA	NA	795.69	585.22	486.65
Europe: Polished CZ ($)						
3-Inch	7.07	1.14	1.14	1.14	1.14	1.14
100mm	12.17	0.97	0.94	0.96	0.94	0.99
125mm	19.02	1.12	1.12	1.11	1.05	1.07
150mm	27.39	1.21	1.21	1.22	1.25	1.31
200mm	48.70	2.37	2.38	2.15	2.51	2.61
Europe: Epitaxial ($)						
3-Inch	7.07	3.35	3.40	3.41	3.41	3.41
100mm	12.17	2.85	2.74	2.74	2.71	2.88
125mm	19.02	3.00	2.91	2.91	2.81	2.87
150mm	27.39	3.17	3.19	3.09	3.03	3.19
200mm	48.70	NA	NA	NA	4.37	4.56

(Continued)

Table 5-2 (Continued)
Regional Average Selling Price of Polished and Epitaxial Wafers, at Start of Year, 1991-1995 Price per Square Inch (U.S. Dollars and Japanese Yen)

Wafer Diameter	Area (Sq. In.)	1991	1992	1993	1994	1995
Asia/Pacific: Polished CZ ($)						
3-Inch	7.07	1.03	1.03	1.03	1.03	1.03
100mm	12.17	0.88	0.86	0.86	0.86	0.97
125mm	19.02	0.98	1.03	1.02	1.01	1.18
150mm	27.39	1.23	1.28	1.26	1.27	1.34
200mm	48.70	NA	NA	2.07	2.36	2.46
Asia/Pacific: Epitaxial ($)						
3-Inch	7.07	3.55	3.55	NA	NA	NA
100mm	12.17	2.88	2.88	2.92	2.83	2.94
125mm	19.02	2.83	2.73	2.73	2.67	2.75
150mm	27.39	3.13	3.04	2.99	2.96	3.10
200mm	48.70	NA	NA	NA	NA	NA

NA = Not applicable or not available
Source: Dataquest (June 1996)

Section 6: Silicon Supplier Major Activities

Table 6-1
Silicon Wafer Plant Expansions/New Lines Since 1990

Company	Location	Status	Size (Inches)	Initial Capacity (K Wafers/Mo.)	Start Date*	Capital Spending ($M)	Capital Spending (¥M)
Komatsu Electronic Metals	Hiratsuka	Technical center			March 1991	14.7	2,000
	Nagasaki	200mm expansion	8	50	1995		4,000
	Miyazaki	200mm expansion	8	10	1995		2,000
	Hillsboro, OR	New 200mm plant	8	100/200	1998/2000	450.0	
Komatsu/Formosa JV	Taiwan	New 200mm plant	8	100/200	1997/TBA	140/250	
LG-Siltron	Kumi City, Korea	200mm production line	8	130/200	1995/6		
	Kumi City, Korea	200mm production line	8	50/110	1997/8		
	Kumi City, Korea	200mm epitaxial facility	8	10	1998		
MEMC	St. Peters, MO	Expansion	8	30	November 1991	31.9	4,340
	St. Peters, MO	Expansion	8	30	1995		
	Utsonomiya	Volume production line	8	30	1995		10,000
	St. Peters, MO	Expansion	8	25	1997		
Posco-Hüls	Korea	Volume production line	6, 8		March 1992	121.8	15,400
(MEMC-Samsung-Pohang JV)	Korea	Expansion	8	50	1994		
	Korea	Expansion	8	60	1995		
	Korea	Expansion	8	150	1996		
	Korea	Expansion	8	50	1997		
Taisil	Hsinchu Park, Taiwan	New 200mm plant	6, 8	125/215	1996/7	191.0	
(MEMC-China Steel JV)							
MEMC Southwest	Sherman, Texas	New 200mm line and upgrades	8	100/200	1997/8	300.0	
(MEMC-Texas Instruments JV)							

(Continued)

Table 6-1 (Continued)
Silicon Wafer Plant Expansions/New Lines Since 1990

Company	Location	Status	Size (Inches)	Initial Capacity (K Wafers/Mo.)	Start Date*	Capital Spending ($M)	Capital Spending (¥M)
MEMC Kulim Elec. Materials (MEMC-Khazanah JV)	Kulim Park, Malaysia	New 200mm plant	8	TBD/150	1998		
Mitsubishi Materials Silicon	Central Research	R&D for 16M	8		1990	13.9	2,000
	Noda	R&D For 4M			April 1990	13.9	2,000
	Noda	Pilot line	8	5	September 1990	27.8	4,000
	Yonezawa	Volume production	6	250	March 1991	29.4	4,000
	Ikuno	200mm volume production	8	20	March 1991	55.1	7,500
	Chitose	Epitaxial production line			July 1993		10,000
	Ikuno	Expansion	8	20	1994		
	Ikuno	Expansion	8	50	1995/6		
	Salem, OR	Prime and epitaxial	8	50/80/120	1996/7/9	250.0	
	Ikuno	Expansion	8	130	1996		
NSC Electron	Hikari	Expansion	8	10	April 1993		10,000
	Hikari	Expansion	8	10/30	1996/7		
Shin-Etsu Handotai	Shirakawa	R&D			March 1990	14.3	2,000
	Isobe	Epitaxial expansion				14.3	2,000
	Nagano	New volume production line	6		February 1991	25.7	3,500
	Camus, OR	200mm volume production	8	10	February 1991	7.4	1,000
	Naoetsu	New volume production line	6		March 1991	33.1	4,500
	England	150mm volume production	6	200	March 1991	33.1	4,500
	Mimasu	Polishing line			April 1991	40.4	5,500
	Shirakawa	200mm volume production	8	30	April 1992	118.6	15,000
	Vancouver, WA	Epitaxial expansion			1994		
	Malaysia	200mm volume production	8	100/200	1994/5		20,000

(Continued)

Table 6-1 (Continued)
Silicon Wafer Plant Expansions/New Lines Since 1990

Company	Location	Status	Size (Inches)	Initial Capacity (K Wafers/Mo.)	Start Date*	Capital Spending ($M)	Capital Spending (¥M)
	Vancouver, WA	200mm expansion	8	50/90	1994/5		
	Japan	200mm expansion	8	40/100	1994/5		
	United States	200mm plant	8	TBA	1997		
SEH/Taiwan JV	Taiwan	New 200mm plant	8	70	1997		
Showa Denko	Chichibu	Expansion	6, 8	30	July 1991	22.1	3,000
	Chichibu	Expansion	6		1997		
	Kawasaki	New prime and epitaxial 200mm plant	8	30/TBA	1997/TBA		
Sumitomo Sitix	Imari	No. 3 volume production line	6, 8	130	1991	125.0	17,000
	Mainville, OH	Expansion			March 1992	23.7	3,000
	Fremont, CA	Epitaxial expansion			1993		1,200
	Mainville, OH	No. 2 plant (substrate production)			March 1994		3,600
	Imari	Expansion of No. 3 line	6, 8	170	1994/5		8,400
	Albuquerque, NM	200mm epitaxial wafer line	8	20	January 1995	32.0	
	Imari	Expansion of No. 3 line	8	110	1996		
	Phoenix, AZ	New 200mm plant	8	50/200	1997/TBA		
	Albuquerque, NM	200mm epitaxial expansion	8	40/50	1996/7		
Tatung	Taipei, Taiwan	100/125mm polished expansion	4, 5		1997	30.0	
Toshiba Ceramics	Yamagata	Expand at Okuni plant	6	300			4,000
	Central Research	Pilot line	8		September 1990	3.5	500
	Niigata	Volume production line	8	100	July 1993		22,210
	Tokuyama	Epitaxial expansion	5	90	1994		5,000
	Niigata	Expansion—pulling/polishing	8	10	1994		
	Niigata	200mm expansion	8	40	1995		

(Continued)

Table 6-1 (Continued)
Silicon Wafer Plant Expansions/New Lines Since 1990

Company	Location	Status	Size (Inches)	Initial Capacity (K Wafers/Mo.)	Start Date*	Capital Spending ($M)	Capital Spending (¥M)
	Yamagato	150mm expansion	6		1996		
	Niigata	200mm expansion	8	110	1996		
Unisil	Mountain View, CA	Expansion for 200mm	8	40/75	1995/6		
		Expansion for 200mm	8	25/50	1997/8		
Wacker Siltronic AG	Wasserburg, Germany	Expansion of epitaxial	6		June 1990	5.0	700
	Portland, OR	Upgrade facility	6, 8		1993	45.0	
	United States and Germany	Expansion of production	8		1994		
	Wasserburg, Germany	200mm expansion	8	50	1995		
	Portland, OR	Line 2	8	50/150	1996/8	230.0	
	Europe	200mm expansion	8	50/90	1997/8		

*Start dates and production levels with format of "x/y" signifies "x" as initial production volume and year, with "y" meaning final production means initial production volume of 50,000 in 1996, expanding to 100,000 total in 1997.

Source: Dataquest (June 1996)

Table 6-2
Key Events In The Silicon Industry, 1985 to Present

Year	Company (That Has Taken Action)	Action	Company (Founded, Acquired, or Established)	Comments
1985	Lucky Advanced Materials (Korea)	Founded	The silicon operation of Lucky Advanced Materials	Organization renamed Siltron in September 1991 and LG-Siltron in 1995
1985	Kawasaki Steel (Japan)	Acquired	NBK Corporation (U.S.)	Organization renamed Kawatec at a later date
1985	Nippon Steel (Japan)	Founded	Nittetsu Denshi (Japan) as a wholly owned subsidiary focused on silicon wafers (also known as NSC Electron)	
1985	Outokumpu (Finland) and Nokia (Finland)	Founded	Okmetic (Finland)	
1986	Mitsubishi Metal (Japan)	Acquired	Siltec Corporation (U.S.)	Organization renamed in 1992 to Mitsubishi Materials Silicon (includes Siltec and Japan Silicon organizations)
1986	Osaka Titanium (Japan)	Acquired	US Semiconductor (U.S.)	
1987	Hüls AG (Germany)	Acquired	Dynamit Nobel Silicon (Italy)	
1987	Mitsubishi Materials Silicon (Japan)	Acquired	50 percent share of Kojundo Silicon (Hi-Silicon) polysilicon operation (Japan) owned by Osaka Titanium (Japan)	Mitsubishi Materials Silicon becomes sole owner of Hi-Silicon
1988	Wacker (Germany)	Acquired	Fairchild's vacated silicon facility (Germany)	
1989	Hüls AG (Germany)	Acquired	Monsanto Electronic Materials Company (U.S.)	Organization renamed MEMC Electronic Materials
1989	Huls/MEMC (Germany)	Acquired	IBM's silicon wafer operation (U.S.)	
1989	Osaka Titanium (Japan	Acquired	Cincinnati Milacron (U.S.)	Osaka Titanium renamed Sumitomo Sitix in 1993

(Continued)

Table 6-2 (Continued)
Key Events In The Silicon Industry, 1985 to Present

Year	Company (That Has Taken Action)	Action	Company (Founded, Acquired, or Established)	Comments
1990	Komatsu Electronic Metals (Japan)	Acquired	Union Carbide's polysilicon operation (U.S.)	New name of polysilicon organization is Advanced Silicon Materials
1990	MEMC (Germany), Pohang Iron and Steel (Korea), and Samsung (Korea)	Established a joint venture	Posco Hüls (Korea)	
1994	M/A-COM Semiconductor Products (U.S.)	Acquired	Spire Corporation's silicon organization (U.S)	
1994	MEMC (Germany)	Acquired	Kawatec (Japan)	
1994	MEMC (Germany) and China Steel (Taiwan)	Established a joint venture	Taisil (Taiwan)	Production began 1996
1995	Komatsu (Japan) and Formosa Plastics (Taiwan)	Established a joint venture	Name not available	Production to begin in late 1996/early 1997
1995	MEMC	Undertakes initial public offering		Hüls ownership reduced from 100 percent to 53 percent through IPO; MEMC considered U.S. company today
1995	MEMC (U.S.)	Acquired	Albemarle polysilicon operation (U.S.)	MEMC ownership is 85 percent; name of polysilicon operation changed to Granular Polysilicon Business
1995	MEMC (U.S.) and Texas Instruments (U.S.)	Established a joint venture after purchase of Texas Instrument's captive operations	MEMC Southwest (U.S.)	MEMC ownership in joint venture is 80 percent in former Texas Instruments' wafer manufacturing operation
1995	LG-Siltron (Korea—formerly Lucky Advanced Materials)	Acquired	Epitaxy Inc. (U.S.)	

(Continued)

Table 6-2 (Continued)
Key Events In The Silicon Industry, 1985 to Present

Year	Company (That Has Taken Action)	Action	Company (Founded, Acquired, or Established)	Comments
1995	Sumitomo Sitix (Japan, formerly Osaka Titanium)	Acquired	Epitech (French)	
1995	Shin-Etsu Handotai (Japan) and Taiwanese partner	Established a joint venture	Name not available	Production expected to begin in 1997
1996	Wacker-Chemtronic	Name change	Wacker Siltronic AG	
1996	MEMC (U.S.) and Khazanah (Malaysia)	Established a joint venture	MEMC Kulim Electronic Materials, SDN. BHD	Production expected to begin in early 1998

Source: Dataquest (June 1996)

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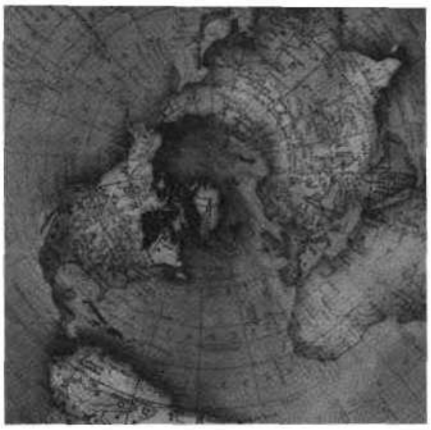

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1995 Wafer Fab Equipment Market Share Estimates Volume 2 of 2

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-MS-9601
Publication Date: May 27, 1996
Filing: Market Statistics

1995 Wafer Fab Equipment Market Share Estimates Volume 2 of 2

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Note: All tables show estimated data.

Chapter 7
Thermal Nondeposition Equipment

This chapter presents tables for the thermal nondeposition equipment market. The chapter consists of nine tables that present a variety of estimates relevant to equipment company sales of thermal nondeposition equipment. Table 7-1 reports estimated thermal nondeposition equipment sales by company nationality or company base into each regional market delineated by Dataquest. As elsewhere, joint venture companies are grouped separately in this table regardless of company base. Also, reported sales by the category "other companies" reflect Dataquest's estimates of unsurveyed activity in the thermal nondeposition equipment market. Table 7-2 reports thermal nondeposition equipment sales to each market region by company base. The table also reports the market share for each company grouping within regional markets. As elsewhere, the market shares reported for each company grouping are based on estimated sales to the relevant market by all identified companies. No market shares are reported for other companies because their estimated sales reflect Dataquest estimates of unsurveyed market activity.

Dataquest segments the thermal nondeposition equipment market into two equipment subcategories: diffusion equipment and rapid thermal processing (RTP) equipment (as shown in Table 1-1). Table 7-3 reports equipment sales for these two subcategories within each regional market. Table 7-4 reports equipment sales for these two thermal nondeposition equipment subcategories by company base. The table also reports the market share of company groupings within each subcategory. Once again, the market shares reported in the table are based on estimated sales for identified companies, and no market shares are reported for other companies.

Tables 7-5 through 7-9 report a variety of estimates concerning individual company sales of diffusion and rapid thermal processing equipment. Tables 7-5 and 7-8 present rankings of the top 10 diffusion and RTP producers based on estimated end-user revenue garnered worldwide. These tables also resummarize the market shares of all diffusion and RTP producers by company base for the respective equipment markets. Note that joint venture companies are grouped separately in this market share summary regardless of nationality. Also note that the reported market shares for the various groupings of companies are based on total estimated sales by identified companies. The remaining tables report estimated individual company sales for diffusion and RTP equipment by regional market, including the world. The set of companies included in each table represents a comprehensive list of surveyed companies with relevant product sales to at least one region of the world. Note that if a company does not have sales in a particular region, zero sales are reported for the company in that region. Although this convention populates the tables with a large number of zeros, it also readily distinguishes the companies that did not participate in a particular regional market. Tables 7-6 and 7-7 report individual company sales of vertical and horizontal diffusion equipment separately.

Table 7-1
Sales Revenue from Shipments of Thermal Nondeposition by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
North American Companies						
Americas Market	68.0	47.1	42.9	72.8	135.8	18.9
Japanese Market	11.5	6.6	4.7	6.1	12.1	1.3
European Market	17.6	12.2	26.3	31.9	32.8	16.9
Asia/Pacific Market	13.8	8.1	7.0	9.5	15.2	2.4
Worldwide Market	110.9	74.0	80.9	120.3	195.9	15.3
Japanese Companies						
Americas Market	7.0	6.3	28.9	23.6	40.0	54.6
Japanese Market	159.9	132.0	121.7	180.1	320.5	19.0
European Market	3.8	0	22.1	8.0	38.7	78.6
Asia/Pacific Market	42.1	29.1	62.2	120.9	216.8	50.6
Worldwide Market	212.8	167.4	234.9	332.5	616.0	30.4
European Companies						
Americas Market	7.7	7.5	10.4	13.5	22.3	30.5
Japanese Market	3.2	2.8	2.9	2.7	4.6	9.5
European Market	18.2	13.3	13.3	13.0	20.0	2.4
Asia/Pacific Market	5.6	3.2	3.9	2.6	10.7	17.6
Worldwide Market	34.7	26.8	30.5	31.8	57.6	13.5
Joint Venture Companies						
Americas Market	7.8	9.7	25.9	65.5	46.7	56.4
Japanese Market	0	0	0	0	0	NM
European Market	6.0	4.6	15.3	16.4	10.7	15.6
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	13.8	14.3	41.2	81.9	57.4	42.8
Other Companies						
Americas Market	0	0	0	0	0	NM
Japanese Market	0	0	0	0	0	NM
European Market	0	0	0	0	0	NM
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	0	0	0	0	0	NM

(Continued)

Table 7-1 (Continued)
Sales Revenue from Shipments of Thermal Nondeposition by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
All Companies						
Americas Market	90.5	70.6	108.1	175.4	244.8	28.2
Japanese Market	174.6	141.4	129.3	188.9	337.2	17.9
European Market	45.6	30.1	77.0	69.3	102.2	22.4
Asia/Pacific Market	61.5	40.4	73.1	133.0	242.7	40.9
Worldwide Market	372.2	282.5	387.5	566.5	926.9	25.6

NM = Not meaningful
Source: Dataquest (May 1996)

Table 7-2
Sales Revenue from Shipments of Thermal Nondeposition into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Americas Market						
North American Companies	42.9	72.8	135.8	39.7	41.5	55.5
Japanese Companies	28.9	23.6	40.0	26.7	13.4	16.3
European Companies	10.4	13.5	22.3	9.6	7.7	9.1
Joint Venture Companies	25.9	65.5	46.7	24.0	37.3	19.1
Identified Companies	108.1	175.4	244.8	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	108.1	175.4	244.8			
Japanese Market						
North American Companies	4.7	6.1	12.1	3.6	3.2	3.6
Japanese Companies	121.7	180.1	320.5	94.1	95.3	95.0
European Companies	2.9	2.7	4.6	2.2	1.4	1.4
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	129.3	188.9	337.2	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	129.3	188.9	337.2			
European Market						
North American Companies	26.3	31.9	32.8	34.2	46.1	32.1
Japanese Companies	22.1	8.0	38.7	28.7	11.5	37.9
European Companies	13.3	13.0	20.0	17.3	18.8	19.6
Joint Venture Companies	15.3	16.4	10.7	19.9	23.7	10.5
Identified Companies	77.0	69.3	102.2	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	77.0	69.3	102.2			

(Continued)

Table 7-2 (Continued)
Sales Revenue from Shipments of Thermal Nondeposition into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Market						
North American Companies	7.0	9.5	15.2	9.6	7.1	6.3
Japanese Companies	62.2	120.9	216.8	85.1	90.9	89.3
European Companies	3.9	2.6	10.7	5.3	2.0	4.4
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	73.1	133.0	242.7	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	73.1	133.0	242.7			
Worldwide Market						
North American Companies	80.9	120.3	195.9	20.9	21.2	21.1
Japanese Companies	234.9	332.5	616.0	60.6	58.7	66.5
European Companies	30.5	31.8	57.6	7.9	5.6	6.2
Joint Venture Companies	41.2	81.9	57.4	10.6	14.5	6.2
Identified Companies	387.5	566.5	926.9	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	387.5	566.5	926.9			

NM = Not meaningful
Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 7-3
Sales Revenue from Shipments of Thermal Nondeposition into Each Region by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Diffusion						
Americas Market	73.1	56.1	89.4	142.5	174.9	24.4
Japanese Market	158.7	129.7	116.2	165.2	300.5	17.3
European Market	35.3	22.6	67.9	60.3	77.6	21.7
Asia/Pacific Market	59.3	37.8	68.8	122.4	220.5	38.9
Worldwide Market	326.4	246.2	342.3	490.3	773.4	24.1
Rapid Thermal Processing						
Americas Market	17.4	14.5	18.7	32.9	69.9	41.6
Japanese Market	15.9	11.7	13.1	23.7	36.7	23.3
European Market	10.3	7.5	9.1	9.0	24.7	24.4
Asia/Pacific Market	2.2	2.6	4.3	10.6	22.2	78.2
Worldwide Market	45.8	36.3	45.2	76.2	153.5	35.3
Thermal Nondeposition						
Americas Market	90.5	70.6	108.1	175.4	244.8	28.2
Japanese Market	174.6	141.4	129.3	188.9	337.2	17.9
European Market	45.6	30.1	77.0	69.3	102.2	22.4
Asia/Pacific Market	61.5	40.4	73.1	133.0	242.7	40.9
Worldwide Market	372.2	282.5	387.5	566.5	926.9	25.6

Source: Dataquest (May 1996)

Table 7-4
Worldwide Sales Revenue from Shipments of Thermal Nondeposition by Company Base by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Diffusion						
North American Companies	54.5	81.5	106.1	15.9	16.6	13.7
Japanese Companies	228.0	316.4	593.0	66.6	64.5	76.7
European Companies	18.6	10.5	16.9	5.4	2.1	2.2
Joint Venture Companies	41.2	81.9	57.4	12.0	16.7	7.4
Identified Companies	342.3	490.3	773.4	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	342.3	490.3	773.4			
Rapid Thermal Processing						
North American Companies	26.4	38.8	89.8	58.4	50.9	58.5
Japanese Companies	6.9	16.1	23.0	15.3	21.1	15.0
European Companies	11.9	21.3	40.7	26.3	28.0	26.5
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	45.2	76.2	153.5	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	45.2	76.2	153.5			
Thermal Nondeposition						
North American Companies	80.9	120.3	195.9	20.9	21.2	21.1
Japanese Companies	234.9	332.5	616.0	60.6	58.7	66.5
European Companies	30.5	31.8	57.6	7.9	5.6	6.2
Joint Venture Companies	41.2	81.9	57.4	10.6	14.5	6.2
Identified Companies	387.5	566.5	926.9	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	387.5	566.5	926.9			

NM = Not meaningful
Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 7-5
Top 10 Companies' Sales Revenue from Shipments of Diffusion to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	1	Tokyo Electron Ltd. (including joint ventures)	198.3	333.2	68	43.1
2	2	Kokusai Electric (including joint ventures)	167.9	275.2	64	35.6
3	3	Silicon Valley Group	74.2	102.3	38	13.2
4	4	Koyo Lindberg	16.8	23.1	38	3.0
5	5	ASM International	10.5	16.9	61	2.2
6	6	Ulvac	10.0	13.4	35	1.7
7	7	Shinko Electric	5.4	5.4	1	0.7
8	10	Tystar	0.8	1.8	125	0.2
9	9	Gasonics	0.8	1.3	63	0.2
10	11	Pacific Western	0.7	0.7	0	0.1
		North American Companies	81.5	106.1	30	13.7
		Japanese Companies	316.4	593.0	87	76.7
		European Countries	10.5	16.9	61	2.2
		Joint Venture Companies	81.9	57.4	-30	7.4
		Identified Companies	490.3	773.4	58	100.0
		Other Companies	0	0	0	
		All Companies	490.3	773.4	58	

Note: "Including joint ventures" indicates figures that include joint ventures.
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 7-6
Each Company's Sales Revenue from Shipments of Vertical Diffusion to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	37.6	27.7	73.0	113.1	140.5	39.0
ASM International	4.0	3.2	4.6	2.4	10.2	26.4
Bruce Technologies	0	0	0.5	13.0	26.4	NM
BTU International	5.0	0	0	0	0	-100.0
Disco	0	0	0	0	0	NM
General Signal Thinfilm Company	2.0	0	0	0	0	-100.0
Kokusai Electric	7.0	6.3	28.9	23.6	22.3	33.6
Koyo Lindberg	0	0	0	0	0	NM
Semitherm	3.0	0.9	4.9	4.4	0	-100.0
Shinko Electric	0	0	0	0	0	NM
Silicon Valley Group	11.8	12.7	15.4	37.0	64.7	53.0
Tempress	0	0.3	0.7	0	0	NM
Tokyo Electron Ltd.	0	0	0	0	16.9	NM
Ulvac	0	0	0	0	0	NM
Varian/TEL	4.8	4.3	18.0	32.7	0	-100.0
Total	37.6	27.7	73.0	113.1	140.5	39.0
Japanese Market	109.3	93.1	83.4	142.5	275.2	26.0
ASM International	1.0	0.7	1.2	0.4	1.5	10.7
Bruce Technologies	0	0	0	0	0	NM
BTU International	0	0	0	0	0	NM
Disco	10.0	5.4	2.2	0	0	-100.0
General Signal Thinfilm Company	0	0	0	0	0	NM
Kokusai Electric	31.7	22.1	24.1	29.9	60.3	17.4
Koyo Lindberg	6.7	9.2	6.5	8.3	8.8	7.1
Semitherm	0	0	0	0	0	NM
Shinko Electric	7.4	3.6	4.0	2.7	2.9	-21.0
Silicon Valley Group	0	0	0	0	0	NM
Tempress	0	0	0	0	0	NM
Tokyo Electron Ltd.	48.3	47.7	41.6	95.3	193.1	41.4
Ulvac	4.2	4.4	3.8	5.9	8.6	19.6
Varian/TEL	0	0	0	0	0	NM
Total	109.3	93.1	83.4	142.5	275.2	26.0

(Continued)

Table 7-6 (Continued)
Each Company's Sales Revenue from Shipments of Vertical Diffusion to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
European Market	15.3	8.8	51.5	45.1	66.3	44.3
ASM International	3.0	3.5	5.5	7.7	4.2	8.8
Bruce Technologies	0	0	0	0	4.0	NM
BTU International	1.0	0	0	0	0	-100.0
Disco	0	0	0	0	0	NM
General Signal Thinfilm Company	0	0	0	0	0	NM
Kokusai Electric	3.8	0	22.1	8.0	5.0	7.1
Koyo Lindberg	0	0	0	0	0.9	NM
Semitherm	0	0	0	0.6	0	NM
Shinko Electric	0	0	0	0	0	NM
Silicon Valley Group	4.2	3.8	14.1	21.6	20.0	47.7
Tempress	0	0.7	0.3	0	0	NM
Tokyo Electron Ltd.	0	0	0	0	32.1	NM
Ulvac	0	0	0	0	0	NM
Varian/TEL	3.3	0.8	9.5	7.2	0	-100.0
Total	15.3	8.8	51.5	45.1	66.3	44.3
Asia/Pacific Market	32.5	31.7	62.3	120.9	218.8	61.1
ASM International	2.0	1.0	0.7	0	1.0	-15.9
Bruce Technologies	0	0	0	0	0	NM
BTU International	0	0	0	0	0	NM
Disco	0	0	0	0	0	NM
General Signal Thinfilm Company	0	0	0	0	0	NM
Kokusai Electric	20.0	15.0	31.4	59.1	124.8	58.1
Koyo Lindberg	0	0	0	2.1	5.1	NM
Semitherm	0	0	0	0	0	NM
Shinko Electric	0	0	0	2.7	2.6	NM
Silicon Valley Group	3.1	2.5	2.6	0	1.0	-24.6
Tempress	0	0	0	0	0	NM
Tokyo Electron Ltd.	7.4	13.2	27.6	57.0	84.3	83.7
Ulvac	0	0	0	0	0	NM
Varian/TEL	0	0	0	0	0	NM
Total	32.5	31.7	62.3	120.9	218.8	61.1

(Continued)

Table 7-6 (Continued)
Each Company's Sales Revenue from Shipments of Vertical Diffusion to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	194.7	161.3	270.2	421.5	700.8	37.7
ASM International	10.0	8.4	12.0	10.5	16.9	14.0
Bruce Technologies	0	0	0.5	13.0	30.4	NM
BTU International	6.0	0	0	0	0	-100.0
Disco	10.0	5.4	2.2	0	0	-100.0
General Signal Thinfilm Company	2.0	0	0	0	0	-100.0
Kokusai Electric	62.5	43.4	106.5	120.6	212.4	35.8
Koyo Lindberg	6.7	9.2	6.5	10.4	14.9	22.0
Semitherm	3.0	0.9	4.9	5.0	0	-100.0
Shinko Electric	7.4	3.6	4.0	5.4	5.4	-7.4
Silicon Valley Group	19.1	19.0	32.1	58.6	85.7	45.5
Tempress	0	1.0	1.0	0	0	NM
Tokyo Electron Ltd.	55.7	60.9	69.2	152.3	326.4	55.6
Ulvac	4.2	4.4	3.8	5.9	8.6	19.6
Varian/TEL	8.1	5.1	27.5	39.9	0	-100.0
Total	194.7	161.3	270.2	421.5	700.8	37.7

NM = Not meaningful
Source: Dataquest (May 1996)

Table 7-7
Each Company's Sales Revenue from Shipments of Horizontal Diffusion to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	35.5	28.4	16.4	29.4	34.4	-0.8
Advanced Crystal Sciences Inc.	0	0	0.1	0	0	NM
ASM International	2.5	1.6	0.5	0	0	-100.0
Bruce Technologies	0	5.4	7.4	19.8	20.3	NM
BTU International	6.0	0	0	0	0	-100.0
Centrotherm	1.2	1.3	0.7	0	0	-100.0
ET Systems Engineering	0	0	0	0	0	NM
Gasonics	7.5	3.7	0.8	0	1.3	-35.5
General Signal Thinfilm Company	1.0	0	0	0	0	-100.0
Kokusai Electric	0	0	0	0	0	NM
Koyo Lindberg	0	0	0	0	0	NM
Pacific Western	0.4	0.6	0	0.4	0.3	-6.9
Silicon Valley Group	13.4	15.6	6.7	8.4	10.7	-5.5
Tokyo Electron Ltd.	0	0	0	0	0	NM
Tystar	0.5	0.2	0.2	0.8	1.8	37.7
Ulvac	0	0	0	0	0	NM
Varian/TEL	3.0	0	0	0	0	-100.0
Wellman Furnaces	0	0	0	0	0	NM
Yamato Semico	0	0	0	0	0	NM
Total	35.5	28.4	16.4	29.4	34.4	-0.8
Japanese Market	49.4	36.6	32.8	22.7	25.3	-15.4
Advanced Crystal Sciences Inc.	0	0	0	0	0	NM
ASM International	2.2	1.1	0.2	0	0	-100.0
Bruce Technologies	0	0	0	0	0	NM
BTU International	0	0	0	0	0	NM
Centrotherm	0	0	0	0	0	NM
ET Systems Engineering	0	0.1	0.6	0	0	NM
Gasonics	0	0.7	0	0.8	0	NM
General Signal Thinfilm Company	0	0	0	0	0	NM
Kokusai Electric	5.6	5.3	3.7	5.3	5.3	-1.2
Koyo Lindberg	5.9	8.2	3.4	6.4	8.3	8.8
Pacific Western	0	0	0	0	0	NM
Silicon Valley Group	0	0	0	0	0	NM
Tokyo Electron Ltd.	22.3	10.8	13.9	6.1	6.8	-25.6
Tystar	0	0	0	0	0	NM
Ulvac	12.6	10.1	11.0	4.1	4.9	-21.2

(Continued)

Table 7-7 (Continued)
Each Company's Sales Revenue from Shipments of Horizontal Diffusion to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Varian/TEL	0	0	0	0	0	NM
Wellman Furnaces	0	0	0	0	0	NM
Yamato Semico	0.8	0.3	0	0	0	-100.0
Total	49.4	36.6	32.8	22.7	25.3	-15.4
European Market	20.0	13.8	16.4	15.2	11.3	-13.3
Advanced Crystal Sciences Inc.	0	0	0	0	0	NM
ASM International	5.0	3.3	1.4	0	0	-100.0
Bruce Technologies	0	1.8	5.8	9.2	6.7	NM
BTU International	3.0	0	0	0	0	-100.0
Centrotherm	4.0	2.0	2.8	0	0	-100.0
ET Systems Engineering	0	0	0	0	0	NM
Gasonics	0	0	0	0	0	NM
General Signal Thinfilm Company	0	0	0	0	0	NM
Kokusai Electric	0	0	0	0	0	NM
Koyo Lindberg	0	0	0	0	0	NM
Pacific Western	0	0	0.3	0	0.1	NM
Silicon Valley Group	4.8	4.7	6.1	6.0	4.5	-1.6
Tokyo Electron Ltd.	0	0	0	0	0	NM
Tystar	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian/TEL	2.7	2.0	0	0	0	-100.0
Wellman Furnaces	0.5	0	0	0	0	-100.0
Yamato Semico	0	0	0	0	0	NM
Total	20.0	13.8	16.4	15.2	11.3	-13.3
Asia/Pacific Market	26.8	6.1	6.5	1.5	1.7	-49.8
Advanced Crystal Sciences Inc.	0	0	0	0	0	NM
ASM International	2.0	2.2	1.0	0	0	-100.0
Bruce Technologies	0	0	0	0	0	NM
BTU International	4.0	0	0	0	0	-100.0
Centrotherm	1.5	0	0	0	0	-100.0
ET Systems Engineering	0	0	0	0	0	NM
Gasonics	1.2	0	0	0	0	-100.0
General Signal Thinfilm Company	0	0	0	0	0	NM
Kokusai Electric	0	0	0	0	0	NM
Koyo Lindberg	0	0	0	0	0	NM

(Continued)

Table 7-7 (Continued)
Each Company's Sales Revenue from Shipments of Horizontal Diffusion to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Pacific Western	0	0	1.2	0.3	0.3	NM
Silicon Valley Group	3.4	3.0	1.1	1.2	1.4	-19.9
Tokyo Electron Ltd.	14.7	0.9	3.2	0	0	-100.0
Tystar	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian/TEL	0	0	0	0	0	NM
Wellman Furnaces	0	0	0	0	0	NM
Yamato Semico	0	0	0	0	0	NM
Total	26.8	6.1	6.5	1.5	1.7	-49.8
Worldwide Market	131.7	84.9	72.1	68.8	72.7	-13.8
Advanced Crystal Sciences Inc.	0	0	0.1	0	0	NM
ASM International	11.7	8.2	3.1	0	0	-100.0
Bruce Technologies	0	7.2	13.2	29.0	27.0	NM
BTU International	13.0	0	0	0	0	-100.0
Centrotherm	6.7	3.3	3.5	0	0	-100.0
ET Systems Engineering	0	0.1	0.6	0	0	NM
Gasonics	8.7	4.4	0.8	0.8	1.3	-37.8
General Signal Thinfilm Company	1.0	0	0	0	0	-100.0
Kokusai Electric	5.6	5.3	3.7	5.3	5.3	-1.2
Koyo Lindberg	5.9	8.2	3.4	6.4	8.3	8.8
Pacific Western	0.4	0.6	1.5	0.7	0.7	15.0
Silicon Valley Group	21.6	23.3	13.9	15.6	16.6	-6.4
Tokyo Electron Ltd.	37.0	11.7	17.1	6.1	6.8	-34.5
Tystar	0.5	0.2	0.2	0.8	1.8	37.7
Ulvac	12.6	10.1	11.0	4.1	4.9	-21.2
Varian/TEL	5.7	2.0	0	0	0	-100.0
Wellman Furnaces	0.5	0	0	0	0	-100.0
Yamato Semico	0.8	0.3	0	0	0	-100.0
Total	131.7	84.9	72.1	68.8	72.7	-13.8

NM = Not meaningful
Source: Dataquest (May 1996)

Table 7-8
Top Nine Companies' Sales Revenue from Shipments of Rapid Thermal Processing to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	1	AG Associates	36.4	61.2	68	39.8
2	2	AST Electronic GmbH	18.7	37.3	99	24.3
3	9	Applied Materials	0	23.2	NM	15.1
4	3	Dainippon Screen	14.6	21.2	45	13.8
5	4	High Temperature Engineering	2.4	5.5	129	3.6
6	5	Jipelec	1.8	2.4	33	1.6
7	6	AET Thermal	0.8	1.0	25	0.7
8	7	Samco	0.8	1.0	25	0.6
9	8	Koyo Lindberg	0.7	0.8	8	0.5
		North American Companies	38.8	89.8	131	58.5
		Japanese Companies	16.1	23.0	43	15.0
		European Countries	21.3	40.7	91	26.5
		Joint Venture Companies	0	0	0	0
		Identified Companies	76.2	153.5	101	100.0
		Other Companies	0	0	0	
		All Companies	76.2	153.5	101	

NM = Not meaningful
Notes: "Including joint ventures" indicates figures that include joint ventures.
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 7-9
Each Company's Sales Revenue from Shipments of Rapid Thermal Processing to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	17.4	14.5	18.7	32.9	69.9	41.6
AET Thermal	0	0	0.6	0.7	0.9	NM
AG Associates	11.9	8.0	11.3	20.4	37.8	33.5
Applied Materials	0	0	0	0	16.2	NM
AST Electronic GmbH	0	1.4	4.0	10.4	11.2	NM
Dainippon Screen	0	0	0	0	0.8	NM
High Temperature Engineering	0.5	0.6	0.9	1.4	3.0	56.5
Jipelec	0	0	0	0	0	NM
Kokusai Electric	0	0	0	0	0	NM
Koyo Lindberg	0	0	0	0	0	NM
Nanosil	0.3	0	0	0	0	-100.0
Peak Systems	4.0	4.5	1.9	0	0	-100.0
Process Products	0.7	0	0	0	0	-100.0
Samco	0	0	0	0	0	NM
Total	17.4	14.5	18.7	32.9	69.9	41.6
Japanese Market	15.9	11.7	13.1	23.7	36.7	23.3
AET Thermal	0	0	0.2	0	0	NM
AG Associates	9.3	2.5	3.8	5.0	9.2	-0.3
Applied Materials	0	0	0	0	2.3	NM
AST Electronic GmbH	0	1.0	1.3	2.3	3.1	NM
Dainippon Screen	3.5	2.8	4.6	14.6	19.8	54.2
High Temperature Engineering	0.2	0.4	0	0.3	0.6	31.6
Jipelec	0	0	0	0	0	NM
Kokusai Electric	0.6	0.6	0	0	0	-100.0
Koyo Lindberg	0.3	0.5	1.4	0.7	0.8	26.0
Nanosil	0	0	0	0	0	NM
Peak Systems	2.0	3.0	0.9	0	0	-100.0
Process Products	0	0	0	0	0	NM
Samco	0	0.9	0.9	0.8	1.0	NM
Total	15.9	11.7	13.1	23.7	36.7	23.3
European Market	10.3	7.5	9.1	9.0	24.7	24.4
AET Thermal	0.6	0.9	0	0.1	0	-100.0
AG Associates	3.2	2.0	4.9	3.0	5.1	12.4
Applied Materials	0	0	0	0	2.3	NM
AST Electronic GmbH	4.1	2.3	2.7	4.3	14.7	37.6

(Continued)

Table 7-9 (Continued)
Each Company's Sales Revenue from Shipments of Rapid Thermal Processing to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Dainippon Screen	0	0	0	0	0.6	NM
High Temperature Engineering	0	0	0.3	0.7	0.8	NM
Jipelec	1.0	1.3	0.9	0.9	1.1	2.4
Kokusai Electric	0	0	0	0	0	NM
Koyo Lindberg	0	0	0	0	0	NM
Nanosil	0	0	0	0	0	NM
Peak Systems	1.0	1.0	0.3	0	0	-100.0
Process Products	0.4	0	0	0	0	-100.0
Samco	0	0	0	0	0	NM
Total	10.3	7.5	9.1	9.0	24.7	24.4
Asia/Pacific Market	2.2	2.6	4.3	10.6	22.2	78.2
AET Thermal	0.1	0	0.3	0	0.1	0
AG Associates	0	1.0	1.7	8.0	9.1	NM
Applied Materials	0	0	0	0	2.3	NM
AST Electronic GmbH	0	0	1.3	1.7	8.3	NM
Dainippon Screen	0	0	0	0	0	NM
High Temperature Engineering	0.1	0	0	0	1.1	82.1
Jipelec	0	0	0.6	0.9	1.3	NM
Kokusai Electric	0	0	0	0	0	NM
Koyo Lindberg	0	0	0	0	0	NM
Nanosil	0	0	0	0	0	NM
Peak Systems	1.6	1.6	0.4	0	0	-100.0
Process Products	0.4	0	0	0	0	-100.0
Samco	0	0	0	0	0	NM
Total	2.2	2.6	4.3	10.6	22.2	78.2
Worldwide Market	45.8	36.3	45.2	76.2	153.5	35.3
AET Thermal	0.7	0.9	1.1	0.8	1.0	9.3
AG Associates	24.4	13.5	21.7	36.4	61.2	25.8
Applied Materials	0	0	0	0	23.2	NM
AST Electronic GmbH	4.1	4.7	9.3	18.7	37.3	73.7
Dainippon Screen	3.5	2.8	4.6	14.6	21.2	56.9
High Temperature Engineering	0.8	1.0	1.2	2.4	5.5	61.9
Jipelec	1.0	1.3	1.5	1.8	2.4	24.5
Kokusai Electric	0.6	0.6	0	0	0	-100.0
Koyo Lindberg	0.3	0.5	1.4	0.7	0.8	26.0

(Continued)

Table 7-9 (Continued)
Each Company's Sales Revenue from Shipments of Rapid Thermal Processing to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Nanosil	0.3	0	0	0	0	-100.0
Peak Systems	8.6	10.1	3.5	0	0	-100.0
Process Products	1.5	0	0	0	0	-100.0
Samco	0	0.9	0.9	0.8	1.0	NM
Total	45.8	36.3	45.2	76.2	153.5	35.3

NM = Not meaningful
Source: Dataquest (May 1996)

Chapter 8
Ion Implantation Equipment

This chapter presents tables for the ion implantation equipment market. The chapter consists of 11 tables that present a variety of estimates relevant to equipment company sales of ion implantation equipment. Table 8-1 reports estimated ion implantation equipment sales by company nationality or company base into each regional market delineated by Dataquest. As elsewhere, joint venture companies are grouped separately in this table regardless of company base. Also, reported sales by the category "other companies" reflect Dataquest estimates of unsurveyed activity in the ion implantation equipment market. Table 8-2 reports ion implantation equipment sales to each market region by company base. The table also reports the market share for each company grouping within regional markets. As elsewhere, the market shares reported for each company grouping are based on estimated sales to the relevant market by all identified companies. No market shares are reported for other companies because their estimated sales reflect Dataquest estimates of unsurveyed market activity.

Dataquest segments the ion implantation equipment market into three equipment subcategories: medium current, high current, and high voltage implanters (as shown in Table 1-1). Table 8-3 reports equipment sales for each of these implanter subcategories categories within each regional market. Table 8-4 reports equipment sales for each of the implantation equipment subcategories by company base. The table also reports the market share of company groupings within each subcategory. Once again, the market shares reported in the table are based on estimated sales for identified companies, and no market shares are reported for other companies.

Tables 8-5 through 8-11 report a variety of estimates concerning individual company sales of ion implanter equipment. Table 8-5 presents a ranking of the top ion implanter producers based on estimated end-user revenue garnered worldwide. This table also resummarizes the market shares of all ion implanter producers by company base for the ion implant equipment market. Note that joint venture companies are grouped separately in this market share summary regardless of nationality. Also note that the reported market shares for the various groupings of companies are based on total estimated sales by identified companies. Tables 8-6 through 8-11 report estimated individual company sales for specific ion implanter equipment by regional market, including the world. The set of companies included in each table represents a comprehensive list of surveyed companies with relevant product sales to at least one region of the world. Note that if a company does not have sales in a particular region, zero sales are reported for the company in that region. Although this convention populates the tables with a large number of zeros, it also readily distinguishes the companies that did not participate in a particular regional market. Tables 8-7, 8-9, and 8-11 report estimated individual company units sold of middle-current, high-current and high-voltage implanters, respectively.

Table 8-1
Sales Revenue from Shipments of Ion Implantation by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
North American Companies						
Americas Market	55.0	62.4	86.6	167.2	291.3	51.7
Japanese Market	58.7	36.9	33.9	49.7	112.7	17.7
European Market	41.7	36.9	55.2	108.3	157.7	39.5
Asia/Pacific Market	36.2	37.7	67.1	130.0	261.3	63.9
Worldwide Market	191.6	173.9	242.8	455.2	823.0	44.0
Japanese Companies						
Americas Market	2.8	0	0	3.8	0	-100.0
Japanese Market	53.9	28.8	38.3	55.9	72.9	7.8
European Market	1.8	0	0	0	2.1	4.0
Asia/Pacific Market	15.2	1.0	3.7	7.6	9.9	-10.1
Worldwide Market	73.7	29.8	42.0	67.3	85.0	3.6
European Companies						
Americas Market	0	0	0	0	0	NM
Japanese Market	0	0	0	0	0	NM
European Market	0	0	0	0	0	NM
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	0	0	0	0	0	NM
Joint Venture Companies						
Americas Market	0	0	0	0	0	NM
Japanese Market	88.1	59.2	74.3	136.9	145.3	13.3
European Market	0	0	0	0	0	NM
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	88.1	59.2	74.3	136.9	145.3	13.3
Other Companies						
Americas Market	0	0	0	0	0	NM
Japanese Market	0	0	0	0	0	NM
European Market	0	0	0	0	0	NM
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	0	0	0	0	0	NM

(Continued)

Table 8-1 (Continued)
Sales Revenue from Shipments of Ion Implantation by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
All Companies						
Americas Market	57.8	62.4	86.6	171.0	291.3	49.8
Japanese Market	200.7	124.9	146.5	242.5	330.9	13.3
European Market	43.5	36.9	55.2	108.3	159.8	38.4
Asia/Pacific Market	51.4	38.7	70.8	137.6	271.2	51.6
Worldwide Market	353.4	262.9	359.1	659.4	1,053.2	31.4

NM = Not meaningful
Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 8-2
Sales Revenue from Shipments of Ion Implantation into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Americas Market						
North American Companies	86.6	167.2	291.3	100.0	97.8	100.0
Japanese Companies	0	3.8	0	0	2.2	NM
European Companies	0	0	0	0	0	NM
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	86.6	171.0	291.3	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	86.6	171.0	291.3			
Japanese Market						
North American Companies	33.9	49.7	112.7	23.1	20.5	34.1
Japanese Companies	38.3	55.9	72.9	26.1	23.0	22.0
European Companies	0	0	0	0	0	NM
Joint Venture Companies	74.3	136.9	145.3	50.7	56.5	43.9
Identified Companies	146.5	242.5	330.9	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	146.5	242.5	330.9			
European Market						
North American Companies	55.2	108.3	157.7	100.0	100.0	98.7
Japanese Companies	0	0	2.1	0	0	1.3
European Companies	0	0	0	0	0	NM
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	55.2	108.3	159.8	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	55.2	108.3	159.8			

(Continued)

Table 8-2 (Continued)
Sales Revenue from Shipments of Ion Implantation into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Market						
North American Companies	67.1	130.0	261.3	94.8	94.5	96.3
Japanese Companies	3.7	7.6	9.9	5.2	5.5	3.7
European Companies	0	0	0	0	0	NM
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	70.8	137.6	271.2	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	70.8	137.6	271.2			
Worldwide Market						
North American Companies	242.8	455.2	823.0	67.6	69.0	78.1
Japanese Companies	42.0	67.3	85.0	11.7	10.2	8.1
European Companies	0	0	0	0	0	NM
Joint Venture Companies	74.3	136.9	145.3	20.7	20.8	13.8
Identified Companies	359.1	659.4	1,053.2	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	359.1	659.4	1,053.2			

NM = Not meaningful
Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 8-3
Sales Revenue from Shipments of Ion Implantation into Each Region by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Medium-Current Implanter						
Americas Market	16.3	10.3	26.5	58.4	106.7	60.0
Japanese Market	59.6	48.8	45.9	101.4	116.2	18.2
European Market	13.7	7.7	15.5	38.1	59.7	44.5
Asia/Pacific Market	17.9	16.6	20.0	43.7	101.1	54.2
Worldwide Market	107.5	83.4	107.9	241.6	383.8	37.5
High-Current Implanter						
Americas Market	38.6	44.9	57.1	112.6	160.8	42.9
Japanese Market	129.7	70.3	95.0	133.9	176.5	8.0
European Market	26.5	26.5	36.8	70.2	85.5	34.0
Asia/Pacific Market	33.5	22.1	44.2	74.5	127.5	39.7
Worldwide Market	228.3	163.8	233.1	391.2	550.3	24.6
High-Voltage Implanter						
Americas Market	2.9	7.2	3.0	0	23.8	69.3
Japanese Market	11.4	5.8	5.6	7.2	38.2	35.3
European Market	3.3	2.7	2.9	0	14.6	45.0
Asia/Pacific Market	0	0	6.6	19.4	42.6	NM
Worldwide Market	17.6	15.7	18.1	26.6	119.2	61.3
Ion Implantation						
Americas Market	57.8	62.4	86.6	171.0	291.3	49.8
Japanese Market	200.7	124.9	146.5	242.5	330.9	13.3
European Market	43.5	36.9	55.2	108.3	159.8	38.4
Asia/Pacific Market	51.4	38.7	70.8	137.6	271.2	51.6
Worldwide Market	353.4	262.9	359.1	659.4	1,053.2	31.4

NM = Not meaningful
Source: Dataquest (May 1996)

Table 8-4
Worldwide Sales Revenue from Shipments of Ion Implantation by Company Base by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Medium-Current Implanter						
North American Companies	65.1	140.4	299.3	60.3	58.1	78.0
Japanese Companies	30.7	67.3	82.3	28.5	27.9	21.4
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	12.1	33.9	2.2	11.2	14.0	0.6
Identified Companies	107.9	241.6	383.8	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	107.9	241.6	383.8			
High-Current Implanter						
North American Companies	162.3	292.2	438.8	69.6	74.7	79.7
Japanese Companies	8.6	0	2.7	3.7	NM	0.5
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	62.2	99.0	108.8	26.7	25.3	19.8
Identified Companies	233.1	391.2	550.3	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	233.1	391.2	550.3			
High-Voltage Implanter						
North American Companies	15.4	22.6	84.9	85.1	85.0	71.2
Japanese Companies	2.7	0	0	14.9	NM	NM
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	0	4.0	34.3	NM	15.0	28.8
Identified Companies	18.1	26.6	119.2	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	18.1	26.6	119.2			

(Continued)

Table 8-4 (Continued)
Worldwide Sales Revenue from Shipments of Ion Implantation by Company Base by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Ion Implantation						
North American Companies	242.8	455.2	823.0	67.6	69.0	78.1
Japanese Companies	42.0	67.3	85.0	11.7	10.2	8.1
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	74.3	136.9	145.3	20.7	20.8	13.8
Identified Companies	359.1	659.4	1,053.2	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	359.1	659.4	1,053.2			

NM = Not meaningful
Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 8-5
Top Six Companies' Sales Revenue from Shipments of Ion Implantation to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	2	Eaton (including joint ventures)	227.2	430.0	89	40.8
2	1	Varian (including joint ventures)	237.5	344.3	45	32.7
3	3	Applied Materials	104.8	154.6	48	14.7
4	4	Nissin Electric	35.8	49.4	38	4.7
5	6	Genus	22.6	39.4	74	3.7
6	5	Ulvac	31.5	35.6	13	3.4
		North American Companies	455.2	823.0	81	78.1
		Japanese Companies	67.3	85.0	26	8.1
		European Countries	0	0	0	0
		Joint Venture Companies	136.9	145.3	6	13.8
		Identified Companies	659.4	1,053.12	60	100.0
		Other Companies	0	0	0	
		All Companies	659.4	1,053.2	60	

Notes: "Including joint ventures" indicates figures that include joint ventures.
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 8-6
Each Company's Sales Revenue from Shipments of Medium-Current Implanters to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	16.3	10.3	26.5	58.4	106.7	60.0
Eaton	4.4	0.7	8.4	17.8	35.5	68.5
Nissin Electric	2.8	0	0	3.8	0	-100.0
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian	9.1	9.6	18.1	36.8	71.2	67.2
Total	16.3	10.3	26.5	58.4	106.7	60.0
Japanese Market	59.6	48.8	45.9	101.4	116.2	18.2
Nissin Electric	18.4	18.4	14.1	24.4	34.6	17.1
Sumitomo/Eaton Nova	0	0	0	0	2.2	NM
TEL/Varian	11.7	17.0	12.1	33.9	0	-100.0
Ulvac	11.1	5.5	12.9	31.5	35.6	33.8
Varian	18.4	7.9	6.8	11.6	43.8	24.2
Total	59.6	48.8	45.9	101.4	116.2	18.2
European Market	13.7	7.7	15.5	38.1	59.7	44.5
Eaton	3.7	2.7	9.5	14.7	27.4	65.0
Nissin Electric	1.8	0	0	0	2.1	4.0
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian	8.2	5.0	6.0	23.4	30.2	38.5
Total	13.7	7.7	15.5	38.1	59.7	44.5
Asia/Pacific Market	17.9	16.6	20.0	43.7	101.1	54.2
Eaton	4.5	7.6	3.2	0	7.4	13.2
Nissin Electric	5.0	1.0	3.7	7.6	9.9	18.7
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian	8.4	8.0	13.1	36.1	83.8	77.7
Total	17.9	16.6	20.0	43.7	101.1	54.2

(Continued)

Table 8-6 (Continued)
Each Company's Sales Revenue from Shipments of Medium-Current Implanters to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	107.5	83.4	107.9	241.6	383.8	37.5
Eaton	12.6	11.0	21.1	32.5	70.3	53.7
Nissin Electric	28.0	19.4	17.8	35.8	46.7	13.6
Sumitomo/Eaton Nova	0	0	0	0	2.2	NM
TEL/Varian	11.7	17.0	12.1	33.9	0	-100.0
Ulvac	11.1	5.5	12.9	31.5	35.6	33.8
Varian	44.1	30.5	44.0	107.9	229.0	51.0
Total	107.5	83.4	107.9	241.6	383.8	37.5

NM = Not meaningful
Source: Dataquest (May 1996)

Table 8-7
Each Company's Unit Shipments of Medium-Current Implanters to the World (Units)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	14	6	18	32	51	38.2
Nissin Electric	2	0	0	1	0	-100.0
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian	7	5	11	19	33	47.4
Total	14	6	18	32	51	38.2
Japanese Market	46	34	32	64	69	10.7
Nissin Electric	17	13	11	16	20	4.1
Sumitomo/Eaton Nova	0	0	0	0	1	NM
TEL/Varian	7	11	6	16	0	-100.0
Ulvac	11	5	10	23	25	22.8
Varian	11	5	5	9	23	20.2
Total	46	34	32	64	69	10.7
European Market	11	6	13	23	34	32.6
Eaton	4	3	9	10	18	45.6
Nissin Electric	2	0	0	0	1	-15.9
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian	5	3	4	13	15	31.6
Total	11	6	13	23	34	32.6
Asia/Pacific Market	18	15	15	26	54	31.6
Eaton	5	8	3	0	5	0
Nissin Electric	5	1	3	5	5	0
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian	8	6	9	21	44	53.1
Total	18	15	15	26	54	31.6

(Continued)

Table 8-7 (Continued)
Each Company's Unit Shipments of Medium-Current Implanters to the World (Units)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	89	61	78	145	208	23.6
Eaton	14	12	19	22	41	30.8
Nissin Electric	26	14	14	22	26	0
Sumitomo/Eaton Nova	0	0	0	0	1	NM
TEL/Varian	7	11	6	16	0	-100.0
Ulvac	11	5	10	23	25	22.8
Varian	31	19	29	62	115	38.8
Total	89	61	78	145	208	23.6

NM = Not meaningful
Source: Dataquest (May 1996)

Table 8-8
Each Company's Sales Revenue from Shipments of High-Current Implanters to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	38.6	44.9	57.1	112.6	160.8	42.9
Applied Materials	12.0	15.0	25.5	40.9	55.8	46.8
Eaton	18.5	15.3	16.7	48.7	67.8	38.4
Hitachi	0	0	0	0	0	NM
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Varian	8.1	14.6	14.9	23.0	37.2	46.4
Total	38.6	44.9	57.1	112.6	160.8	42.9
Japanese Market	129.7	70.3	95.0	133.9	176.5	8.0
Applied Materials	12.7	15.0	24.2	33.0	49.6	40.6
Hitachi	10.2	4.9	2.7	0	0	-100.0
Nissin Electric	11.2	0	5.9	0	2.7	-29.9
Sumitomo/Eaton Nova	45.7	18.6	47.0	86.4	108.8	24.2
TEL/Varian	30.7	23.6	15.2	12.6	0	-100.0
Varian	19.2	8.2	0	1.9	15.4	-5.4
Total	129.7	70.3	95.0	133.9	176.5	8.0
European Market	26.5	26.5	36.8	70.2	85.5	34.0
Applied Materials	9.2	7.5	12.4	28.0	41.1	45.4
Eaton	10.5	9.8	11.2	22.8	35.3	35.4
Hitachi	0	0	0	0	0	NM
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Varian	6.8	9.2	13.2	19.4	9.1	7.6
Total	26.5	26.5	36.8	70.2	85.5	34.0
Asia/Pacific Market	33.5	22.1	44.2	74.5	127.5	39.7
Applied Materials	0	0	0	2.9	8.1	NM
Eaton	11.6	11.5	20.9	32.8	65.8	54.3
Hitachi	10.2	0	0	0	0	-100.0
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Varian	11.7	10.6	23.3	38.8	53.6	46.3
Total	33.5	22.1	44.2	74.5	127.5	39.7

(Continued)

Table 8-8 (Continued)
Each Company's Sales Revenue from Shipments of High-Current Implanters to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	228.3	163.8	233.1	391.2	550.3	24.6
Applied Materials	33.9	37.5	62.1	104.8	154.6	46.1
Eaton	40.6	36.6	48.8	104.3	168.9	42.8
Hitachi	20.4	4.9	2.7	0	0	-100.0
Nissin Electric	11.2	0	5.9	0	2.7	-29.9
Sumitomo/Eaton Nova	45.7	18.6	47.0	86.4	108.8	24.2
TEL/Varian	30.7	23.6	15.2	12.6	0	-100.0
Varian	45.8	42.6	51.4	83.1	115.3	26.0
Total	228.3	163.8	233.1	391.2	550.3	24.6

NM = Not meaningful
Source: Dataquest (May 1996)

Table 8-9
Each Company's Unit Shipments of High-Current Implanters to the World (Units)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	18	21	25	45	63	36.8
Applied Materials	5	6	9	14	20	41.4
Eaton	9	9	10	22	27	31.6
Hitachi	0	0	0	0	0	NM
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Varian	4	6	6	9	16	41.4
Total	18	21	25	45	63	36.8
Japanese Market	66	29	37	47	61	-2.0
Applied Materials	5	6	9	11	17	35.8
Hitachi	6	2	1	0	0	-100.0
Nissin Electric	6	0	3	0	1	-36.1
Sumitomo/Eaton Nova	23	10	19	31	37	12.6
TEL/Varian	16	8	5	4	0	-100.0
Varian	10	3	0	1	6	-12.0
Total	66	29	37	47	61	-2.0
European Market	14	12	18	30	35	25.7
Applied Materials	4	3	5	11	15	39.2
Eaton	7	5	7	11	16	23.0
Hitachi	0	0	0	0	0	NM
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Varian	3	4	6	8	4	7.5
Total	14	12	18	30	35	25.7
Asia/Pacific Market	19	12	22	34	55	30.4
Applied Materials	0	0	0	1	3	NM
Eaton	7	7	11	15	29	42.7
Hitachi	6	0	0	0	0	-100.0
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
TEL/Varian	0	0	0	0	0	NM
Varian	6	5	11	18	23	39.9
Total	19	12	22	34	55	30.4

(Continued)

Table 8-9 (Continued)
Each Company's Unit Shipments of High-Current Implanters to the World (Units)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	117	74	102	156	214	16.3
Applied Materials	14	15	23	37	55	40.8
Eaton	23	21	28	48	72	33.0
Hitachi	12	2	1	0	0	-100.0
Nissin Electric	6	0	3	0	1	-36.1
Sumitomo/Eaton Nova	23	10	19	31	37	12.6
TEL/Varian	16	8	5	4	0	-100.0
Varian	23	18	23	36	49	20.8
Total	117	74	102	156	214	16.3

NM = Not meaningful
Source: Dataquest (May 1996)

Table 8-10
Each Company's Sales Revenue from Shipments of High-Voltage Implanters to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	2.9	7.2	3.0	0	23.8	69.3
Eaton	0	7.2	3.0	0	17.2	NM
Genus	2.9	0	0	0	6.6	22.8
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
Total	2.9	7.2	3.0	0	23.8	69.3
Japanese Market	11.4	5.8	5.6	7.2	38.2	35.3
Genus	8.4	5.8	2.9	3.2	3.9	-17.5
Nissin Electric	3.0	0	2.7	0	0	-100.0
Sumitomo/Eaton Nova	0	0	0	4.0	34.3	NM
Total	11.4	5.8	5.6	7.2	38.2	35.3
European Market	3.3	2.7	2.9	0	14.6	45.0
Eaton	3.3	0	0	0	11.3	36.0
Genus	0	2.7	2.9	0	3.3	NM
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
Total	3.3	2.7	2.9	0	14.6	45.0
Asia/Pacific Market	0	0	6.6	19.4	42.6	NM
Eaton	0	0	0	0	17.0	NM
Genus	0	0	6.6	19.4	25.6	NM
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
Total	0	0	6.6	19.4	42.6	NM
Worldwide Market	17.6	15.7	18.1	26.6	119.2	61.3
Eaton	3.3	7.2	3.0	0	45.5	92.7
Genus	11.3	8.5	12.4	22.6	39.4	36.6
Nissin Electric	3.0	0	2.7	0	0	-100.0
Sumitomo/Eaton Nova	0	0	0	4.0	34.3	NM
Total	17.6	15.7	18.1	26.6	119.2	61.3

NM = Not meaningful
Source: Dataquest (May 1996)

Table 8-11
Each Company's Unit Shipments of High-Voltage Implanters to the World (Units)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	1	2	1	0	7	62.7
Eaton	0	2	1	0	5	NM
Genus	1	0	0	0	2	18.9
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
Total	1	2	1	0	7	62.7
Japanese Market	4	2	2	2	9	22.5
Genus	3	2	1	1	1	-24.0
Nissin Electric	1	0	1	0	0	-100.0
Sumitomo/Eaton Nova	0	0	0	1	8	NM
Total	4	2	2	2	9	22.5
European Market	1	1	1	0	5	49.5
Eaton	1	0	0	0	4	41.4
Genus	0	1	1	0	1	NM
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
Total	1	1	1	0	5	49.5
Asia/Pacific Market	0	0	2	6	13	NM
Eaton	0	0	0	0	5	NM
Genus	0	0	2	6	8	NM
Nissin Electric	0	0	0	0	0	NM
Sumitomo/Eaton Nova	0	0	0	0	0	NM
Total	0	0	2	6	13	NM
Worldwide Market	6	5	6	8	34	54.3
Eaton	1	2	1	0	14	93.4
Genus	4	3	4	7	12	31.6
Nissin Electric	1	0	1	0	0	-100.0
Sumitomo/Eaton Nova	0	0	0	1	8	NM
Total	6	5	6	8	34	54.3

NM = Not meaningful
Source: Dataquest (May 1996)

Chapter 9
Process Control Equipment

This chapter presents tables for the process control equipment market. The chapter consists of 11 tables that present a variety of estimates relevant to equipment company sales of process control equipment. Table 9-1 reports estimated process control equipment sales by company nationality or company base into each regional market delineated by Dataquest. As elsewhere, joint venture companies are grouped separately in this table regardless of company base. Also, reported sales by the category "other companies" reflect Dataquest estimates of unsurveyed activity in the process control equipment market. Table 9-2 reports process control equipment sales to each market region by company base. The table also reports the market share for each company grouping within regional markets. As elsewhere, the market shares reported for each company grouping are based on estimated sales to the relevant market by all identified companies. No market shares are reported for other companies because their estimated sales reflect Dataquest estimates of unsurveyed market activity.

Dataquest segments the process control equipment market into eight equipment subcategories (as shown in Table 1-1). Table 9-3 reports equipment sales for each of these eight subcategories within each regional market. Table 9-4 reports equipment sales for each of the eight process control equipment subcategories by company base. The table also reports the market share of company groupings within each subcategory. Once again, the market shares reported in the table are based on estimated sales for identified companies, and no market shares are reported for other companies.

Tables 9-5 through 9-11 report estimated individual company sales for seven of the eight process control equipment subcategories. No individual company data is reported for the category "other process control" because the segment is not surveyed and all reported figures reflect Dataquest's estimates. Each of the tables concerns a specific process control equipment subcategory. Each table reports the estimated sales of all surveyed companies known to sell equipment in the relevant equipment subcategory. The set of companies included in each table represents a comprehensive list of surveyed companies with relevant product sales to at least one region of the world. Within each table, estimated company sales are reported for each regional market as well as for the world overall. If a company does not have sales in a particular region, zero sales are reported for the company in that region. Although this convention populates the tables with a large number of zeros, it also readily distinguishes the companies that did not participate in a particular regional market.

Table 9-1
Sales Revenue from Shipments of Process Control by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
North American Companies						
Americas Market	123.5	134.9	164.3	270.2	386.9	33.1
Japanese Market	85.6	64.4	86.0	157.6	313.1	38.3
European Market	44.1	45.5	63.4	91.6	141.7	33.9
Asia/Pacific Market	36.8	44.4	74.8	142.9	255.3	62.3
Worldwide Market	290.0	289.2	388.5	662.2	1,096.9	39.5
Japanese Companies						
Americas Market	17.2	20.4	20.6	29.3	68.7	41.4
Japanese Market	140.5	82.3	83.3	167.3	253.8	15.9
European Market	7.8	5.4	3.3	8.3	38.2	48.7
Asia/Pacific Market	20.6	16.0	16.4	58.2	150.8	64.5
Worldwide Market	186.1	124.1	123.6	263.1	511.5	28.8
European Companies						
Americas Market	4.2	5.3	7.9	23.8	21.5	50.4
Japanese Market	0	2.0	1.1	6.8	10.0	NM
European Market	16.7	16.5	4.1	13.1	25.2	10.9
Asia/Pacific Market	2.6	1.5	1.3	10.9	10.9	43.7
Worldwide Market	23.4	25.3	14.4	54.5	67.5	30.3
Joint Venture Companies						
Americas Market	0	0	0	0	0	NM
Japanese Market	0	0	0	0	0	NM
European Market	0	0	0	0	0	NM
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	0	0	0	0	0	NM
Other Companies						
Americas Market	38.1	31.2	33.0	37.0	47.9	5.9
Japanese Market	81.1	52.2	51.5	53.4	75.0	-1.9
European Market	3.8	5.1	6.9	4.6	7.6	18.9
Asia/Pacific Market	9.4	15.2	25.7	28.4	47.1	49.6
Worldwide Market	132.4	103.7	117.1	123.4	177.6	7.6

(Continued)

Table 9-1 (Continued)
Sales Revenue from Shipments of Process Control by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
All Companies						
Americas Market	183.0	191.8	225.8	360.2	525.0	30.2
Japanese Market	307.2	200.9	222.0	385.0	651.9	20.7
European Market	72.4	72.5	77.7	117.6	212.6	30.9
Asia/Pacific Market	69.4	77.1	118.1	240.4	464.1	60.8
Worldwide Market	631.9	542.3	643.6	1,103.3	1,853.5	30.9

NM = Not meaningful

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.

Source: Dataquest (May 1996)

Table 9-2
Sales Revenue from Shipments of Process Control into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Americas Market						
North American Companies	164.3	270.2	386.9	85.2	83.6	81.1
Japanese Companies	20.6	29.3	68.7	10.7	9.1	14.4
European Companies	7.9	23.8	21.5	4.1	7.3	4.5
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	192.8	323.2	477.1	100.0	100.0	100.0
Other Companies	33.0	37.0	47.9			
All Companies	225.8	360.2	525.0			
Japanese Market						
North American Companies	86.0	157.6	313.1	50.5	47.5	54.3
Japanese Companies	83.3	167.3	253.8	48.9	50.4	44.0
European Companies	1.1	6.8	10.0	0.6	2.1	1.7
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	170.5	331.6	576.9	100.0	100.0	100.0
Other Companies	51.5	53.4	75.0			
All Companies	222.0	385.0	651.9			
European Market						
North American Companies	63.4	91.6	141.7	89.6	81.0	69.1
Japanese Companies	3.3	8.3	38.2	4.6	7.3	18.6
European Companies	4.1	13.1	25.2	5.8	11.6	12.3
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	70.8	113.0	205.0	100.0	100.0	100.0
Other Companies	6.9	4.6	7.6			
All Companies	77.7	117.6	212.6			

(Continued)

Table 9-2 (Continued)
Sales Revenue from Shipments of Process Control into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Market						
North American Companies	74.8	142.9	255.3	80.9	67.4	61.2
Japanese Companies	16.4	58.2	150.8	17.7	27.5	36.2
European Companies	1.3	10.9	10.9	1.4	5.1	2.6
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	92.4	212.0	417.0	100.0	100.0	100.0
Other Companies	25.7	28.4	47.1			
All Companies	118.1	240.4	464.1			
Worldwide Market						
North American Companies	388.5	662.2	1,096.9	73.8	67.6	65.5
Japanese Companies	123.6	263.1	511.5	23.5	26.9	30.5
European Companies	14.4	54.5	67.5	2.7	5.6	4.0
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	526.5	979.9	1,675.9	100.0	100.0	100.0
Other Companies	117.1	123.4	177.6			
All Companies	643.6	1,103.3	1,853.5			

NM = Not meaningful

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.

Source: Dataquest (May 1996)

Table 9-3
Sales Revenue from Shipments of Process Control into Each Region by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Optical Metrology						
Americas Market	17.3	11.3	13.8	22.5	27.1	11.8
Japanese Market	23.6	13.6	15.3	21.4	36.3	11.4
European Market	11.3	9.7	7.4	8.2	12.0	1.5
Asia/Pacific Market	6.5	5.3	6.4	14.8	22.2	36.0
Worldwide Market	58.7	39.9	42.9	66.8	97.6	13.6
CD-SEM						
Americas Market	17.9	25.7	27.1	31.9	72.4	41.8
Japanese Market	57.3	35.3	35.4	65.2	108.6	17.3
European Market	5.4	4.4	3.6	12.0	32.6	56.8
Asia/Pacific Market	12.0	13.0	16.6	44.8	99.2	69.6
Worldwide Market	92.6	78.4	82.7	153.9	312.9	35.6
Thin-Film Measurement						
Americas Market	13.6	23.9	32.8	40.3	71.0	51.2
Japanese Market	16.7	20.2	16.4	26.4	51.6	32.6
European Market	6.4	9.5	11.4	11.1	28.4	45.2
Asia/Pacific Market	5.9	4.2	11.0	21.9	45.0	66.2
Worldwide Market	42.6	57.8	71.6	99.7	196.1	46.5
Auto Patterned Detection						
Americas Market	29.7	39.6	38.8	78.1	133.1	45.5
Japanese Market	34.1	31.0	53.8	102.5	207.6	57.1
European Market	16.6	17.7	19.8	30.2	47.1	29.8
Asia/Pacific Market	9.3	20.6	31.5	70.2	147.3	99.5
Worldwide Market	89.7	108.9	143.9	281.0	535.1	56.3
Auto Review and Classification						
Americas Market	3.2	8.2	14.3	41.4	52.5	102.1
Japanese Market	15.9	6.8	10.6	53.5	76.3	48.0
European Market	2.5	4.0	4.1	8.2	20.3	68.8
Asia/Pacific Market	1.0	0.7	0.4	16.5	45.0	159.1
Worldwide Market	22.6	19.6	29.4	119.6	194.2	71.3

(Continued)

Table 9-3 (Continued)
Sales Revenue from Shipments of Process Control into Each Region by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Manual Detection and Review						
Americas Market	5.9	4.6	7.9	23.1	25.6	44.3
Japanese Market	15.9	9.0	8.0	11.2	15.5	-0.7
European Market	1.6	2.0	1.5	5.3	13.6	70.7
Asia/Pacific Market	3.3	1.1	1.6	15.1	14.2	44.0
Worldwide Market	26.7	16.7	19.0	54.8	68.9	26.7
Auto Unpatterned Detection						
Americas Market	9.7	10.6	14.3	20.9	38.9	41.5
Japanese Market	22.6	11.7	9.5	20.0	37.7	13.7
European Market	3.9	3.3	3.8	5.4	12.6	34.4
Asia/Pacific Market	5.1	4.1	4.7	10.1	21.4	43.4
Worldwide Market	41.2	29.7	32.3	56.4	110.6	28.0
Other Process Control						
Americas Market	85.7	67.9	76.8	102.1	104.4	5.1
Japanese Market	121.1	73.4	73.1	84.8	118.3	-0.6
European Market	24.7	21.9	26.1	37.2	46.0	16.8
Asia/Pacific Market	26.3	28.1	45.9	47.0	69.7	27.6
Worldwide Market	257.8	191.3	221.8	271.1	338.3	7.0
Process Control						
Americas Market	183.0	191.8	225.8	360.2	525.0	30.2
Japanese Market	307.2	200.9	222.0	385.0	651.9	20.7
European Market	72.4	72.5	77.7	117.6	212.6	30.9
Asia/Pacific Market	69.4	77.1	118.1	240.4	464.1	60.8
Worldwide Market	631.9	542.3	643.6	1,103.3	1,853.5	30.9

Source: Dataquest (May 1996)

Table 9-4
Worldwide Sales Revenue from Shipments of Process Control by Company Base and Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Optical Metrology						
North American Companies	37.0	56.1	86.8	86.2	84.0	88.9
Japanese Companies	5.0	10.3	10.5	11.7	15.4	10.8
European Companies	0.9	0.4	0.3	2.1	0.6	0.3
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	42.9	66.8	97.6	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	42.9	66.8	97.6			
CD-SEM						
North American Companies	23.0	32.7	52.5	27.8	21.3	16.8
Japanese Companies	59.7	120.5	260.4	72.2	78.3	83.2
European Companies	0	0.7	0	NM	0.5	NM
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	82.7	153.9	312.9	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	82.7	153.9	312.9			
Thin-Film Measurement						
North American Companies	61.2	91.2	184.4	87.7	93.4	96.3
Japanese Companies	6.7	5.0	6.3	9.6	5.2	3.3
European Companies	1.9	1.4	0.8	2.7	1.4	0.4
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	69.8	97.6	191.5	100.0	100.0	100.0
Other Companies	1.8	2.1	4.6			
All Companies	71.6	99.7	196.1			

(Continued)

Table 9-4 (Continued)
Worldwide Sales Revenue from Shipments of Process Control by Company Base and Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Auto Patterned Detection						
North American Companies	125.1	250.6	470.5	86.9	89.2	87.9
Japanese Companies	18.8	27.5	58.5	13.1	9.8	10.9
European Companies	0	2.9	6.1	NM	1.0	1.1
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	143.9	281.0	535.1	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	143.9	281.0	535.1			
Auto Review and Classification						
North American Companies	10.5	34.8	44.5	35.7	29.1	22.9
Japanese Companies	9.2	63.1	119.9	31.3	52.7	61.8
European Companies	9.7	21.7	29.8	33.0	18.2	15.3
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	29.4	119.6	194.2	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	29.4	119.6	194.2			
Manual Detection and Review						
North American Companies	0	0	0	NM	NM	NM
Japanese Companies	17.8	27.4	38.3	93.7	50.0	55.6
European Companies	1.2	27.4	30.5	6.3	50.0	44.4
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	19.0	54.8	68.9	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	19.0	54.8	68.9			

(Continued)

Table 9-4 (Continued)
Worldwide Sales Revenue from Shipments of Process Control by Company Base and Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Auto Unpatterned Detection						
North American Companies	25.2	47.0	93.0	78.0	83.4	84.1
Japanese Companies	6.4	9.3	17.6	19.9	16.6	15.9
European Companies	0.7	0	0	2.2	NM	NM
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	32.3	56.4	110.6	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	32.3	56.4	110.6			
Other Process Control						
North American Companies	106.5	149.8	165.3	100.0	100.0	100.0
Japanese Companies	0	0	0	NM	NM	NM
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	106.5	149.8	165.3	100.0	100.0	100.0
Other Companies	115.3	121.3	173.0			
All Companies	221.8	271.1	338.3			
Process Control						
North American Companies	388.5	662.2	1,096.9	73.8	67.6	65.5
Japanese Companies	123.6	263.1	511.5	23.5	26.9	30.5
European Companies	14.4	54.5	67.5	2.7	5.6	4.0
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	526.5	979.9	1,675.9	100.0	100.0	100.0
Other Companies	117.1	123.4	177.6			
All Companies	643.6	1,103.3	1,853.5			

NM = Not meaningful
Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 9-5
Each Company's Sales Revenue from Shipments of Optical Metrology to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	17.3	11.3	13.8	22.5	27.1	11.8
Biorad	3.0	1.2	3.5	7.8	10.5	36.8
Hitachi	0	0	0	0	0	NM
IVS Inc.	4.8	1.2	1.2	2.1	1.4	-27.2
KLA Instruments	2.8	4.6	5.0	9.8	13.8	49.0
Leica	0.6	0	0	0.3	0.1	-36.1
Nano-Master	0.8	0.8	0	0	0	-100.0
Nanometrics	0.9	0.8	0.8	0	0	-100.0
Nikon	0	0	0	0	0	NM
Optical Specialties Inc.	1.0	1.1	2.6	2.5	1.3	6.8
Others	0.8	0.7	0.5	0	0	-100.0
Ryokosha	0	0	0	0	0	NM
SiScan Systems	2.2	0.9	0.2	0	0	-100.0
Tokyo Aircraft Instruments	0.4	0	0	0	0	-100.0
Total	17.3	11.3	13.8	22.5	27.1	11.8
Japanese Market	23.6	13.6	15.3	21.4	36.3	11.4
Biorad	0	0	0	0	0.9	NM
Hitachi	3.6	1.4	2.4	3.1	3.6	-0.2
IVS Inc.	0	0.2	0.3	0	0	NM
KLA Instruments	3.4	2.8	6.6	9.3	22.3	59.9
Leica	0	0.3	0	0	0	NM
Nano-Master	0	0	0	0	0	NM
Nanometrics	0.9	1.0	1.0	0	0	-100.0
Nikon	6.9	0.5	0.3	0.9	1.9	-27.9
Optical Specialties Inc.	3.9	3.8	1.9	4.4	3.5	-2.7
Others	1.3	0.5	0.5	0	0	-100.0
Ryokosha	0.7	0.3	0.3	0	0	-100.0
SiScan Systems	0	0	0	0	0	NM
Tokyo Aircraft Instruments	2.9	2.8	2.0	3.7	4.2	9.9
Total	23.6	13.6	15.3	21.4	36.3	11.4
European Market	11.3	9.7	7.4	8.2	12.0	1.5
Biorad	1.7	0.8	1.6	2.5	3.9	23.1
Hitachi	0.6	0	0	0	0	-100.0
IVS Inc.	1.6	0.7	0.9	0.6	0.6	-21.7
KLA Instruments	1.2	1.3	3.6	4.9	7.3	57.0

(Continued)

Table 9-5 (Continued)
Each Company's Sales Revenue from Shipments of Optical Metrology to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Leica	0.5	0.3	0.4	0	0.1	-33.1
Nano-Master	5.2	6.3	0	0	0	-100.0
Nanometrics	0	0	0	0	0	NM
Nikon	0	0	0	0	0	NM
Optical Specialties Inc.	0	0.1	0.7	0.2	0.1	NM
Others	0.5	0.2	0.2	0	0	-100.0
Ryokosha	0	0	0	0	0	NM
SiScan Systems	0	0	0	0	0	NM
Tokyo Aircraft Instruments	0	0	0	0	0	NM
Total	11.3	9.7	7.4	8.2	12.0	1.5
Asia/Pacific Market	6.5	5.3	6.4	14.8	22.2	36.0
Biorad	0.9	0.4	1.3	1.9	2.2	25.0
Hitachi	0	0	0	2.6	0.9	NM
IVS Inc.	1.2	0.2	0.6	0.9	0.9	-8.3
KLA Instruments	1.9	2.5	2.8	6.2	6.8	37.5
Leica	0.7	0.2	0.5	0.2	0.1	-38.5
Nano-Master	0	0	0	0	0	NM
Nanometrics	0	0	0	0	0	NM
Nikon	0	0	0	0	0	NM
Optical Specialties Inc.	0.8	1.4	1.2	3.1	11.4	94.3
Others	1.0	0.6	0	0	0	-100.0
Ryokosha	0	0	0	0	0	NM
SiScan Systems	0	0	0	0	0	NM
Tokyo Aircraft Instruments	0	0	0	0	0	NM
Total	6.5	5.3	6.4	14.8	22.2	36.0
Worldwide Market	58.7	39.9	42.9	66.8	97.6	13.6
Biorad	5.6	2.4	6.4	12.2	17.5	33.0
Hitachi	4.2	1.4	2.4	5.7	4.5	1.5
IVS Inc.	7.6	2.3	3.0	3.5	2.8	-22.1
KLA Instruments	9.3	11.2	18.0	30.2	50.2	52.4
Leica	1.8	0.8	0.9	0.4	0.3	-36.1
Nano-Master	6.0	7.1	0	0	0	-100.0
Nanometrics	1.8	1.8	1.8	0	0	-100.0
Nikon	6.9	0.5	0.3	0.9	1.9	-27.9
Optical Specialties Inc.	5.7	6.4	6.4	10.2	16.3	30.0

(Continued)

Table 9-5 (Continued)
Each Company's Sales Revenue from Shipments of Optical Metrology to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Others	3.6	2.0	1.2	0	0	-100.0
Ryokosha	0.7	0.3	0.3	0	0	-100.0
SiScan Systems	2.2	0.9	0.2	0	0	-100.0
Tokyo Aircraft Instruments	3.3	2.8	2.0	3.7	4.2	6.4
Total	58.7	39.9	42.9	66.8	97.6	13.6

NM = Not meaningful
Note: Figures for "others" reflect estimates of unsurveyed company market activity.
Source: Dataquest (May 1996)

Table 9-6
Each Company's Sales Revenue from Shipments of CD-SEM to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	17.9	25.7	27.1	31.9	72.4	41.8
Amray	2.8	1.8	0.9	0	0	-100.0
Angstrom Measurements	2.2	0	0	0	0	-100.0
Biorad	4.9	0	0	0	0	-100.0
Hitachi	8.0	15.8	12.6	12.8	35.0	44.7
Holon	0	0	0	0	0	NM
IVS Inc.	0	0	1.6	1.2	0	NM
Jenoptik	0	0	0	0	0	NM
JEOL	0	0	0	0	0	NM
KLA Instruments	0	0	0	2.5	5.0	NM
Metrologix	0	2.2	2.5	0	0	NM
Nanometrics	0	0.3	0	0	0	NM
Nikon	0	0	0	0	0	NM
Opal	0	5.6	9.5	15.4	32.4	NM
Topcon	0	0	0	0	0	NM
Total	17.9	25.7	27.1	31.9	72.4	41.8
Japanese Market	57.3	35.3	35.4	65.2	108.6	17.3
Amray	0	0	0.6	0	0	NM
Angstrom Measurements	0	0	0	0	0	NM
Biorad	0	0	0	0	0	NM
Hitachi	45.6	20.8	23.7	49.2	85.3	16.9
Holon	8.0	5.0	6.3	6.3	8.5	1.4
IVS Inc.	0	0	0	0	0	NM
Jenoptik	0	0	0	0	0	NM
JEOL	0	1.4	0.7	1.6	0	NM
KLA Instruments	0	0	0	0	0	NM
Metrologix	0	0	0.9	0	0	NM
Nanometrics	0	0	0	0	0	NM
Nikon	0	0	0.8	1.8	1.0	NM
Opal	1.6	3.8	1.0	2.1	3.0	17.0
Topcon	2.1	4.3	1.4	4.2	10.9	51.0
Total	57.3	35.3	35.4	65.2	108.6	17.3

(Continued)

Table 9-6 (Continued)
Each Company's Sales Revenue from Shipments of CD-SEM to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
European Market	5.4	4.4	3.6	12.0	32.6	56.8
Amray	0.6	1.2	0	0	0	-100.0
Angstrom Measurements	0	0	0	0	0	NM
Biorad	0	0	0	0	0	NM
Hitachi	4.0	3.2	0.7	4.9	25.7	59.3
Holon	0	0	0	0	0	NM
IVS Inc.	0	0	0.8	0	0	NM
Jenoptik	0	0	0	0.7	0	NM
JEOL	0	0	0	0	0	NM
KLA Instruments	0	0	0	2.2	0	NM
Metrologix	0	0	0	0	0	NM
Nanometrics	0	0	0	0	0	NM
Nikon	0	0	0	0	0	NM
Opal	0.8	0	2.1	4.2	6.9	71.4
Topcon	0	0	0	0	0	NM
Total	5.4	4.4	3.6	12.0	32.6	56.8
Asia/Pacific Market	12.0	13.0	16.6	44.8	99.2	69.6
Amray	0	0	0	0	0	NM
Angstrom Measurements	0	0	0	0	0	NM
Biorad	0	0	0	0	0	NM
Hitachi	12.0	13.0	13.5	29.5	88.9	65.0
Holon	0	0	0	7.9	5.1	NM
IVS Inc.	0	0	0	0	0	NM
Jenoptik	0	0	0	0	0	NM
JEOL	0	0	0	2.3	0	NM
KLA Instruments	0	0	0	0	0	NM
Metrologix	0	0	1.0	0	0	NM
Nanometrics	0	0	0	0	0	NM
Nikon	0	0	0	0	0	NM
Opal	0	0	2.1	5.1	5.2	NM
Topcon	0	0	0	0	0	NM
Total	12.0	13.0	16.6	44.8	99.2	69.6

(Continued)

Table 9-6 (Continued)
Each Company's Sales Revenue from Shipments of CD-SEM to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	92.6	78.4	82.7	153.9	312.9	35.6
Amray	3.4	3.0	1.5	0	0	-100.0
Angstrom Measurements	2.2	0	0	0	0	-100.0
Biorad	4.9	0	0	0	0	-100.0
Hitachi	69.6	52.8	50.5	96.4	235.0	35.5
Holon	8.0	5.0	6.3	14.2	13.6	14.1
IVS Inc.	0	0	2.4	1.2	0	NM
Jenoptik	0	0	0	0.7	0	NM
JEOL	0	1.4	0.7	3.9	0	NM
KLA Instruments	0	0	0	4.7	5.0	NM
Metrologix	0	2.2	4.4	0	0	NM
Nanometrics	0	0.3	0	0	0	NM
Nikon	0	0	0.8	1.8	1.0	NM
Opal	2.4	9.4	14.7	26.8	47.5	110.9
Topcon	2.1	4.3	1.4	4.2	10.9	51.0
Total	92.6	78.4	82.7	153.9	312.9	35.6

NM = Not meaningful
Source: Dataquest (May 1996)

Table 9-7
Each Company's Sales Revenue from Shipments of Thin-Film Measurement to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	13.6	23.9	32.8	40.3	71.0	51.2
Dainippon Screen	0.1	0	0	0	0	-100.0
Leica	0.7	0.5	1.0	0.9	0.1	-33.1
Nanometrics	2.9	2.7	2.8	2.6	5.3	16.3
Others	0	0.2	0.5	0.5	2.3	NM
Rudolph Research	2.5	3.4	4.6	9.0	14.4	54.9
Tencor Instruments	7.1	15.2	22.4	21.8	27.5	40.3
Thermawave	0.3	1.9	1.5	5.5	21.4	190.6
Total	13.6	23.9	32.8	40.3	71.0	51.2
Japanese Market	16.7	20.2	16.4	26.4	51.6	32.6
Dainippon Screen	5.2	10.4	5.8	4.0	5.6	1.8
Leica	0	0	0	0	0	NM
Nanometrics	6.1	3.2	2.8	4.6	7.4	4.9
Others	0.2	1.7	0.9	1.0	1.6	68.2
Rudolph Research	1.1	1.8	2.9	6.2	12.7	84.3
Tencor Instruments	4.1	3.1	3.0	10.1	20.9	50.3
Thermawave	0	0	1.0	0.5	3.4	NM
Total	16.7	20.2	16.4	26.4	51.6	32.6
European Market	6.4	9.5	11.4	11.1	28.4	45.2
Dainippon Screen	0.3	0	0.6	0.5	0	-100.0
Leica	0.6	0.8	0.5	0.2	0.2	-23.1
Nanometrics	0.4	0.3	1.1	1.2	2.3	54.9
Others	2.4	0.4	0.2	0.4	0.6	-29.3
Rudolph Research	0.2	1.4	1.4	1.4	2.5	88.6
Tencor Instruments	2.5	6.6	7.2	5.5	19.9	68.0
Thermawave	0	0	0.4	1.9	2.9	NM
Total	6.4	9.5	11.4	11.1	28.4	45.2
Asia/Pacific Market	5.9	4.2	11.0	21.9	45.0	66.2
Dainippon Screen	1.4	0.2	0.3	0.5	0.7	-16.1
Leica	0.5	0.6	0.4	0.3	0.4	-4.3
Nanometrics	1.1	2.0	3.7	1.1	1.8	13.1
Others	0.4	0.2	0.2	0.2	0.1	-29.3
Rudolph Research	1.6	1.2	1.5	4.0	8.7	52.7

(Continued)

Table 9-7 (Continued)
Each Company's Sales Revenue from Shipments of Thin-Film Measurement to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Tencor Instruments	0.9	0	3.9	9.9	14.9	101.7
Thermawave	0	0	1.0	5.9	18.4	NM
Total	5.9	4.2	11.0	21.9	45.0	66.2
Worldwide Market	42.6	57.8	71.6	99.7	196.1	46.5
Dainippon Screen	7.0	10.6	6.7	5.0	6.3	-2.7
Leica	1.8	1.9	1.9	1.4	0.8	-19.1
Nanometrics	10.5	8.2	10.4	9.5	16.8	12.5
Others	3.0	2.5	1.8	2.1	4.6	11.3
Rudolph Research	5.4	7.8	10.4	20.6	38.3	63.2
Tencor Instruments	14.6	24.9	36.5	47.3	83.2	54.5
Thermawave	0.3	1.9	3.9	13.8	46.1	252.1
Total	42.6	57.8	71.6	99.7	196.1	46.5

Figures for "others" reflect estimates of unsurveyed company market activity.
Source: Dataquest (May 1996)

Table 9-8
Each Company's Sales Revenue from Shipments of Automated Patterned Detection to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	29.7	39.6	38.8	78.1	133.1	45.5
Hitachi	2.3	0	0.8	0	0	-100.0
Inspex	5.7	7.1	5.1	6.0	6.9	4.7
Insystems	6.5	0	0	0	0	-100.0
KLA Instruments	11.0	23.1	22.6	50.9	93.5	70.7
Nano-Master	0	0	0	0	0	NM
Optical Specialties Inc.	0	4.4	3.1	0.6	0.6	NM
Orbot	0	0	0	0	0	NM
Tencor Instruments	4.2	5.0	7.2	20.6	32.1	66.3
Toray Industries	0	0	0	0	0	NM
Total	29.7	39.6	38.8	78.1	133.1	45.5
Japanese Market	34.1	31.0	53.8	102.5	207.6	57.1
Hitachi	14.4	8.7	15.7	22.0	34.6	24.5
Inspex	1.0	1.1	0.9	1.0	1.8	16.6
Insystems	3.9	0	0	0	0	-100.0
KLA Instruments	9.9	16.8	30.9	62.1	136.4	92.7
Nano-Master	0	0	0	0	0	NM
Optical Specialties Inc.	0	0	0.7	2.0	7.0	NM
Orbot	0	0	0	0	0	NM
Tencor Instruments	3.7	1.8	4.0	9.9	21.0	54.4
Toray Industries	1.2	2.6	1.6	5.5	6.7	53.8
Total	34.1	31.0	53.8	102.5	207.6	57.1
European Market	16.6	17.7	19.8	30.2	47.1	29.8
Hitachi	0.6	0	0.7	0	0	-100.0
Inspex	1.9	3.5	2.1	2.0	3.3	14.8
Insystems	2.6	0	0	0	0	-100.0
KLA Instruments	3.3	5.7	12.6	19.5	27.6	70.1
Nano-Master	5.4	5.4	0	0	0	-100.0
Optical Specialties Inc.	0	0	0	0	0	NM
Orbot	0	0	0	2.9	6.1	NM
Tencor Instruments	2.8	3.1	4.4	5.8	10.1	37.8
Toray Industries	0	0	0	0	0	NM

(Continued)

Table 9-8 (Continued)
Each Company's Sales Revenue from Shipments of Automated Patterned Detection to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Asia/Pacific Market	9.3	20.6	31.5	70.2	147.3	99.5
Hitachi	1.2	0	0	0	17.1	94.4
Inspex	4.5	4.4	10.7	13.1	16.9	39.2
Insystems	0	0	0	0	0	NM
KLA Instruments	2.2	14.4	18.7	49.8	97.0	157.7
Nano-Master	0	0	0	0	0	NM
Optical Specialties Inc.	0	0	0	0	3.4	NM
Orbot	0	0	0	0	0	NM
Tencor Instruments	1.4	1.8	2.1	7.3	12.9	74.1
Toray Industries	0	0	0	0	0	NM
Total	9.3	20.6	31.5	70.2	147.3	99.5
Worldwide Market	89.7	108.9	143.9	281.0	535.1	56.3
Hitachi	18.5	8.7	17.2	22.0	51.8	29.3
Inspex	13.1	16.1	18.8	22.1	28.9	21.9
Insystems	13.0	0	0	0	0	-100.0
KLA Instruments	26.4	60.0	84.8	182.3	354.5	91.4
Nano-Master	5.4	5.4	0	0	0	-100.0
Optical Specialties Inc.	0	4.4	3.8	2.6	11.0	NM
Orbot	0	0	0	2.9	6.1	NM
Tencor Instruments	12.1	11.7	17.7	43.6	76.1	58.4
Toray Industries	1.2	2.6	1.6	5.5	6.7	53.8
Total	89.7	108.9	143.9	281.0	535.1	56.3

NM = Not meaningful
Notes: Segment encompasses automated patterned wafer defect and particle detection systems.
KLA and Tencor figures may include auto review systems.
Source: Dataquest (May 1996)

Table 9-9
Each Company's Sales Revenue from Shipments of Automated Review and Classification to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	3.2	8.2	14.3	41.4	52.5	102.1
Amray	0.9	5.4	7.8	20.8	14.4	103.0
Hitachi	0.9	0	0	0	2.7	31.6
Inspex	0	0	0	0.6	0.7	NM
JEOL	0	0	0	7.9	16.9	NM
Leica	1.4	2.8	6.2	8.1	7.3	51.1
Philips	0	0	0	0	2.4	NM
Seiko	0	0	0	0	0	NM
Topcon	0	0	0	0	0	NM
Ultrapointe	0	0	0.3	4.0	8.1	NM
Total	3.2	8.2	14.3	41.4	52.5	102.1
Japanese Market	15.9	6.8	10.6	53.5	76.3	48.0
Amray	0	0	0	0	0	NM
Hitachi	9.8	1.9	4.3	7.1	8.7	-2.9
Inspex	0	0	0	0.7	1.8	NM
JEOL	0	1.1	2.1	36.6	50.6	NM
Leica	0	0.3	1.1	6.4	9.6	NM
Philips	0	0	0	0	0	NM
Seiko	6.1	2.9	2.1	2.1	2.1	-23.4
Topcon	0	0.6	0.7	0	0	NM
Ultrapointe	0	0	0.3	0.6	3.5	NM
Total	15.9	6.8	10.6	53.5	76.3	48.0
European Market	2.5	4.0	4.1	8.2	20.3	68.8
Amray	0	1.8	1.8	1.0	2.4	NM
Hitachi	0	0	0	1.2	4.1	NM
Inspex	0	0	0	0	0.4	NM
JEOL	0	0	0	1.0	7.3	NM
Leica	2.5	2.2	2.0	2.7	3.8	10.9
Philips	0	0	0	2.0	2.4	NM
Seiko	0	0	0	0	0	NM
Topcon	0	0	0	0	0	NM
Ultrapointe	0	0	0.3	0.3	0	NM
Total	2.5	4.0	4.1	8.2	20.3	68.8

(Continued)

Table 9-9 (Continued)
Each Company's Sales Revenue from Shipments of Automated Review and Classification to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Asia/Pacific Market	1.0	0.7	0.4	16.5	45.0	159.1
Amray	0	0	0	0	3.6	NM
Hitachi	0	0	0	2.5	2.7	NM
Inspex	0	0	0	6.5	9.2	NM
JEOL	0	0	0	4.7	22.9	NM
Leica	1.0	0.7	0.4	2.5	4.3	43.6
Philips	0	0	0	0	0	NM
Seiko	0	0	0	0	2.0	NM
Topcon	0	0	0	0	0	NM
Ultrapointe	0	0	0	0.3	0.4	NM
Total	1.0	0.7	0.4	16.5	45.0	159.1
Worldwide Market	22.6	19.6	29.4	119.6	194.2	71.3
Amray	0.9	7.2	9.6	21.8	20.4	121.4
Hitachi	10.7	1.9	4.3	10.8	18.2	14.2
Inspex	0	0	0	7.8	12.0	NM
JEOL	0	1.1	2.1	50.2	97.6	NM
Leica	4.9	6.0	9.7	19.7	24.9	50.2
Philips	0	0	0	2.0	4.9	NM
Seiko	6.1	2.9	2.1	2.1	4.1	-9.5
Topcon	0	0.6	0.7	0	0	NM
Ultrapointe	0	0	0.9	5.2	12.0	NM
Total	22.6	19.6	29.4	119.6	194.2	71.3

NM = Not meaningful
Notes: Segment encompasses automated patterned wafer defect review and classification systems.
Segment includes both optical- and SEM-based systems.
Source: Dataquest (May 1996)

Table 9-10
Each Company's Sales Revenue from Shipments of Manual Detection and Review to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	5.9	4.6	7.9	23.1	25.6	44.3
Canon	0	0	0	0	0	NM
Carl Zeiss	0.7	0.5	0.7	0.7	1.5	21.3
Lasertec Corporation	0	0	0	0.5	0.9	NM
Leica	0	0	0	13.8	10.0	NM
Nidek	1.7	1.1	1.8	2.0	5.6	34.7
Nikon	3.4	3.0	5.4	6.1	7.6	22.3
Optical Specialties Inc.	0.1	0	0	0	0	-100.0
Total	5.9	4.6	7.9	23.1	25.6	44.3
Japanese Market	15.9	9.0	8.0	11.2	15.5	-0.7
Canon	4.0	2.5	1.1	0.9	0.4	-45.6
Carl Zeiss	0	0	0	0	0	NM
Lasertec Corporation	0	0	0.5	2.4	3.4	NM
Leica	0	0	0	0.4	0.4	NM
Nidek	5.2	3.7	2.6	4.5	6.1	4.0
Nikon	6.7	2.8	3.8	3.0	5.3	-5.8
Optical Specialties Inc.	0	0	0	0	0	NM
Total	15.9	9.0	8.0	11.2	15.5	-0.7
European Market	1.6	2.0	1.5	5.3	13.6	70.7
Canon	0	0	0	0	0	NM
Carl Zeiss	0.7	0.5	0.5	0.5	1.1	12.6
Lasertec Corporation	0	0	0	0.1	0.3	NM
Leica	0	0	0	4.1	11.4	NM
Nidek	0.2	0.3	0.2	0.2	0	-100.0
Nikon	0.7	1.2	0.8	0.4	0.8	4.0
Optical Specialties Inc.	0	0	0	0	0	NM
Total	1.6	2.0	1.5	5.3	13.6	70.7
Asia/Pacific Market	3.3	1.1	1.6	15.1	14.2	44.0
Canon	0.4	0	0	0	0	-100.0
Carl Zeiss	0	0	0	0	0	NM
Lasertec Corporation	0	0	0	0.7	1.0	NM
Leica	0	0	0	7.9	6.1	NM
Nidek	0	0	0	2.8	0	NM
Nikon	2.9	1.1	1.6	3.7	7.2	25.3
Optical Specialties Inc.	0	0	0	0	0	NM
Total	3.3	1.1	1.6	15.1	14.2	44.0

(Continued)

Table 9-10 (Continued)
Each Company's Sales Revenue from Shipments of Manual Detection and Review to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	26.7	16.7	19.0	54.8	68.9	26.7
Canon	4.4	2.5	1.1	0.9	0.4	-46.8
Carl Zeiss	1.4	1.0	1.2	1.2	2.6	17.2
Lasertec Corporation	0	0	0.5	3.8	5.4	NM
Leica	0	0	0	26.2	27.9	NM
Nidek	7.1	5.1	4.6	9.5	11.7	13.2
Nikon	13.7	8.1	11.6	13.2	20.9	11.1
Optical Specialties Inc.	0.1	0	0	0	0	-100.0
Total	26.7	16.7	19.0	54.8	68.9	26.7

NM = Not meaningful
Note: Segment encompasses operator-based patterned wafer defect and particle detection systems.
Source: Dataquest (May 1996)

Table 9-11
Each Company's Sales Revenue from Shipments of Automated Unpatterned Detection to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	9.7	10.6	14.3	20.9	38.9	41.5
ADE Corporation	0	0	1.3	2.8	3.8	NM
Censor	0	0.7	0	0	0	NM
Estek	2.4	1.0	0	0	0	-100.0
Hitachi	0.4	0.5	0	0	0	-100.0
Tencor Instruments	6.9	8.4	13.0	18.1	35.1	50.2
Topcon	0	0	0	0	0	NM
Total	9.7	10.6	14.3	20.9	38.9	41.5
Japanese Market	22.6	11.7	9.5	20.0	37.7	13.7
ADE Corporation	0	0	0.5	2.8	4.8	NM
Censor	0	1.4	0	0	0	NM
Estek	1.5	0.5	0	0	0	-100.0
Hitachi	10.0	3.4	3.0	6.8	10.5	1.3
Tencor Instruments	5.2	2.4	3.8	8.9	17.8	36.0
Topcon	5.9	4.0	2.2	1.5	4.6	-6.0
Total	22.6	11.7	9.5	20.0	37.7	13.7
European Market	3.9	3.3	3.8	5.4	12.6	34.4
ADE Corporation	0	0	0.6	1.0	3.5	NM
Censor	1.2	0.7	0.7	0	0	-100.0
Estek	0.2	0.2	0	0	0	-100.0
Hitachi	0.8	0.7	0.3	0	0	-100.0
Tencor Instruments	1.1	1.7	2.2	4.4	9.1	69.6
Topcon	0.6	0	0	0	0	-100.0
Total	3.9	3.3	3.8	5.4	12.6	34.4
Asia/Pacific Market	5.1	4.1	4.7	10.1	21.4	43.4
ADE Corporation	0	0	0.5	1.1	2.6	NM
Censor	0.4	0	0	0	0	-100.0
Estek	0.4	0.2	0	0	0	-100.0
Hitachi	2.1	1.3	1.0	1.1	2.4	3.9
Tencor Instruments	2.2	2.6	3.3	7.9	16.4	65.2
Topcon	0	0	0	0	0	NM
Total	5.1	4.1	4.7	10.1	21.4	43.4

(Continued)

Table 9-11 (Continued)
Each Company's Sales Revenue from Shipments of Automated Unpatterned Detection to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	41.2	29.7	32.3	56.4	110.6	28.0
ADE Corporation	0	0	2.9	7.7	14.6	NM
Censor	1.5	2.8	0.7	0	0	-100.0
Estek	4.5	1.9	0	0	0	-100.0
Hitachi	13.3	5.9	4.2	7.8	13.0	-0.6
Tencor Instruments	15.4	15.1	22.3	39.3	78.4	50.2
Topcon	6.5	4.0	2.2	1.5	4.6	-8.2
Total	41.2	29.7	32.3	56.4	110.6	28.0

Segment encompasses automated unpatterned wafer defect and particle detection systems.
Source: Dataquest (May 1996)

Appendix A
Company Rankings and Segment Revenue Detail

This appendix presents a comprehensive ranking of wafer fab equipment producers by end-user revenue garnered from sales of all equipment worldwide in 1995. The appendix also details company-by-company estimates of revenue garnered from worldwide sales of various equipment categories over the period 1991 through 1995. Table A-1 presents a comprehensive ranking of wafer equipment companies based on 1995 worldwide revenue garnered for sales of all equipment marketed. The table is an extension of the top 20 table in Chapter 2, Table 2-1. The table reports 1995 total revenue for each company and each company's ranking based on that revenue. The table also reports each company's 1994 total revenue and ranking based on that revenue. The percentage change in company total revenue between 1995 and 1994 is also reported. Finally, total revenue for all surveyed companies, estimated revenue for unsurveyed market activity, and total revenue for the wafer fab equipment market as whole are reported at the foot of the table for 1995 and 1994. Table A-2 presents the same information as Table A-1 but reorganized so that companies are reported alphabetically.

Table A-3 presents company-by-company estimates of worldwide revenue garnered from sales of specific equipment for 1991 through 1995. Summary totals for all surveyed companies, estimated unsurveyed market activity, and the market as a whole are reported at the foot of the table. The individual company data reported in the table accounts for practically all the total wafer fab equipment market between 1991 and 1995. In 1991, reported surveyed company data accounted for 90.8 percent of the $5.45 billion market. In 1995, reported surveyed company data accounts for 93.3 percent of the $19.05 billion market. The companies listed in the table encompass virtually all worldwide market activity in key front-end equipment categories of lithography (contact/proximity, projection aligners, steppers, direct-write lithography, maskmaking lithography, and X-ray aligners), resist processing (track), etch and clean (auto wet stations, spray processors, vapor phase clean, post-CMP clean, other clean process, chemical mechanical polishing, dry strip, low-density etch and high-density etch), deposition (horizontal tube LPCVD, vertical tube LPCVD, horizontal tube PECVD, atmospheric/subpressure CVD, high-density plasma CVD, dedicated LPCVD reactors, dedicated PECVD reactors, sputtering, and silicon epitaxy), thermal nondeposition (vertical diffusion, horizontal diffusion, and rapid thermal processing), ion implantation (medium-current implanter, high-current implanter, and high-voltage implanter), and process control (optical metrology, CD-SEM, thin-film measurement, auto patterned detection, auto review and classification, manual detection and review, and auto unpatterned detection).

The remaining fraction of the market consists of equipment segments for which little or no detailed company information is available. Equipment segments for which some company data is available (and reported in the table) are other deposition, other process control, and other wafer fab equipment. Segments for which no company data is available are ion milling and factory automation. Dataquest estimates market activity where no company data is available. These estimates, together with estimates of unsurveyed market activity in the equipment segments where only partial company detail is available, are reported in the summary section of Table A-3 as data for the category "others."

The tables of this appendix include only estimated revenue from sales of front-end wafer fab equipment. Accordingly, the reported figures do not include revenue from sales of test and assembly equipment. Moreover, the revenue reported in the tables is estimated calendar year revenue. Revenue of companies with fiscal years that differ from the calendar year have been adjusted to a calendar year basis. The reported revenue in the tables include system sales, upgrades, and retrofits. They do not, however, include service and spare parts. Also, no revenue is included from equipment sales for nonsemiconductor applications such as thin-film head manufacturing or flat-panel display manufacturing. Consequently, the revenue reported here will differ from the sales companies report in their financial statements.

Some companies have experienced significant growth in the wafer fab equipment market as a result of mergers and acquisitions. Similarly, other companies have experienced divestitures and management buyouts over the past several years. These events, of course, have reduced their presence in the market. Please refer to Chapter 1, Table 1-3, for a summary of merger and acquisition activity in the wafer fab equipment market.

Several companies (Eaton, Kokusai Electric, Tokyo Electron Ltd., and Varian), are or have been involved in joint ventures with other wafer fab companies. Under the terms of these ventures, equipment produced by one partner is offered for sale by the other and vice versa. When ranking companies, we have combined the revenue of joint venture partners and ranked the combination as a combined company. This is indicated in the tables by appending "including JVs" to relevant company names in the tables. When reporting the detailed equipment segment sales of joint venture companies, we have reported both the segment sales of the combined joint venture and the sales of the joint venture partners. Thus, in the ranking tables A-1 and A-2, the combined revenue of Eaton and Sumitomo/Eaton Nova is reported as revenue for "Eaton (including JVs)" and ranked accordingly. In Table A-3, however, the detailed equipment segment sales of both Eaton (including JVs) as well as Eaton and Sumitomo/Eaton Nova are reported. The same holds true for Kokusai Electric (paired with Bruce Technologies), Tokyo Electron Ltd. (paired with Varian/TEL), and Varian (paired with TEL/Varian). In the case of the latter two, 1995 data for joint venture partners Varian/TEL and TEL/Varian equals zero because the parent companies dissolved their partnership in 1994.

Table A-1
Company Sales Revenue Ranking from Shipments of Wafer Fab Equipment to the World, 1995 versus 1994—Ordered by 1995 Ranking

	1995 Revenue	1995 Rank	1994 Revenue	1994 Rank	% Change in Revenue
Applied Materials	2,904.9	1	1,480.7	1	96.2
Tokyo Electron Ltd. (including JVs)	2,098.2	2	1,066.3	2	96.8
Nikon	1,675.1	3	1,027.1	3	63.1
Canon	984.1	4	499.9	5	96.9
Lam Research	899.2	5	520.6	4	72.7
Hitachi	643.2	6	387.2	6	66.1
Dainippon Screen	545.3	7	342.5	8	59.2
Varian (including JVs)	535.4	8	375.3	7	42.7
Kokusai Electric (including JVs)	523.1	9	306.1	9	70.9
ASM Lithography	498.3	10	272.7	10	82.7
Silicon Valley Group	490.1	11	269.9	11	81.6
KLA Instruments	459.6	12	255.5	12	79.9
Eaton (including JVs)	430.0	13	227.2	13	89.3
Novellus Systems Inc.	345.2	14	197.4	15	74.9
Tencor Instruments	309.1	15	210.4	14	46.9
Anelva	256.3	16	170.1	16	50.7
ASM International	210.4	17	120.1	19	75.2
Watkins-Johnson	202.0	18	122.4	18	65.0
Alcan Technology (see note)	188.3	19	93.6	21	101.2
Ulvac	173.6	20	116.0	20	49.6
Materials Research Corporation	169.9	21	124.5	17	36.5
FSI International	152.3	22	74.1	22	105.5
Sugai	123.7	23	34.1	41	263.2
IPEC/Planar	118.9	24	43.0	34	176.5
JEOL	115.7	25	71.1	23	62.8
Ultratech	112.0	26	56.4	27	98.7
Steag Microtech	111.6	27	18.2	57	513.2
Integrated Solutions	97.8	28	-	-	NM
Kaijo Denki	96.1	29	45.1	33	113.0
Semitool (including Semitherm)	92.9	30	37.3	39	149.4
Genus	86.3	31	46.0	32	87.6
E.T. Electrotech	85.8	32	52.7	29	62.8
Gasonics	81.6	33	56.6	26	44.2
Sankyo Engineering	77.5	34	62.0	24	24.9
SubMicron Systems, Inc.	77.2	35	53.4	28	44.6
Santa Clara Plastics	71.8	36	51.5	30	39.4
Leica	63.5	37	58.6	25	8.3

(Continued)

Table A-1 (Continued)
Company Sales Revenue Ranking from Shipments of Wafer Fab Equipment to the World, 1995 versus 1994—Ordered by 1995 Ranking

	1995 Revenue	1995 Rank	1994 Revenue	1994 Rank	% Change in Revenue
Sumitomo Metals	63.5	38	24.4	49	160.0
AG Associates	61.2	39	36.4	40	68.0
ADE Corporation	58.6	40	39.0	35	50.2
Nissin Electric	53.4	41	38.2	38	39.8
Etec	53.1	42	50.7	31	4.7
Plasma Systems	51.9	43	38.3	37	35.5
Mattson Technologies	50.8	44	19.5	55	160.5
MC Electronics	49.5	45	30.4	42	62.6
Tegal	48.3	46	38.7	36	24.8
Opal	47.5	47	26.8	45	77.2
Fairchild Convac	46.9	48	22.6	51	107.5
Thermawave	46.1	49	13.8	61	234.1
Verteq	44.3	50	25.5	46	73.5
Amaya	42.3	51	3.9	98	984.1
Shibaura Engineering Works	41.4	52	24.6	48	68.5
Inspex	40.9	53	29.9	43	36.8
Karl Suss	39.2	54	25.2	47	55.6
Rudolph Research	38.3	55	20.6	53	86.1
Fusion Semiconductor Systems	37.3	56	26.8	44	39.2
AST Electronic GmbH	37.3	57	18.7	56	99.5
Strasbaugh	36.0	58	7.5	83	380.0
OnTrak Systems	31.7	59	11.4	69	178.1
Semiconductor Systems	27.9	60	24.0	50	16.3
Optical Specialties Inc.	27.3	61	12.8	65	113.3
Koyo Lindberg	26.5	62	20.2	54	31.0
CFM Technology	25.2	63	13.2	62	90.9
Matrix Integrated Systems	23.6	64	17.4	58	35.6
Toho Kasei	22.8	65	15.1	59	51.1
CVC Products	22.8	66	7.7	82	195.7
Toshiba	21.9	67	9.6	72	128.1
Amray	20.4	68	21.8	52	-6.1
Maruwa	18.5	69	13.2	63	40.7
Speedfam	18.4	70	3.8	100	384.3
Tazmo	17.9	71	12.9	64	38.8
Biorad	17.5	72	12.2	66	43.4
Nanometrics	16.8	73	9.5	73	76.8
ET Systems Engineering	16.3	74	8.9	78	83.3

(Continued)

Table A-1 (Continued)
Company Sales Revenue Ranking from Shipments of Wafer Fab Equipment to the World, 1995 versus 1994—Ordered by 1995 Ranking

	1995 Revenue	1995 Rank	1994 Revenue	1994 Rank	% Change in Revenue
Topcon	15.5	75	5.7	89	172.4
Plasma & Materials Technologies	15.5	76	9.9	71	56.6
Yuasa	15.5	77	11.3	70	36.7
Tokyo Ohka Kogyo	14.0	78	11.9	67	17.7
Concept Systems Design	13.9	79	8.5	80	63.5
Moore Epitaxial Inc.	13.6	80	11.7	68	16.5
Shimada	13.6	81	9.2	76	47.8
Holon	13.6	82	14.2	60	-4.4
Ebara Corp.	13.3	83	4.7	93	183.2
Toyoko Kagaku	12.9	84	9.3	75	38.7
Ultrapointe	12.0	85	5.2	91	130.8
Dan Science Co. Ltd.	11.9	86	6.8	86	75.3
Nidek	11.7	87	9.5	74	22.9
Samco	10.0	88	8.7	79	15.2
Shinko Electric	8.7	89	7.9	81	10.5
Sputtered Films	8.0	90	7.0	85	14.3
Jenoptik	7.8	91	9.0	77	-13.3
Oxford Instruments Inc.	7.4	92	6.5	87	13.9
SCI Manufacturing	7.2	93	2.3	108	213.0
Cybeq Systems	7.0	94	7.0	84	0
Toray Industries	6.7	95	5.5	90	21.1
Enya	6.1	96	4.4	95	38.6
LPE	6.1	97	3.9	99	56.4
Orbot	6.1	98	2.9	105	110.3
Musashi	5.6	99	4.1	96	36.6
High Temperature Engineering	5.5	100	2.4	107	129.2
Lasertec Corporation	5.4	101	3.8	101	44.7
Lepton Inc.	5.3	102	-	-	NM
Philips	4.9	103	2.0	110	139.8
Denton Vacuum	4.5	104	4.0	97	12.5
Tokyo Aircraft Instruments	4.2	105	3.7	103	14.3
Japan Production Engineering	4.1	106	3.1	104	32.3
Seiko	4.1	107	2.1	109	95.2
Matsushita Electric	3.7	108	0.7	120	453.1
Sapi Equipements	3.6	109	5.7	88	-36.8
Kurt J. Lesker	3.4	110	2.7	106	25.9
IVS Inc.	2.8	111	4.7	94	-40.4

(Continued)

Table A-1 (Continued)
Company Sales Revenue Ranking from Shipments of Wafer Fab Equipment to the World, 1995 versus 1994—Ordered by 1995 Ranking

	1995 Revenue	1995 Rank	1994 Revenue	1994 Rank	% Change in Revenue
Carl Zeiss	2.6	112	1.2	115	120.1
Jipelec	2.4	113	1.8	111	33.3
CHA Industries	2.3	114	1.7	112	35.3
Tystar	2.2	115	1.2	114	83.3
Shinko Seiki	1.8	116	3.7	102	-51.1
PRESI	1.5	117	1.2	113	25.0
Kuwano Electric	1.3	118	5.0	92	-74.0
AET Thermal	1.0	119	0.8	117	25.0
Pacific Western	0.7	120	0.7	119	0
Advanced Crystal Sciences Inc.	0.5	121	1.1	116	-54.6
Fujikoshi	0.1	122	0.3	121	-69.0
Process Technology Ltd.	-	-	0.8	118	NM
Identified Companies	17,780.9		9,962.2		78.5
Other Companies	1,272.6		825.1		54.2
All Companies	19,053.5		10,787.3		76.6

NM = Not meaningful
Notes: "Including joint ventures" indicates figures that include joint ventures.
Figures reported for Alcan Technology include sales by Alcan/Canon/Quester joint venture.
Figures reported for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table A-2
Company Sales Revenue Ranking from Shipments of Wafer Fab Equipment to the World, 1995 versus 1994—Alphabetized by Company Name

	1995 Revenue	1995 Rank	1994 Revenue	1994 Rank	% Change in Revenue
ADE Corporation	58.6	40	39.0	35	50.2
Advanced Crystal Sciences Inc.	0.5	121	1.1	116	-54.6
AET Thermal	1.0	119	0.8	117	25.0
AG Associates	61.2	39	36.4	40	68.0
Alcan Technology (see note)	188.3	19	93.6	21	101.2
Amaya	42.3	51	3.9	98	984.1
Amray	20.4	68	21.8	52	-6.1
Anelva	256.3	16	170.1	16	50.7
Applied Materials	2,904.9	1	1,480.7	1	96.2
ASM International	210.4	17	120.1	19	75.2
ASM Lithography	498.3	10	272.7	10	82.7
AST Electronic GmbH	37.3	57	18.7	56	99.5
Biorad	17.5	72	12.2	66	43.4
Canon	984.1	4	499.9	5	96.9
Carl Zeiss	2.6	112	1.2	115	120.1
CFM Technology	25.2	63	13.2	62	90.9
CHA Industries	2.3	114	1.7	112	35.3
Concept Systems Design	13.9	79	8.5	80	63.5
CVC Products	22.8	66	7.7	82	195.7
Cybeq Systems	7.0	94	7.0	84	0
Dainippon Screen	545.3	7	342.5	8	59.2
Dan Science Co. Ltd.	11.9	86	6.8	86	75.3
Denton Vacuum	4.5	104	4.0	97	12.5
E.T. Electrotech	85.8	32	52.7	29	62.8
Eaton (including JVs)	430.0	13	227.2	13	89.3
Ebara Corp.	13.3	83	4.7	93	183.2
Enya	6.1	96	4.4	95	38.6
ET Systems Engineering	16.3	74	8.9	78	83.3
Etec	53.1	42	50.7	31	4.7
Fairchild Convac	46.9	48	22.6	51	107.5
FSI International	152.3	22	74.1	22	105.5
Fujikoshi	0.1	122	0.3	121	-69.0
Fusion Semiconductor Systems	37.3	56	26.8	44	39.2
Gasonics	81.6	33	56.6	26	44.2
Genus	86.3	31	46.0	32	87.6
High Temperature Engineering	5.5	100	2.4	107	129.2
Hitachi	643.2	6	387.2	6	66.1

(Continued)

Table A-2 (Continued)
Company Sales Revenue Ranking from Shipments of Wafer Fab Equipment to the World, 1995 versus 1994—Alphabetized by Company Name

	1995 Revenue	1995 Rank	1994 Revenue	1994 Rank	% Change in Revenue
Holon	13.6	82	14.2	60	-4.4
Inspex	40.9	53	29.9	43	36.8
Integrated Solutions	97.8	28	-	-	NM
IPEC/Planar	118.9	24	43.0	34	176.5
IVS Inc.	2.8	111	4.7	94	-40.4
Japan Production Engineering	4.1	106	3.1	104	32.3
Jenoptik	7.8	91	9.0	77	-13.3
JEOL	115.7	25	71.1	23	62.8
Jipelec	2.4	113	1.8	111	33.3
Kaijo Denki	96.1	29	45.1	33	113.0
Karl Suss	39.2	54	25.2	47	55.6
KLA Instruments	459.6	12	255.5	12	79.9
Kokusai Electric (including JVs)	523.1	9	306.1	9	70.9
Koyo Lindberg	26.5	62	20.2	54	31.0
Kurt J. Lesker	3.4	110	2.7	106	25.9
Kuwano Electric	1.3	118	5.0	92	-74.0
Lam Research	899.2	5	520.6	4	72.7
Lasertec Corporation	5.4	101	3.8	101	44.7
Leica	63.5	37	58.6	25	8.3
Lepton Inc.	5.3	102	-	-	NM
LPE	6.1	97	3.9	99	56.4
Maruwa	18.5	69	13.2	63	40.7
Materials Research Corporation	169.9	21	124.5	17	36.5
Matrix Integrated Systems	23.6	64	17.4	58	35.6
Matsushita Electric	3.7	108	0.7	120	453.1
Mattson Technologies	50.8	44	19.5	55	160.5
MC Electronics	49.5	45	30.4	42	62.6
Moore Epitaxial Inc.	13.6	80	11.7	68	16.5
Musashi	5.6	99	4.1	96	36.6
Nanometrics	16.8	73	9.5	73	76.8
Nidek	11.7	87	9.5	74	22.9
Nikon	1,675.1	3	1,027.1	3	63.1
Nissin Electric	53.4	41	38.2	38	39.8
Novellus Systems Inc.	345.2	14	197.4	15	74.9
OnTrak Systems	31.7	59	11.4	69	178.1
Opal	47.5	47	26.8	45	77.2
Optical Specialties Inc.	27.3	61	12.8	65	113.3

(Continued)

Table A-2 (Continued)
Company Sales Revenue Ranking from Shipments of Wafer Fab Equipment to the World, 1995 versus 1994—Alphabetized by Company Name

	1995 Revenue	1995 Rank	1994 Revenue	1994 Rank	% Change in Revenue
Orbot	6.1	98	2.9	105	110.3
Oxford Instruments Inc.	7.4	92	6.5	87	13.9
Pacific Western	0.7	120	0.7	119	0
Philips	4.9	103	2.0	110	139.8
Plasma & Materials Technologies	15.5	76	9.9	71	56.6
Plasma Systems	51.9	43	38.3	37	35.5
PRESI	1.5	117	1.2	113	25.0
Process Technology Ltd.	-	-	0.8	118	NM
Rudolph Research	38.3	55	20.6	53	86.1
Samco	10.0	88	8.7	79	15.2
Sankyo Engineering	77.5	34	62.0	24	24.9
Santa Clara Plastics	71.8	36	51.5	30	39.4
Sapi Equipements	3.6	109	5.7	88	-36.8
SCI Manufacturing	7.2	93	2.3	108	213.0
Seiko	4.1	107	2.1	109	95.2
Semiconductor Systems	27.9	60	24.0	50	16.3
Semitool (including Semitherm)	92.9	30	37.3	39	149.4
Shibaura Engineering Works	41.4	52	24.6	48	68.5
Shimada	13.6	81	9.2	76	47.8
Shinko Electric	8.7	89	7.9	81	10.5
Shinko Seiki	1.8	116	3.7	102	-51.1
Silicon Valley Group	490.1	11	269.9	11	81.6
Speedfam	18.4	70	3.8	100	384.3
Sputtered Films	8.0	90	7.0	85	14.3
Steag Microtech	111.6	27	18.2	57	513.2
Strasbaugh	36.0	58	7.5	83	380.0
SubMicron Systems, Inc.	77.2	35	53.4	28	44.6
Sugai	123.7	23	34.1	41	263.2
Sumitomo Metals	63.5	38	24.4	49	160.0
Tazmo	17.9	71	12.9	64	38.8
Tegal	48.3	46	38.7	36	24.8
Tencor Instruments	309.1	15	210.4	14	46.9
Thermawave	46.1	49	13.8	61	234.1
Toho Kasei	22.8	65	15.1	59	51.1
Tokyo Aircraft Instruments	4.2	105	3.7	103	14.3
Tokyo Electron Ltd. (including JVs)	2,098.2	2	1,066.3	2	96.8
Tokyo Ohka Kogyo	14.0	78	11.9	67	17.7

(Continued)

Table A-2 (Continued)
Company Sales Revenue Ranking from Shipments of Wafer Fab Equipment to the World, 1995 versus 1994—Alphabetized by Company Name

	1995 Revenue	1995 Rank	1994 Revenue	1994 Rank	% Change in Revenue
Topcon	15.5	75	5.7	89	172.4
Toray Industries	6.7	95	5.5	90	21.1
Toshiba	21.9	67	9.6	72	128.1
Toyoko Kagaku	12.9	84	9.3	75	38.7
Tystar	2.2	115	1.2	114	83.3
Ultrapointe	12.0	85	5.2	91	130.8
Ultratech	112.0	26	56.4	27	98.7
Ulvac	173.6	20	116.0	20	49.6
Varian (including JVs)	535.4	8	375.3	7	42.7
Verteq	44.3	50	25.5	46	73.5
Watkins-Johnson	202.0	18	122.4	18	65.0
Yuasa	15.5	77	11.3	70	36.7
Identified Companies	17,780.9		9,962.2		78.5
Other Companies	1,272.6		825.1		54.2
All Companies	19,053.5		10,787.3		76.6

NM = Not meaningful
Notes: Figures reported for Alcan Technology include sales by Alcan/Canon/Quester joint venture.
"Including joint ventures" indicates figures that include joint ventures.
Figures reported for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table A-3
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Applied Materials						1
Dry Etch	154.0	187.0	317.2	416.1	904.5	
Dedicated LPCVD Reactors	32.0	60.9	88.7	121.0	240.9	
Dedicated PECVD Reactors	194.4	168.8	232.8	292.9	544.3	
Atmospheric/Subpressure CVD	0	0	0	0	61.9	
High-Density Plasma CVD	0	0	0	0	2.7	
Sputtering	52.3	124.8	249.3	504.4	880.9	
Silicon Epitaxy	32.0	23.0	21.9	41.5	92.0	
Rapid Thermal Processing	0	0	0	0	23.2	
High-Current Implanter	33.9	33.9	33.9	33.9	33.9	
Wafer Fab Equipment	498.6	602.0	972.0	1,480.7	2,904.9	
Tokyo Electron Ltd. (including JVs)						2
Resist Processing (Track)	150.2	126.7	194.6	360.6	782.1	
Auto Wet Stations	5.6	7.5	7.2	22.5	108.5	
Dry Etch	120.9	95.3	165.8	291.4	481.2	
Horizontal Tube LPCVD	9.0	5.7	3.1	2.0	0	
Vertical Tube LPCVD	60.7	56.1	88.1	176.7	319.1	
Dedicated LPCVD Reactors	2.7	0	1.5	14.8	74.1	
Vertical Diffusion	63.8	66.0	96.7	192.2	326.4	
Horizontal Diffusion	42.7	13.7	17.1	6.1	6.8	
Wafer Fab Equipment	455.6	371.0	574.1	1,066.3	2,098.2	
Tokyo Electron Ltd.						
Resist Processing (Track)	126.2	96.7	130.5	302.5	782.1	
Auto Wet Stations	5.6	7.5	7.2	22.5	108.5	
Dry Etch	110.0	88.3	145.4	279.8	481.2	
Horizontal Tube LPCVD	7.1	5.1	3.1	2.0	0	
Vertical Tube LPCVD	53.0	50.5	73.1	144.5	319.1	
Dedicated LPCVD Reactors	2.7	0	1.5	14.8	74.1	
Vertical Diffusion	55.7	60.9	69.2	152.3	326.4	
Horizontal Diffusion	37.0	11.7	17.1	6.1	6.8	
Wafer Fab Equipment	397.3	320.7	447.1	924.5	2,098.2	
Varian/TEL						
Resist Processing (Track)	24.0	30.0	64.1	58.1	0	
Dry Etch	10.9	7.0	20.4	11.6	0	
Horizontal Tube LPCVD	1.9	0.6	0	0	0	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Vertical Tube LPCVD	7.7	5.6	15.0	32.2	0	
Vertical Diffusion	8.1	5.1	27.5	39.9	0	
Horizontal Diffusion	5.7	2.0	0	0	0	
Wafer Fab Equipment	58.3	50.3	127.0	141.8	0	
Nikon						3
Steppers	538.2	291.1	490.5	1,011.2	1,651.4	
Optical Metrology	6.9	0.5	0.3	0.9	1.9	
CD SEM	0	0	0.8	1.8	1.0	
Manual Detection and Review	13.7	8.1	11.6	13.2	20.9	
Wafer Fab Equipment	558.8	299.7	503.2	1,027.1	1,675.1	
Canon						4
Contact/Proximity	11.9	3.6	4.0	2.5	2.0	
Projection Aligners	56.2	36.6	35.1	23.7	11.0	
Steppers	181.2	137.6	267.7	468.6	968.7	
Resist Processing (Track)	12.3	15.1	5.4	4.1	2.0	
Manual Detection and Review	4.4	2.5	1.1	0.9	0.4	
Wafer Fab Equipment	266.0	195.4	313.3	499.9	984.1	
Lam Research						5
Dry Etch	127.1	163.9	321.8	510.7	881.5	
Dedicated LPCVD Reactors	1.9	7.3	4.0	2.0	8.1	
High-Density Plasma CVD	0	0	4.2	7.9	9.6	
Wafer Fab Equipment	129.0	171.2	330.0	520.6	899.2	
Hitachi						6
Steppers	86.7	39.8	25.2	0	0	
Direct-Write Lithography	17.8	3.2	7.2	13.8	17.1	
Maskmaking Lithography	6.7	7.1	8.1	11.3	6.9	
Dry Strip	5.6	4.8	6.3	11.0	11.3	
Dry Etch	115.2	95.1	128.4	208.4	285.5	
High-Current Implanter	20.4	4.9	2.7	0	0	
Optical Metrology	4.2	1.4	2.4	5.7	4.5	
CD SEM	69.6	52.8	50.5	96.4	235.0	
Auto Patterned Detection	18.5	8.7	17.2	22.0	51.8	
Auto Review and Classification	10.7	1.9	4.3	10.8	18.2	
Auto Unpatterned Detection	13.3	5.9	4.2	7.8	13.0	
Wafer Fab Equipment	368.7	225.6	256.5	387.2	643.2	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Dainippon Screen						7
Resist Processing (Track)	69.5	77.4	107.5	130.7	218.1	
Auto Wet Stations	57.7	75.9	51.7	131.1	187.6	
Spray Processors	NS	NS	NS	10.2	12.9	
Vapor Phase Clean	NS	0	0	0.4	1.8	
Post-CMP Clean	0	0	0	6.2	13.9	
Other Clean Process	37.1	12.8	61.5	44.2	83.5	
Rapid Thermal Processing	3.5	2.8	4.6	14.6	21.2	
Thin-Film Measurement	7.0	10.6	6.7	5.0	6.3	
Wafer Fab Equipment	174.8	179.5	232.0	342.5	545.3	
Varian (including JVs)						8
Sputtering	90.9	71.8	78.8	137.8	191.1	
Medium-Current Implanter	55.8	47.5	56.1	141.8	229.0	
High-Current Implanter	76.5	66.2	66.6	95.7	115.3	
Wafer Fab Equipment	223.2	185.5	201.5	375.3	535.4	
Varian						
Sputtering	90.9	71.8	78.8	137.8	191.1	
Medium-Current Implanter	44.1	30.5	44.0	107.9	229.0	
High-Current Implanter	45.8	42.6	51.4	83.1	115.3	
Wafer Fab Equipment	180.8	144.9	174.2	328.8	535.4	
TEL/Varian						
Medium-Current Implanter	11.7	17.0	12.1	33.9	0	
High-Current Implanter	30.7	23.6	15.2	12.6	0	
Wafer Fab Equipment	42.4	40.6	27.3	46.5	0	
Kokusai Electric (including JVs)						9
Dry Etch	0	1.3	0.6	0	0	
Horizontal Tube LPCVD	1.6	2.9	7.0	7.6	6.6	
Vertical Tube LPCVD	62.0	54.5	90.3	129.8	233.2	
Silicon Epitaxy	5.9	11.1	4.6	0.8	8.1	
Vertical Diffusion	62.5	43.4	107.0	133.6	242.8	
Horizontal Diffusion	5.6	12.5	16.9	34.3	32.3	
Rapid Thermal Processing	0.6	0.6	0	0	0	
Wafer Fab Equipment	138.2	126.3	226.4	306.1	523.1	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Kokusai Electric						
Dry Etch	0	1.3	0.6	0	0	
Horizontal Tube LPCVD	1.6	0	1.2	0.4	0.0	
Vertical Tube LPCVD	62.0	54.5	89.8	126.6	223.2	
Silicon Epitaxy	5.9	11.1	4.6	0.8	8.1	
Vertical Diffusion	62.5	43.4	106.5	120.6	212.4	
Horizontal Diffusion	5.6	5.3	3.7	5.3	5.3	
Rapid Thermal Processing	0.6	0.6	0	0	0	
Wafer Fab Equipment	138.2	116.2	206.4	253.7	449.1	
Bruce Technologies						
Horizontal Tube LPCVD	0	2.9	5.8	7.2	6.6	
Vertical Tube LPCVD	0	0	0.5	3.2	10.0	
Vertical Diffusion	0	0	0.5	13.0	30.4	
Horizontal Diffusion	0	7.2	13.2	29.0	27.0	
Wafer Fab Equipment	0	10.1	20.0	52.4	74.0	
ASM Lithography						10
Steppers	71.3	102.0	169.9	272.7	498.3	
Wafer Fab Equipment	71.3	102.0	169.9	272.7	498.3	
Silicon Valley Group						11
Projection Aligners	22.2	11.6	22.1	27.1	24.8	
Steppers	30.4	23.2	22.3	23.8	76.7	
X-Ray Aligners	0	0	11.4	11.2	2.8	
Resist Processing (Track)	38.0	44.8	89.6	93.3	207.0	
Horizontal Tube LPCVD	7.3	7.8	5.9	8.5	6.8	
Vertical Tube LPCVD	12.2	12.2	13.8	31.8	69.7	
Vertical Diffusion	19.1	19.0	32.1	58.6	85.7	
Horizontal Diffusion	21.6	23.3	13.9	15.6	16.6	
Wafer Fab Equipment	150.8	141.9	211.1	269.9	490.1	
KLA Instruments						12
Optical Metrology	9.3	11.2	18.0	30.2	50.2	
CD SEM	0	0	0	4.7	5.0	
Auto Patterned Detection	26.4	60.0	84.8	182.3	354.5	
Other Process Control	62.3	25.5	32.9	38.3	49.9	
Wafer Fab Equipment	98.0	96.7	135.7	255.5	459.6	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Eaton (including JVs)						13
Resist Processing (Track)	4.2	2.6	2.1	0	0	
Medium-Current Implanter	12.6	11.0	21.1	32.5	72.5	
High-Current Implanter	86.3	55.2	95.8	190.7	277.7	
High-Voltage Implanter	3.3	7.2	3.0	4.0	79.8	
Wafer Fab Equipment	106.4	76.0	122.0	227.2	430.0	
Eaton						
Resist Processing (Track)	4.2	2.6	2.1	0	0	
Medium-Current Implanter	12.6	11.0	21.1	32.5	70.3	
High-Current Implanter	40.6	36.6	48.8	104.3	168.9	
High-Voltage Implanter	3.3	7.2	3.0	0	45.5	
Wafer Fab Equipment	60.7	57.4	75.0	136.8	284.7	
Sumitomo/Eaton Noversus						
Medium-Current Implanter	0	0	0	0	2.2	
High-Current Implanter	45.7	18.6	47.0	86.4	108.8	
High-Voltage Implanter	0	0	0	4.0	34.3	
Wafer Fab Equipment	45.7	18.6	47.0	90.4	145.3	
Novellus Systems Inc.						14
Dedicated LPCVD Reactors	5.7	6.7	19.0	44.1	100.1	
Dedicated PECVD Reactors	64.0	48.4	70.5	146.1	240.1	
Sputtering	1.8	2.4	4.8	7.2	5.0	
Wafer Fab Equipment	71.5	57.5	94.3	197.4	345.2	
Tencor Instruments						15
Thin-Film Measurement	14.6	24.9	36.5	47.3	83.2	
Auto Patterned Detection	12.1	11.7	17.7	43.6	76.1	
Auto Unpatterned Detection	15.4	15.1	22.3	39.3	78.4	
Other Process Control	44.8	40.1	46.5	80.2	71.4	
Wafer Fab Equipment	86.9	91.8	123.0	210.4	309.1	
Anelva						16
Dry Etch	21.3	19.6	15.2	26.9	81.3	
Dedicated LPCVD Reactors	0	0	0	0.9	1.7	
High-Density Plasma CVD	3.8	0	0	0	0	
Sputtering	114.5	81.8	78.3	134.7	158.5	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Other Deposition	12.8	6.2	12.6	7.6	14.7	
Wafer Fab Equipment	152.4	107.6	106.1	170.1	256.3	
ASM International						17
Horizontal Tube LPCVD	7.9	5.3	2.1	0	0	
Vertical Tube LPCVD	22.6	19.0	22.6	35.1	63.3	
Horizontal Tube PECVD	40.0	28.4	25.2	26.0	27.9	
Dedicated PECVD Reactors	0	0	1.6	8.0	45.3	
Silicon Epitaxy	29.9	31.2	38.6	40.5	57.0	
Vertical Diffusion	10.0	8.4	12.0	10.5	16.9	
Horizontal Diffusion	11.7	8.2	3.1	0	0	
Wafer Fab Equipment	122.1	100.5	105.2	120.1	210.4	
Watkins-Johnson						
Atmospheric/Subatmospheric CVD	48.5	45.0	66.2	122.4	202.0	18
Wafer Fab Equipment	48.5	45.0	66.2	122.4	202.0	
Alcan Technology (see note)						19
Dry Strip	19.2	15.7	16.8	25.8	71.5	
Dry Etch	5.6	3.8	2.2	3.1	1.7	
Atmospheric/Subatmospheric CVD	26.8	28.5	30.1	64.7	115.0	
Wafer Fab Equipment	51.6	48.0	49.1	93.6	188.3	
Ulvac						20
Dry Strip	2.3	1.9	3.1	2.0	2.1	
Dry Etch	6.2	2.0	3.2	2.5	5.3	
Horizontal Tube LPCVD	2.3	2.5	1.8	1.3	2.5	
Vertical Tube LPCVD	5.6	5.8	7.3	8.2	11.7	
Dedicated LPCVD Reactors	9.4	9.4	9.6	6.4	22.6	
Sputtering	45.3	37.5	47.3	54.3	80.4	
Other Deposition	18.7	0	0	0	0	
Vertical Diffusion	4.2	4.4	3.8	5.9	8.6	
Horizontal Diffusion	12.6	10.1	11.0	4.1	4.9	
Medium-Current Implanter	11.1	5.5	12.9	31.5	35.6	
Wafer Fab Equipment	117.7	79.1	100.0	116.0	173.6	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Materials Research Corporation						21
Dry Etch	9.6	0	0	0	0	
Dedicated LPCVD Reactors	0	4.1	0	5.5	14.9	
Sputtering	84.5	102.9	96.5	119.0	155.0	
Wafer Fab Equipment	94.1	107.0	96.5	124.5	169.9	
FSI International						22
Resist Processing (Track)	5.1	16.6	21.0	35.5	86.5	
Spray Processors	NS	NS	NS	29.0	56.0	
Vapor Phase Clean	NS	2.4	5.6	7.5	9.7	
Post-CMP Clean	0	0	0.4	0.8	0	
Other Clean Process	17.2	18.4	18.0	1.3	0.1	
Wafer Fab Equipment	22.3	37.4	45.0	74.1	152.3	
Sugai						23
Auto Wet Stations	31.4	32.0	31.5	32.6	121.5	
Other Clean Process	1.2	1.6	1.1	1.5	2.2	
Wafer Fab Equipment	32.6	33.6	32.6	34.1	123.7	
IPEC/Planar						24
Post-CMP Clean	0.4	2.4	4.0	3.3	1.5	
Other Clean Process	0	0	0	0	1.2	
Chemical Mechanical Polishing	8.0	14.0	30.6	39.7	116.2	
Wafer Fab Equipment	8.4	16.4	34.6	43.0	118.9	
JEOL						25
Direct-Write Lithography	26.8	8.7	7.2	7.8	8.1	
Maskmaking Lithography	11.1	11.1	0	9.2	10.0	
CD SEM	0	1.4	0.7	3.9	0	
Auto Review and Classification	0	1.1	2.1	50.2	97.6	
Wafer Fab Equipment	37.9	22.3	10.0	71.1	115.7	
Ultratech						26
Steppers	24.6	19.2	31.7	56.4	112.0	
Wafer Fab Equipment	24.6	19.2	31.7	56.4	112.0	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Steag Microtech						27
Auto Wet Stations	0	0	0	17.7	94.0	
Other Clean Process	0	0	0	0.5	17.6	
Wafer Fab Equipment	0	0	0	18.2	111.6	
Integrated Solutions						28
Steppers	0	0	0	0	24.5	
Resist Processing (Track)	0	0	0	0	8.7	
Other Wafer Fab Equipment	0	0	0	0	64.7	
Wafer Fab Equipment	0	0	0	0	97.8	
Kaijo Denki						29
Auto Wet Stations	29.9	17.1	19.1	45.1	96.1	
Other Clean Process	3.2	0	0.4	0	0	
Wafer Fab Equipment	33.1	17.1	19.5	45.1	96.1	
Semitool (including Semitherm)						30
Spray Processors	NS	NS	NS	21.4	53.9	
Other Clean Process	12.1	0	15.0	7.7	11.6	
Vertical Tube LPCVD	1.5	0.5	2.5	3.2	27.4	
Vertical Diffusion	3.0	0.9	4.9	5.0	0	
Wafer Fab Equipment	16.6	1.4	22.4	37.3	92.9	
Semitherm						
Vertical Tube LPCVD	1.5	0.5	2.5	3.2	27.4	
Vertical Diffusion	3.0	0.9	4.9	5.0	0	
Wafer Fab Equipment	4.5	1.4	7.4	8.2	27.4	
Semitool						
Spray Processors	NS	NS	NS	21.4	53.9	
Other Clean Process	12.1	0	15.0	7.7	11.6	
Wafer Fab Equipment	12.1	0	15.0	29.1	65.5	
Genus						31
Dedicated LPCVD Reactors	29.7	21.9	24.5	23.4	46.9	
High-Voltage Implanter	11.3	8.5	12.4	22.6	39.4	
Wafer Fab Equipment	41.0	30.4	36.9	46.0	86.3	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
E.T. Electrotech						32
Dry Etch	12.0	6.6	12.3	13.0	17.2	
Dedicated PECVD Reactors	20.0	12.6	7.7	11.2	15.0	
Sputtering	12.0	7.2	9.9	28.5	53.6	
Wafer Fab Equipment	44.0	26.4	29.9	52.7	85.8	
Gasonics						33
Dry Strip	22.9	24.4	38.5	51.6	79.4	
Dry Etch	5.0	3.0	3.1	4.2	0.9	
Horizontal Diffusion	8.7	4.4	0.8	0.8	1.3	
Wafer Fab Equipment	36.6	31.8	42.4	56.6	81.6	
Sankyo Engineering						34
Auto Wet Stations	27.4	19.4	16.8	58.1	74.3	
Other Clean Process	5.3	1.7	8.5	3.9	3.2	
Wafer Fab Equipment	32.7	21.1	25.3	62.0	77.5	
SubMicron Systems, Inc.						35
Auto Wet Stations	12.0	22.4	35.4	46.4	68.1	
Other Clean Process	0	0	0	7.0	9.1	
Wafer Fab Equipment	12.0	22.4	35.4	53.4	77.2	
Santa Clara Plastics						36
Auto Wet Stations	19.5	43.7	45.8	46.3	60.6	
Other Clean Process	0.7	0	2.2	5.2	11.2	
Wafer Fab Equipment	20.2	43.7	48.0	51.5	71.8	
Leica						37
Direct-Write Lithography	5.6	5.9	5.4	8.0	7.2	
Maskmaking Lithography	4.5	5.7	5.0	2.9	2.4	
Optical Metrology	1.8	0.8	0.9	0.4	0.3	
Thin-Film Measurement	1.8	1.9	1.9	1.4	0.8	
Auto Review and Classification	4.9	6.0	9.7	19.7	24.9	
Manual Detection and Review	0	0	0	26.2	27.9	
Wafer Fab Equipment	18.6	20.3	22.9	58.6	63.5	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Sumitomo Metals						38
Chemical Mechanical Polishing	0	0	0	0	4.2	
Dry Strip	2.1	4.5	1.7	2.2	8.1	
Dry Etch	15.4	13.2	20.1	22.2	51.2	
High-Density Plasma CVD	2.7	0	5.2	0	0	
Wafer Fab Equipment	20.2	17.7	27.0	24.4	63.5	
AG Associates						39
Rapid Thermal Processing	24.4	13.5	21.7	36.4	61.2	
Wafer Fab Equipment	24.4	13.5	21.7	36.4	61.2	
ADE Corporation						40
Auto Unpatterned Detection	0	0	2.9	7.7	14.6	
Other Process Control	19.0	22.8	27.1	31.3	44.0	
Wafer Fab Equipment	19.0	22.8	30.0	39.0	58.6	
Nissin Electric						41
Other Deposition	1.7	0	1.4	2.4	4.0	
Medium-Current Implanter	28.0	19.4	17.8	35.8	46.7	
High-Current Implanter	11.2	0	5.9	0	2.7	
High-Voltage Implanter	3.0	0	2.7	0	0	
Wafer Fab Equipment	43.9	19.4	27.8	38.2	53.4	
Etec						42
Direct-Write Lithography	0	8.0	0	2.0	0	
Maskmaking Lithography	10.5	28.8	34.6	48.7	53.1	
Wafer Fab Equipment	10.5	36.8	34.6	50.7	53.1	
Plasma Systems						43
Dry Strip	21.2	16.1	27.1	34.4	48.7	
Dry Etch	2.0	0.2	1.8	3.9	3.2	
Wafer Fab Equipment	23.2	16.3	28.9	38.3	51.9	
Mattson Technologies						44
Dry Strip	1.5	1.8	3.2	19.5	50.8	
Wafer Fab Equipment	1.5	1.8	3.2	19.5	50.8	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
MC Electronics						45
Dry Strip	0	14.9	19.1	30.4	49.5	
Wafer Fab Equipment	0	14.9	19.1	30.4	49.5	
Tegal						46
Dry Strip	3.5	1.6	0.2	2.5	1.5	
Dry Etch	29.0	33.1	29.7	36.2	46.8	
Wafer Fab Equipment	32.5	34.7	29.9	38.7	48.3	
Opal						47
CD SEM	2.4	9.4	14.7	26.8	47.5	
Wafer Fab Equipment	2.4	9.4	14.7	26.8	47.5	
Fairchild Convac						48
Resist Processing (Track)	15.0	16.6	17.6	22.6	46.9	
Wafer Fab Equipment	15.0	16.6	17.6	22.6	46.9	
Thermawaversus						49
Thin-Film Measurement	0.3	1.9	3.9	13.8	46.1	
Wafer Fab Equipment	0.3	1.9	3.9	13.8	46.1	
Verteq						50
Auto Wet Stations	2.3	1.1	0.8	0	8.8	
Post-CMP Clean	0	0	0	0.0	0.3	
Other Clean Process	13.2	15.4	19.1	25.5	35.2	
Wafer Fab Equipment	15.5	16.5	19.9	25.5	44.3	
Amaya						51
Atmospheric/Subpressure CVD	12.3	6.3	5.4	3.9	42.3	
Wafer Fab Equipment	12.3	6.3	5.4	3.9	42.3	
Shibaura Engineering Works						52
Dry Strip	0	0	0	0	0.6	
Dry Etch	26.9	14.8	36.3	24.6	40.7	
Sputtering	2.6	4.4	0	0	0	
Wafer Fab Equipment	29.5	19.2	36.3	24.6	41.4	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Inspex						53
Auto Patterned Detection	13.1	16.1	18.8	22.1	28.9	
Auto Review and Classification	0	0	0	7.8	12.0	
Wafer Fab Equipment	13.1	16.1	18.8	29.9	40.9	
Karl Suss						54
Contact/Proximity	12.9	23.1	22.2	25.2	31.9	
X-Ray Aligners	1.8	5.0	2.0	0	7.4	
Wafer Fab Equipment	14.7	28.1	24.2	25.2	39.2	
Rudolph Research						55
Thin-Film Measurement	5.4	7.8	10.4	20.6	38.3	
Wafer Fab Equipment	5.4	7.8	10.4	20.6	38.3	
AST Electronic GmbH						56
Rapid Thermal Processing	4.1	4.7	9.3	18.7	37.3	
Wafer Fab Equipment	4.1	4.7	9.3	18.7	37.3	
Fusion Semiconductor Systems						57
Dry Strip	1.9	3.6	6.2	12.9	19.9	
Other Wafer Fab Equipment	0	0	12.0	13.9	17.4	
Wafer Fab Equipment	1.9	3.6	18.2	26.8	37.3	
Strasbaugh						58
Chemical Mechanical Polishing	2.6	2.9	5.7	7.5	36.0	
Wafer Fab Equipment	2.6	2.9	5.7	7.5	36.0	
OnTrak Systems						59
Post-CMP Clean	0	0	4.5	11.4	31.7	
Wafer Fab Equipment	0	0	4.5	11.4	31.7	
Semiconductor Systems						60
Resist Processing (Track)	17.2	20.9	21.9	24.0	27.9	
Wafer Fab Equipment	17.2	20.9	21.9	24.0	27.9	
Optical Specialties Inc.						61
Optical Metrology	5.7	6.4	6.4	10.2	16.3	
Auto Patterned Detection	0	4.4	3.8	2.6	11.0	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Manual Detection and Review	0.1	0	0	0	0	
Wafer Fab Equipment	5.8	10.8	10.2	12.8	27.3	
Koyo Lindberg						62
Horizontal Tube LPCVD	0	0.8	1.3	1.6	1.8	
Vertical Tube LPCVD	1.9	1.3	0.8	1.1	0.8	
Atmospheric/Subatmospheric CVD	0.6	0	0.5	0	0	
Vertical Diffusion	6.7	9.2	6.5	10.4	14.9	
Horizontal Diffusion	5.9	8.2	3.4	6.4	8.3	
Rapid Thermal Processing	0.3	0.5	1.4	0.7	0.8	
Wafer Fab Equipment	15.4	20.0	13.9	20.2	26.5	
CFM Technology						63
Auto Wet Stations	4.8	5.9	12.3	13.2	25.2	
Wafer Fab Equipment	4.8	5.9	12.3	13.2	25.2	
Matrix Integrated Systems						64
Dry Strip	7.5	7.0	9.0	12.7	17.5	
Dry Etch	2.3	1.5	2.9	4.7	6.1	
Wafer Fab Equipment	9.8	8.5	11.9	17.4	23.6	
Toho Kasei						65
Auto Wet Stations	5.2	10.3	12.6	12.6	17.7	
Other Clean Process	1.9	1.0	4.8	2.5	5.1	
Wafer Fab Equipment	7.1	11.3	17.4	15.1	22.8	
CVC Products						66
Sputtering	7.0	6.0	6.9	7.7	22.8	
Other Deposition	2.7	0	0	0	0	
Wafer Fab Equipment	9.7	6.0	6.9	7.7	22.8	
Toshiba						67
Maskmaking Lithography	0	0	0	2.0	2.1	
Atmospheric/Subatmospheric CVD	3.2	2.1	1.2	0.4	3.7	
Silicon Epitaxy	12.5	9.5	4.5	7.2	16.0	
Wafer Fab Equipment	15.7	11.6	5.7	9.6	21.9	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Amray						68
CD SEM	3.4	3.0	1.5	0	0	
Auto Review and Classification	0.9	7.2	9.6	21.8	20.4	
Wafer Fab Equipment	4.3	10.2	11.1	21.8	20.4	
Maruwa						69
Auto Wet Stations	8.1	2.0	2.7	5.4	9.2	
Other Clean Process	6.9	4.3	6.7	7.7	9.3	
Wafer Fab Equipment	15.0	6.3	9.4	13.2	18.5	
Speedfam						70
Chemical Mechanical Polishing	0	0	2.0	3.8	18.4	
Wafer Fab Equipment	0	0	2.0	3.8	18.4	
Tazmo						71
Resist Processing (Track)	15.2	10.0	18.0	12.9	17.9	
Wafer Fab Equipment	15.2	10.0	18.0	12.9	17.9	
Biorad						72
Optical Metrology	5.6	2.4	6.4	12.2	17.5	
CD SEM	4.9	0	0	0	0	
Wafer Fab Equipment	10.5	2.4	6.4	12.2	17.5	
Nanometrics						73
Optical Metrology	1.8	1.8	1.8	0	0	
CD SEM	0	0.3	0	0	0	
Thin-Film Measurement	10.5	8.2	10.4	9.5	16.8	
Wafer Fab Equipment	12.3	10.3	12.2	9.5	16.8	
ET Systems Engineering						74
Auto Wet Stations	10.4	10.0	8.3	6.9	12.0	
Other Clean Process	0.5	0	1.9	2.0	4.3	
Horizontal Tube LPCVD	0	0	0.2	0	0	
Other Deposition	0	0	2.5	0	0	
Horizontal Diffusion	0	0.1	0.6	0	0	
Wafer Fab Equipment	10.9	10.1	13.5	8.9	16.3	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Topcon						75
CD SEM	2.1	4.3	1.4	4.2	10.9	
Auto Review and Classification	0	0.6	0.7	0	0	
Auto Unpatterned Detection	6.5	4.0	2.2	1.5	4.6	
Wafer Fab Equipment	8.6	8.9	4.3	5.7	15.5	
Plasma & Materials Technologies						76
Dry Etch	0	0	4.7	9.9	15.5	
Dedicated PECVD Reactors	0	0	1.5	0	0	
Wafer Fab Equipment	0	0	6.2	9.9	15.5	
Yuasa						77
Resist Processing (Track)	5.9	2.4	8.1	11.3	15.5	
Wafer Fab Equipment	5.9	2.4	8.1	11.3	15.5	
Tokyo Ohka Kogyo						78
Dry Strip	15.7	8.9	3.8	5.9	6.6	
Dry Etch	15.3	5.5	4.7	6.0	7.4	
Wafer Fab Equipment	31.0	14.4	8.5	11.9	14.0	
Concept Systems Design						79
Silicon Epitaxy	0.4	1.6	3.2	8.5	13.9	
Wafer Fab Equipment	0.4	1.6	3.2	8.5	13.9	
Moore Epitaxial Inc.						80
Silicon Epitaxy	3.3	4.5	5.8	11.7	13.6	
Wafer Fab Equipment	3.3	4.5	5.8	11.7	13.6	
Shimada						81
Auto Wet Stations	13.4	6.3	3.6	7.1	10.4	
Other Clean Process	8.9	2.4	1.1	2.1	3.2	
Wafer Fab Equipment	22.3	8.7	4.7	9.2	13.6	
Holon						82
CD SEM	8.0	5.0	6.3	14.2	13.6	
Wafer Fab Equipment	8.0	5.0	6.3	14.2	13.6	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Ebara Corp.						83
Chemical Mechanical Polishing	0	0	0	4.7	13.3	
Wafer Fab Equipment	0	0	0	4.7	13.3	
Toyoko Kagaku						84
Auto Wet Stations	0.9	0	0	3.5	5.8	
Other Clean Process	0	0.8	1.0	1.9	2.5	
Vertical Tube LPCVD	5.0	1.3	1.2	3.9	4.6	
Wafer Fab Equipment	5.9	2.1	2.2	9.3	12.9	
Ultrapointe						85
Auto Review and Classification	0	0	0.9	5.2	12.0	
Wafer Fab Equipment	0	0	0.9	5.2	12.0	
Dan Science Co. Ltd.						86
Auto Wet Stations	14.2	5.0	4.1	4.8	8.5	
Other Clean Process	4.9	0	4.8	2.1	3.4	
Wafer Fab Equipment	19.1	5.0	8.9	6.8	11.9	
Nidek						87
Manual Detection and Review	7.1	5.1	4.6	9.5	11.7	
Wafer Fab Equipment	7.1	5.1	4.6	9.5	11.7	
Samco						88
Dry Strip	1.1	0.9	0.5	0.5	0.5	
Dry Etch	3.8	4.7	1.9	3.3	3.6	
Dedicated PECVD Reactors	4.3	5.4	3.1	4.1	4.9	
Other Deposition	0.9	0	0	0	0	
Rapid Thermal Processing	0	0.9	0.9	0.8	1.0	
Wafer Fab Equipment	10.1	11.9	6.4	8.7	10.0	
Shinko Electric						89
Vertical Tube LPCVD	6.2	1.9	2.3	2.5	3.3	
Vertical Diffusion	7.4	3.6	4.0	5.4	5.4	
Wafer Fab Equipment	13.6	5.5	6.3	7.9	8.7	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Sputtered Films						90
Sputtering	2.3	2.7	5.9	7.0	8.0	
Wafer Fab Equipment	2.3	2.7	5.9	7.0	8.0	
Jenoptik						91
Direct-Write Lithography	0	0	3.2	3.3	5.6	
Maskmaking Lithography	0	0	4.3	5.0	2.2	
CD SEM	0	0	0	0.7	0	
Wafer Fab Equipment	0	0	7.5	9.0	7.8	
Oxford Instruments Inc.						92
Dry Etch	6.3	3.8	5.6	3.9	4.4	
Dedicated PECVD Reactors	0	0	2.4	1.8	2.2	
High-Density Plasma CVD	1.5	0.8	1.1	0.8	0.8	
Wafer Fab Equipment	7.8	4.6	9.1	6.5	7.4	
SCI Manufacturing						93
Auto Wet Stations	4.8	5.0	4.5	2.3	7.2	
Wafer Fab Equipment	4.8	5.0	4.5	2.3	7.2	
Cybeq Systems						94
Chemical Mechanical Polishing	0	2.5	4.5	7.0	7.0	
Wafer Fab Equipment	0	2.5	4.5	7.0	7.0	
Toray Industries						95
Auto Patterned Detection	1.2	2.6	1.6	5.5	6.7	
Wafer Fab Equipment	1.2	2.6	1.6	5.5	6.7	
Enya						96
Auto Wet Stations	10.7	3.6	1.3	2.4	3.3	
Other Clean Process	3.1	0.9	2.3	2.0	2.8	
Dedicated PECVD Reactors	1.6	0.8	0	0	0	
Wafer Fab Equipment	15.4	5.3	3.6	4.4	6.1	
LPE						97
Silicon Epitaxy	5.0	3.1	4.0	3.9	6.1	
Wafer Fab Equipment	5.0	3.1	4.0	3.9	6.1	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Orbot						98
Auto Patterned Detection	0	0	0	2.9	6.1	
Wafer Fab Equipment	0	0	0	2.9	6.1	
Musashi						99
Auto Wet Stations	4.1	1.6	2.3	2.6	3.8	
Vapor Phase Clean	NS	0	0	0.9	1.1	
Other Clean Process	1.4	0.7	1.1	0.6	0.7	
Wafer Fab Equipment	5.5	2.3	3.4	4.1	5.6	
High Temperature Engineering						100
Rapid Thermal Processing	0.8	1.0	1.2	2.4	5.5	
Wafer Fab Equipment	0.8	1.0	1.2	2.4	5.5	
Lasertec Corporation						101
Manual Detection and Review	0	0	0.5	3.8	5.4	
Wafer Fab Equipment	0	0	0.5	3.8	5.4	
Lepton Inc.						102
Maskmaking Lithography	0	0	0	0	5.3	
Wafer Fab Equipment	0	0	0	0	5.3	
Philips						103
Auto Review and Classification	0	0	0	2.0	4.9	
Wafer Fab Equipment	0	0	0	2.0	4.9	
Denton Vacuum						104
Sputtering	1.8	1.0	3.0	4.0	4.5	
Other Deposition	3.2	0	0	0	0	
Wafer Fab Equipment	5.0	1.0	3.0	4.0	4.5	
Tokyo Aircraft Instruments						105
Optical Metrology	3.3	2.8	2.0	3.7	4.2	
Wafer Fab Equipment	3.3	2.8	2.0	3.7	4.2	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Japan Production Engineering						106
Dedicated PECVD Reactors	5.6	3.2	2.2	3.1	4.1	
Wafer Fab Equipment	5.6	3.2	2.2	3.1	4.1	
Seiko						107
Auto Review and Classification	6.1	2.9	2.1	2.1	4.1	
Wafer Fab Equipment	6.1	2.9	2.1	2.1	4.1	
Matsushita Electric						108
Dry Etch	0	3.1	0	0.7	3.7	
Wafer Fab Equipment	0	3.1	0	0.7	3.7	
Sapi Equipements						109
Auto Wet Stations	2.0	2.0	1.5	2.0	3.6	
Other Clean Process	1.5	0	1.0	3.7	0	
Wafer Fab Equipment	3.5	2.0	2.5	5.7	3.6	
Kurt J. Lesker						110
Sputtering	1.0	0.8	2.4	2.7	3.4	
Other Deposition	0.8	0	0	0	0	
Wafer Fab Equipment	1.8	0.8	2.4	2.7	3.4	
IVS Inc.						111
Optical Metrology	7.6	2.3	3.0	3.5	2.8	
CD SEM	0	0	2.4	1.2	0	
Wafer Fab Equipment	7.6	2.3	5.4	4.7	2.8	
Carl Zeiss						112
Manual Detection and Review	1.4	1.0	1.2	1.2	2.6	
Wafer Fab Equipment	1.4	1.0	1.2	1.2	2.6	
Jipelec						113
Rapid Thermal Processing	1.0	1.3	1.5	1.8	2.4	
Wafer Fab Equipment	1.0	1.3	1.5	1.8	2.4	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
CHA Industries						114
Sputtering	0.7	0.2	0.2	1.7	2.3	
Other Deposition	3.7	0	0	0	0	
Wafer Fab Equipment	4.4	0.2	0.2	1.7	2.3	
Tystar						115
Horizontal Tube LPCVD	0.3	0.6	0.6	0.4	0.4	
Horizontal Diffusion	0.5	0.2	0.2	0.8	1.8	
Wafer Fab Equipment	0.8	0.8	0.8	1.2	2.2	
Shinko Seiki						116
Dry Strip	1.1	0.4	1.8	1.2	0.7	
Sputtering	0.4	1.4	0.9	2.5	1.1	
Wafer Fab Equipment	1.5	1.8	2.7	3.7	1.8	
PRESI						117
Chemical Mechanical Polishing	0.2	0.3	0.5	1.2	1.5	
Wafer Fab Equipment	0.2	0.3	0.5	1.2	1.5	
Kuwano Electric						118
Auto Wet Stations	7.1	1.6	1.9	5.0	1.3	
Wafer Fab Equipment	7.1	1.6	1.9	5.0	1.3	
AET Thermal						119
Rapid Thermal Processing	0.7	0.9	1.1	0.8	1.0	
Wafer Fab Equipment	0.7	0.9	1.1	0.8	1.0	
Pacific Western						120
Horizontal Tube PECVD	1.0	1.0	1.2	0	0	
Horizontal Diffusion	0.4	0.6	1.5	0.7	0.7	
Wafer Fab Equipment	1.4	1.6	2.7	0.7	0.7	
Advanced Crystal Sciences Inc.						121
Horizontal Tube LPCVD	0	0.7	1.0	1.1	0.5	
Horizontal Diffusion	0	0	0.1	0	0	
Wafer Fab Equipment	0	0.7	1.1	1.1	0.5	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Fujikoshi						122
Chemical Mechanical Polishing	0	0	0.3	0.3	0.1	
Wafer Fab Equipment	0	0	0.3	0.3	0.1	
Advanced Film Technology, Inc.						-
Sputtering	0.8	0	0	0	0	
Wafer Fab Equipment	0.8	0	0	0	0	
Advantage Production Technology						-
Other Clean Process	3.4	0	0	0	0	
Wafer Fab Equipment	3.4	0	0	0	0	
Aixtron						-
Other Deposition	15.0	0	0	0	0	
Wafer Fab Equipment	15.0	0	0	0	0	
Alameda Instruments						-
Other Clean Process	1.6	0	0	0	0	
Wafer Fab Equipment	1.6	0	0	0	0	
Angstrom Measurements						-
CD SEM	2.2	0	0	0	0	
Wafer Fab Equipment	2.2	0	0	0	0	
Ateq						-
Maskmaking Lithography	15.0	0	0	0	0	
Wafer Fab Equipment	15.0	0	0	0	0	
Athens						-
Other Clean Process	1.2	0	0	0	0	
Wafer Fab Equipment	1.2	0	0	0	0	
BCT Spectrum						-
Dedicated LPCVD Reactors	2.0	0	0	0	0	
Wafer Fab Equipment	2.0	0	0	0	0	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
BTU International						-
Horizontal Tube LPCVD	6.0	0	0	0	0	
Vertical Tube LPCVD	4.5	0	0	0	0	
Vertical Diffusion	6.0	0	0	0	0	
Horizontal Diffusion	13.0	0	0	0	0	
Wafer Fab Equipment	29.5	0	0	0	0	
Censor						-
Auto Unpatterned Detection	1.5	2.8	0.7	0	0	
Wafer Fab Equipment	1.5	2.8	0.7	0	0	
Centrotherm						-
Horizontal Tube LPCVD	3.1	1.6	1.6	0	0	
Horizontal Diffusion	6.7	3.3	3.5	0	0	
Wafer Fab Equipment	9.8	4.9	5.1	0	0	
CPA						-
Sputtering	2.0	1.0	0	0	0	
Wafer Fab Equipment	2.0	1.0	0	0	0	
CVD Equipment						-
Other Deposition	0.7	0	0	0	0	
Wafer Fab Equipment	0.7	0	0	0	0	
CVT						-
Other Deposition	1.0	0	0	0	0	
Wafer Fab Equipment	1.0	0	0	0	0	
Daido Sanso						-
Other Deposition	1.8	0	0	0	0	
Wafer Fab Equipment	1.8	0	0	0	0	
Dalton Corporation						-
Auto Wet Stations	1.2	0	0	0	0	
Other Clean Process	0.7	0	0	0	0	
Wafer Fab Equipment	1.9	0	0	0	0	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Disco						-
Vertical Tube LPCVD	2.7	0.9	0	0	0	
Vertical Diffusion	10.0	5.4	2.2	0	0	
Wafer Fab Equipment	12.7	6.3	2.2	0	0	
Drytek						-
Dry Etch	25.0	17.1	4.5	0	0	
Wafer Fab Equipment	25.0	17.1	4.5	0	0	
Eiko						-
Other Deposition	2.2	0	0	0	0	
Wafer Fab Equipment	2.2	0	0	0	0	
Elionix						-
Dry Etch	0.7	0.4	0	0	0	
Wafer Fab Equipment	0.7	0.4	0	0	0	
Emcore						-
Other Deposition	12.2	0	0	0	0	
Wafer Fab Equipment	12.2	0	0	0	0	
Estek						-
Auto Unpatterned Detection	4.5	1.9	0	0	0	
Wafer Fab Equipment	4.5	1.9	0	0	0	
Fuji Electric						-
Auto Wet Stations	1.6	1.2	0	0	0	
High-Density Plasma CVD	0	4.0	2.2	0	0	
Wafer Fab Equipment	1.6	5.2	2.2	0	0	
GCA						-
Steppers	46.8	33.5	0	0	0	
Wafer Fab Equipment	46.8	33.5	0	0	0	
General Signal Thinfilm Company						-
Vertical Tube LPCVD	3.0	0	0	0	0	
Atmospheric/Subatmospheric CVD	0.5	0	0	0	0	
Vertical Diffusion	2.0	0	0	0	0	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Horizontal Diffusion	1.0	0	0	0	0	
Wafer Fab Equipment	6.5	0	0	0	0	
Hampshire Instruments						-
X-Ray Aligners	2.4	0	0	0	0	
Wafer Fab Equipment	2.4	0	0	0	0	
Innotec						-
Sputtering	0.7	0.4	0	0	0	
Other Deposition	0.5	0	0	0	0	
Wafer Fab Equipment	1.2	0.4	0	0	0	
Insystems						-
Auto Patterned Detection	13.0	0	0	0	0	
Wafer Fab Equipment	13.0	0	0	0	0	
Intevac						-
Other Deposition	5.2	0	0	0	0	
Wafer Fab Equipment	5.2	0	0	0	0	
Ion Tech						-
Sputtering	0.2	0.1	0	0	0	
Wafer Fab Equipment	0.2	0.1	0	0	0	
ISA Riber						-
Other Deposition	14.0	0	0	0	0	
Wafer Fab Equipment	14.0	0	0	0	0	
Japan Storage Battery						-
Dry Strip	0	0.2	0.2	0	0	
Wafer Fab Equipment	0	0.2	0.2	0	0	
Leybold-Heraeus						-
Sputtering	4.4	0	0	0	0	
Other Deposition	2.0	0	0	0	0	
Wafer Fab Equipment	6.4	0	0	0	0	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
LFE Plasma Systems						-
Dry Strip	1.5	0	0	0	0	
Wafer Fab Equipment	1.5	0	0	0	0	
m.FSI						-
Other Clean Process	0	4.2	11.7	0	0	
Dry Strip	1.7	0.9	0	0	0	
Wafer Fab Equipment	1.7	5.1	11.7	0	0	
Machine Technology Inc.						-
Resist Processing (Track)	26.6	17.2	13.2	0	0	
Wafer Fab Equipment	26.6	17.2	13.2	0	0	
Metrologix						-
CD SEM	0	2.2	4.4	0	0	
Wafer Fab Equipment	0	2.2	4.4	0	0	
MR Semicon						-
Other Deposition	4.6	0	0	0	0	
Wafer Fab Equipment	4.6	0	0	0	0	
Nano-Master						-
Optical Metrology	6.0	7.1	0	0	0	
Auto Patterned Detection	5.4	5.4	0	0	0	
Wafer Fab Equipment	11.4	12.5	0	0	0	
Nanosil						-
Rapid Thermal Processing	0.3	0	0	0	0	
Wafer Fab Equipment	0.3	0	0	0	0	
Nippon EMC						-
Other Deposition	2.2	0	0	0	0	
Wafer Fab Equipment	2.2	0	0	0	0	
Nippon Sanso						-
Other Deposition	6.9	0	0	0	0	
Wafer Fab Equipment	6.9	0	0	0	0	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Peak Systems						-
Rapid Thermal Processing	8.6	10.1	3.5	0	0	
Wafer Fab Equipment	8.6	10.1	3.5	0	0	
Plasma-Therm						-
Dry Etch	13.8	6.5	1.0	0	0	
Dedicated PECVD Reactors	1.2	0.8	0	0	0	
Wafer Fab Equipment	15.0	7.3	1.0	0	0	
Pokorny						-
Auto Wet Stations	6.6	5.2	14.0	0	0	
Other Clean Process	1.2	0	0	0	0	
Wafer Fab Equipment	7.8	5.2	14.0	0	0	
Poly-Flow Engineering						-
Other Clean Process	0.2	0	0.3	0	0	
Wafer Fab Equipment	0.2	0	0.3	0	0	
Process Products						-
Rapid Thermal Processing	1.5	0	0	0	0	
Wafer Fab Equipment	1.5	0	0	0	0	
Process Technology Ltd.						-
Horizontal Tube LPCVD	1.4	1.1	1.5	0.8	0	
Wafer Fab Equipment	1.4	1.1	1.5	0.8	0	
Pure Aire Corporation						-
Auto Wet Stations	1.2	1.0	0	0	0	
Other Clean Process	0.2	0	0	0	0	
Wafer Fab Equipment	1.4	1.0	0	0	0	
Ramco						-
Dry Strip	10.3	14.9	0	0	0	
Wafer Fab Equipment	10.3	14.9	0	0	0	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
Ryokosha						-
Optical Metrology	0.7	0.3	0.3	0	0	
Wafer Fab Equipment	0.7	0.3	0.3	0	0	
S&K Products International						-
Other Clean Process	8.2	0	9.9	0	0	
Wafer Fab Equipment	8.2	0	9.9	0	0	
Semifab						-
Auto Wet Stations	3.0	0	0	0	0	
Other Clean Process	3.5	0	6.4	0	0	
Wafer Fab Equipment	6.5	0	6.4	0	0	
SiScan Systems						-
Optical Metrology	2.2	0.9	0.2	0	0	
Wafer Fab Equipment	2.2	0.9	0.2	0	0	
Solitec						-
Resist Processing (Track)	4.9	2.9	1.1	0	0	
Wafer Fab Equipment	4.9	2.9	1.1	0	0	
Spire						-
Other Deposition	1.0	0	0	0	0	
Wafer Fab Equipment	1.0	0	0	0	0	
Temescal						-
Other Deposition	10.8	0	0	0	0	
Wafer Fab Equipment	10.8	0	0	0	0	
Tempress						-
Vertical Tube LPCVD	0	1.4	1.9	0	0	
Vertical Diffusion	0	1.0	1.0	0	0	
Wafer Fab Equipment	0	2.4	2.9	0	0	
Universal Plastics						-
Auto Wet Stations	5.5	6.0	8.0	0	0	
Other Clean Process	3.6	0	4.7	0	0	
Wafer Fab Equipment	9.1	6.0	12.7	0	0	

(Continued)

Table A-3 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to the World, 1991-1995—Ordered by 1995 Revenue Ranking

	1991	1992	1993	1994	1995	Ranking
VG Instruments						-
Other Deposition	15.0	0	0	0	0	
Wafer Fab Equipment	15.0	0	0	0	0	
Wellman Furnaces						-
Horizontal Diffusion	0.5	0	0	0	0	
Wafer Fab Equipment	0.5	0	0	0	0	
Yamato Semico						-
Horizontal Tube LPCVD	0.3	0	0	0	0	
Other Deposition	7.0	0	0	0	0	
Horizontal Diffusion	0.8	0.3	0	0	0	
Wafer Fab Equipment	8.1	0.3	0	0	0	
Surveyed Companies						
Wafer Fab Equipment	5,452.4	4,503.7	6,262.4	9,962.2	17,780.9	
Others						
Wafer Fab Equipment	550.5	594.6	605.3	825.1	1,272.6	
All Companies						
Wafer Fab Equipment	6,002.9	5,098.3	6,867.7	10,787.3	19,053.5	

Notes: "Including joint ventures" indicates figures that include joint ventures.
Figures reported for "others" reflect estimates of unsurveyed market activity.
"Other clean process" was called was called "other wet process" prior to 1994.
"Other deposition" not comprehensively surveyed since 1991. Revenue of individual companies not surveyed since 1991 set equal to zero. Estimated revenue of these companies included in figures reported for "others."
Alcan Technology sales of atmospheric/subatmospheric pressure CVD represent sales by Alcan/Canon/Quester joint venture.
Source: Dataquest (May 1996)

Appendix B
Semiconductor Equipment Product Category Definitions

The following semiconductor equipment product category definitions begin with total wafer fab equipment and continue through each subcategory in the same order as shown in the preceding semiconductor equipment hierarchy. At each level in the hierarchy, all subcategories that continue to this level are shown as a subcategory summation in the right-hand column. Comprehensive definitions are furnished at every level. Dataquest has organized the wafer fab equipment market into five major categories of front-end processing equipment. The equipment is defined on the basis of the function it performs in the manufacturing process.

Table B-1
Semiconductor Equipment Product Category Definitions

Wafer Fab Equipment	Lithography + Resist Processing (Track) + Etch and Clean + Deposition + Thermal Nondeposition + Ion Implantation + Process Control + Factory Automation + Other Wafer Fab Equipment
Patterning, exposure, and development of a thin film (lithography and track)	
Lithography	Contact/Proximity + Projection Aligners + Total Steppers + Direct-Write Lithography + Maskmaking Lithography + X-Ray Aligners
Contact/Proximity	Defined as an optical patterning system in which a wafer size photomask is aligned over a wafer and exposed to collimated light to create patterning.
Projection Aligners	Defined as an optical exposure system in which an image on a photomask is projected through an optical system onto a wafer to create patterning.
Stepper	Defined as a step-and-repeat optical exposure system that projects a photomask (reticle) image directly onto a wafer to create patterning.
Direct-Write Lithography	Defined as a maskless exposure system. Direct Write Lithography = Direct-Write E-Beam + Direct-Write Optical
Direct-Write E-Beam	Defined as an electron beam lithographic process used in semiconductor manufacturing to directly transfer the circuit pattern to the integrated circuit being fabricated. This equipment uses no photomask or reticle to generate the pattern.
Direct Write Optical	Defined as a lithographic process similar to direct-write e-beam that uses a laser to transfer the circuit pattern directly to the wafer.
Maskmaking Lithography	Maskmaking E-Beam + Maskmaking Optical
Maskmaking E-Beam	Defined as lithographic equipment used in semiconductor manufacturing to generate patterns on photomasks. An electron beam is used to transfer the circuit pattern to a chemically-coated photoblank.
Maskmaking Optical	Defined as a lithographic process similar to maskmaking e-beam but that uses a laser to transfer the circuit pattern to a chemically-coated photoblank.
X-Ray Aligners	Defined as an imaging system using X-rays as the exposure source
Resist Processing (Track)	Defined as equipment used to coat, bake, and develop photoresist material on wafer surfaces.
Etching and cleaning of thin films and/or substrate surfaces (clean process, dry strip, and dry etch equipment)	
Clean Process (Formerly Wet Process)	Refers to a wide range of liquid and gaseous cleaning process equipment used throughout semiconductor manufacturing whereby photoresist, organic residue, trace metal and/or dielectric, or particles are removed from the wafer surface.

(Continued)

Table B-1 (Continued)
Semiconductor Equipment Product Category Definitions

	Clean Process = Auto Wet (Immersion) Stations + Spray Processors + Vapor Phase Clean + Post-CMP Clean + Other Clean Process
Auto Wet (Immersion) Stations	Defined as a cleaning station whereby the wafer and/or the wafer carriers are automatically transported through the equipment and the various immersion cleaning steps.
Spray Processors	Batch Spray Processor + Single-Wafer Spray Processor
Batch Spray Processor	A standalone piece of equipment, manual or automated, that uses nozzles inside a chamber to spray liquid process chemicals as the reagent over a carrier of wafers. This is a cleaning/etching application on the wafer surface and does not include chemical reprocessors that reclaim spent chemicals from the manufacturing process.
Single-Wafer Spray Processor	A standalone piece of equipment (manual or automated) that uses nozzles inside a chamber to spray liquid process chemical as the reagent over a single wafer, used as a cleaning application.
Vapor Phase Clean	Defined as a piece of equipment that introduces cleaning reagents to the surface of the wafer in a gaseous or vapor form and where by-products are pumped away using a vacuum-type pump.
Post-CMP Clean	Refers specifically to equipment that removes from the wafer surface the slurry residue from a chemical mechanical polishing (CMP) process.
Other Clean Process	This category includes equipment that is not included as part of the equipment specifically addressed in clean process and used as standalone wafer processing equipment. Examples include manual wet benches, wet etch, rinser/dryers, megasonic cleaners, and scrubbers.
Manual Wet Bench	Defined as a cleaning station whereby the wafer carriers must be manually transported through the equipment.
Rinser/Dryers	Defined as a technique for removing wet chemicals from the surface of a wafer and/or drying the wafer.
Megasonics	Defined as equipment that uses acoustical energy in the 700-kHz to 1200-kHz frequency range that augments standard cleaning chemicals.
Scrubber	Defined as an equipment set using a brush (or similar physical structure) to remove particles from wafers. This cleaning technique may be augmented with an ultrasonic energy source.
Dry Strip	Defined as a process that removes a material (usually photoresist) from a wafer surface after etching using an oxygen plasma or ozone.
Ion Milling	Defined as a process that uses a beam of charged particles to remove material from a wafer. Also known as sputter etching or ion beam etching.

(Continued)

Table B-1 (Continued)
Semiconductor Equipment Product Category Definitions

Dry Etch	Low-Density Etch + High-Density Etch
Low-Density Etch	Defined as a process that selectively removes unwanted material from a wafer by using a radio frequency (RF) plasma as the primary etch medium whereby the wafers are etched without wet chemicals. Dry etch includes both plasma etching (barrel and planer) and reactive ion etching (RIE).
High-Density Etch	Defined as a dry etch process in which the plasma is generated using a source designed to generate a high-density plasma (>=10^{11} ions/cm^3) in a low-pressure environment. Sources in this category include inductively coupled plasma (ICP), transformer-coupled plasma (TCP), helicon wave, HRe', and microwave-based sources (for example, ECR and microwave).
Chemical Mechanical Polishing	Defined as a process that removes unwanted material from a wafer by using a corrosive liquid/solid slurry inside equipment designed to apply pressure on the active surface. This segment is specifically limited to removal of significant amounts of dielectric or metal material and does not include the process of contamination removal by chemical "scrubbing." This latter type of equipment is considered under clean processing.
Deposition of a thin film (chemical vapor deposition, physical vapor deposition, molecular beam epitaxy, and metalorganic CVD equipment)	
Deposition	Total CVD + Sputtering + Silicon Epitaxy + Other Deposition
Chemical Vapor Deposition (CVD)	Defined as a method for depositing thin films of materials that function as dielectrics, conductors, or semiconductors. A chemical containing atoms of the material to be deposited reacts with another chemical, either at an elevated temperature or in a plasma, producing the desired material, which is deposited on the wafer surface while by-products of the reaction are removed from the process chamber.
	Total CVD = Tube CVD + Nontube CVD
Tube CVD	Defined as a CVD process in which wafers are heated and processed in batches using tube furnaces.
	Tube CVD = Horizontal Tube LPCVD + Vertical Tube LPCVD + Horizontal Tube PECVD.
Horizontal Tube LPCVD	Defined as a CVD process in which both the reaction and the deposition take place at an elevated temperature and reduced pressure in a horizontally oriented furnace tube.
Vertical Tube LPCVD	Defined as a CVD process in which both the reaction and deposition take place at an elevated temperature and reduced pressure, in a vertically oriented furnace tube.
Horizontal Tube PECVD	Defined as a system based on a standard horizontal tube furnace design in which reaction and deposition occur in an RF plasma, usually at reduced pressure.

(Continued)

Table B-1 (Continued)
Semiconductor Equipment Product Category Definitions

Nontube CVD	Defined as a CVD process in which wafers are heated and processed individually or in small groups within single-wafer or multiwafer reaction chambers.
	Nontube CVD = Atmospheric Pressure CVD/Subatmospheric Pressure CVD + Dedicated LPCVD Reactors + Dedicated PECVD Reactors + High-Density Plasma CVD
Atmospheric Pressure CVD/ Subatmospheric Pressure CVD	Defined as a chemical vapor deposition process in which both the reaction and deposition occur at atmospheric or subatmospheric pressure.
Dedicated LPCVD Reactors	Defined as a reactor in which the reaction and deposition occur at an elevated temperature and low pressure. Reactors in this category include W, WSiX , CVDTiN, and other metal CVD systems.
Dedicated PECVD Reactors	Defined as a reactor in which the reaction and deposition occur in an RF plasma, usually at reduced pressure.
High-Density Plasma CVD	Defined as a reactor in which the reaction and deposition occur in a high-density plasma (for example, ECR, ICP, and helicon), usually at reduced pressure.
Sputtering	A method of depositing a thin film of material on wafer surfaces. A given material (target) is bombarded with ions generated in an RF plasma, which dislodge atoms of the target material. The displaced target material atoms are deposited on the wafer surface.
Silicon Epitaxy	Defined as a process for depositing single-crystal silicon on a substrate by decomposition of a silicon precursor gas such as silane, silicon tetrachloride, or dichlorosilane.
Other Deposition	Metalorganic CVD + Molecular Beam Epitaxy + Evaporation
Metalorganic CVD	Defined as a CVD technique using metalorganic precursors such as trimethylgallium that react at elevated temperatures to deposit thin films of compound semiconductor materials such as GaAs.
Molecular Beam Epitaxy	Defined as a process for depositing thin films of elemental or compound materials by direct transport of the film materials from a heated source to the wafer surface, carried out in a high vacuum. This process is similar to evaporation.
Evaporation	A process that uses heat to change a material (usually a metal or metal alloy) from a solid to a gaseous state, with the atoms in the resulting vapor being deposited on the wafer as a solid thin film.
Modification properties of a thin film or substrate (diffusion, RTP, and ion implantation)	
Thermal Nondeposition	Diffusion + Rapid Thermal Processing
Diffusion	Horizontal Diffusion + Vertical Diffusion

(Continued)

Table B-1 (Continued)
Semiconductor Equipment Product Category Definitions

Horizontal Diffusion	Diffusion is a high-temperature annealing process that allows impurities (dopants) introduced into substrate material to spread or diffuse into the substrate. Horizontal diffusion equipment employs horizontally oriented tubes.
Vertical Diffusion	Vertical diffusion equipment employs vertically oriented tubes.
Rapid Thermal Processing	A process that performs a high-temperature diffusion, CVD, or epitaxial process in a short period.
Ion Implantation	Medium-Current Implanter + High-Current Implanter + High-Voltage Implanter
Medium-Current Implanter	Ion implantation is a process that introduces impurities into a substrate by means of ion bombardment to achieve the desired electrical properties in defined areas of a wafer. Medium-current implanters generate singly charged ion energies of less than 750 keV and deliver implant doses less than or equal 1 E14 ions per cm^2.
High-Current Implanter	High-current implanters generate singly charged ion energies of less than 750 keV and deliver implant doses greater than 1 E14 ions per cm^2 but typically between 1 E15 ions to 1 E18 ions per cm^2.
High-Voltage Implanter	High-voltage implanters generate singly charged ion energies greater than 750 keV.
Verification that process steps in fabrication have been performed within specifications (process control equipment including optical metrology, CD-SEM, thin-film measurement, wafer defect detection, review, and classification, and other process control)	
Process Control	Optical Metrology + CD-SEM + Thin-Film Measurement + Auto Patterned Detection + Auto Review and Classification + Manual Detection and Review + Auto Unpatterned Detection
Optical Metrology (Overlay)	Defined as equipment that measures wafers after lithographic exposure to check for layer-to layer-overlap registration.
CD-SEM	A critical dimension (CD) of a semiconductor device refers to the finest geometry that must be manufactured and controlled to the tightest specifications on the chip. CD-SEM equipment measures the critical dimension by using scanning electron microscopes (SEMs).
Thin-Film Measurement	Defined as a measurement tool used to ascertain the composition, thickness, and quality of the thin-film layer deposited on the wafer. The tool may use some assumptions on the physical parameters of the film to measure its reflectivity, thickness, and refractive index. Semiconductor manufacturing processes such as planarization, PVD, CVD, diffusion, etch, and lithography are among the segments that may use these tools.

(Continued)

Table B-1 (Continued)
Semiconductor Equipment Product Category Definitions

Auto Patterned Detection	Defined as automated patterned (processed) wafer defect and particle detection systems.
Auto Review and Classification	Defined as automated equipment that identifies and classifies defects and contaminants in patterned wafers. This equipment is usually attached to patterned wafer inspection stations. Category includes both optical- and SEM-based equipment.
Manual Detection and Review	Defined as operator-based equipment used to detect and classify defects and contaminants in patterned wafers. This equipment includes sophisticated microscope stations.
Auto Unpatterned Detection	Defined as automated unpatterned (preprocessed) wafer defect and particle detection systems.
Other Process Control	Other process control represents a broad market that includes mask, metrology, inspection and repair equipment well as other categories of process monitoring equipment, and analytical instrumentation. This is a highly fragmented market with dozens of companies selling into a multitude of noncompetitive market niches.
Factory Automation	Includes CIM software for shop floor control, factory host computer systems, cell controllers and interface hardware, and wafer transport systems, including automatic guided vehicles and rail transport systems.
Other Wafer Fab Equipment	A general catchall category that includes the other capital equipment used throughout the fab but not classified within the other five major types of wafer processing equipment. Included in this segment are decontamination systems, wafer markers, gas analyzers, storage stations, and other types of equipment.

Source: Dataquest (May 1996)

Appendix C
Worldwide Geographic Region Definitions

Dataquest has revised its regional definitions effective this year. The region formerly known as Rest of World has been eliminated and its components have been redistributed across the remaining regions. The remaining regions, in turn, have been redefined to accommodate this change. Central America, South America, and the Caribbean have been combined with North America to define the new region "Americas." The Middle East (including Israel) and Africa have been combined with Europe in the new region "Europe, Middle East, and Africa." The Pacific Island nations of Oceania have been combined with Asia/Pacific in the new region "Asia/Pacific." Note that Asia/Pacific is further divided into two mutually exclusive subregions, Korea and Rest of Asia Pacific.

Americas

North America

Includes Canada, Mexico, and the United States (50 states)

Central America

South America

Caribbean

Japan

Japan is the only sngle-country region.

Europe, Middle East and Africa

Europe

Western Europe

Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).

Eastern Europe

Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).

Middle East (Includes Israel)

Africa

Asia/Pacific

Korea
Korea is a single-country subregion.

Rest of Asia/Pacific
Includes Asia/Pacific's Newly Industrialized Economies (NIEs) and the remainder of Asia/Pacific including Oceania. Asia/Pacific's Newly Industrialized Economies include Hong Kong, Korea, Singapore, and Taiwan. The remainder of Asia/Pacific includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam as well as the Pacific Island nations that make up Oceania.

Appendix D
Exchange Rate Definitions

When converting a company's local currency sales into U.S. dollars, or vice versa, it is important to use the 1995 exchange rates provided in Table D-1. These rates will prevent inconsistencies in the conversion of offshore sales between companies. These exchange rates will be used in the 1995 market share survey. Exchange rates for historical years are available on request.

Table D-1
Average 1995 Exchange Rates per U.S. Dollar

Country	1995 Rate	1994 Rate	U.S.$ Appreciation (%)
Austria (Schilling)	10.06	11.40	-11.77
Belgium (Franc)	29.42	33.36	-11.82
China (Yuan)	8.35	8.54	-2.17
Denmark (Krone)	5.59	6.35	-11.94
ECU	0.77	0.84	-8.30
Finland (Markka)	4.37	5.21	-16.05
France (Franc)	4.97	5.54	-10.22
Germany (Mark)	1.43	1.62	-11.69
Greece (Drachma)	231.34	242.06	-4.43
Hong Kong (Dollar)	7.74	7.73	0.10
India (Rupee)	32.38	31.15	3.94
Ireland (Punt)	0.62	0.67	-6.69
Italy (Lira)	1,628.21	1,609.34	1.17
Japan (Yen)	93.90	101.81	-7.77
Malaysia (Ringgit)	2.51	2.62	-4.32
Netherlands (Guilder)	1.60	1.82	-11.80
Norway (Krone)	6.33	7.04	-10.18
Portugal (Escudo)	149.77	165.63	-9.58
Singapore (Dollar)	1.43	1.53	-6.58
South Korea (Won)	770.57	802.84	-4.02
Span (Peseta)	124.40	133.48	-6.80
Sweden (Krona)	7.14	7.70	-7.28
Switzerland (Franc)	1.18	1.37	-13.62
Taiwan (Dollar)	26.48	26.45	0.09
Thailand (Baht)	24.91	25.36	-1.77
United Kingdom (Pound)	0.63	0.65	-3.16

Source: Dataquest (January 1966)

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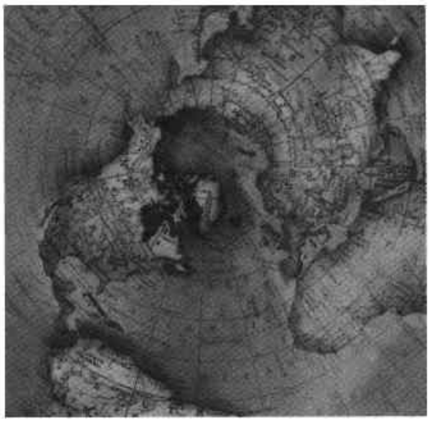

Dataquest

1995 Wafer Fab Equipment Market Share Estimates Volume 1 of 2

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
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Note: All tables show estimated data.

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Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

Preface

Welcome to Dataquest's 1995 Wafer Fab Equipment Market Share Estimates. Dataquest has revised the format of this annual report in an effort to present the estimates in a more accessible and logical manner. As part of our effort, we have reorganized the chapters and appendixes of the report. We have also standardized the format and look of the report's tables. The report now consists of nine chapters and four appendixes. Following the introductory chapter, each of the remaining eight chapters is devoted exclusively to a specific segment of the wafer fab equipment market. All the estimates relevant to a particular segment are now presented together in the report's segment-specific chapters. Thus readers interested in lithography can turn immediately to Chapter 3 and find all the market share estimates relevant to lithography equipment. Likewise, readers interested in deposition or process control equipment can turn directly to Chapters 6 and 9, respectively, and find all the market share estimates relevant to those equipment segments.

Although the look and format of the report have been revised, there has been no change in the nature or character of the estimates presented. Indeed, we have actually introduced several new estimates never reported before. For the first time, we are also reporting company rankings for specific equipment segments. Note that Chapter 2 presents a ranking of the top 20 revenue-earning equipment companies. This table summarizes Dataquest's annual ranking of all equipment companies by total end-user revenue, which now appears in the report's expanded appendixes (see Appendix A, Table A-1). Also in the appendixes now is our annual listing of companies with detail on the equipment segments that the companies market (see Appendix A, Table A-3).

We hope you will find our new format helpful and more informative. We would greatly appreciate any comments or suggestions you have regarding our new format. In the meantime, we thank you for your continued support of this challenging and valuable research.

Chapter 1
Introduction to the Wafer Fab Equipment Market

Introduction

This document contains detailed information on Dataquest's estimates of the semiconductor wafer fabrication equipment market for the years 1991 through 1995. Each year, Dataquest surveys semiconductor equipment vendors to estimate their annual revenue derived from front-end semiconductor equipment sales. The 1995 survey covered about 120 semiconductor equipment vendors worldwide (this number of companies varies year to year according to mergers, acquisitions, liquidations, and start-ups, among others) by 30-plus individual semiconductor equipment product categories (excluding subtotals), in four world regions. This exercise helps Dataquest maintain its dynamic database of semiconductor equipment supply by company, and semiconductor equipment shipment by world region and product. The information gained is supplemented and cross-checked with Dataquest's various other information sources. Dataquest conducts this research on an annual basis.

Market

Dataquest has organized the wafer fab equipment market into 11 major categories of front-end processing equipment. These categories, along with key subcategories, are shown in Table 1-1. (Appendix B presents a semiconductor equipment product category hierarchy.)

Wafer fab equipment is used to perform five key tasks in the semiconductor device fabrication process, as follows:

- Patterning, exposure, and development of a thin film (lithography and resist processing (track))
- Etching and cleaning of thin films or substrate surfaces and plananization of thin film surfaces (cleaning processes, dry strip, dry etch, and chemical mechanical polishing equipment)
- Depositing a thin film (chemical vapor deposition, (CVD), silicon epitaxy, and other deposition equipment)
- Modifying the properties of a thin film or substrate (diffusion and ion implantation)
- Verifying that all previous steps in the fabrication process have been performed correctly (process control equipment including optical metrology, CD scanning electron microscopy (SEM), patterned and unpatterned wafer defect detection, review, and classification, and thin film measurement equipment)

Capital spending by the world's merchant and captive semiconductor manufacturers consists of four components: spending for front-end, or wafer fab equipment; spending for back-end, or assembly and test equipment; spending for CIM/software and computer control systems; and spending for property and plant. The total world market for the

Table 1-1
Wafer Fab Equipment Categories

Category
Lithography
Contact/Proximity
Projection Aligners
Steppers
Direct-Write Lithography
Maskmaking Lithography
X-Ray
Resist Processing (Track)
Etch and Clean
Auto Wet Stations (Immersion)
Spray Processors
Post-CMP Clean
Vapor Phase Clean
Other Clean Processes
Dry Strip
Dry Etch
Chemical Mechanical Polishing (CMP)
Deposition
Chemical Vapor Deposition (CVD)
Tube CVD
Nontube CVD
Sputtering
Silicon Epitaxy
Other Deposition
Diffusion
Rapid Thermal Processing
Ion Implantation
Medium-Current
High-Current
High-Voltage
Process Control
Optical Metrology (Overlay)
CD-SEM
Automated Patterned Wafer Detection
Automated Patterned Wafer Review and Classification
Manual Patterned Wafer Detection and Review
Automated Unpatterned Wafer Detection
Other Process Control
Factory Automation
Other Equipment

Source: Dataquest (May 1996)

categories of wafer fab equipment as defined in this database is equal to the total capital spending for front-end equipment by the world's semiconductor manufacturers.

Most of the equipment categories are self-explanatory; however, a few categories require further definition. The "other process control" category represents a broad market that includes mask inspection and repair equipment, process monitoring equipment, surface analysis equipment, and analytical instrumentation. This is a highly fragmented market with dozens of companies selling into a multitude of noncompetitive market niches.

"Factory automation" includes wafer transport systems including automatic guided vehicles, robotics, rail transport systems, minienvironment systems, and other wafer transport and storage automated systems.

"Other equipment" is a general, catchall category that includes the other capital equipment used throughout the fab but not classified with the other 10 major types of wafer processing equipment. Included in this segment are decontamination systems, wafer markers, gas analyzers, ion milling, and other types of equipment.

General Sales Definitions

The data in the tables represents end-user revenue for calendar year shipments, organized by company or by region. For companies with a different fiscal year, calendar year shipments have been estimated.

All sales are reported according to customer location, that is, shipping destination. These destinations are defined regionally. The regions are Americas, Europe, Japan, and Asia/Pacific. (Appendix C lists the specific countries that compose these major geographical regions.) Sales do not include spare parts or service but do include retrofits and upgrades. Our market estimates only include equipment used in the front-end wafer fabrication process. We do not include equipment used in other market applications such as flat-panel display manufacturing, thin-film head manufacturing, or multichip modules. Finally, as part of our convention to report end-user revenue, the revenue associated with equipment kits sent from one company to be fabricated and assembled by another company is valued at the full system shipment price paid by the semiconductor manufacturer. This revenue is assigned to the company that originated the kits, with the exception of implant joint ventures. Thus, for public companies, the sales reported here may differ from the sales reported in annual reports.

Exchange Rates

Worldwide market share estimates combine data from many countries, each of which has different and fluctuating exchange rates. Estimates of non-U.S. market consumption or revenue are based upon the average exchange rate for the given year. As a rule, our estimates are calculated in local currencies and then converted to U.S. dollars. Appendix D lists 1995 exchange rates for various currencies.

Equipment Companies

Table 1-2 presents a list of the equipment companies found in the database tables, by region of company ownership. (Please note that Table 1-2 includes companies now active in the wafer fab equipment industry and those companies that, for whatever reason, are no longer participants.) These historical tables include a total of 189 companies: 93 North American equipment companies, 60 Japanese companies, 30 European companies, and six joint venture companies. These companies account for virtually all of the world's wafer processing equipment for lithography, resist processing (track), etch and clean, deposition, nonthermal deposition, ion implantation, and process control.

Table 1-3 summarizes recent mergers and acquisitions in the wafer fab equipment industry. Merger and acquisition activity is often accompanied by a change in company name. These changes have been incorporated in our market share tables.

Notes on Market Share

In the process of conducting data collection and evaluating market statistics, Dataquest will sometimes consolidate or revise previously published market estimates. We revise beyond one year of history only in those situations when an individual company's market position or the size of a given regional market for a segment of wafer fab equipment would be altered significantly.

Dataquest believes that the estimates presented within this document are the most accurate and meaningful statistics available.

Despite the care taken in gathering, analyzing, and categorizing the data in a meaningful way, careful attention must be paid to the definitions and assumptions used herein when interpreting the estimates presented in this document. Various companies, government agencies, and trade associations may use slightly different definitions of product categories and regional groupings, or they may include different companies in their summaries. These differences should be kept in mind when making comparisons between data and numbers provided by Dataquest and those provided by other suppliers.

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Table 1-2
Wafer Fab Equipment Companies

North American Companies		
ADE Corporation	High Temperature Engineering	Process Products
Advantage Production Technology	Innotec	Process Technology Ltd.
AG Associates	Inspex	Pure Aire Corporation
Alameda Instruments	Insystems	Rudolph Research
Amray	Integrated Solutions, Inc.	S&K Products International
Angstrom Measurements	Intevac	Santa Clara Plastics
Applied Materials	Ion Tech	SCI Manufacturing
Ateq	Ipec/Planar	Semiconductor Systems Inc.
Athens	IVS Inc.	Semifab
Biorad	KLA Instruments	Semitherm
BTU International	Kurt J. Lesker	Semitool
CFM Technology	Lam Research	Silicon Valley Group
CHA Industrial	Lepton Inc.	SiScan Systems
Concept Systems Design	LFE Plasma Systems	Solitec
CPA	Machine Technology Inc.	Speedfam
CVC Products	Matrix Integrated Systems	Spire
CVD Equipment	Mattson Technologies	Sputtered Films
Cybeq Systems	Metrologix	Strasbaugh
Denton Vacuum	Moore Epitaxial Inc.	SubMicron Systems Inc.
Drytek	MR Semicon	Tegal
Eaton	Nanometrics	Tempress
Emcore	Nanosil	Tencor Instruments
Estek	Novellus Systems Inc.	Thermawave
Etec	On Trak Systems	Tystar
FSI International	Opal	Ultrapointe
Fusion Semiconductor Systems	Optical Specialties Inc.	Ultratech
Gasonics	Pacific Western	Universal Plastics
GCA	Peak Systems	Varian
General Signal Thinfilm Company	Plasma & Materials Technologies	Verteq
Genus	Plasma-Therm	Watkins-Johnson
Hampshire Instruments	Poly-Flow Engineering	
Japanese Companies		
Amaya	JEOL	Sankyo Engineering
Advanced Film Technology Inc.	Kaijo Denki	Seiko
Anelva	Kokusai Electric	Shibaura Engineering Works
Canon	Koyo Lindberg	Shimada
Daido Sanso	Kuwano Electric	Shinko Electric
Dainippon Screen	Lasertec Corporation	Shinko Seiki
Dalton Corporation	Materials Research Corporation	Sugai

(Continued)

Table 1-2 (Continued)
Wafer Fab Equipment Companies

Dan Science Co. Ltd.	Maruwa	Sumitomo Metals
Disco	Matsushita Electric	Tazmo
Ebara Corporation	MC Electronics	Toho Kasei
Eiko	Musashi	Tokyo Electroc Ltd.
Elionix	Nidek	Topcon
Enya	Nikon	Tokyo Airacraft Instruments
ET Systems Engineering	Nippon EMC	Tokyo Ohka Kogyo
Fuji Electric	Nippon Sanso	Toray Instruments
Fujikoshi	Nissin Electric	Toshiba
Hitachi	Plasma Systems	Toyoko Kagaku
Holon	Ramco	Ulvac
Japan Production Engineering	Ryokosha	Yamato Semico
Japan Storage Battery	Samco	Yuasa
	European Companies	
AET Thermal	Fairchild Convac	Oxford Instruments
Aixtron	ISA Riber	Philips
ASM International	Jenoptik	Pokorny
ASM Lithography	Jipelec	PRESI
AST Electronic GmbH	Karl Suss	Sapi Equipments
BCT Spectrum	Leica	Steag Microtech (formerly Pokorny)
Censor	Leybold-Heraeus	Temescal
Centrotherm	LPE	VG Instruments
CVT	Nano-Master	Wellman Furnaces
E.T. Electrotech	Orbot	Carl Zeiss
	Joint Venture Companies	
Alcan Technology (Alcan/Canon/Quester)	m.FSI	TEL/Varian
Bruce Technologies	Sumitomo/Eaton Nova	Varian/TEL

Source: Dataquest (May 1996)

Table 1-3
Summary of Mergers and Acquisitions Incorporated in the Wafer Fab Equipment Database, by Year and Company

Company	Action	Company	Now Identified As	First Year Change Noted in Database
ETS Company Ltd.	Name change	ETS Systems Engineering	ET Systems Engineering	1995
Ipec/Westech	Name change	Ipec/Planar	Ipec/Planar	1995
TEL/Varian	Joint venture dissolved	-	Varian	1995
Varian/TEL	Joint venture dissolved	-	TEL	1995
Addax	Name change	AET Thermal	AET Thermal (in 1994)	1994
Convac	Acquired by	Fairchild	Fairchild-Convac	1994
ETE Company Ltd.	Name change	ETS Company Ltd.	ETS Company Ltd.	1994
Metrologix	Acquired by	KLA Instruments	KLA Instruments	1994
Oxford Plasma Technology	Name change	Oxford Instruments Inc.	Oxford Instruments Inc.	1994
Peak Systems	Acquired by	Mattson Technology	Mattson Technology	1994
Universal Plastics	Acquired by	SubMicron Systems Inc.	SubMicron Systems Inc.	1994
Pokorny	Reorganized	Steag AG	Steag Microtech	1994
Drytek	Acquired by	Lam Research	Lam Research	1993
Censor	Acquired by	Tencor Instruments	Tencor Instruments	1993
Prometrix	Acquired by	Tencor Instruments	Tencor Instruments	1993
Ramco	Acquired by	MC Electronics	MC Electronics	1993
Ultratech Stepper	Management buyout from	General Signal	Ultratech Stepper	1993
Westech	Acquired by	IPEC	IPEC/Westech	1993
Yamato Semico	Merged with	ETE	ETE	1993
Angstrom Measurement	Acquired by	IVS Inc.	IVS Inc.	1992
Ateq Corporation	Merged with	Etec Systems	Etec Systems	1992
BCT Spectrum	Acquired by	MRC Sony	MRC Sony	1992
BTU International (front-end equipment)	Acquired by	Kokusai Electric	Bruce Technologies	1992

(Continued)

Table 1-3 (Continued)
Summary of Mergers and Acquisitions Incorporated in the Wafer Fab Equipment Database, by Year and Company

Company	Action	Company	Now Identified As	First Year Change Noted in Database
Estek	Acquired by	ADE Corporation	ADE Corporation	1992
Insystems	Acquired by	Optical Specialties Inc.	Optical Specialties Inc.	1992
Musashi	Acquired by	Sumitomo Precision Products	Musashi	1992
Tempress (GSTC)	Management buyout from	General Signal Thinfilm	Tempress	1992
ABT Corporation	Acquired by	Toshiba	Topcon	1991
Branson	Merged by	Gasonics	Gasonics	1991
BTU/Ulvac	Acquired by	Ulvac	Ulvac	1991
Denko Systems	Acquired by	Shinko Electric	Shinko Electric	1991
Micro-Controle	Name change to	-	Nano-Master	1991
Semiconductor Systems Inc.	Management buyout from	General Signal	Semiconductor Systems Inc.	1991
Sitesa S.A.	Acquired by	Addax Technologies	Addax Technologies	1991
Solitec (CVD operations)	Acquired by	Advanced Crystal Science	Advanced Crystal Science	1991
Spectrum CVD	Acquired by	Balzers AG	BCT Spectrum	1991
Tokuda	Acquired by	Shibaura	Shibaura	1991
Ulvac/BTU	Acquired by	Ulvac	Ulvac	1991
ASM Lithography (e-beam lithography group)	Acquired by	Cambridge Instruments	Leica	1990
Circuits Processing Apparatus (GSTC)	Management buyout from	General Signal Thin Film	CPA	1990
Materials Research Corp.	Acquired by	Sony	Materials Research Corp.	1990
Nanoquest	Name change to	-	BioRad Micromeasurements	1990
Perkim-Elmer (e-beam lithography group)	Acquired by	Industry consortium	Etec Systems Inc.	1990
Perkim-Elmer (optical lithography group)	Acquired by	Silicon Valley Group	SVG Lithography	1990
Wild Leitz	Merged with	Cambridge Instruments	Leica	1990
Wild Leitz Instruments	Name change to	-	Leica Lasertechnik	1990

Source: Dataquest (May 1996)

Chapter 2
Wafer Fab Equipment—All Categories

This chapter presents summary tables for the wafer fab equipment market as a whole. The chapter consists of five tables that present a variety of estimates relevant to company sales of all wafer fab equipment. Table 2-1 presents a ranking of the top 20 wafer fab equipment companies based on estimated end-user revenue generated by sales of all wafer fab equipment. Note that a complete ranking of all surveyed wafer fab equipment companies appears in Appendix A (see Table A-1). Table 2-1 also summarizes the market shares of companies by nationality for the overall wafer fab equipment market. Note that joint venture companies are grouped separately in this market share summary regardless of nationality. Also note that the reported market shares for the various groupings of companies are based on total estimated sales by identified companies. Dataquest estimates market activity in several segments of the wafer fab equipment market where company detail is unavailable (for example, ion milling, factory automation, and other wafer fab Equipment). The sales reported for the category "other companies" in the market share summary reflect Dataquest's estimates of this activity. In 1995, Dataquest estimates of unsurveyed activity accounted for 6.7 percent of wafer fab equipment market activity.

Table 2-2 reports wafer fab equipment sales by company nationality or company base into each regional market delineated by Dataquest. Note again that joint venture companies are grouped separately in this table regardless of company base. Also, note that sales reported for other companies reflect Dataquest's estimates of unsurveyed wafer fab equipment market activity. Table 2-3 reports wafer fab equipment sales to each market region by company base. The table also reports the market share for each company grouping within regional markets. Here again, the market shares reported for each company grouping are based on estimated sales to the relevant market by all identified companies. Hence, no market shares are reported for other companies.

Finally, Dataquest segments the wafer fab equipment market into nine principal equipment categories (as shown in Table 1-1). Table 2-4 reports equipment sales for each of these nine categories within each regional market. Table 2-5 reports equipment sales for each of these nine categories by company base. The table also reports the market share of company groupings within each category. Once again, the market shares reported in the table are based on estimated sales for identified companies. No market shares are reported for other companies because their estimated sales reflect Dataquest estimates of unsurveyed market activity.

Table 2-1
Top 20 Companies' Sales Revenue from Shipments of Wafer Fab Equipment to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	1	Applied Materials	1,480.7	2,904.9	96	16.3
2	2	Tokyo Electron Ltd. (including joint ventures)	1,066.3	2,098.2	97	11.8
3	3	Nikon	1,027.1	1,675.1	63	9.4
4	5	Canon	499.9	984.1	97	5.5
5	4	Lam Research	520.6	899.2	73	5.1
6	6	Hitachi	387.2	643.2	66	3.6
7	8	Dainippon Screen	342.5	545.3	59	3.1
8	7	Varian (including joint ventures)	375.3	535.4	43	3.0
9	9	Kokusai Electric (including joint ventures)	306.1	523.1	71	2.9
10	10	ASM Lithography	272.7	498.3	83	2.8
11	11	Silicon Valley Group	269.9	490.1	82	2.8
12	12	KLA Instruments	255.5	459.6	80	2.6
13	13	Eaton (including joint ventures)	227.2	430.0	89	2.4
14	15	Novellus Systems Inc.	197.4	345.2	75	1.9
15	14	Tencor Instruments	210.4	309.1	47	1.7
16	16	Anelva	170.1	256.3	51	1.4
17	19	ASM International	120.1	210.4	75	1.2
18	18	Watkins-Johnson	122.4	202.0	65	1.1
19	21	Alcan Technology (see note)	93.6	188.3	101	1.1
20	20	Ulvac	116.0	173.6	50	1.0
		North American Companies	4,480.7	8,219.5	83	46.2
		Japanese Companies	4,433.0	8,017.4	81	45.1
		European Companies	623.9	1,136.4	82	6.4
		Joint Venture Companies	424.7	407.6	-4	2.3
		Identified Companies	9,962.2	17,780.9	78	100.0
		Other Companies	825.1	1,272.6	54	
		All Companies	10,787.3	19,053.5	77	

Notes: "Including joint ventures" indicates figures include joint ventures.
Figures reported for Alcan Technology include sales by Alcan/Canon/Quester joint venture.
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 2-2
Sales Revenue from Shipments of Wafer Fab Equipment by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
North American Companies						
Americas Market	927.2	987.5	1,323.1	1,912.2	3,363.7	38.0
Japanese Market	493.2	367.7	477.8	791.5	1,479.8	31.6
European Market	306.4	324.2	540.8	762.1	1,303.3	43.6
Asia/Pacific Market	283.9	306.0	557.2	1,014.9	2,072.6	64.4
Worldwide Market	2,010.7	1,985.4	2,898.9	4,480.7	8,219.5	42.2
Japanese Companies						
Americas Market	302.8	253.8	373.9	680.9	979.5	34.1
Japanese Market	2,022.3	1,347.2	1,566.0	2,280.2	4,077.7	19.2
European Market	122.7	96.5	179.2	277.7	551.0	45.6
Asia/Pacific Market	394.9	314.3	537.3	1,194.2	2,409.3	57.2
Worldwide Market	2,842.7	2,011.8	2,656.4	4,433.0	8,017.4	29.6
European Companies						
Americas Market	134.1	127.7	179.7	272.6	500.0	39.0
Japanese Market	62.2	36.0	32.8	56.2	89.9	9.6
European Market	139.0	119.7	142.5	212.3	340.8	25.1
Asia/Pacific Market	70.0	54.1	71.2	82.7	205.8	31.0
Worldwide Market	405.2	337.5	426.2	623.9	1,136.4	29.4
Joint Venture Companies						
Americas Market	37.4	47.1	94.1	146.2	64.4	14.5
Japanese Market	129.5	96.0	117.0	183.8	252.2	18.1
European Market	28.5	24.8	60.9	56.2	22.1	-6.2
Asia/Pacific Market	4.3	4.8	10.1	38.5	68.9	100.1
Worldwide Market	199.7	172.7	282.1	424.7	407.6	19.5
Other Companies						
Americas Market	117.0	159.6	147.3	178.5	270.9	23.4
Japanese Market	304.4	251.0	255.9	348.8	452.0	10.4
European Market	44.5	76.2	64.9	61.4	98.6	22.0
Asia/Pacific Market	78.7	104.1	136.0	236.4	451.1	54.7
Worldwide Market	544.6	590.9	604.1	825.1	1,272.6	23.6

(Continued)

Table 2-2 (Continued)
Sales Revenue from Shipments of Wafer Fab Equipment by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
All Companies						
Americas Market	1,518.5	1,575.7	2,118.1	3,190.4	5,178.5	35.9
Japanese Market	3,011.6	2,097.9	2,449.6	3,660.5	6,351.6	20.5
European Market	641.1	641.4	988.3	1,369.7	2,315.7	37.9
Asia/Pacific Market	831.8	783.3	1,311.7	2,566.7	5,207.7	58.2
Worldwide Market	6,002.9	5,098.3	6,867.7	10,787.3	19,053.5	33.5

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 2-3
Sales Revenue from Shipments of Wafer Fab Equipment into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Americas Market						
North American Companies	1,323.1	1,912.2	3,363.7	67.1	63.5	68.5
Japanese Companies	373.9	680.9	979.5	19.0	22.6	20.0
European Companies	179.7	272.6	500.0	9.1	9.1	10.2
Joint Venture Companies	94.1	146.2	64.4	4.8	4.9	1.3
Identified Companies	1,970.8	3,011.9	4,907.6	100.0	100.0	100.0
Other Companies	147.3	178.5	270.9			
All Companies	2,118.1	3,190.4	5,178.5			
Japanese Market						
North American Companies	477.8	791.5	1,479.8	21.8	23.9	25.1
Japanese Companies	1,566.0	2,280.2	4,077.7	71.4	68.9	69.1
European Companies	32.8	56.2	89.9	1.5	1.7	1.5
Joint Venture Companies	117.0	183.8	252.2	5.3	5.5	4.3
Identified Companies	2,193.7	3,311.7	5,899.6	100.0	100.0	100.0
Other Companies	255.9	348.8	452.0			
All Companies	2,449.6	3,660.5	6,351.6			
European Market						
North American Companies	540.8	762.1	1,303.3	58.6	58.2	58.8
Japanese Companies	179.2	277.7	551.0	19.4	21.2	24.9
European Companies	142.5	212.3	340.8	15.4	16.2	15.4
Joint Venture Companies	60.9	56.2	22.1	6.6	4.3	1.0
Identified Companies	923.4	1,308.3	2,217.1	100.0	100.0	100.0
Other Companies	64.9	61.4	98.6			
All Companies	988.3	1,369.7	2,315.7			

(Continued)

Table 2-3 (Continued)
Sales Revenue from Shipments of Wafer Fab Equipment into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Market						
North American Companies	557.2	1,014.9	2,072.6	47.4	43.6	43.6
Japanese Companies	537.3	1,194.2	2,409.3	45.7	51.2	50.7
European Companies	71.2	82.7	205.8	6.1	3.6	4.3
Joint Venture Companies	10.1	38.5	68.9	0.9	1.7	1.4
Identified Companies	1,175.7	2,330.3	4,756.6	100.0	100.0	100.0
Other Companies	136.0	236.4	451.1			
All Companies	1,311.7	2,566.7	5,207.7			
Worldwide Market						
North American Companies	2,898.9	4,480.7	8,219.5	46.3	45.0	46.2
Japanese Companies	2,656.4	4,433.0	8,017.4	42.4	44.5	45.1
European Companies	426.2	623.9	1,136.4	6.8	6.3	6.4
Joint Venture Companies	282.1	424.7	407.6	4.5	4.3	2.3
Identified Companies	6,263.6	9,962.2	17,780.9	100.0	100.0	100.0
Other Companies	604.1	825.1	1,272.6			
All Companies	6,867.7	10,787.3	19,053.5			

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 2-4
Sales Revenue from Shipments of Wafer Fab Equipment into Each Region by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Lithography						
Americas Market	298.7	242.9	360.9	639.8	905.4	31.9
Japanese Market	605.9	324.8	449.0	657.3	1,326.5	21.6
European Market	112.2	94.9	142.6	279.3	379.2	35.6
Asia/Pacific Market	167.8	142.2	226.6	460.1	920.5	53.0
Worldwide Market	1,184.6	804.8	1,179.1	2,036.5	3,531.5	31.4
Resist Processing (Track)						
Americas Market	108.7	127.1	171.3	189.7	384.0	37.1
Japanese Market	179.3	141.6	148.7	232.2	427.2	24.2
European Market	36.5	41.6	107.4	88.4	204.7	53.9
Asia/Pacific Market	39.6	42.9	72.7	184.7	396.7	77.9
Worldwide Market	364.1	353.2	500.1	695.1	1,412.5	40.3
Etch and Clean						
Americas Market	328.4	371.1	534.8	724.9	1,269.6	40.2
Japanese Market	663.2	531.0	632.0	883.8	1,528.8	23.2
European Market	133.0	155.1	230.9	307.6	575.6	44.2
Asia/Pacific Market	173.3	168.6	361.8	632.2	1,349.7	67.1
Worldwide Market	1,297.9	1,225.8	1,759.5	2,548.5	4,723.8	38.1
Deposition						
Americas Market	376.3	439.0	554.1	816.9	1,331.0	37.1
Japanese Market	664.4	487.5	540.2	796.9	1,397.2	20.4
European Market	159.3	170.1	257.8	357.3	585.4	38.5
Asia/Pacific Market	203.3	203.4	297.9	582.2	1,166.3	54.8
Worldwide Market	1,403.3	1,300.0	1,650.0	2,553.2	4,479.9	33.7
Thermal Nondeposition						
Americas Market	90.5	70.6	108.1	175.4	244.8	28.2
Japanese Market	174.6	141.4	129.3	188.9	337.2	17.9
European Market	45.6	30.1	77.0	69.3	102.2	22.4
Asia/Pacific Market	61.5	40.4	73.1	133.0	242.7	40.9
Worldwide Market	372.2	282.5	387.5	566.5	926.9	25.6

(Continued)

Table 2-4 (Continued)
Sales Revenue from Shipments of Wafer Fab Equipment into Each Region by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Ion Implantation						
Americas Market	57.8	62.4	86.6	171.0	291.3	49.8
Japanese Market	200.7	124.9	146.5	242.5	330.9	13.3
European Market	43.5	36.9	55.2	108.3	159.8	38.4
Asia/Pacific Market	51.4	38.7	70.8	137.6	271.2	51.6
Worldwide Market	353.4	262.9	359.1	659.4	1,053.2	31.4
Process Control						
Americas Market	183.0	191.8	225.8	360.2	525.0	30.2
Japanese Market	307.2	200.9	222.0	385.0	651.9	20.7
European Market	72.4	72.5	77.7	117.6	212.6	30.9
Asia/Pacific Market	69.4	77.1	118.1	240.4	464.1	60.8
Worldwide Market	631.9	542.3	643.6	1,103.3	1,853.5	30.9
Factory Automation						
Americas Market	36.0	39.0	45.0	70.0	122.0	35.7
Japanese Market	132.0	87.0	116.0	174.0	235.0	15.5
European Market	23.0	23.0	23.0	25.0	45.0	18.3
Asia/Pacific Market	36.0	45.0	66.0	143.0	284.0	67.6
Worldwide Market	227.0	194.0	250.0	412.0	686.0	31.8
Other Wafer Fab Equipment						
Americas Market	39.1	31.8	31.5	42.5	105.4	28.1
Japanese Market	84.3	58.8	65.9	100.0	117.0	8.5
European Market	15.6	17.2	16.7	16.9	51.2	34.6
Asia/Pacific Market	29.5	25.0	24.7	53.5	112.5	39.8
Worldwide Market	168.5	132.8	138.8	212.9	386.1	23.0
Wafer Fab Equipment						
Americas Market	1,518.5	1,575.7	2,118.1	3,190.4	5,178.5	35.9
Japanese Market	3,011.6	2,097.9	2,449.6	3,660.5	6,351.6	20.5
European Market	641.1	641.4	988.3	1,369.7	2,315.7	37.9
Asia/Pacific Market	831.8	783.3	1,311.7	2,566.7	5,207.7	58.2
Worldwide Market	6,002.9	5,098.3	6,867.7	10,787.3	19,053.5	33.5

Source: Dataquest (May 1996)

Table 2-5
Worldwide Sales Revenue from Shipments of Wafer Fab Equipment by Company Base and Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Lithography						
North American Companies	122.1	169.2	299.2	10.4	8.3	8.5
Japanese Companies	845.0	1,550.1	2,677.4	71.7	76.1	75.8
European Companies	212.0	317.1	554.9	18.0	15.6	15.7
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	1,179.1	2,036.5	3,531.5	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	1,179.1	2,036.5	3,531.5			
Resist Processing (Track)						
North American Companies	148.9	152.8	330.1	29.8	22.0	23.4
Japanese Companies	269.5	461.6	1,035.5	53.9	66.4	73.3
European Companies	17.6	22.6	46.9	3.5	3.3	3.3
Joint Venture Companies	64.1	58.1	0	12.8	8.4	NM
Identified Companies	500.1	695.1	1,412.5	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	500.1	695.1	1,412.5			
Etch and Clean						
North American Companies	981.7	1,367.3	2,593.3	56.2	53.7	54.9
Japanese Companies	679.8	1,098.7	1,918.9	38.9	43.1	40.6
European Companies	34.9	42.0	138.3	2.0	1.6	2.9
Joint Venture Companies	51.1	40.5	73.2	2.9	1.6	1.6
Identified Companies	1,747.5	2,548.5	4,723.8	100.0	100.0	100.0
Other Companies	12.0	0	0			
All Companies	1,759.5	2,548.5	4,723.8			

(Continued)

Table 2-5 (Continued)
Worldwide Sales Revenue from Shipments of Wafer Fab Equipment by Company Base and Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Deposition						
North American Companies	922.0	1,539.8	2,798.9	59.4	62.5	64.0
Japanese Companies	461.6	659.7	1,173.2	29.7	26.8	26.8
European Companies	116.8	155.8	271.2	7.5	6.3	6.2
Joint Venture Companies	51.4	107.3	131.6	3.3	4.4	3.0
Identified Companies	1,551.8	2,462.5	4,374.9	100.0	100.0	100.0
Other Companies	98.2	90.7	105.0			
All Companies	1,650.0	2,553.2	4,479.9			
Thermal Nondeposition						
North American Companies	80.9	120.3	195.9	20.9	21.2	21.1
Japanese Companies	234.9	332.5	616.0	60.6	58.7	66.5
European Companies	30.5	31.8	57.6	7.9	5.6	6.2
Joint Venture Companies	41.2	81.9	57.4	10.6	14.5	6.2
Identified Companies	387.5	566.5	926.9	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	387.5	566.5	926.9			
Ion Implantation						
North American Companies	242.8	455.2	823.0	67.6	69.0	78.1
Japanese Companies	42.0	67.3	85.0	11.7	10.2	8.1
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	74.3	136.9	145.3	20.7	20.8	13.8
Identified Companies	359.1	659.4	1,053.2	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	359.1	659.4	1,053.2			

(Continued)

Table 2-5 (Continued)
Worldwide Sales Revenue from Shipments of Wafer Fab Equipment by Company Base and Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Process Control						
North American Companies	388.5	662.2	1,096.9	73.8	67.6	65.5
Japanese Companies	123.6	263.1	511.5	23.5	26.9	30.5
European Companies	14.4	54.5	67.5	2.7	5.6	4.0
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	526.5	979.9	1,675.9	100.0	100.0	100.0
Other Companies	117.1	123.4	177.6			
All Companies	643.6	1,103.3	1,853.5			
Factory Automation						
North American Companies	0	0	0	NM	NM	NM
Japanese Companies	0	0	0	NM	NM	NM
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	0	0	0	NM	NM	NM
Other Companies	250.0	412.0	686.0			
All Companies	250.0	412.0	686.0			
Other Wafer Fab Equipment						
North American Companies	12.0	13.9	82.1	100.0	100.0	100.0
Japanese Companies	0	0	0	NM	NM	NM
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	12.0	13.9	82.1	100.0	100.0	100.0
Other Companies	126.8	199.0	304.0			
All Companies	138.8	212.9	386.1			

(Continued)

Table 2-5 (Continued)
Worldwide Sales Revenue from Shipments of Wafer Fab Equipment by Company Base and Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Wafer Fab Equipment						
North American Companies	2,898.9	4,480.7	8,219.5	46.3	45.0	46.2
Japanese Companies	2,656.4	4,433.0	8,017.4	42.4	44.5	45.1
European Companies	426.2	623.9	1,136.4	6.8	6.3	6.4
Joint Venture Companies	282.1	424.7	407.6	4.5	4.3	2.3
Identified Companies	6,263.6	9,962.2	17,780.9	100.0	100.0	100.0
Other Companies	604.1	825.1	1,272.6			
All Companies	6,867.7	10,787.3	19,053.5			

NM = Not meaningful

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.

Source: Dataquest (May 1996)

Chapter 3
Lithography Equipment

This chapter presents tables for the lithography equipment market. The chapter consists of 11 tables that present a variety of estimates relevant to equipment company sales of lithography equipment. Table 3-1 reports estimated lithography equipment sales by company nationality or company base into each regional market delineated by Dataquest. As elsewhere, joint venture companies are grouped separately in this table, regardless of company base. Also, reported sales by the category "Other Companies" reflect Dataquest estimates of unsurveyed activity in the lithography equipment market. Table 3-2 reports lithography equipment sales to each market region by company base. The table also reports the market share for each company grouping within regional markets. As elsewhere, the market shares reported for each company grouping are based on estimated sales to the relevant market by all identified companies. No market shares are reported for other companies because their estimated sales reflect Dataquest estimates of unsurveyed market activity.

Dataquest segments the lithography equipment market into six equipment subcategories (which are shown in Table 1-1). Table 3-3 reports equipment sales for each of these six subcategories within each regional market. Table 3-4 reports equipment sales for each of the six lithography equipment subcategories by company base. The table also reports the market share of company groupings within each subcategory. Once again, the market shares reported in the table are based on estimated sales for identified companies, and no market shares are reported for other companies.

Tables 3-5 through 3-11 report estimated individual company sales for each of the six lithography equipment subcategories. Each table concerns a specific lithography equipment subcategory and reports the estimated sales for all surveyed companies known to sell equipment in the relevant equipment subcategory. The set of companies included in each table represents a comprehensive list of surveyed companies with relevant product sales to at least one region of the world. Within each table, estimated company sales are reported for each regional market as well as for the world overall. If a company does not have sales in a particular region, zero sales are reported for the company in that region. Although this convention populates the tables with a large number of zeros, it also readily distinguishes the companies that did not participate in a particular regional market. Note that Table 3-8 reports estimated units of steppers sold.

Table 3-1
Sales Revenue from Shipments of Lithography by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
North American Companies						
Americas Market	86.2	71.5	72.6	83.8	159.3	16.6
Japanese Market	34.3	26.6	20.0	25.2	41.4	4.8
European Market	23.7	11.2	15.3	23.8	36.9	11.7
Asia/Pacific Market	7.7	15.0	14.2	36.4	61.5	68.1
Worldwide Market	151.9	124.3	122.1	169.2	299.2	18.5
Japanese Companies						
Americas Market	168.4	105.7	178.6	382.8	468.4	29.1
Japanese Market	568.1	296.0	427.3	628.5	1,279.2	22.5
European Market	66.7	46.9	79.2	178.4	235.1	37.0
Asia/Pacific Market	133.4	90.2	159.9	360.4	694.7	51.1
Worldwide Market	936.6	538.8	845.0	1,550.1	2,677.4	30.0
European Companies						
Americas Market	44.1	65.7	109.7	173.2	277.7	58.4
Japanese Market	3.5	2.2	1.7	3.6	5.9	13.7
European Market	21.8	36.8	48.1	77.1	107.2	48.9
Asia/Pacific Market	26.7	37.0	52.5	63.3	164.2	57.5
Worldwide Market	96.1	141.7	212.0	317.1	554.9	55.0
Joint Venture Companies						
Americas Market	0	0	0	0	0	NM
Japanese Market	0	0	0	0	0	NM
European Market	0	0	0	0	0	NM
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	0	0	0	0	0	NM
Other Companies						
Americas Market	0	0	0	0	0	NM
Japanese Market	0	0	0	0	0	NM
European Market	0	0	0	0	0	NM
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	0	0	0	0	0	NM

(Continued)

Table 3-1 (Continued)
Sales Revenue from Shipments of Lithography by Company Base into Each Region
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
All Companies						
Americas Market	298.7	242.9	360.9	639.8	905.4	31.9
Japanese Market	605.9	324.8	449.0	657.3	1,326.5	21.6
European Market	112.2	94.9	142.6	279.3	379.2	35.6
Asia/Pacific Market	167.8	142.2	226.6	460.1	920.5	53.0
Worldwide Market	1,184.6	804.8	1,179.1	2,036.5	3,531.5	31.4

NM = Not meaningful
Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 3-2
Sales Revenue from Shipments of Lithography into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Americas Market						
North American Companies	72.6	83.8	159.3	20.1	13.1	17.6
Japanese Companies	178.6	382.8	468.4	49.5	59.8	51.7
European Companies	109.7	173.2	277.7	30.4	27.1	30.7
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	360.9	639.8	905.4	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	360.9	639.8	905.4			
Japanese Market						
North American Companies	20.0	25.2	41.4	4.5	3.8	3.1
Japanese Companies	427.3	628.5	1,279.2	95.2	95.6	96.4
European Companies	1.7	3.6	5.9	0.4	0.5	0.4
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	449.0	657.3	1,326.5	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	449.0	657.3	1,326.5			
European Market						
North American Companies	15.3	23.8	36.9	10.7	8.5	9.7
Japanese Companies	79.2	178.4	235.1	55.5	63.9	62.0
European Companies	48.1	77.1	107.2	33.7	27.6	28.3
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	142.6	279.3	379.2	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	142.6	279.3	379.2			

(Continued)

Table 3-2 (Continued)
Sales Revenue from Shipments of Lithography into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Market						
North American Companies	14.2	36.4	61.5	6.3	7.9	6.7
Japanese Companies	159.9	360.4	694.7	70.6	78.3	75.5
European Companies	52.5	63.3	164.2	23.2	13.8	17.8
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	226.6	460.1	920.5	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	226.6	460.1	920.5			
Worldwide Market						
North American Companies	122.1	169.2	299.2	10.4	8.3	8.5
Japanese Companies	845.0	1,550.1	2,677.4	71.7	76.1	75.8
European Companies	212.0	317.1	554.9	18.0	15.6	15.7
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	1,179.1	2,036.5	3,531.5	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	1,179.1	2,036.5	3,531.5			

NM= Not meaningful
Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 3-3
Sales Revenue from Shipments of Lithography into Each Region by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Contact/Proximity						
Americas Market	2.6	4.0	3.7	4.3	5.5	20.6
Japanese Market	11.9	5.0	4.8	3.6	4.4	-22.2
European Market	7.0	12.3	12.8	13.9	13.8	18.5
Asia/Pacific Market	3.3	5.4	4.9	5.9	10.2	32.6
Worldwide Market	24.8	26.7	26.2	27.7	33.9	8.1
Projection Aligners						
Americas Market	16.4	9.7	9.1	8.3	11.1	-9.3
Japanese Market	42.0	28.1	38.4	26.8	13.9	-24.2
European Market	7.3	3.4	6.3	13.1	9.4	6.5
Asia/Pacific Market	12.7	7.0	3.4	2.6	1.4	-42.4
Worldwide Market	78.4	48.2	57.2	50.8	35.8	-17.8
Steppers						
Americas Market	263.5	207.1	309.5	588.8	850.9	34.1
Japanese Market	487.3	249.4	378.8	581.2	1,251.6	26.6
European Market	85.6	69.0	107.7	237.0	337.9	40.9
Asia/Pacific Market	142.8	120.9	211.3	425.8	891.2	58.1
Worldwide Market	979.2	646.4	1,007.3	1,832.7	3,331.6	35.8
Direct-Write Lithography						
Americas Market	4.3	3.9	6.2	7.9	4.0	-1.8
Japanese Market	35.6	12.7	10.8	14.8	25.8	-7.7
European Market	6.9	5.2	6.0	7.3	7.5	2.1
Asia/Pacific Market	3.4	4.0	0	5.0	0.7	-32.6
Worldwide Market	50.2	25.8	23.0	34.9	38.0	-6.7
Maskmaking Lithography						
Americas Market	9.5	13.2	19.0	19.3	23.7	25.7
Japanese Market	27.3	29.6	16.2	30.9	30.8	3.1
European Market	5.4	5.0	9.8	8.0	10.6	18.4
Asia/Pacific Market	5.6	4.9	7.0	20.9	16.9	31.8
Worldwide Market	47.8	52.7	52.0	79.1	82.0	14.5

(Continued)

Table 3-3 (Continued)
Sales Revenue from Shipments of Lithography into Each Region by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
X-Ray Aligners						
Americas Market	2.4	5.0	13.4	11.2	10.2	43.4
Japanese Market	1.8	0	0	0	0	-100.0
European Market	0	0	0	0	0	NM
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	4.2	5.0	13.4	11.2	10.2	24.7
Lithography						
Americas Market	298.7	242.9	360.9	639.8	905.4	31.9
Japanese Market	605.9	324.8	449.0	657.3	1,326.5	21.6
European Market	112.2	94.9	142.6	279.3	379.2	35.6
Asia/Pacific Market	167.8	142.2	226.6	460.1	920.5	53.0
Worldwide Market	1,184.6	804.8	1,179.1	2,036.5	3,531.5	31.4

NM = Not meaningful
Source: Dataquest (May 1996)

Table 3-4
Worldwide Sales Revenue from Shipments of Lithography by Company Base by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Contact/Proximity						
North American Companies	0	0	0	NM	NM	NM
Japanese Companies	4.0	2.5	2.0	15.3	9.0	5.9
European Companies	22.2	25.2	31.9	84.7	91.0	94.1
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	26.2	27.7	33.9	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	26.2	27.7	33.9			
Projection Aligners						
North American Companies	22.1	27.1	24.8	38.6	53.4	69.3
Japanese Companies	35.1	23.7	11.0	61.4	46.6	30.7
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	57.2	50.8	35.8	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	57.2	50.8	35.8			
Steppers						
North American Companies	54.0	80.2	213.2	5.4	4.4	6.4
Japanese Companies	783.4	1,479.8	2,620.2	77.8	80.7	78.6
European Companies	169.9	272.7	498.3	16.9	14.9	15.0
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	1,007.3	1,832.7	3,331.6	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	1,007.3	1,832.7	3,331.6			

(Continued)

Table 3-4 (Continued)
Worldwide Sales Revenue from Shipments of Lithography by Company Base by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Direct-Write Lithography						
North American Companies	0	2.0	0	NM	5.7	NM
Japanese Companies	14.4	21.6	25.2	62.6	61.9	66.3
European Companies	8.6	11.3	12.8	37.4	32.4	33.7
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	23.0	34.9	38.0	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	23.0	34.9	38.0			
Maskmaking Lithography						
North American Companies	34.6	48.7	58.4	66.5	61.5	71.2
Japanese Companies	8.1	22.5	19.0	15.6	28.5	23.2
European Companies	9.3	7.9	4.6	17.9	10.0	5.6
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	52.0	79.1	82.0	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	52.0	79.1	82.0			
X-Ray Aligners						
North American Companies	11.4	11.2	2.8	85.1	100.0	27.6
Japanese Companies	0	0	0	NM	NM	NM
European Companies	2.0	0	7.4	14.9	NM	72.4
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	13.4	11.2	10.2	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	13.4	11.2	10.2			

(Continued)

Table 3-4 (Continued)
Worldwide Sales Revenue from Shipments of Lithography by Company Base by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Lithography						
North American Companies	122.1	169.2	299.2	10.4	8.3	8.5
Japanese Companies	845.0	1,550.1	2,677.4	71.7	76.1	75.8
European Companies	212.0	317.1	554.9	18.0	15.6	15.7
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	1,179.1	2,036.5	3,531.5	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	1,179.1	2,036.5	3,531.5			

NM = Not meaningful
Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 3-5
Each Company's Sales Revenue from Shipments of Contact/Proximity to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	2.6	4.0	3.7	4.3	5.5	20.6
Canon	0.5	0	0	0	0	-100.0
Karl Suss	2.1	4.0	3.7	4.3	5.5	27.2
Total	2.6	4.0	3.7	4.3	5.5	20.6
Japanese Market	11.9	5.0	4.8	3.6	4.4	-22.2
Canon	10.2	2.8	3.1	2.0	1.5	-38.1
Karl Suss	1.7	2.2	1.7	1.6	2.9	13.8
Total	11.9	5.0	4.8	3.6	4.4	-22.2
European Market	7.0	12.3	12.8	13.9	13.8	18.5
Canon	0.5	0	0	0	0	-100.0
Karl Suss	6.5	12.3	12.8	13.9	13.8	20.7
Total	7.0	12.3	12.8	13.9	13.8	18.5
Asia/Pacific Market	3.3	5.4	4.9	5.9	10.2	32.6
Canon	0.7	0.8	0.9	0.5	0.5	-8.1
Karl Suss	2.6	4.6	4.0	5.4	9.7	39.0
Total	3.3	5.4	4.9	5.9	10.2	32.6
Worldwide Market	24.8	26.7	26.2	27.7	33.9	8.1
Canon	11.9	3.6	4.0	2.5	2.0	-36.0
Karl Suss	12.9	23.1	22.2	25.2	31.9	25.4
Total	24.8	26.7	26.2	27.7	33.9	8.1

NM = Not meaningful
Source: Dataquest (May 1996)

Table 3-6
Each Company's Sales Revenue from Shipments of Projection Aligners to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	16.4	9.7	9.1	8.3	11.1	-9.3
Canon	5.7	3.5	1.2	0	0	-100.0
Silicon Valley Group	10.7	6.2	7.9	8.3	11.1	0.9
Total	16.4	9.7	9.1	8.3	11.1	-9.3
Japanese Market	42.0	28.1	38.4	26.8	13.9	-24.2
Canon	35.9	25.2	33.9	23.7	11.0	-25.6
Silicon Valley Group	6.1	2.9	4.5	3.1	2.9	-17.0
Total	42.0	28.1	38.4	26.8	13.9	-24.2
European Market	7.3	3.4	6.3	13.1	9.4	6.5
Canon	1.9	0.9	0	0	0	-100.0
Silicon Valley Group	5.4	2.5	6.3	13.1	9.4	14.9
Total	7.3	3.4	6.3	13.1	9.4	6.5
Asia/Pacific Market	12.7	7.0	3.4	2.6	1.4	-42.4
Canon	12.7	7.0	0	0	0	-100.0
Silicon Valley Group	0	0	3.4	2.6	1.4	NM
Total	12.7	7.0	3.4	2.6	1.4	-42.4
Worldwide Market	78.4	48.2	57.2	50.8	35.8	-17.8
Canon	56.2	36.6	35.1	23.7	11.0	-33.5
Silicon Valley Group	22.2	11.6	22.1	27.1	24.8	2.8
Total	78.4	48.2	57.2	50.8	35.8	-17.8

NM = Not meaningful
Source: Dataquest (May 1996)

Table 3-7
Each Company's Sales Revenue from Shipments of Steppers to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	263.5	207.1	309.5	588.8	850.9	34.1
ASM Lithography	40.7	56.0	98.9	166.9	260.8	59.1
Canon	41.4	32.8	62.6	139.9	209.9	50.1
GCA	38.2	27.5	0	0	0	-100.0
Hitachi	0	3.3	3.6	0	0	NM
Integrated Solutions Inc.	0	0	0	0	19.5	NM
Nikon	117.8	62.9	107.6	239.0	258.5	21.7
Silicon Valley Group	15.0	15.4	18.5	20.0	68.3	46.1
Ultratech	10.4	9.2	18.3	23.0	33.9	34.4
Total	263.5	207.1	309.5	588.8	850.9	34.1
Japanese Market	487.3	249.4	378.8	581.2	1,251.6	26.6
ASM Lithography	0	0	0	0	0	NM
Canon	83.0	48.1	110.1	181.7	435.5	51.3
GCA	1.7	0.4	0	0	0	-100.0
Hitachi	50.7	29.9	10.8	0	0	-100.0
Integrated Solutions Inc.	0	0	0	0	0	NM
Nikon	334.9	163.1	254.5	391.5	794.0	24.1
Silicon Valley Group	7.8	3.8	0	0	0	-100.0
Ultratech	9.2	4.1	3.4	8.0	22.2	24.6
Total	487.3	249.4	378.8	581.2	1,251.6	26.6
European Market	85.6	69.0	107.7	237.0	337.9	40.9
ASM Lithography	9.0	14.3	22.5	50.8	83.7	74.6
Canon	22.2	14.8	34.6	62.7	114.1	50.6
GCA	5.2	2.3	0	0	0	-100.0
Hitachi	0	0	3.6	0	0	NM
Integrated Solutions Inc.	0	0	0	0	1.7	NM
Nikon	39.1	31.2	41.0	115.7	121.0	32.6
Silicon Valley Group	7.6	4.0	0	0	0	-100.0
Ultratech	2.5	2.4	6.0	7.8	17.5	62.6
Total	85.6	69.0	107.7	237.0	337.9	40.9

(Continued)

Table 3-7 (Continued)
Each Company's Sales Revenue from Shipments of Steppers to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Asia/Pacific Market	142.8	120.9	211.3	425.8	891.2	58.1
ASM Lithography	21.6	31.7	48.5	55.1	153.8	63.4
Canon	34.6	41.9	60.4	84.3	209.3	56.8
GCA	1.7	3.3	0	0	0	-100.0
Hitachi	36.0	6.6	7.2	0	0	-100.0
Integrated Solutions Inc.	0	0	0	0	3.3	NM
Nikon	46.4	33.9	87.4	265.0	478.0	79.2
Silicon Valley Group	0	0	3.8	3.8	8.4	NM
Ultratech	2.5	3.5	4.0	17.6	38.4	98.0
Total	142.8	120.9	211.3	425.8	891.2	58.1
Worldwide Market	979.2	646.4	1,007.3	1,832.7	3,331.6	35.8
ASM Lithography	71.3	102.0	169.9	272.7	498.3	62.6
Canon	181.2	137.6	267.7	468.6	968.7	52.1
GCA	46.8	33.5	0	0	0	-100.0
Hitachi	86.7	39.8	25.2	0	0	-100.0
Integrated Solutions Inc.	0	0	0	0	24.5	NM
Nikon	538.2	291.1	490.5	1,011.2	1,651.4	32.4
Silicon Valley Group	30.4	23.2	22.3	23.8	76.7	26.0
Ultratech	24.6	19.2	31.7	56.4	112.0	46.1
Total	979.2	646.4	1,007.3	1,832.7	3,331.6	35.8

NM = Not meaningful
Source: Dataquest (May 1996)

Table 3-8
Each Company's Unit Shipments of Steppers to the World (Units)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	172	122	159	261	335	18.1
ASM Lithography	23	28	39	64	106	46.5
Canon	25	20	33	63	77	32.5
GCA	26	16	0	0	0	-100.0
Hitachi	0	2	2	0	0	NM
Integrated Solutions Inc.	0	0	0	0	9	NM
Nikon	80	40	58	101	86	1.8
Silicon Valley Group	4	4	6	5	17	43.6
Ultratech	14	12	21	28	40	30.0
Total	172	122	159	261	335	18.1
Japanese Market	322	162	204	264	442	8.2
ASM Lithography	0	0	0	0	0	NM
Canon	54	30	57	83	160	31.2
GCA	1	0	0	0	0	-100.0
Hitachi	38	18	6	0	0	-100.0
Integrated Solutions Inc.	0	0	0	0	0	NM
Nikon	215	108	137	170	263	5.2
Silicon Valley Group	2	1	0	0	0	-100.0
Ultratech	12	5	4	11	19	12.2
Total	322	162	204	264	442	8.2
European Market	54	41	59	111	138	26.4
ASM Lithography	5	7	9	20	30	56.5
Canon	16	10	19	29	44	28.8
GCA	3	0	0	0	0	-100.0
Hitachi	0	0	2	0	0	NM
Integrated Solutions Inc.	0	0	0	0	1	NM
Nikon	25	20	22	50	41	13.2
Silicon Valley Group	2	1	0	0	0	-100.0
Ultratech	3	3	7	12	22	64.6
Total	54	41	59	111	138	26.4

(Continued)

Table 3-8 (Continued)
Each Company's Unit Shipments of Steppers to the World (Units)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Asia/Pacific Market	99	72	110	190	313	33.3
ASM Lithography	12	16	21	23	41	36.0
Canon	25	26	32	40	78	32.9
GCA	1	0	0	0	0	-100.0
Hitachi	27	4	4	0	0	-100.0
Integrated Solutions Inc.	0	0	0	0	2	NM
Nikon	30	22	48	110	162	52.4
Silicon Valley Group	0	0	1	1	2	NM
Ultratech	4	4	4	16	28	62.7
Total	99	72	110	190	313	33.3
Worldwide Market	647	397	532	826	1,228	17.4
ASM Lithography	40	51	69	107	177	45.0
Canon	120	86	141	215	359	31.5
GCA	31	16	0	0	0	-100.0
Hitachi	65	24	14	0	0	-100.0
Integrated Solutions Inc.	0	0	0	0	12	NM
Nikon	350	190	265	431	552	12.1
Silicon Valley Group	8	6	7	6	19	24.1
Ultratech	33	24	36	67	109	34.8
Total	647	397	532	826	1,228	17.4

NM = Not meaningful
Source: Dataquest (May 1996)

Table 3-9
Each Company's Sales Revenue from Shipments of Direct-Write Lithography to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	4.3	3.9	6.2	7.9	4.0	-1.8
Etec	0	0	0	2.0	0	NM
Hitachi	0	0	0	0	0	NM
Jenoptik	0	0	0	0	4.0	NM
JEOL	3.0	3.2	3.6	3.9	0	-100.0
Leica	1.3	0.7	2.6	2.0	0	-100.0
Total	4.3	3.9	6.2	7.9	4.0	-1.8
Japanese Market	35.6	12.7	10.8	14.8	25.8	-7.7
Etec	0	4.0	0	0	0	NM
Hitachi	17.8	3.2	7.2	8.9	17.1	-1.0
Jenoptik	0	0	0	0	0	NM
JEOL	17.8	5.5	3.6	3.9	8.1	-17.9
Leica	0	0	0	2.0	0.6	NM
Total	35.6	12.7	10.8	14.8	25.8	-7.7
European Market	6.9	5.2	6.0	7.3	7.5	2.1
Etec	0	0	0	0	0	NM
Hitachi	0	0	0	0	0	NM
Jenoptik	0	0	3.2	3.3	1.6	NM
JEOL	3.0	0	0	0	0	-100.0
Leica	3.9	5.2	2.8	4.0	5.9	10.9
Total	6.9	5.2	6.0	7.3	7.5	2.1
Asia/Pacific Market	3.4	4.0	0	5.0	0.7	-32.6
Etec	0	4.0	0	0	0	NM
Hitachi	0	0	0	5.0	0	NM
Jenoptik	0	0	0	0	0	NM
JEOL	3.0	0	0	0	0	-100.0
Leica	0.4	0	0	0	0.7	15.0
Total	3.4	4.0	0	5.0	0.7	-32.6

(Continued)

Table 3-9 (Continued)
Each Company's Sales Revenue from Shipments of Direct-Write Lithography to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	50.2	25.8	23.0	34.9	38.0	-6.7
Etec	0	8.0	0	2.0	0	NM
Hitachi	17.8	3.2	7.2	13.8	17.1	-1.0
Jenoptik	0	0	3.2	3.3	5.6	NM
JEOL	26.8	8.7	7.2	7.8	8.1	-25.9
Leica	5.6	5.9	5.4	8.0	7.2	6.5
Total	50.2	25.8	23.0	34.9	38.0	-6.7

NM = Not meaningful
Source: Dataquest (May 1996)

Table 3-10
Each Company's Sales Revenue from Shipments of Maskmaking Lithography to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	9.5	13.2	19.0	19.3	23.7	25.7
Ateq	6.0	0	0	0	0	-100.0
Etec	3.5	13.2	16.5	19.3	18.4	51.4
Hitachi	0	0	0	0	0	NM
Jenoptik	0	0	0	0	0	NM
JEOL	0	0	0	0	0	NM
Leica	0	0	2.5	0	0	NM
Lepton Inc.	0	0	0	0	5.3	NM
Toshiba	0	0	0	0	0	NM
Total	9.5	13.2	19.0	19.3	23.7	25.7
Japanese Market	27.3	29.6	16.2	30.9	30.8	3.1
Ateq	6.0	0	0	0	0	-100.0
Etec	3.5	11.4	12.1	14.1	16.3	46.9
Hitachi	6.7	7.1	4.1	5.6	0	-100.0
Jenoptik	0	0	0	0	0	NM
JEOL	11.1	11.1	0	9.2	10.0	-2.6
Leica	0	0	0	0	2.4	NM
Lepton Inc.	0	0	0	0	0	NM
Toshiba	0	0	0	2.0	2.1	NM
Total	27.3	29.6	16.2	30.9	30.8	3.1
European Market	5.4	5.0	9.8	8.0	10.6	18.4
Ateq	3.0	0	0	0	0	-100.0
Etec	0	0	3.0	2.9	8.4	NM
Hitachi	0	0	0	0	0	NM
Jenoptik	0	0	4.3	2.2	2.2	NM
JEOL	0	0	0	0	0	NM
Leica	2.4	5.0	2.5	2.9	0	-100.0
Lepton Inc.	0	0	0	0	0	NM
Toshiba	0	0	0	0	0	NM
Total	5.4	5.0	9.8	8.0	10.6	18.4

(Continued)

Table 3-10 (Continued)
Each Company's Sales Revenue from Shipments of Maskmaking Lithography to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Asia/Pacific Market	5.6	4.9	7.0	20.9	16.9	31.8
Ateq	0	0	0	0	0	NM
Etec	3.5	4.2	3.0	12.4	10.0	30.0
Hitachi	0	0	4.0	5.7	6.9	NM
Jenoptik	0	0	0	2.8	0	NM
JEOL	0	0	0	0	0	NM
Leica	2.1	0.7	0	0	0	-100.0
Lepton Inc.	0	0	0	0	0	NM
Toshiba	0	0	0	0	0	NM
Total	5.6	4.9	7.0	20.9	16.9	31.8
Worldwide Market	47.8	52.7	52.0	79.1	82.0	14.5
Ateq	15.0	0	0	0	0	-100.0
Etec	10.5	28.8	34.6	48.7	53.1	50.0
Hitachi	6.7	7.1	8.1	11.3	6.9	0.8
Jenoptik	0	0	4.3	5.0	2.2	NM
JEOL	11.1	11.1	0	9.2	10.0	-2.6
Leica	4.5	5.7	5.0	2.9	2.4	-14.5
Lepton Inc.	0	0	0	0	5.3	NM
Toshiba	0	0	0	2.0	2.1	NM
Total	47.8	52.7	52.0	79.1	82.0	14.5

NM = Not meaningful
Source: Dataquest (May 1996)

Table 3-11
Each Company's Sales Revenue from Shipments of X-Ray Aligners to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	2.4	5.0	13.4	11.2	10.2	43.4
Hampshire Instruments	2.4	0	0	0	0	-100.0
Karl Suss	0	5.0	2.0	0	7.4	NM
Silicon Valley Group	0	0	11.4	11.2	2.8	NM
Total	2.4	5.0	13.4	11.2	10.2	43.4
Japanese Market	1.8	0	0	0	0	-100.0
Hampshire Instruments	0	0	0	0	0	NM
Karl Suss	1.8	0	0	0	0	-100.0
Silicon Valley Group	0	0	0	0	0	NM
Total	1.8	0	0	0	0	-100.0
Worldwide Market	4.2	5.0	13.4	11.2	10.2	24.7
Hampshire Instruments	2.4	0	0	0	0	-100.0
Karl Suss	1.8	5.0	2.0	0	7.4	42.2
Silicon Valley Group	0	0	11.4	11.2	2.8	NM
Total	4.2	5.0	13.4	11.2	10.2	24.7

NM = Not meaningful
Note: There were no shipments to the European or Asia/Pacific markets, 1991-1995.
Source: Dataquest (May 1996)

Chapter 4
Resist Processing (Track) Equipment

This chapter presents tables for the resist processing or track equipment market. The chapter consists of four tables that present a variety of estimates relevant to equipment company sales of track equipment. Table 4-1 reports estimated track equipment sales by company nationality or company base into each regional market delineated by Dataquest. As elsewhere, joint venture companies are grouped separately in this table regardless of company base. Also, reported sales by the category "other companies" reflect Dataquest estimates of unsurveyed activity in the track equipment market. Table 4-2 reports track equipment sales to each market region by company base. The table also reports the market share for each company grouping within regional markets. As elsewhere, the market shares reported for each company grouping are based on estimated sales to the relevant market by all identified companies. No market shares are reported for other companies because their estimated sales reflect Dataquest estimates of unsurveyed market activity.

Table 4-3 presents a ranking of the top 10 track equipment companies based on estimated end-user revenue garnered worldwide. Table 4-3 also resummarizes the market shares of all track producers by company base for the track equipment market. Note that joint venture companies are grouped separately in this market share summary regardless of nationality. Also note that the reported market shares for the various groupings of companies are based on total estimated sales by identified companies. Finally, Table 4-4 reports estimated individual company sales for track equipment by regional market. The set of companies included in the table represents a comprehensive list of surveyed companies with track equipment sales to at least one region of the world. If a company does not have sales in a particular region, zero sales are reported for the company in that region. Although this convention populates the tables with a large number of zeros, it also readily distinguishes the companies that did not participate in a particular regional market.

Table 4-1
Sales Revenue from Shipments of Resist Processing (Track) by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
North American Companies						
Americas Market	73.4	80.1	101.3	99.3	215.5	30.9
Japanese Market	1.6	1.0	0	0	1.3	-5.1
European Market	14.4	16.5	40.6	38.8	55.2	39.9
Asia/Pacific Market	6.6	7.4	7.0	14.7	58.2	72.3
Worldwide Market	96.0	105.0	148.9	152.8	330.1	36.2
Japanese Companies						
Americas Market	14.1	18.5	31.3	47.0	163.3	84.5
Japanese Market	177.7	140.6	148.7	232.2	425.9	24.4
European Market	4.8	7.8	24.9	14.3	113.0	120.3
Asia/Pacific Market	32.5	34.7	64.6	168.0	333.3	79.0
Worldwide Market	229.1	201.6	269.5	461.6	1,035.5	45.8
European Companies						
Americas Market	8.0	9.0	3.4	6.2	5.2	-10.2
Japanese Market	0	0	0	0	0	NM
European Market	6.5	6.8	13.1	14.4	36.5	53.9
Asia/Pacific Market	0.5	0.8	1.1	2.0	5.2	79.6
Worldwide Market	15.0	16.6	17.6	22.6	46.9	33.0
Joint Venture Companies						
Americas Market	13.2	19.5	35.3	37.2	0	-100.0
Japanese Market	0	0	0	0	0	NM
European Market	10.8	10.5	28.8	20.9	0	-100.0
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	24.0	30.0	64.1	58.1	0	-100.0
Other Companies						
Americas Market	0	0	0	0	0	NM
Japanese Market	0	0	0	0	0	NM
European Market	0	0	0	0	0	NM
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	0	0	0	0	0	NM

(Continued)

Table 4-1 (Continued)
Sales Revenue from Shipments of Resist Processing (Track) by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
All Companies						
Americas Market	108.7	127.1	171.3	189.7	384.0	37.1
Japanese Market	179.3	141.6	148.7	232.2	427.2	24.2
European Market	36.5	41.6	107.4	88.4	204.7	53.9
Asia/Pacific Market	39.6	42.9	72.7	184.7	396.7	77.9
Worldwide Market	364.1	353.2	500.1	695.1	1,412.5	40.3

NM = Not meaningful
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 4-2
Sales Revenue from Shipments of Resist Processing (Track) into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Americas Market						
North American Companies	101.3	99.3	215.5	59.1	52.4	56.1
Japanese Companies	31.3	47.0	163.3	18.3	24.8	42.5
European Companies	3.4	6.2	5.2	2.0	3.3	1.4
Joint Venture Companies	35.3	37.2	0	20.6	19.6	NM
Identified Companies	171.3	189.7	384.0	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	171.3	189.7	384.0			
Japanese Market						
North American Companies	0	0	1.3	0	0	0.3
Japanese Companies	148.7	232.2	425.9	100.0	100.0	99.7
European Companies	0	0	0	0	0	NM
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	148.7	232.2	427.2	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	148.7	232.2	427.2			
European Market						
North American Companies	40.6	38.8	55.2	37.8	43.9	27.0
Japanese Companies	24.9	14.3	113.0	23.2	16.2	55.2
European Companies	13.1	14.4	36.5	12.2	16.3	17.8
Joint Venture Companies	28.8	20.9	0	26.8	23.6	NM
Identified Companies	107.4	88.4	204.7	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	107.4	88.4	204.7			

(Continued)

Table 4-2 (Continued)
Sales Revenue from Shipments of Resist Processing (Track) into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Market						
North American Companies	7.0	14.7	58.2	9.6	8.0	14.7
Japanese Companies	64.6	168.0	333.3	88.9	91.0	84.0
European Companies	1.1	2.0	5.2	1.5	1.1	1.3
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	72.7	184.7	396.7	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	72.7	184.7	396.7			
Worldwide Market						
North American Companies	148.9	152.8	330.1	29.8	22.0	23.4
Japanese Companies	269.5	461.6	1,035.5	53.9	66.4	73.3
European Companies	17.6	22.6	46.9	3.5	3.3	3.3
Joint Venture Companies	64.1	58.1	0	12.8	8.4	NM
Identified Companies	500.1	695.1	1,412.5	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	500.1	695.1	1,412.5			

NM = Not meaningful
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 4-3
Top 10 Companies' Sales Revenue from Shipments of Resist Processing (Track) to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	1	Tokyo Electron Ltd. (including joint ventures)	360.6	782.1	117	55.4
2	2	Dainippon Screen	130.7	218.1	67	15.4
3	3	Silicon Valley Group	93.3	207.0	122	14.7
4	4	FSI International	35.5	86.5	144	6.1
5	6	Fairchild Convac	22.6	46.9	108	3.3
6	5	Semiconductor Systems	24.0	27.9	16	2.0
7	7	Tazmo	12.9	17.9	39	1.3
8	8	Yuasa	11.3	15.5	37	1.1
9	10	Integrated Solutions Inc.	0	8.7	0	0.6
10	9	Canon	4.1	2.0	-52	0.1
		North American Companies	152.8	330.1	116	23.4
		Japanese Companies	461.6	1,035.5	124	73.3
		European Companies	22.6	46.9	108	3.3
		Joint Venture Companies	58.1	0	-100	0
		Identified Companies	695.1	1,412.5	103	100
		Other Companies	0	0	0	
		All Companies	695.1	1,412.5	103	

Notes: "Including joint ventures" indicates figures that include joint ventures.
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 4-4
Each Company's Sales Revenue from Shipments of Resist Processing (Track) to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	108.7	127.1	171.3	189.7	384.0	37.1
Canon	0	0	0	0	0	NM
Dainippon Screen	11.1	16.4	24.1	37.6	75.6	61.6
Eaton	0.3	0.4	0.3	0	0	-100.0
Fairchild Convac	8.0	9.0	3.4	6.2	5.2	-10.2
FSI International	5.1	15.6	21.0	27.2	51.4	78.2
Integrated Solutions Inc.	0	0	0	0	5.9	NM
Machine Technology Inc.	18.5	7.2	6.2	0	0	-100.0
Semiconductor Systems	17.2	20.9	21.3	23.2	26.1	11.0
Silicon Valley Group	29.3	33.5	51.6	48.9	132.0	45.7
Solitec	3.0	2.5	0.9	0	0	-100.0
Tazmo	1.5	2.1	4.5	3.5	4.1	28.6
Tokyo Electron Ltd.	0	0	0	0	75.8	NM
Varian/TEL	13.2	19.5	35.3	37.2	0	-100.0
Yuasa	1.5	0	2.7	5.9	7.8	51.0
Total	108.7	127.1	171.3	189.7	384.0	37.1
Japanese Market	179.3	141.6	148.7	232.2	427.2	24.2
Canon	12.3	11.1	3.6	4.1	2.0	-36.7
Dainippon Screen	51.3	47.1	38.9	45.1	86.4	13.9
Eaton	0	0	0	0	0	NM
Fairchild Convac	0	0	0	0	0	NM
FSI International	0	0	0	0	0	NM
Integrated Solutions Inc.	0	0	0	0	0	NM
Machine Technology Inc.	1.6	0.5	0	0	0	-100.0
Semiconductor Systems	0	0	0	0	1.3	NM
Silicon Valley Group	0	0.5	0	0	0	NM
Solitec	0	0	0	0	0	NM
Tazmo	11.9	7.0	11.7	5.9	8.7	-7.5
Tokyo Electron Ltd.	97.8	73.0	90.9	173.2	322.9	34.8
Varian/TEL	0	0	0	0	0	NM
Yuasa	4.4	2.4	3.6	3.9	5.8	7.2
Total	179.3	141.6	148.7	232.2	427.2	24.2

(Continued)

Table 4-4 (Continued)
Each Company's Sales Revenue from Shipments of Resist Processing (Track) to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
European Market	36.5	41.6	107.4	88.4	204.7	53.9
Canon	0	2.8	0	0	0	NM
Dainippon Screen	4.8	4.7	23.1	12.8	23.1	48.2
Eaton	2.2	0.1	0	0	0	-100.0
Fairchild Convac	6.5	6.8	13.1	14.4	36.5	53.9
FSI International	0	0	0	1.5	10.6	NM
Integrated Solutions Inc.	0	0	0	0	2.1	NM
Machine Technology Inc.	6.5	9.0	6.5	0	0	-100.0
Semiconductor Systems	0	0	0	0	0.5	NM
Silicon Valley Group	4.2	7.2	34.0	37.3	42.0	77.8
Solitec	1.5	0.2	0.1	0	0	-100.0
Tazmo	0	0.3	0	0	0	NM
Tokyo Electron Ltd.	0	0	0	0	88.0	NM
Varian/TEL	10.8	10.5	28.8	20.9	0	-100.0
Yuasa	0	0	1.8	1.5	1.9	NM
Total	36.5	41.6	107.4	88.4	204.7	53.9
Asia/Pacific Market	39.6	42.9	72.7	184.7	396.7	77.9
Canon	0	1.2	1.8	0	0	NM
Dainippon Screen	2.3	9.2	21.4	35.2	32.9	94.4
Eaton	1.7	2.1	1.8	0	0	-100.0
Fairchild Convac	0.5	0.8	1.1	2.0	5.2	79.6
FSI International	0	1.0	0	6.8	24.5	NM
Integrated Solutions Inc.	0	0	0	0	0.7	NM
Machine Technology Inc.	0	0.5	0.5	0	0	NM
Semiconductor Systems	0	0	0.6	0.8	0	NM
Silicon Valley Group	4.5	3.6	4.0	7.1	33.0	64.6
Solitec	0.4	0.2	0.1	0	0	-100.0
Tazmo	1.8	0.6	1.8	3.5	5.1	29.7
Tokyo Electron Ltd.	28.4	23.7	39.6	129.3	295.4	79.6
Varian/TEL	0	0	0	0	0	NM
Yuasa	0	0	0	0	0	NM
Total	39.6	42.9	72.7	184.7	396.7	77.9

(Continued)

Table 4-4 (Continued)
Each Company's Sales Revenue from Shipments of Resist Processing (Track) to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	364.1	353.2	500.1	695.1	1,412.5	40.3
Canon	12.3	15.1	5.4	4.1	2.0	-36.7
Dainippon Screen	69.5	77.4	107.5	130.7	218.1	33.1
Eaton	4.2	2.6	2.1	0	0	-100.0
Fairchild Convac	15.0	16.6	17.6	22.6	46.9	33.0
FSI International	5.1	16.6	21.0	35.5	86.5	102.9
Integrated Solutions Inc.	0	0	0	0	8.7	NM
Machine Technology Inc.	26.6	17.2	13.2	0	0	-100.0
Semiconductor Systems	17.2	20.9	21.9	24.0	27.9	12.9
Silicon Valley Group	38.0	44.8	89.6	93.3	207.0	52.8
Solitec	4.9	2.9	1.1	0	0	-100.0
Tazmo	15.2	10.0	18.0	12.9	17.9	4.2
Tokyo Electron Ltd.	126.2	96.7	130.5	302.5	782.1	57.8
Varian/TEL	24.0	30.0	64.1	58.1	0	-100.0
Yuasa	5.9	2.4	8.1	11.3	15.5	27.2
Total	364.1	353.2	500.1	695.1	1,412.5	40.3

NM = Not meaningful
Source: Dataquest (May 1996)

Chapter 5
Etch and Clean Equipment

This chapter presents tables for the etch and clean equipment market. The chapter consists of 15 tables that present a variety of estimates relevant to equipment company sales of etch and clean equipment. Table 5-1 reports estimated etch and clean equipment sales by company nationality or company base into each regional market delineated by Dataquest. As elsewhere, joint venture companies are grouped separately in this table regardless of company base. Also, reported sales by the category "other companies" reflect Dataquest's estimates of unsurveyed activity in the etch and clean equipment market. Table 5-2 reports etch and clean equipment sales to each market region by company base. The table also reports the market share for each company grouping within regional markets. As elsewhere, the market shares reported for each company grouping are based on estimated sales to the relevant market by all identified companies. No market shares are reported for other companies because their estimated sales reflect Dataquest estimates of unsurveyed market activity.

Dataquest segments the etch and clean equipment market into nine equipment subcategories (as shown in Table 1-1). Table 5-3 reports equipment sales for each of these nine subcategories within each regional market. Table 5-4 reports equipment sales for each of the nine etch and clean equipment subcategories by company base. The table also reports the market share of company groupings within each subcategory. Once again, the market shares reported in the table are based on estimated sales for identified companies, and no market shares are reported for other companies.

Finally, Tables 5-5 through 5-15 report a variety of estimates regarding individual company sales of the nine etch and clean equipment subcategories. Tables 5-5, 5-11, and 5-13 present rankings of the top 10 auto wet station, dry strip, and dry etch producers, respectively, based on end-user revenue garnered worldwide. These tables also resummarize the market shares of all producers by company base for the relevant equipment markets. Note that joint venture companies are grouped separately in these market share summaries regardless of nationality. Also note that the reported market shares for the various groupings of companies are based on total estimated sales by identified companies.

The remaining tables report estimated individual company sales for eight of the nine etch and clean equipment subcategories. No individual company data is reported for ion milling because the segment is no longer surveyed and all reported figures reflect Dataquest's estimates. Each of the tables concerns a specific etch and clean equipment subcategory. Each table reports the estimated sales of all surveyed companies known to sell equipment in the relevant equipment subcategory. The set of companies included in each table represents a comprehensive list of surveyed companies with relevant product sales to at least one region of the world. Within each table, estimated company sales are reported for each regional market as well as for the world overall. If a company does not have sales in a particular region, zero sales are reported for the company in that region. Although this convention populates the tables with a large number of zeros, it also readily distinguishes the companies that did not participate in a particular regional market. Note that Tables 5-14 and 5-15 report estimated individual company sales of low- and high-density etch equipment separately.

Table 5-1
Sales Revenue from Shipments of Etch and Clean by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
North American Companies						
Americas Market	276.8	327.2	477.3	635.4	1,082.6	40.6
Japanese Market	95.0	76.0	119.5	179.8	366.5	40.2
European Market	82.2	110.9	183.5	250.1	462.3	54.0
Asia/Pacific Market	70.2	79.5	201.4	302.0	681.9	76.5
Worldwide Market	524.2	593.6	981.7	1,367.3	2,593.3	49.1
Japanese Companies						
Americas Market	29.9	13.2	24.8	67.3	101.9	35.9
Japanese Market	541.2	423.2	484.4	682.6	1,113.7	19.8
European Market	23.4	16.5	18.0	25.5	59.3	26.2
Asia/Pacific Market	95.3	82.5	152.6	323.3	644.0	61.2
Worldwide Market	689.8	535.4	679.8	1,098.7	1,918.9	29.1
European Companies						
Americas Market	9.5	4.0	12.6	16.3	84.7	72.8
Japanese Market	0	0	2.2	0.4	0.4	NM
European Market	17.9	13.1	18.1	25.3	51.1	30.0
Asia/Pacific Market	2.4	0.8	2.0	0	2.1	-3.3
Worldwide Market	29.8	17.9	34.9	42.0	138.3	46.8
Joint Venture Companies						
Americas Market	8.4	6.3	17.1	5.9	0.4	-54.1
Japanese Market	20.0	17.8	22.9	21.0	48.2	24.6
European Market	7.4	5.9	9.3	6.7	2.9	-20.8
Asia/Pacific Market	1.6	1.6	1.8	6.9	21.7	92.0
Worldwide Market	37.4	31.6	51.1	40.5	73.2	18.3
Other Companies						
Americas Market	3.8	20.4	3.0	0	0	-100.0
Japanese Market	7.0	14.0	3.0	0	0	-100.0
European Market	2.1	8.7	2.0	0	0	-100.0
Asia/Pacific Market	3.8	4.2	4.0	0	0	-100.0
Worldwide Market	16.7	47.3	12.0	0	0	-100.0

(Continued)

Table 5-1 (Continued)
Sales Revenue from Shipments of Etch and Clean by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
All Companies						
Americas Market	328.4	371.1	534.8	724.9	1,269.6	40.2
Japanese Market	663.2	531.0	632.0	883.8	1,528.8	23.2
European Market	133.0	155.1	230.9	307.6	575.6	44.2
Asia/Pacific Market	173.3	168.6	361.8	632.2	1,349.7	67.1
Worldwide Market	1,297.9	1,225.8	1,759.5	2,548.5	4,723.8	38.1

NM = Not meaningful
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 5-2
Sales Revenue from Shipments of Etch and Clean into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Americas Market						
North American Companies	477.3	635.4	1,082.6	89.8	87.6	85.3
Japanese Companies	24.8	67.3	101.9	4.7	9.3	8.0
European Companies	12.6	16.3	84.7	2.4	2.2	6.7
Joint Venture Companies	17.1	5.9	0.4	3.2	0.8	0
Identified Companies	531.8	724.9	1,269.6	100.0	100.0	100.0
Other Companies	3.0	0	0			
All Companies	534.8	724.9	1,269.6			
Japanese Market						
North American Companies	119.5	179.8	366.5	19.0	20.3	24.0
Japanese Companies	484.4	682.6	1,113.7	77.0	77.2	72.8
European Companies	2.2	0.4	0.4	0.3	0	0
Joint Venture Companies	22.9	21.0	48.2	3.6	2.4	3.2
Identified Companies	629.0	883.8	1,528.8	100.0	100.0	100.0
Other Companies	3.0	0	0			
All Companies	632.0	883.8	1,528.8			
European Market						
North American Companies	183.5	250.1	462.3	80.2	81.3	80.3
Japanese Companies	18.0	25.5	59.3	7.9	8.3	10.3
European Companies	18.1	25.3	51.1	7.9	8.2	8.9
Joint Venture Companies	9.3	6.7	2.9	4.1	2.2	0.5
Identified Companies	228.9	307.6	575.6	100.0	100.0	100.0
Other Companies	2.0	0	0			
All Companies	230.9	307.6	575.6			

(Continued)

Table 5-2 (Continued)
Sales Revenue from Shipments of Etch and Clean into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Market						
North American Companies	201.4	302.0	681.9	56.3	47.8	50.5
Japanese Companies	152.6	323.3	644.0	42.6	51.1	47.7
European Companies	2.0	0	2.1	0.6	0	0.2
Joint Venture Companies	1.8	6.9	21.7	0.5	1.1	1.6
Identified Companies	357.8	632.2	1,349.7	100.0	100.0	100.0
Other Companies	4.0	0	0			
All Companies	361.8	632.2	1,349.7			
Worldwide Market						
North American Companies	981.7	1,367.3	2,593.3	56.2	53.7	54.9
Japanese Companies	679.8	1,098.7	1,918.9	38.9	43.1	40.6
European Companies	34.9	42.0	138.3	2.0	1.6	2.9
Joint Venture Companies	51.1	40.5	73.2	2.9	1.6	1.6
Identified Companies	1,747.5	2,548.5	4,723.8	100.0	100.0	100.0
Other Companies	12.0	0	0			
All Companies	1,759.5	2,548.5	4,723.8			

Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 5-3
Sales Revenue from Shipments of Etch and Clean into Each Region by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Auto Wet Stations						
Americas Market	62.9	70.7	90.2	130.7	237.7	39.4
Japanese Market	158.7	150.0	100.8	160.1	284.8	15.7
European Market	23.0	24.3	29.4	41.1	86.4	39.2
Asia/Pacific Market	46.0	40.8	65.0	135.7	318.6	62.2
Worldwide Market	290.6	285.8	285.4	467.6	927.6	33.7
Spray Processors						
Americas Market	NS	NS	NS	28.0	60.1	NM
Japanese Market	NS	NS	NS	16.5	26.1	NM
European Market	NS	NS	NS	9.5	27.9	NM
Asia/Pacific Market	NS	NS	NS	6.5	8.7	NM
Worldwide Market	NS	NS	NS	60.6	122.8	NM
Vapor Phase Clean						
Americas Market	NS	0.9	1.7	3.0	3.6	NM
Japanese Market	NS	0	1.7	2.2	3.4	NM
European Market	NS	0.6	0	0.9	1.5	NM
Asia/Pacific Market	NS	0.9	2.2	2.7	4.0	NM
Worldwide Market	NS	2.4	5.6	8.8	12.6	NM
Post-CMP Clean						
Americas Market	0.4	1.6	5.3	12.7	28.8	191.2
Japanese Market	0	0	0.8	3.4	7.4	NM
European Market	0	0.8	2.4	3.4	7.1	NM
Asia/Pacific Market	0	0	0.4	2.2	4.1	NM
Worldwide Market	0.4	2.4	8.9	21.7	47.4	229.9
Other Clean Process						
Americas Market	47.6	38.1	58.9	41.9	74.3	11.8
Japanese Market	66.1	35.6	70.3	46.0	65.4	-0.3
European Market	18.8	14.7	17.8	13.8	18.3	-0.7
Asia/Pacific Market	10.4	9.8	36.5	19.8	48.2	46.7
Worldwide Market	142.9	98.2	183.5	121.4	206.1	9.6

(Continued)

Table 5-3 (Continued)
Sales Revenue from Shipments of Etch and Clean into Each Region by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Chemical Mechanical Polishing						
Americas Market	8.4	15.7	29.7	39.1	135.1	100.3
Japanese Market	0	1.2	7.6	14.2	34.2	NM
European Market	2.1	2.8	4.8	9.3	18.4	72.0
Asia/Pacific Market	0.3	0	1.5	1.6	9.0	134.0
Worldwide Market	10.8	19.7	43.6	64.2	196.7	106.6
Dry Strip						
Americas Market	32.2	29.5	35.1	56.8	89.9	29.3
Japanese Market	62.1	58.9	52.1	68.4	120.0	17.9
European Market	9.2	7.2	20.0	23.6	33.1	37.7
Asia/Pacific Market	15.6	26.9	30.3	63.8	125.8	68.5
Worldwide Market	119.1	122.5	137.5	212.5	368.8	32.7
Ion Milling						
Americas Market	3.8	3.3	3.0	NS	NS	NM
Japanese Market	7.0	5.0	3.0	NS	NS	NM
European Market	2.1	1.7	2.0	NS	NS	NM
Asia/Pacific Market	3.8	3.3	4.0	NS	NS	NM
Worldwide Market	16.7	13.3	12.0	NS	NS	NM
Dry Etch						
Americas Market	173.1	211.3	310.9	412.8	640.0	38.7
Japanese Market	369.3	280.3	395.7	572.9	987.6	27.9
European Market	77.8	103.0	154.5	206.0	382.9	48.9
Asia/Pacific Market	97.2	86.9	221.9	400.0	831.3	71.0
Worldwide Market	717.4	681.5	1,083.0	1,591.6	2,841.8	41.1
Etch and Clean						
Americas Market	328.4	371.1	534.8	724.9	1,269.6	40.2
Japanese Market	663.2	531.0	632.0	883.8	1,528.8	23.2
European Market	133.0	155.1	230.9	307.6	575.6	44.2
Asia/Pacific Market	173.3	168.6	361.8	632.2	1,349.7	67.1
Worldwide Market	1,297.9	1,225.8	1,759.5	2,548.5	4,723.8	38.1

NM = Not meaningful
NS = Equipment segment not surveyed
Note: "Other clean process" called "other wet process" prior to 1994
Source: Dataquest (May 1996)

Table 5-4
Worldwide Sales Revenue from Shipments of Etch and Clean by Company Base by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Auto Wet Stations						
North American Companies	106.8	108.2	169.9	37.4	23.1	18.3
Japanese Companies	163.1	339.7	660.1	57.1	72.6	71.2
European Companies	15.5	19.7	97.6	5.4	4.2	10.5
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	285.4	467.6	927.6	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	285.4	467.6	927.6			
Spray Processors						
North American Companies	NS	50.4	109.9	NM	83.2	89.5
Japanese Companies	NS	10.2	12.9	NM	16.8	10.5
European Companies	NS	0	0	NM	NM	NM
Joint Venture Companies	NS	0	0	NM	NM	NM
Identified Companies	NS	60.6	122.8	NM	100.0	100.0
Other Companies	NS	0	0			
All Companies	NS	60.6	122.8			
Vapor Phase Clean						
North American Companies	5.6	7.5	9.7	100.0	84.8	76.8
Japanese Companies	0	1.3	2.9	NM	15.2	23.2
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	5.6	8.8	12.6	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	5.6	8.8	12.6			

(Continued)

Table 5-4 (Continued)
Worldwide Sales Revenue from Shipments of Etch and Clean by Company Base by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Post-CMP Clean						
North American Companies	8.9	15.5	33.5	100.0	71.5	70.7
Japanese Companies	0	6.2	13.9	NM	28.5	29.3
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	8.9	21.7	47.4	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	8.9	21.7	47.4			
Other Clean Process						
North American Companies	75.6	46.7	68.4	41.2	38.5	33.2
Japanese Companies	95.2	70.5	120.1	51.9	58.1	58.3
European Companies	1.0	4.2	17.6	0.5	3.5	8.5
Joint Venture Companies	11.7	0	0	6.4	NM	NM
Identified Companies	183.5	121.4	206.1	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	183.5	121.4	206.1			
Chemical Mechanical Polishing						
North American Companies	42.8	58.0	177.6	98.2	90.3	90.3
Japanese Companies	0.3	5.0	17.6	0.7	7.9	8.9
European Companies	0.5	1.2	1.5	1.1	1.9	0.8
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	43.6	64.2	196.7	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	43.6	64.2	196.7			

(Continued)

Table 5-4 (Continued)
Worldwide Sales Revenue from Shipments of Etch and Clean by Company Base by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Dry Strip						
North American Companies	57.1	99.2	169.1	41.5	46.7	45.8
Japanese Companies	63.6	87.5	128.2	46.3	41.2	34.8
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	16.8	25.8	71.5	12.2	12.1	19.4
Identified Companies	137.5	212.5	368.8	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	137.5	212.5	368.8			
Ion Milling						
North American Companies	0	NS	NS	NM	NM	NM
Japanese Companies	0	NS	NS	NM	NM	NM
European Companies	0	NS	NS	NM	NM	NM
Joint Venture Companies	0	NS	NS	NM	NM	NM
Identified Companies	0	NS	NS	NM	NM	NM
Other Companies	12.0	NS	NS			
All Companies	12.0	NS	NS			
Dry Etch						
North American Companies	684.9	981.8	1,855.3	63.2	61.7	65.3
Japanese Companies	357.6	578.2	963.2	33.0	36.3	33.9
European Companies	17.9	16.9	21.6	1.7	1.1	0.8
Joint Venture Companies	22.6	14.7	1.7	2.1	0.9	0.1
Identified Companies	1,083.0	1,591.6	2,841.8	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	1,083.0	1,591.6	2,841.8			

(Continued)

Table 5-4 (Continued)
Worldwide Sales Revenue from Shipments of Etch and Clean by Company Base by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Etch and Clean						
North American Companies	981.7	1,367.3	2,593.3	56.2	53.7	54.9
Japanese Companies	679.8	1,098.7	1,918.9	38.9	43.1	40.6
European Companies	34.9	42.0	138.3	2.0	1.6	2.9
Joint Venture Companies	51.1	40.5	73.2	2.9	1.6	1.6
Identified Companies	1,747.5	2,548.5	4,723.8	100.0	100.0	100.0
Other Companies	12.0	0	0			
All Companies	1,759.5	2,548.5	4,723.8			

NM = Not meaningful
NS = Equipment segment not surveyed
Notes: Figures for "other companies" reflect estimates of unsurveyed market activity.
"Other clean process" called "other wet process" prior to 1994
Source: Dataquest (May 1996)

Table 5-5
Top 10 Companies' Sales Revenue from Shipments of Auto Wet Stations to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	1	Dainippon Screen	131.1	187.6	43	20.2
2	6	Sugai	32.6	121.5	273	13.1
3	7	Tokyo Electron Ltd. (including joint ventures)	22.5	108.5	382	11.7
4	5	Kaijo Denki	45.1	96.1	113	10.4
5	8	Steag Microtech	17.7	94.0	431	10.1
6	2	Sankyo Engineering	58.1	74.3	28	8.0
7	3	SubMicron Systems Inc.	46.4	68.1	47	7.3
8	4	Santa Clara Plastics	46.3	60.6	31	6.5
9	9	CFM Technology	13.2	25.2	91	2.7
10	10	Toho Kasei	12.6	17.7	40	1.9
		North American Companies	108.2	169.9	57	18.3
		Japanese Companies	339.7	660.1	94	71.2
		European Countries	19.7	97.6	395	10.5
		Joint Venture Companies	0	0	0	0
		Identified Companies	467.0	927.6	98	100
		Other Companies	0	0	0	
		All Companies	467.6	927.6	98	

Notes: "Including joint ventures" indicates figures that include joint ventures.
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 5-6
Each Company's Sales Revenue from Shipments of Auto Wet Stations to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	62.9	70.7	90.2	130.7	237.7	39.4
CFM Technology	2.3	3.2	7.3	7.3	14.2	57.6
Dainippon Screen	8.8	0	2.2	25.1	23.3	27.6
Dalton Corporation	0	0	0	0	0	NM
Dan Science Co. Ltd.	0	0	0	0	0	NM
Enya	0	1.1	0	0	0	NM
ET Systems Engineering	0	0	0	0	0	NM
Fuji Electric	0	0	0	0	0	NM
Kaijo Denki	6.7	0	1.5	6.5	0.5	-46.9
Kuwano Electric	0	0	0	0	0	NM
Maruwa	0	0	0	0	0	NM
Musashi	0	0	0	0	0	NM
Pokorny	0	0	2.8	0	0	NM
Pure Aire Corporation	1.1	1.0	0	0	0	-100.0
Sankyo Engineering	0	0	0	0	0	NM
Santa Clara Plastics	15.0	37.6	37.9	37.2	56.6	39.4
Sapi Equipements	2.0	0	0	0	0	-100.0
SCI Manufacturing	4.8	5.0	4.5	2.3	7.2	10.7
Semifab	3.0	0	0	0	0	-100.0
Shimada	0	0	0	0	0	NM
Steag Microtech	0	0	0	8.3	64.2	NM
SubMicron Systems Inc.	12.0	15.7	26.2	37.0	51.8	44.1
Sugai	0	0	0	0	0	NM
Toho Kasei	0	0	0	0.7	0.6	NM
Tokyo Electron Ltd.	0	0	0	4.7	8.7	NM
Toyoko Kagaku	0	0	0	1.6	1.7	NM
Universal Plastics	5.5	6.0	7.0	0	0	-100.0
Verteq	1.7	1.1	0.8	0	8.8	50.8
Total	62.9	70.7	90.2	130.7	237.7	39.4
Japanese Market	158.7	150.0	100.8	160.1	284.8	15.7
CFM Technology	0	0.7	1.2	1.2	0.7	NM
Dainippon Screen	28.0	66.8	27.5	43.1	99.2	37.2
Dalton Corporation	1.2	0	0	0	0	-100.0
Dan Science Co. Ltd.	5.8	2.5	0.9	2.6	4.5	-6.0
Enya	10.7	2.5	1.3	2.4	3.3	-25.5
ET Systems Engineering	10.4	10.0	8.3	6.9	12.0	3.7
Fuji Electric	0.7	1.2	0	0	0	-100.0

(Continued)

Table 5-6 (Continued)
Each Company's Sales Revenue from Shipments of Auto Wet Stations to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Kaijo Denki	13.5	8.3	3.5	19.6	25.8	17.6
Kuwano Electric	7.1	1.6	1.9	5.0	1.3	-34.7
Maruwa	5.9	2.0	2.7	3.8	7.2	4.9
Musashi	3.1	1.1	2.3	2.6	3.8	5.2
Pokorny	0	0	0	0	0	NM
Pure Aire Corporation	0	0	0	0	0	NM
Sankyo Engineering	23.8	12.2	16.3	34.0	55.2	23.4
Santa Clara Plastics	0	0	0	0	0	NM
Sapi Equipements	0	0	0	0	0	NM
SCI Manufacturing	0	0	0	0	0	NM
Semifab	0	0	0	0	0	NM
Shimada	13.4	6.3	3.6	7.1	10.4	-6.1
Steag Microtech	0	0	0	0	0	NM
SubMicron Systems Inc.	0	0	0	0	0	NM
Sugai	23.4	17.8	15.3	13.1	10.9	-17.4
Toho Kasei	5.2	9.5	11.2	10.0	12.8	25.2
Tokyo Electron Ltd.	5.6	7.5	4.8	7.0	33.5	56.4
Toyoko Kagaku	0.9	0	0	1.9	4.1	46.1
Universal Plastics	0	0	0	0	0	NM
Verteq	0	0	0	0	0	NM
Total	158.7	150.0	100.8	160.1	284.8	15.7
European Market	23.0	24.3	29.4	41.1	86.4	39.2
CFM Technology	2.5	2.0	3.8	2.4	9.0	37.7
Dainippon Screen	8.9	4.2	3.8	7.5	20.1	22.6
Dalton Corporation	0	0	0	0	0	NM
Dan Science Co. Ltd.	0	0	0	0	0	NM
Enya	0	0	0	0	0	NM
ET Systems Engineering	0	0	0	0	0	NM
Fuji Electric	0	0	0	0	0	NM
Kaijo Denki	0	0	0	1.5	0	NM
Kuwano Electric	0	0	0	0	0	NM
Maruwa	0	0	0	0	0	NM
Musashi	0	0	0	0	0	NM
Pokorny	6.6	5.2	10.2	0	0	-100.0
Pure Aire Corporation	0	0	0	0	0	NM
Sankyo Engineering	2.4	1.1	0.5	0	1.4	-12.0
Santa Clara Plastics	2.0	3.1	5.6	6.5	4.0	18.9

(Continued)

Table 5-6 (Continued)
Each Company's Sales Revenue from Shipments of Auto Wet Stations to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Sapi Equipements	0	2.0	1.5	2.0	3.6	NM
SCI Manufacturing	0	0	0	0	0	NM
Semifab	0	0	0	0	0	NM
Shimada	0	0	0	0	0	NM
Steag Microtech	0	0	0	9.5	29.8	NM
SubMicron Systems Inc.	0	6.7	4.0	9.4	16.3	NM
Sugai	0	0	0	0	0	NM
Toho Kasei	0	0	0	0.6	2.1	NM
Tokyo Electron Ltd.	0	0	0	1.8	0	NM
Toyoko Kagaku	0	0	0	0	0	NM
Universal Plastics	0	0	0	0	0	NM
Verteq	0.6	0	0	0	0	-100.0
Total	23.0	24.3	29.4	41.1	86.4	39.2
Asia/Pacific Market	46.0	40.8	65.0	135.7	318.6	62.2
CFM Technology	0	0	0	2.3	1.3	NM
Dainippon Screen	12.0	4.9	18.2	55.4	45.0	39.1
Dalton Corporation	0	0	0	0	0	NM
Dan Science Co. Ltd.	8.4	2.5	3.2	2.2	4.0	-17.0
Enya	0	0	0	0	0	NM
ET Systems Engineering	0	0	0	0	0	NM
Fuji Electric	0.9	0	0	0	0	-100.0
Kaijo Denki	9.7	8.8	14.1	17.6	69.8	63.8
Kuwano Electric	0	0	0	0	0	NM
Maruwa	2.2	0	0	1.6	2.1	-1.4
Musashi	1.0	0.5	0	0	0	-100.0
Pokorny	0	0	1.0	0	0	NM
Pure Aire Corporation	0.1	0	0	0	0	-100.0
Sankyo Engineering	1.2	6.1	0	24.2	17.6	95.8
Santa Clara Plastics	2.5	3.0	2.3	2.6	0	-100.0
Sapi Equipements	0	0	0	0	0	NM
SCI Manufacturing	0	0	0	0	0	NM
Semifab	0	0	0	0	0	NM
Shimada	0	0	0	0	0	NM
Steag Microtech	0	0	0	0	0	NM
SubMicron Systems Inc.	0	0	5.2	0	0	NM
Sugai	8.0	14.2	16.2	19.5	110.6	92.8
Toho Kasei	0	0.8	1.4	1.3	2.1	NM

(Continued)

Table 5-6 (Continued)
Each Company's Sales Revenue from Shipments of Auto Wet Stations to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Tokyo Electron Ltd.	0	0	2.4	9.0	66.2	NM
Toyoko Kagaku	0	0	0	0	0	NM
Universal Plastics	0	0	1.0	0	0	NM
Verteq	0	0	0	0	0	NM
Total	46.0	40.8	65.0	135.7	318.6	62.2
Worldwide Market	290.6	285.8	285.4	467.6	927.6	33.7
CFM Technology	4.8	5.9	12.3	13.2	25.2	51.4
Dainippon Screen	57.7	75.9	51.7	131.1	187.6	34.3
Dalton Corporation	1.2	0	0	0	0	-100.0
Dan Science Co. Ltd.	14.2	5.0	4.1	4.8	8.5	-12.0
Enya	10.7	3.6	1.3	2.4	3.3	-25.5
ET Systems Engineering	10.4	10.0	8.3	6.9	12.0	3.7
Fuji Electric	1.6	1.2	0	0	0	-100.0
Kaijo Denki	29.9	17.1	19.1	45.1	96.1	33.9
Kuwano Electric	7.1	1.6	1.9	5.0	1.3	-34.7
Maruwa	8.1	2.0	2.7	5.4	9.2	3.3
Musashi	4.1	1.6	2.3	2.6	3.8	-1.9
Pokorny	6.6	5.2	14.0	0	0	-100.0
Pure Aire Corporation	1.2	1.0	0	0	0	-100.0
Sankyo Engineering	27.4	19.4	16.8	58.1	74.3	28.3
Santa Clara Plastics	19.5	43.7	45.8	46.3	60.6	32.8
Sapi Equipements	2.0	2.0	1.5	2.0	3.6	15.8
SCI Manufacturing	4.8	5.0	4.5	2.3	7.2	10.7
Semifab	3.0	0	0	0	0	-100.0
Shimada	13.4	6.3	3.6	7.1	10.4	-6.1
Steag Microtech	0	0	0	17.7	94.0	NM
SubMicron Systems Inc.	12.0	22.4	35.4	46.4	68.1	54.3
Sugai	31.4	32.0	31.5	32.6	121.5	40.3
Toho Kasei	5.2	10.3	12.6	12.6	17.7	35.8
Tokyo Electron Ltd.	5.6	7.5	7.2	22.5	108.5	109.8
Toyoko Kagaku	0.9	0	0	3.5	5.8	59.3
Universal Plastics	5.5	6.0	8.0	0	0	-100.0
Verteq	2.3	1.1	0.8	0	8.8	39.8
Total	290.6	285.8	285.4	467.6	927.6	33.7

NM = Not meaningful
Source: Dataquest (May 1996)

Table 5-7
Each Company's Sales Revenue from Shipments of Spray Processors to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	NS	NS	NS	28.0	60.1	NM
Dainippon Screen	NS	NS	NS	0.5	0.4	NM
FSI International	NS	NS	NS	17.6	30.0	NM
Semitool	NS	NS	NS	9.9	29.7	NM
Total	NS	NS	NS	28.0	60.1	NM
Japanese Market	NS	NS	NS	16.5	26.1	NM
Dainippon Screen	NS	NS	NS	9.0	12.2	NM
FSI International	NS	NS	NS	3.2	6.4	NM
Semitool	NS	NS	NS	4.3	7.4	NM
Total	NS	NS	NS	16.5	26.1	NM
European Market	NS	NS	NS	9.5	27.9	NM
Dainippon Screen	NS	NS	NS	0.2	0.3	NM
FSI International	NS	NS	NS	4.0	13.4	NM
Semitool	NS	NS	NS	5.3	14.3	NM
Total	NS	NS	NS	9.5	27.9	NM
Asia/Pacific Market	NS	NS	NS	6.5	8.7	NM
Dainippon Screen	NS	NS	NS	0.4	0	NM
FSI International	NS	NS	NS	4.2	6.2	NM
Semitool	NS	NS	NS	1.9	2.5	NM
Total	NS	NS	NS	6.5	8.7	NM
Worldwide Market	NS	NS	NS	60.6	122.8	NM
Dainippon Screen	NS	NS	NS	10.2	12.9	NM
FSI International	NS	NS	NS	29.0	56.0	NM
Semitool	NS	NS	NS	21.4	53.9	NM
Total	NS	NS	NS	60.6	122.8	NM

NS = Equipment segment not surveyed
NM = Not meaningful
Note: Spray processors not surveyed prior to 1994
Source: Dataquest (May 1996)

Table 5-8
Each Company's Sales Revenue from Shipments of Vapor Phase Clean to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	NS	0.9	1.7	3.0	3.6	NM
Dainippon Screen	NS	0	0	0	0	NM
FSI International	NS	0.9	1.7	3.0	3.6	NM
Musashi	NS	0	0	0	0	NM
Total	NS	0.9	1.7	3.0	3.6	NM
Japanese Market	NS	0	1.7	2.2	3.4	NM
Dainippon Screen	NS	0	0	0.4	1.8	NM
FSI International	NS	0	1.7	0.9	0.5	NM
Musashi	NS	0	0	0.9	1.1	NM
Total	NS	0	1.7	2.2	3.4	NM
European Market	NS	0.6	0	0.9	1.5	NM
Dainippon Screen	NS	0	0	0	0	NM
FSI International	NS	0.6	0	0.9	1.5	NM
Musashi	NS	0	0	0	0	NM
Total	NS	0.6	0	0.9	1.5	NM
Asia/Pacific Market	NS	0.9	2.2	2.7	4.0	NM
Dainippon Screen	NS	0	0	0	0	NM
FSI International	NS	0.9	2.2	2.7	4.0	NM
Musashi	NS	0	0	0	0	NM
Total	NS	0.9	2.2	2.7	4.0	NM
Worldwide Market	NS	2.4	5.6	8.8	12.6	NM
Dainippon Screen	NS	0	0	0.4	1.8	NM
FSI International	NS	2.4	5.6	7.5	9.7	NM
Musashi	NS	0	0	0.9	1.1	NM
Total	NS	2.4	5.6	8.8	12.6	NM

NS = Equipment segment not surveyed
NM = Not meaningful
Note: Vapor phase clean not surveyed prior to 1992
Source: Dataquest (May 1996)

Table 5-9
Each Company's Sales Revenue from Shipments of Post-CMP Clean to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	0.4	1.6	5.3	12.7	28.8	191.2
Dainippon Screen	0	0	0	2.4	5.7	NM
FSI International	0	0	0.4	0	0	NM
IPEC/Planar	0.4	1.6	0.8	1.3	0	-100.0
OnTrak Systems	0	0	4.1	9.0	22.8	NM
Verteq	0	0	0	0	0.3	NM
Total	0.4	1.6	5.3	12.7	28.8	191.2
Japanese Market	0	0	0.8	3.4	7.4	NM
Dainippon Screen	0	0	0	2.8	6.0	NM
FSI International	0	0	0	0	0	NM
IPEC/Planar	0	0	0.8	0	0	NM
OnTrak Systems	0	0	0	0.6	1.4	NM
Verteq	0	0	0	0	0	NM
Total	0	0	0.8	3.4	7.4	NM
European Market	0	0.8	2.4	3.4	7.1	NM
Dainippon Screen	0	0	0	1.0	1.5	NM
FSI International	0	0	0	0	0	NM
IPEC/Planar	0	0.8	2.0	1.0	0	NM
OnTrak Systems	0	0	0.4	1.4	5.6	NM
Verteq	0	0	0	0	0	NM
Total	0	0.8	2.4	3.4	7.1	NM
Asia/Pacific Market	0	0	0.4	2.2	4.1	NM
Dainippon Screen	0	0	0	0	0.7	NM
FSI International	0	0	0	0.8	0	NM
IPEC/Planar	0	0	0.4	1.0	1.5	NM
OnTrak Systems	0	0	0	0.4	1.9	NM
Verteq	0	0	0	0	0	NM
Total	0	0	0.4	2.2	4.1	NM
Worldwide Market	0.4	2.4	8.9	21.7	47.4	229.9
Dainippon Screen	0	0	0	6.2	13.9	NM
FSI International	0	0	0.4	0.8	0	NM
IPEC/Planar	0.4	2.4	4.0	3.3	1.5	39.2
OnTrak Systems	0	0	4.5	11.4	31.7	NM
Verteq	0	0	0	0	0.3	NM
Total	0.4	2.4	8.9	21.7	47.4	229.9

NM = Not meaningful
Source: Dataquest (May 1996)

Table 5-10
Each Company's Sales Revenue from Shipments of Chemical Mechanical Polishing to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	8.4	15.7	29.7	39.1	135.1	100.3
Cybeq Systems	0	2.0	2.9	2.0	2.0	NM
Ebara Corp.	0	0	0	0	0	NM
Fujikoshi	0	0	0	0	0	NM
IPEC/Planar	5.8	10.8	22.2	28.1	85.9	96.2
PRESI	0	0	0	0	0	NM
Speedfam	0	0	0	3.0	16.5	NM
Strasbaugh	2.6	2.9	4.6	6.0	30.7	85.4
Sumitomo Metals	0	0	0	0	0	NM
Total	8.4	15.7	29.7	39.1	135.1	100.3
Japanese Market	0	1.2	7.6	14.2	34.2	NM
Cybeq Systems	0	0.5	1.6	3.0	3.0	NM
Ebara Corp.	0	0	0	4.7	13.3	NM
Fujikoshi	0	0	0.3	0.3	0.1	NM
IPEC/Planar	0	0.7	2.6	3.9	9.3	NM
PRESI	0	0	0	0	0	NM
Speedfam	0	0	2.0	0.8	0	NM
Strasbaugh	0	0	1.1	1.5	4.3	NM
Sumitomo Metals	0	0	0	0	4.2	NM
Total	0	1.2	7.6	14.2	34.2	NM
European Market	2.1	2.8	4.8	9.3	18.4	72.0
Cybeq Systems	0	0	0	2.0	2.0	NM
Ebara Corp.	0	0	0	0	0	NM
Fujikoshi	0	0	0	0	0	NM
IPEC/Planar	1.9	2.5	4.3	6.1	12.5	60.2
PRESI	0.2	0.3	0.5	1.2	1.5	65.5
Speedfam	0	0	0	0	1.9	NM
Strasbaugh	0	0	0	0	0.5	NM
Sumitomo Metals	0	0	0	0	0	NM
Total	2.1	2.8	4.8	9.3	18.4	72.0

(Continued)

Table 5-10 (Continued)
Each Company's Sales Revenue from Shipments of Chemical Mechanical Polishing to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Asia/Pacific Market	0.3	0	1.5	1.6	9.0	134.0
Cybeq Systems	0	0	0	0	0	NM
Ebara Corp.	0	0	0	0	0	NM
Fujikoshi	0	0	0	0	0	NM
IPEC/Planar	0.3	0	1.5	1.6	8.5	130.7
PRESI	0	0	0	0	0	NM
Speedfam	0	0	0	0	0	NM
Strasbaugh	0	0	0	0	0.5	NM
Sumitomo Metals	0	0	0	0	0	NM
Total	0.3	0	1.5	1.6	9.0	134.0
Worldwide Market	10.8	19.7	43.6	64.2	196.7	106.6
Cybeq Systems	0	2.5	4.5	7.0	7.0	NM
Ebara Corp.	0	0	0	4.7	13.3	NM
Fujikoshi	0	0	0.3	0.3	0.1	NM
IPEC/Planar	8.0	14.0	30.6	39.7	116.2	95.2
PRESI	0.2	0.3	0.5	1.2	1.5	65.5
Speedfam	0	0	2.0	3.8	18.4	NM
Strasbaugh	2.6	2.9	5.7	7.5	36.0	92.9
Sumitomo Metals	0	0	0	0	4.2	NM
Total	10.8	19.7	43.6	64.2	196.7	106.6

NM = Not meaningful
Source: Dataquest (May 1996)

Table 5-11
Top 10 Companies' Sales Revenue from Shipments of Dry Strip to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	1	Gasonics	51.6	79.4	54	21.5
2	4	Alcan Technology	25.8	71.5	177	19.4
3	5	Mattson Technologies	19.5	50.8	161	13.8
4	3	MC Electronics	30.4	49.5	63	13.4
5	2	Plasma Systems	34.4	48.7	42	13.2
6	6	Fusion Semiconductor Systems	12.9	19.9	54	5.4
7	7	Matrix Integrated Systems	12.7	17.5	38	4.7
8	8	Hitachi	11.0	11.3	3	3.1
9	11	Sumitomo Metals	2.2	8.1	267	2.2
10	9	Tokyo Ohka Kogyo	5.9	6.6	12	1.8
		North American Companies	99.2	169.1	70	45.8
		Japanese Companies	87.5	128.2	46	34.8
		European Countries	0	0	0	0
		Joint Venture Companies	25.8	71.5	177	19.4
		Identified Companies	212.5	368.8	74	100
		Other Companies	0	0	0	
		All Companies	212.5	368.8	74	

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 5-12
Each Company's Sales Revenue from Shipments of Dry Strip to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	32.2	29.5	35.1	56.8	89.9	29.3
Alcan Technology	4.0	4.3	4.9	1.0	0.4	-44.7
Fusion Semiconductor Systems	0.8	2.5	3.0	5.9	8.9	82.6
Gasonics	14.9	13.6	18.9	31.0	47.8	33.8
Hitachi	0	0	0	0.5	0	NM
Japan Storage Battery	0	0	0	0	0	NM
LFE Plasma Systems	1.1	0	0	0	0	-100.0
m.FSI	0	0	0	0	0	NM
Matrix Integrated Systems	4.1	4.2	5.0	7.2	10.2	25.6
Mattson Technologies	1.5	0.8	1.2	7.3	14.6	76.6
MC Electronics	0	1.1	1.2	2.5	2.8	NM
Plasma Systems	1.2	0.8	0.6	0	0	-100.0
Ramco	2.1	1.1	0	0	0	-100.0
Samco	0.2	0.3	0.2	0.2	0.1	-7.1
Shibaura Engineering Works	0	0	0	0	0	NM
Shinko Seiki	0	0	0	0	0	NM
Sumitomo Metals	0	0	0	0	3.7	NM
Tegal	1.6	0.8	0.1	1.3	1.0	-11.1
Tokyo Ohka Kogyo	0.7	0	0	0	0.4	-13.1
Ulvac	0	0	0	0	0	NM
Total	32.2	29.5	35.1	56.8	89.9	29.3
Japanese Market	62.1	58.9	52.1	68.4	120.0	17.9
Alcan Technology	12.7	8.9	9.0	17.9	46.5	38.4
Fusion Semiconductor Systems	0	0	0	0	0	NM
Gasonics	1.0	0	0	0	0.6	-13.7
Hitachi	4.5	3.6	6.3	8.9	8.6	17.6
Japan Storage Battery	0	0.2	0.2	0	0	NM
LFE Plasma Systems	0	0	0	0	0	NM
m.FSI	1.7	0.9	0	0	0	-100.0
Matrix Integrated Systems	0.3	0	0.9	1.4	2.0	60.7
Mattson Technologies	0	0.5	1.7	8.2	16.4	NM
MC Electronics	0	12.1	11.2	15.4	25.0	NM
Plasma Systems	16.7	4.1	12.1	7.5	11.0	-9.9
Ramco	5.6	12.1	0	0	0	-100.0
Samco	0.9	0.6	0.3	0.3	0.3	-22.2

(Continued)

Table 5-12 (Continued)
Each Company's Sales Revenue from Shipments of Dry Strip to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Shibaura Engineering Works	0	0	0	0	0.6	NM
Shinko Seiki	1.1	0.4	1.8	1.2	0.7	-9.3
Sumitomo Metals	2.1	4.5	1.7	2.2	1.4	-10.2
Tegal	0.7	0.2	0	0	0	-100.0
Tokyo Ohka Kogyo	12.5	8.9	3.8	3.5	4.6	-22.1
Ulvac	2.3	1.9	3.1	2.0	2.1	-1.9
Total	62.1	58.9	52.1	68.4	120.0	17.9
European Market	9.2	7.2	20.0	23.6	33.1	37.7
Alcan Technology	0.9	0.9	1.1	0	2.9	34.1
Fusion Semiconductor Systems	0.5	1.1	3.0	3.6	5.4	81.3
Gasonics	2.0	1.7	11.8	11.8	17.1	71.1
Hitachi	0	0	0	0.5	0	NM
Japan Storage Battery	0	0	0	0	0	NM
LFE Plasma Systems	0	0	0	0	0	NM
m.FSI	0	0	0	0	0	NM
Matrix Integrated Systems	2.4	1.8	2.5	2.6	3.0	5.7
Mattson Technologies	0	0.5	0.3	1.5	3.5	NM
MC Electronics	0	0.6	1.3	0.7	0.8	NM
Plasma Systems	0	0	0	0	0	NM
Ramco	1.6	0.6	0	0	0	-100.0
Samco	0	0	0	0	0	NM
Shibaura Engineering Works	0	0	0	0	0	NM
Shinko Seiki	0	0	0	0	0	NM
Sumitomo Metals	0	0	0	0	0	NM
Tegal	0.8	0	0	0.5	0	-100.0
Tokyo Ohka Kogyo	1.0	0	0	2.4	0.4	-20.5
Ulvac	0	0	0	0	0	NM
Total	9.2	7.2	20.0	23.6	33.1	37.7
Asia/Pacific Market	15.6	26.9	30.3	63.8	125.8	68.5
Alcan Technology	1.6	1.6	1.8	6.9	21.7	92.0
Fusion Semiconductor Systems	0.6	0	0.2	3.4	5.6	74.8
Gasonics	5.0	9.1	7.8	8.8	13.9	29.0
Hitachi	1.1	1.2	0	1.2	2.7	25.5
Japan Storage Battery	0	0	0	0	0	NM

(Continued)

Table 5-12 (Continued)
Each Company's Sales Revenue from Shipments of Dry Strip to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
LFE Plasma Systems	0.4	0	0	0	0	-100.0
m.FSI	0	0	0	0	0	NM
Matrix Integrated Systems	0.7	1.0	0.6	1.5	2.3	34.6
Mattson Technologies	0	0	0	2.5	16.3	NM
MC Electronics	0	1.1	5.4	11.9	20.9	NM
Plasma Systems	3.3	11.2	14.4	26.9	37.7	83.8
Ramco	1.0	1.1	0	0	0	-100.0
Samco	0	0	0	0	0	NM
Shibaura Engineering Works	0	0	0	0	0	NM
Shinko Seiki	0	0	0	0	0	NM
Sumitomo Metals	0	0	0	0	3.0	NM
Tegal	0.4	0.6	0.1	0.7	0.5	5.7
Tokyo Ohka Kogyo	1.5	0	0	0	1.2	-5.4
Ulvac	0	0	0	0	0	NM
Total	15.6	26.9	30.3	63.8	125.8	68.5
Worldwide Market	119.1	122.5	137.5	212.5	368.8	32.7
Alcan Technology	19.2	15.7	16.8	25.8	71.5	38.9
Fusion Semiconductor Systems	1.9	3.6	6.2	12.9	19.9	79.9
Gasonics	22.9	24.4	38.5	51.6	79.4	36.4
Hitachi	5.6	4.8	6.3	11.0	11.3	19.2
Japan Storage Battery	0	0.2	0.2	0	0	NM
LFE Plasma Systems	1.5	0	0	0	0	-100.0
m.FSI	1.7	0.9	0	0	0	-100.0
Matrix Integrated Systems	7.5	7.0	9.0	12.7	17.5	23.6
Mattson Technologies	1.5	1.8	3.2	19.5	50.8	141.2
MC Electronics	0	14.9	19.1	30.4	49.5	NM
Plasma Systems	21.2	16.1	27.1	34.4	48.7	23.1
Ramco	10.3	14.9	0	0	0	-100.0
Samco	1.1	0.9	0.5	0.5	0.5	-18.8
Shibaura Engineering Works	0	0	0	0	0.6	NM
Shinko Seiki	1.1	0.4	1.8	1.2	0.7	-9.3
Sumitomo Metals	2.1	4.5	1.7	2.2	8.1	40.0
Tegal	3.5	1.6	0.2	2.5	1.5	-19.1
Tokyo Ohka Kogyo	15.7	8.9	3.8	5.9	6.6	-19.5
Ulvac	2.3	1.9	3.1	2.0	2.1	-1.9
Total	119.1	122.5	137.5	212.5	368.8	32.7

NM = Not meaningful
Source: Dataquest (May 1996)

Table 5-13
Top 10 Companies' Sales Revenue from Shipments of Dry Etch to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	2	Applied Materials	416.1	904.5	117	31.8
2	1	Lam Research	510.7	881.5	73	31.0
3	3	Tokyo Electron Ltd. (including joint ventures)	291.4	481.2	65	16.9
4	4	Hitachi	208.4	285.5	37	10.0
5	6	Anelva	26.9	81.3	202	2.9
6	8	Sumitomo Metals	22.2	51.2	131	1.8
7	5	Tegal	36.2	46.8	29	1.6
8	7	Shibaura Engineering Works	24.6	40.7	66	1.4
9	9	E.T. Electrotech	13.0	17.2	32	0.6
10	10	Plasma & Materials Technologies	9.9	15.5	57	0.5
		North American Companies	981.8	1,855.3	89	65.3
		Japanese Companies	578.2	963.2	67	33.9
		European Countries	16.9	21.6	28	0.8
		Joint Venture Companies	14.7	1.7	-88	0.1
		Identified Companies	1,591.6	2,841.8	79	0.1
		Other Companies	0	0	0	
		All Companies	1,591.6	2.841.8	79	

Note: "Including joint ventures" indicates figures that include joint ventures.
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 5-14
Each Company's Sales Revenue from Shipments of Low-Density Etch to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	168.7	196.7	262.0	310.9	450.2	27.8
Alcan Technology	0	0	0	0	0	NM
Anelva	0	0	0	0.4	0	NM
Applied Materials	60.0	80.4	101.5	118.8	212.2	37.1
Drytek	15.0	12.6	3.6	0	0	-100.0
E.T. Electrotech	4.8	2.4	8.0	1.8	0	-100.0
Gasonics	3.5	2.5	2.3	3.0	0	-100.0
Hitachi	0	0	0	0	0	NM
Kokusai Electric	0	0	0	0	0	NM
Lam Research	63.0	74.0	121.6	167.9	210.3	35.2
Materials Research Corporation	2.6	0	0	0	0	-100.0
Matrix Integrated Systems	2.1	1.5	1.4	2.2	2.8	7.5
Matsushita Electric	0	0	0	0	0	NM
Oxford Instruments Inc.	1.6	0.9	1.8	1.1	1.6	0
Plasma Systems	0	0	0	0	0	NM
Plasma-Therm	0.7	4.5	1.0	0	0	-100.0
Samco	0	0	0	0	0	NM
Shibaura Engineering Works	0	0.8	1.7	1.4	0.7	NM
Tegal	11.0	15.1	6.9	9.4	16.4	10.5
Tokyo Electron Ltd.	0	0	0	0	6.2	NM
Tokyo Ohka Kogyo	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian/TEL	4.4	2.0	12.2	4.9	0	-100.0
Total	168.7	196.7	262.0	310.9	450.2	27.8
Japanese Market	255.9	188.4	270.8	370.8	639.6	25.7
Alcan Technology	5.6	3.8	2.2	3.1	1.7	-25.7
Anelva	15.6	7.1	12.6	21.0	74.9	48.0
Applied Materials	47.0	43.2	60.2	67.7	133.1	29.7
Drytek	3.0	1.8	0	0	0	-100.0
E.T. Electrotech	0	0	0	0	0	NM
Gasonics	0	0	0	0	0	NM
Hitachi	1.5	1.2	0.7	0.5	0	-100.0
Kokusai Electric	0	1.3	0.6	0	0	NM
Lam Research	21.1	21.2	31.0	42.8	46.6	21.9
Materials Research Corporation	5.2	0	0	0	0	-100.0

(Continued)

Table 5-14 (Continued)
Each Company's Sales Revenue from Shipments of Low-Density Etch to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Matrix Integrated Systems	0	0	0.3	0.6	0.6	NM
Matsushita Electric	0	3.1	0	0.7	0.7	NM
Oxford Instruments Inc.	0	0	0.6	0.4	0.4	NM
Plasma Systems	2.0	0.2	1.8	3.9	2.1	1.6
Plasma-Therm	11.0	0	0	0	0	-100.0
Samco	3.8	4.7	1.9	3.3	3.6	-1.2
Shibaura Engineering Works	26.9	12.8	33.6	22.5	34.2	6.2
Tegal	7.0	4.1	3.1	3.5	7.8	2.7
Tokyo Electron Ltd.	86.0	76.4	114.3	192.4	321.0	39.0
Tokyo Ohka Kogyo	14.0	5.5	4.7	6.0	7.4	-14.7
Ulvac	6.2	2.0	3.2	2.5	5.3	-3.7
Varian/TEL	0	0	0	0	0	NM
Total	255.9	188.4	270.8	370.8	639.6	25.7
European Market	72.2	92.8	139.0	153.4	292.3	41.8
Alcan Technology	0	0	0	0	0	NM
Anelva	0	0	0	0.3	0	NM
Applied Materials	28.0	39.4	60.3	75.5	162.3	55.2
Drytek	5.0	1.8	0.9	0	0	-100.0
E.T. Electrotech	4.8	3.4	4.3	1.6	2.0	-19.7
Gasonics	1.5	0.5	0.8	0.6	0.9	-11.3
Hitachi	0	0	0	0	0	NM
Kokusai Electric	0	0	0	0	0	NM
Lam Research	12.0	30.3	55.5	58.8	102.7	71.0
Materials Research Corporation	1.8	0	0	0	0	-100.0
Matrix Integrated Systems	0	0	0.5	0.7	1.0	NM
Matsushita Electric	0	0	0	0	0	NM
Oxford Instruments Inc.	2.5	1.5	1.2	1.4	1.4	-13.5
Plasma Systems	0	0	0	0	0	NM
Plasma-Therm	2.1	2.0	0	0	0	-100.0
Samco	0	0	0	0	0	NM
Shibaura Engineering Works	0	0.8	1.0	0.7	5.9	NM
Tegal	8.0	8.1	6.3	7.1	4.9	-11.5
Tokyo Electron Ltd.	0	0	0	0	11.2	NM
Tokyo Ohka Kogyo	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian/TEL	6.5	5.0	8.2	6.7	0	-100.0
Total	72.2	92.8	139.0	153.4	292.3	41.8

(Continued)

Table 5-14 (Continued)
Each Company's Sales Revenue from Shipments of Low-Density Etch to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Asia/Pacific Market	83.6	70.9	183.9	304.5	650.7	67.0
Alcan Technology	0	0	0	0	0	NM
Anelva	0.7	1.9	0.8	0	0.4	-15.2
Applied Materials	19.0	24.0	95.2	129.0	324.5	103.3
Drytek	2.0	0.9	0	0	0	-100.0
E.T. Electrotech	2.4	0.8	0	0	2.1	-3.3
Gasonics	0	0	0	0.6	0	NM
Hitachi	0	0	0	0	0	NM
Kokusai Electric	0	0	0	0	0	NM
Lam Research	31.0	25.2	46.5	77.4	172.9	53.7
Materials Research Corporation	0	0	0	0	0	NM
Matrix Integrated Systems	0.2	0	0.7	1.2	1.7	70.7
Matsushita Electric	0	0	0	0	0	NM
Oxford Instruments Inc.	0	0	1.0	0	0	NM
Plasma Systems	0	0	0	0	1.1	NM
Plasma-Therm	0	0	0	0	0	NM
Samco	0	0	0	0	0	NM
Shibaura Engineering Works	0	0.4	0	0	0	NM
Tegal	3.0	5.8	8.6	8.9	5.3	15.3
Tokyo Electron Ltd.	24.0	11.9	31.1	87.4	142.8	56.2
Tokyo Ohka Kogyo	1.3	0	0	0	0	-100.0
Ulvac	0	0	0	0	0	NM
Varian/TEL	0	0	0	0	0	NM
Total	83.6	70.9	183.9	304.5	650.7	67.0
Worldwide Market	580.4	548.8	855.7	1,139.6	2,032.7	36.8
Alcan Technology	5.6	3.8	2.2	3.1	1.7	-25.7
Anelva	16.3	9.0	13.4	21.7	75.3	46.6
Applied Materials	154.0	187.0	317.2	391.0	832.1	52.5
Drytek	25.0	17.1	4.5	0	0	-100.0
E.T. Electrotech	12.0	6.6	12.3	3.4	4.1	-23.5
Gasonics	5.0	3.0	3.1	4.2	0.9	-34.4
Hitachi	1.5	1.2	0.7	0.5	0	-100.0
Kokusai Electric	0	1.3	0.6	0	0	NM
Lam Research	127.1	150.7	254.6	346.9	532.5	43.1
Materials Research Corporation	9.6	0	0	0	0	-100.0

(Continued)

Table 5-14 (Continued)
Each Company's Sales Revenue from Shipments of Low-Density Etch to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Matrix Integrated Systems	2.3	1.5	2.9	4.7	6.1	27.6
Matsushita Electric	0	3.1	0	0.7	0.7	NM
Oxford Instruments Inc.	4.1	2.4	4.6	2.9	3.4	-4.6
Plasma Systems	2.0	0.2	1.8	3.9	3.2	12.4
Plasma-Therm	13.8	6.5	1.0	0	0	-100.0
Samco	3.8	4.7	1.9	3.3	3.6	-1.2
Shibaura Engineering Works	26.9	14.8	36.3	24.6	40.7	10.9
Tegal	29.0	33.1	24.9	28.9	34.4	4.4
Tokyo Electron Ltd.	110.0	88.3	145.4	279.8	481.2	44.6
Tokyo Ohka Kogyo	15.3	5.5	4.7	6.0	7.4	-16.6
Ulvac	6.2	2.0	3.2	2.5	5.3	-3.7
Varian/TEL	10.9	7.0	20.4	11.6	0	-100.0
Total	580.4	548.8	855.7	1,139.6	2,032.7	36.8

NM = Not meaningful
Source: Dataquest (May 1996)

Table 5-15
Each Company's Sales Revenue from Shipments of High-Density Etch to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	4.4	14.6	48.9	101.9	189.9	156.3
Anelva	0	0	0	0	0	NM
Applied Materials	0	0	0	14.3	20.4	NM
E.T. Electrotech	0	0	0	2.4	3.1	NM
Elionix	0	0	0	0	0	NM
Hitachi	3.3	6.8	9.0	13.8	37.3	83.4
Lam Research	0	7.1	35.3	62.9	119.3	NM
Matsushita Electric	0	0	0	0	0	NM
Oxford Instruments Inc.	1.1	0.7	0	0	0	-100.0
Plasma & Materials Technologies	0	0	1.9	3.6	7.9	NM
Sumitomo Metals	0	0	0	0	0	NM
Tegal	0	0	2.7	4.9	1.8	NM
Total	4.4	14.6	48.9	101.9	189.9	156.3
Japanese Market	113.4	91.9	124.9	202.1	348.0	32.4
Anelva	3.7	10.6	1.8	3.9	6.0	12.8
Applied Materials	0	0	0	7.2	17.3	NM
E.T. Electrotech	0	0	0	0	0	NM
Elionix	0.7	0.4	0	0	0	-100.0
Hitachi	93.6	66.6	94.4	147.4	170.5	16.2
Lam Research	0	1.1	3.1	23.2	96.5	NM
Matsushita Electric	0	0	0	0	3.0	NM
Oxford Instruments Inc.	0	0	0.6	0	0	NM
Plasma & Materials Technologies	0	0	2.8	2.9	5.6	NM
Sumitomo Metals	15.4	13.2	20.1	16.1	45.0	30.8
Tegal	0	0	2.1	1.4	4.1	NM
Total	113.4	91.9	124.9	202.1	348.0	32.4
European Market	5.6	10.2	15.5	52.6	90.6	100.6
Anelva	0	0	0	0	0	NM
Applied Materials	0	0	0	3.6	7.8	NM
E.T. Electrotech	0	0	0	7.2	10.0	NM
Elionix	0	0	0	0	0	NM
Hitachi	4.5	8.5	6.3	2.5	8.5	17.4
Lam Research	0	1.0	8.8	34.1	60.8	NM
Matsushita Electric	0	0	0	0	0	NM
Oxford Instruments Inc.	1.1	0.7	0.4	1.0	1.0	-2.4

(Continued)

Table 5-15 (Continued)
Each Company's Sales Revenue from Shipments of High-Density Etch to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Plasma & Materials Technologies	0	0	0	0	0	NM
Sumitomo Metals	0	0	0	3.2	0	NM
Tegal	0	0	0	1.0	2.5	NM
Total	5.6	10.2	15.5	52.6	90.6	100.6
Asia/Pacific Market	13.6	16.0	38.0	95.5	180.6	90.9
Anelva	1.3	0	0	1.3	0	-100.0
Applied Materials	0	0	0	0	26.8	NM
E.T. Electrotech	0	0	0	0	0	NM
Elionix	0	0	0	0	0	NM
Hitachi	12.3	12.0	18.0	44.3	69.2	54.0
Lam Research	0	4.0	20.0	43.6	72.4	NM
Matsushita Electric	0	0	0	0	0	NM
Oxford Instruments Inc.	0	0	0	0	0	NM
Plasma & Materials Technologies	0	0	0	3.4	2.0	NM
Sumitomo Metals	0	0	0	2.9	6.2	NM
Tegal	0	0	0	0	4.0	NM
Total	13.6	16.0	38.0	95.5	180.6	90.9
Worldwide Market	137.0	132.7	227.3	452.0	809.1	55.9
Anelva	5.0	10.6	1.8	5.2	6.0	4.6
Applied Materials	0	0	0	25.1	72.4	NM
E.T. Electrotech	0	0	0	9.6	13.1	NM
Elionix	0.7	0.4	0	0	0	-100.0
Hitachi	113.7	93.9	127.7	207.9	285.5	25.9
Lam Research	0	13.2	67.2	163.8	349.0	NM
Matsushita Electric	0	0	0	0	3.0	NM
Oxford Instruments Inc.	2.2	1.4	1.0	1.0	1.0	-17.9
Plasma & Materials Technologies	0	0	4.7	9.9	15.5	NM
Sumitomo Metals	15.4	13.2	20.1	22.2	51.2	35.0
Tegal	0	0	4.8	7.3	12.4	NM
Total	137.0	132.7	227.3	452.0	809.1	55.9

NM = Not meaningful
Source: Dataquest (May 1996)

Chapter 6
Deposition Equipment

This chapter presents tables for the deposition equipment market. The chapter consists of 21 tables that present a variety of estimates relevant to equipment company sales of deposition equipment. Table 6-1 reports estimated deposition equipment sales by company nationality or company base into each regional market delineated by Dataquest. As elsewhere, joint venture companies are grouped separately in this table regardless of company base. Also, reported sales by the category "other companies" reflect Dataquest estimates of unsurveyed activity in the deposition equipment market. Table 6-2 reports deposition equipment sales to each market region by company base. The table also reports the market share for each company grouping within regional markets. As elsewhere, the market shares reported for each company grouping are based on estimated sales to the relevant market by all identified companies. No market shares are reported for other companies because their estimated sales reflect Dataquest estimates of unsurveyed market activity.

Dataquest segments the deposition equipment market into four equipment subcategories (as shown in Table 1-1). Table 6-3 reports equipment sales for each of these four deposition subcategories within each regional market. Table 6-4 reports equipment sales for each of the four deposition equipment subcategories by company base. The table also reports the market share of company groupings within each subcategory. Once again, the market shares reported in the table are based on estimated sales for identified companies, and no market shares are reported for other companies.

Tables 6-5 through 6-21 report a variety of estimates regarding sales of the four deposition equipment subcategories. Dataquest further subdivides the chemical vapor deposition (CVD) subcategory of deposition equipment into two broad subcategories: tube CVD and nontube CVD. These subcategories are, in turn, further subdivided into specific equipment subcategories (see Appendix B). Tables 6-5 through 6-16 present estimates regarding company sales of the various CVD equipment and equipment groupings Tables 6-5, 6-6, and 6-12 present rankings of the top 10 total CVD, total tube CVD, and total nontube CVD producers, respectively, based on end-user revenue garnered worldwide. These tables also resummarize the market shares of all producers by company base for the relevant equipment markets. Note that joint venture companies are grouped separately in these market share summaries regardless of nationality. Also note that the reported market shares for the various groupings of companies are based on total estimated sales by identified companies. Tables 6-7 and 6-13 report company sales of all tube and all nontube CVD equipment by company base for each regional market in the manner of Table 6-1. In turn, Tables 6-8 and 6-14 report company sales of all tube and nontube CVD equipment into each regional market by company base in the manner of Table 6-2.

Tables 6-9 through 6-11 and 6-15 through 6-21 report individual estimated individual company sales for specific tube and nontube CVD equipment, respectively. Each of these tables concerns a specific CVD equipment. Each table reports the estimated sales of all surveyed companies known to sell the relevant equipment. The set of companies included in each table represents a comprehensive list of surveyed companies with relevant product sales to at least one region of the world. Within each table, estimated company sales are reported for each regional market as well as for the world overall. If a company does not have sales in a particular region, zero sales are reported for the company in that region. Although this convention populates the tables with a large number of zeros, it also readily distinguishes the companies that did not participate in a particular regional market

The remaining tables report estimates relevant to the other three deposition equipment subcategories. Note that no individual company data is reported for the category "other deposition" because the segment is no longer surveyed and all reported figures reflect Dataquest's estimates. Table 6-19 presents a ranking of the top 10 producers of sputtering equipment based on end-user revenue garnered worldwide. The table also resummarizes the market shares of all sputtering equipment producers by company base in the manner of Tables 6-5, 6-6, and 6-12. Tables 6-20 and 6-21 report estimated individual company sales for sputtering and silicon epitaxy equipment, respectively, in the manner of Tables 6-9 through 6-11 and 6-15 through 6-18.

Table 6-1
Sales Revenue from Shipments of Deposition by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
North American Companies						
Americas Market	244.3	264.3	372.3	577.0	1,047.9	43.9
Japanese Market	206.5	156.2	213.7	373.2	632.7	32.3
European Market	82.7	91.0	150.9	213.7	391.5	47.5
Asia/Pacific Market	112.6	113.9	185.1	375.9	726.8	59.4
Worldwide Market	646.1	625.4	922.0	1,539.8	2,798.9	44.3
Japanese Companies						
Americas Market	63.4	89.7	89.7	127.1	137.2	21.3
Japanese Market	381.0	244.3	262.3	333.7	611.7	12.6
European Market	14.4	19.9	31.7	43.2	64.6	45.5
Asia/Pacific Market	55.8	60.8	77.9	155.7	359.6	59.3
Worldwide Market	514.6	414.7	461.6	659.7	1,173.2	22.9
European Companies						
Americas Market	60.6	36.2	35.7	39.7	88.6	10.0
Japanese Market	55.5	29.0	24.9	42.7	69.0	5.6
European Market	57.9	33.2	45.8	69.4	100.9	14.9
Asia/Pacific Market	32.2	10.8	10.4	4.0	12.7	-20.8
Worldwide Market	206.2	109.2	116.8	155.8	271.2	7.1
Joint Venture Companies						
Americas Market	8.0	11.6	15.8	37.6	17.3	21.3
Japanese Market	21.4	19.0	19.8	25.9	58.7	28.7
European Market	4.3	3.8	7.5	12.2	8.5	18.4
Asia/Pacific Market	2.7	3.2	8.3	31.6	47.2	104.5
Worldwide Market	36.4	37.6	51.4	107.3	131.6	37.9
Other Companies						
Americas Market	0	37.2	40.6	35.5	40.0	NM
Japanese Market	0	39.0	19.5	21.4	25.0	NM
European Market	0	22.2	21.9	18.8	20.0	NM
Asia/Pacific Market	0	14.7	16.2	15.0	20.0	NM
Worldwide Market	0	113.1	98.2	90.7	105.0	NM

(Continued)

Table 6-1 (Continued)
Sales Revenue from Shipments of Deposition by Company Base into Each Region
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
All Companies						
Americas Market	376.3	439.0	554.1	816.9	1,331.0	37.1
Japanese Market	664.4	487.5	540.2	796.9	1,397.2	20.4
European Market	159.3	170.1	257.8	357.3	585.4	38.5
Asia/Pacific Market	203.3	203.4	297.9	582.2	1,166.3	54.8
Worldwide Market	1,403.3	1,300.0	1,650.0	2,553.2	4,479.9	33.7

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 6-2
Sales Revenue from Shipments of Deposition into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Americas Market						
North American Companies	372.3	577.0	1,047.9	72.5	73.8	81.2
Japanese Companies	89.7	127.1	137.2	17.5	16.3	10.6
European Companies	35.7	39.7	88.6	7.0	5.1	6.9
Joint Venture Companies	15.8	37.6	17.3	3.1	4.8	1.3
Identified Companies	513.5	781.4	1,291.0	100.0	100.0	100.0
Other Companies	40.6	35.5	40.0			
All Companies	554.1	816.9	1,331.0			
Japanese Market						
North American Companies	213.7	373.2	632.7	41.0	48.1	46.1
Japanese Companies	262.3	333.7	611.7	50.4	43.0	44.6
European Companies	24.9	42.7	69.0	4.8	5.5	5.0
Joint Venture Companies	19.8	25.9	58.7	3.8	3.3	4.3
Identified Companies	520.7	775.5	1,372.2	100.0	100.0	100.0
Other Companies	19.5	21.4	25.0			
All Companies	540.2	796.9	1,397.2			
European Market						
North American Companies	150.9	213.7	391.5	64.0	63.1	69.2
Japanese Companies	31.7	43.2	64.6	13.4	12.8	11.4
European Companies	45.8	69.4	100.9	19.4	20.5	17.8
Joint Venture Companies	7.5	12.2	8.5	3.2	3.6	1.5
Identified Companies	235.9	338.5	565.4	100.0	100.0	100.0
Other Companies	21.9	18.8	20.0			
All Companies	257.8	357.3	585.4			

(Continued)

Table 6-2 (Continued)
Sales Revenue from Shipments of Deposition into Each Region by Company Base
(End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Market						
North American Companies	185.1	375.9	726.8	65.7	66.3	63.4
Japanese Companies	77.9	155.7	359.6	27.7	27.4	31.4
European Companies	10.4	4.0	12.7	3.7	0.7	1.1
Joint Venture Companies	8.3	31.6	47.2	2.9	5.6	4.1
Identified Companies	281.7	567.2	1,146.3	100.0	100.0	100.0
Other Companies	16.2	15.0	20.0			
All Companies	297.9	582.2	1,166.3			
Worldwide Market						
North American Companies	922.0	1,539.8	2,798.9	59.4	62.5	64.0
Japanese Companies	461.6	659.7	1,173.2	29.7	26.8	26.8
European Companies	116.8	155.8	271.2	7.5	6.3	6.2
Joint Venture Companies	51.4	107.3	131.6	3.3	4.4	3.0
Identified Companies	1,551.8	2,462.5	4,374.9	100.0	100.0	100.0
Other Companies	98.2	90.7	105.0			
All Companies	1,650.0	2,553.2	4,479.9			

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 6-3
Sales Revenue from Shipments of Deposition into Each Region by Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
CVD						
Americas Market	203.4	222.6	260.2	368.3	693.5	35.9
Japanese Market	343.0	247.4	279.8	413.9	783.4	22.9
European Market	84.7	83.1	143.9	199.5	339.2	41.5
Asia/Pacific Market	111.4	97.2	184.6	345.1	766.8	62.0
Worldwide Market	742.5	650.3	868.5	1,327.0	2,582.9	36.6
Sputtering						
Americas Market	108.8	152.4	221.7	369.5	509.1	47.1
Japanese Market	209.1	148.6	199.9	319.4	509.0	24.9
European Market	38.6	57.9	71.1	109.1	182.1	47.4
Asia/Pacific Market	68.7	87.5	91.5	213.5	366.3	52.0
Worldwide Market	425.2	446.4	584.2	1,011.5	1,566.5	38.5
Silicon Epitaxy						
Americas Market	25.2	26.8	31.6	43.5	88.5	36.9
Japanese Market	46.1	46.3	25.4	32.2	62.5	7.9
European Market	11.0	6.9	20.9	29.9	44.1	41.5
Asia/Pacific Market	6.7	4.0	4.7	8.5	11.7	15.0
Worldwide Market	89.0	84.0	82.6	114.1	206.7	23.5
Other Deposition						
Americas Market	38.9	37.2	40.6	35.5	40.0	0.7
Japanese Market	66.2	45.2	35.1	31.4	42.3	-10.6
European Market	25.0	22.2	21.9	18.8	20.0	-5.4
Asia/Pacific Market	16.5	14.7	17.1	15.0	21.5	6.8
Worldwide Market	146.6	119.3	114.7	100.7	123.7	-4.2
Deposition						
Americas Market	376.3	439.0	554.1	816.9	1,331.0	37.1
Japanese Market	664.4	487.5	540.2	796.9	1,397.2	20.4
European Market	159.3	170.1	257.8	357.3	585.4	38.5
Asia/Pacific Market	203.3	203.4	297.9	582.2	1,166.3	54.8
Worldwide Market	1,403.3	1,300.0	1,650.0	2,553.2	4,479.9	33.7

Source: Dataquest (May 1996)

Table 6-4
Worldwide Sales Revenue from Shipments of Deposition by Company Base and Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
CVD						
North American Companies	539.8	805.6	1,561.5	62.2	60.7	60.5
Japanese Companies	213.0	331.2	735.3	24.5	25.0	28.5
European Companies	64.3	82.9	154.5	7.4	6.2	6.0
Joint Venture Companies	51.4	107.3	131.6	5.9	8.1	5.1
Identified Companies	868.5	1,327.0	2,582.9	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	868.5	1,327.0	2,582.9			
Sputtering						
North American Companies	351.3	672.5	1,117.9	60.1	66.5	71.4
Japanese Companies	223.0	310.5	395.0	38.2	30.7	25.2
European Companies	9.9	28.5	53.6	1.7	2.8	3.4
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	584.2	1,011.5	1,566.5	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	584.2	1,011.5	1,566.5			
Silicon Epitaxy						
North American Companies	30.9	61.7	119.5	37.4	54.1	57.8
Japanese Companies	9.1	8.0	24.1	11.0	7.0	11.7
European Companies	42.6	44.4	63.1	51.6	38.9	30.5
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	82.6	114.1	206.7	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	82.6	114.1	206.7			

(Continued)

Table 6-4 (Continued)
Worldwide Sales Revenue from Shipments of Deposition by Company Base and Equipment Segment (End-User Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Other Deposition						
North American Companies	0	0	0	NM	NM	NM
Japanese Companies	16.5	10.0	18.7	100.0	100.0	100.0
European Companies	0	0	0	NM	NM	NM
Joint Venture Companies	0	0	0	NM	NM	NM
Identified Companies	16.5	10.0	18.7	100.0	100.0	100.0
Other Companies	98.2	90.7	105.0			
All Companies	114.7	100.7	123.7			
Deposition						
North American Companies	922.0	1,539.8	2,798.9	59.4	62.5	64.0
Japanese Companies	461.6	659.7	1,173.2	29.7	26.8	26.8
European Companies	116.8	155.8	271.2	7.5	6.3	6.2
Joint Venture Companies	51.4	107.3	131.6	3.3	4.4	3.0
Identified Companies	1,551.8	2,462.5	4,374.9	100.0	100.0	100.0
Other Companies	98.2	90.7	105.0			
All Companies	1,650.0	2,553.2	4,479.9			

NM = Not meaningful
Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 6-5
Top 10 Companies' Sales Revenue from Shipments of CVD to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	1	Applied Materials	413.9	849.9	105	32.9
2	2	Tokyo Electron Ltd. (including joint ventures)	193.5	393.3	103	15.2
3	3	Novellus Systems Inc.	190.2	340.2	79	13.2
4	4	Kokusai Electric (including joint ventures)	137.4	239.8	75	9.3
5	5	Watkins-Johnson	122.4	202.0	65	7.8
6	6	ASM International	69.1	136.5	98	5.3
7	7	Alcan/Canon/Quester (see note)	64.7	115.0	78	4.5
8	8	Silicon Valley Group	40.3	76.5	90	3.0
9	9	Genus	23.4	46.9	100	1.8
10	15	Amaya	3.9	42.3	984	1.6
		North American Companies	805.6	1,561.5	94	60.5
		Japanese Companies	331.2	753.3	122	28.5
		European Countries	82.9	154.5	86	6.0
		Joint Venture Companies	107.3	131.6	23	5.1
		Identified Companies	1,327.0	2,582.9	95	100
		Other Companies	0	0	0	
		All Companies	1,327.0	2.582.9	95	

Notes: "Including joint ventures" indicates figures that include joint ventures.
Figures reported for Alcan/Canon/Quester are included in totals for Alcan Technology.
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 6-6
Top 10 Companies' Sales Revenue from Shipments of Tube CVD to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	1	Tokyo Electron Ltd. (including joint ventures)	178.7	319.1	79	40.9
2	2	Kokusai Electric (including joint ventures)	137.4	239.8	75	30.8
3	3	ASM International	61.1	91.2	49	11.7
4	4	Silicon Valley Group	40.3	76.5	90	9.8
5	7	Semitool (including Semitherm)	3.2	27.4	758	3.5
6	5	Ulvac	9.4	14.2	50	1.8
7	6	Toyoko Kagaku	3.9	4.6	18	0.6
8	9	Shinko Electric	2.5	3.3	32	0.4
9	8	Koyo Lindberg	2.7	2.6	-4	0.3
10	10	Advanced Crystal Sciences Inc.	1.1	0.5	-55	0.1
		North American Companies	45.8	104.8	129	13.4
		Japanese Companies	292.2	567.0	94	72.7
		European Countries	61.1	91.2	49	11.7
		Joint Venture Companies	42.6	16.6	-61	2.1
		Identified Companies	441.5	779.6	77	100.0
		Other Companies	0	0	0	
		All Companies	441.5	779.6	77	

Notes: "Including joint ventures" indicates figures that include joint ventures.
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 6-7
Sales Revenue from Shipments of Tube CVD by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
North American Companies						
Americas Market	24.8	18.1	16.6	30.0	60.7	25.1
Japanese Market	0	0	0	0	0	NM
European Market	7.0	4.6	10.0	14.9	41.7	56.3
Asia/Pacific Market	5.4	2.6	1.8	0.9	2.5	-17.9
Worldwide Market	37.2	25.3	28.4	45.8	104.8	29.6
Japanese Companies						
Americas Market	5.5	4.9	13.4	15.1	37.4	61.5
Japanese Market	106.2	83.2	92.0	136.2	210.1	18.6
European Market	2.2	2.1	6.0	3.4	29.3	91.0
Asia/Pacific Market	33.8	34.4	70.7	137.2	290.2	71.2
Worldwide Market	147.7	124.6	182.1	292.0	567.0	40.0
European Companies						
Americas Market	15.6	13.3	13.6	11.8	43.4	29.1
Japanese Market	34.0	18.2	14.3	15.4	14.9	-18.6
European Market	12.5	14.9	18.4	33.3	28.9	23.3
Asia/Pacific Market	11.5	7.9	5.2	0.6	4.0	-23.2
Worldwide Market	73.6	54.3	51.5	61.1	91.2	5.5
Joint Venture Companies						
Americas Market	5.3	5.3	13.8	32.7	12.4	23.7
Japanese Market	0	0	0	0	0	NM
European Market	4.3	3.8	7.5	9.9	4.2	-0.6
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	9.6	9.1	21.3	42.6	16.6	14.7
Other Companies						
Americas Market	0	0	0	0	0	NM
Japanese Market	0	0	0	0	0	NM
European Market	0	0	0	0	0	NM
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	0	0	0	0	0	NM

(Continued)

Table 6-7 (Continued)
Sales Revenue from Shipments of Tube CVD by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
All Companies						
Americas Market	51.2	41.6	57.4	89.6	153.9	31.7
Japanese Market	140.2	101.4	106.3	151.6	225.0	12.6
European Market	26.0	25.4	41.9	61.5	104.1	41.5
Asia/Pacific Market	50.7	44.9	77.7	138.7	296.7	55.5
Worldwide Market	268.1	213.3	283.3	441.5	779.6	30.6

NM = Not meaningful

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.

Source: Dataquest (May 1996)

Table 6-8
Sales Revenue from Shipments of Tube CVD into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Americas Market						
North American Companies	16.6	30.0	60.7	28.9	33.5	39.4
Japanese Companies	13.4	15.1	37.4	23.3	16.9	24.3
European Companies	13.6	11.8	43.4	23.7	13.2	28.2
Joint Venture Companies	13.8	32.7	12.4	24.0	36.5	8.1
Identified Companies	57.4	89.6	153.9	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	57.4	89.6	153.9			
Japanese Market						
North American Companies	0	0	0	0	0	NM
Japanese Companies	92.0	136.2	210.1	86.5	89.8	93.4
European Companies	14.3	15.4	14.9	13.5	10.2	6.6
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	106.3	151.6	225.0	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	106.3	151.6	225.0			
European Market						
North American Companies	10.0	14.9	41.7	23.9	24.2	40.1
Japanese Companies	6.0	3.4	29.3	14.3	5.6	28.1
European Companies	18.4	33.3	28.9	43.9	54.1	27.8
Joint Venture Companies	7.5	9.9	4.2	17.9	16.1	4.0
Identified Companies	41.9	61.5	104.1	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	41.9	61.5	104.1			

(Continued)

Table 6-8 (Continued)
Sales Revenue from Shipments of Tube CVD into Each Region by Company Base
(End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Market						
North American Companies	1.8	0.9	2.5	2.3	0.6	0.8
Japanese Companies	70.7	137.2	290.2	91.0	98.9	97.8
European Companies	5.2	0.6	4.0	6.7	0.4	1.3
Joint Venture Companies	0	0	0	0	0	NM
Identified Companies	77.7	138.7	296.7	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	77.7	138.7	296.7			
Worldwide Market						
North American Companies	28.4	45.8	104.8	10.0	10.4	13.4
Japanese Companies	182.1	292.0	567.0	64.3	66.1	72.7
European Companies	51.5	61.1	91.2	18.2	13.8	11.7
Joint Venture Companies	21.3	42.6	16.6	7.5	9.6	2.1
Identified Companies	283.3	441.5	779.6	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	283.3	441.5	779.6			

NM = Not meaningful

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.

Source: Dataquest (May 1996)

Table 6-9
Each Company's Sales Revenue from Shipments of Horizontal Tube LPCVD to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	11.8	12.3	11.5	11.8	8.3	-8.4
Advanced Crystal Sciences Inc.	0	0.6	1.0	1.1	0.5	NM
ASM International	2.0	1.8	0.9	0	0	-100.0
Bruce Technologies	0	2.2	3.8	4.9	5.1	NM
BTU International	2.5	0	0	0	0	-100.0
Centrotherm	1.6	0.8	0.8	0	0	-100.0
ET Systems Engineering	0	0	0	0	0	NM
Kokusai Electric	0	0	0	0	0	NM
Koyo Lindberg	0	0	0	0	0	NM
Process Technology Ltd.	1.2	1.1	1.5	0.7	0	-100.0
Silicon Valley Group	4.5	5.2	2.9	4.7	2.3	-15.4
Tokyo Electron Ltd.	0	0	0	0	0	NM
Tystar	0	0.6	0.6	0.4	0.4	NM
Ulvac	0	0	0	0	0	NM
Varian/TEL	0	0	0	0	0	NM
Yamato Semico	0	0	0	0	0	NM
Total	11.8	12.3	11.5	11.8	8.3	-8.4
Japanese Market	10.6	8.4	6.1	5.3	4.3	-20.2
Advanced Crystal Sciences Inc.	0	0	0	0	0	NM
ASM International	0.9	0	0	0	0	-100.0
Bruce Technologies	0	0	0	0	0	NM
BTU International	0	0	0	0	0	NM
Centrotherm	0	0	0	0	0	NM
ET Systems Engineering	0	0	0.2	0	0	NM
Kokusai Electric	0	0	1.2	0.4	0	NM
Koyo Lindberg	0	0.8	1.3	1.6	1.8	NM
Process Technology Ltd.	0	0	0	0	0	NM
Silicon Valley Group	0	0	0	0	0	NM
Tokyo Electron Ltd.	7.1	5.1	1.6	2.0	0	-100.0
Tystar	0	0	0	0	0	NM
Ulvac	2.3	2.5	1.8	1.3	2.5	1.7
Varian/TEL	0	0	0	0	0	NM
Yamato Semico	0.3	0	0	0	0	-100.0
Total	10.6	8.4	6.1	5.3	4.3	-20.2

(Continued)

Table 6-9 (Continued)
Each Company's Sales Revenue from Shipments of Horizontal Tube LPCVD to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
European Market	10.2	6.3	6.3	5.9	5.2	-15.5
Advanced Crystal Sciences Inc.	0	0.1	0	0	0	NM
ASM International	3.5	2.5	0.8	0	0	-100.0
Bruce Technologies	0	0.7	2.0	2.3	1.5	NM
BTU International	1.5	0	0	0	0	-100.0
Centrotherm	1.5	0.8	0.8	0	0	-100.0
ET Systems Engineering	0	0	0	0	0	NM
Kokusai Electric	0	0	0	0	0	NM
Koyo Lindberg	0	0	0	0	0	NM
Process Technology Ltd.	0.2	0	0	0.1	0	-100.0
Silicon Valley Group	1.6	1.6	2.7	3.5	3.7	23.3
Tokyo Electron Ltd.	0	0	0	0	0	NM
Tystar	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian/TEL	1.9	0.6	0	0	0	-100.0
Yamato Semico	0	0	0	0	0	NM
Total	10.2	6.3	6.3	5.9	5.2	-15.5
Asia/Pacific Market	6.6	2.0	2.2	0.3	0.8	-41.0
Advanced Crystal Sciences Inc.	0	0	0	0	0	NM
ASM International	1.5	1.0	0.4	0	0	-100.0
Bruce Technologies	0	0	0	0	0	NM
BTU International	2.0	0	0	0	0	-100.0
Centrotherm	0	0	0	0	0	NM
ET Systems Engineering	0	0	0	0	0	NM
Kokusai Electric	1.6	0	0	0	0	-100.0
Koyo Lindberg	0	0	0	0	0	NM
Process Technology Ltd.	0	0	0	0	0	NM
Silicon Valley Group	1.2	1.0	0.3	0.3	0.8	-9.6
Tokyo Electron Ltd.	0	0	1.5	0	0	NM
Tystar	0.3	0	0	0	0	-100.0
Ulvac	0	0	0	0	0	NM
Varian/TEL	0	0	0	0	0	NM
Yamato Semico	0	0	0	0	0	NM
Total	6.6	2.0	2.2	0.3	0.8	-41.0

(Continued)

Table 6-9 (Continued)
Each Company's Sales Revenue from Shipments of Horizontal Tube LPCVD to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	39.2	29.0	26.1	23.3	18.6	-17.0
Advanced Crystal Sciences Inc.	0	0.7	1.0	1.1	0.5	NM
ASM International	7.9	5.3	2.1	0	0	-100.0
Bruce Technologies	0	2.9	5.8	7.2	6.6	NM
BTU International	6.0	0	0	0	0	-100.0
Centrotherm	3.1	1.6	1.6	0	0	-100.0
ET Systems Engineering	0	0	0.2	0	0	NM
Kokusai Electric	1.6	0	1.2	0.4	0	-59.6
Koyo Lindberg	0	0.8	1.3	1.6	1.8	NM
Process Technology Ltd.	1.4	1.1	1.5	0.8	0	-100.0
Silicon Valley Group	7.3	7.8	5.9	8.5	6.8	-1.8
Tokyo Electron Ltd.	7.1	5.1	3.1	2.0	0	-100.0
Tystar	0.3	0.6	0.6	0.4	0.4	7.5
Ulvac	2.3	2.5	1.8	1.3	2.5	1.7
Varian/TEL	1.9	0.6	0	0	0	-100.0
Yamato Semico	0.3	0	0	0	0	-100.0
Total	39.2	29.0	26.1	23.3	18.6	-17.0

NM = Not meaningful
Source: Dataquest (May 1996)

Table 6-10
Each Company's Sales Revenue from Shipments of Vertical Tube LPCVD to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	28.4	20.5	37.5	70.6	140.6	49.2
ASM International	2.0	2.9	4.1	4.6	38.4	109.3
Bruce Technologies	0	0	0.5	3.2	7.3	NM
BTU International	3.5	0	0	0	0	-100.0
Disco	0	0	0	0	0	NM
General Signal Thinfilm Company	3.0	0	0	0	0	-100.0
Kokusai Electric	5.5	4.9	13.4	14.5	24.9	45.9
Koyo Lindberg	0	0	0	0	0	NM
Semitherm	1.5	0.5	2.5	3.2	14.4	75.9
Shinko Electric	0	0	0	0	0	NM
Silicon Valley Group	7.6	8.2	6.6	19.9	43.1	54.3
Tempress	0	0.9	0.9	0	0	NM
Tokyo Electron Ltd.	0	0	0	0	12.5	NM
Toyoko Kagaku	0	0	0	0.6	0	NM
Ulvac	0	0	0	0	0	NM
Varian/TEL	5.3	3.1	9.5	24.6	0	-100.0
Total	28.4	20.5	37.5	70.6	140.6	49.2
Japanese Market	110.6	82.8	92.4	137.9	211.7	17.6
ASM International	14.1	8.0	6.5	7.0	5.9	-19.6
Bruce Technologies	0	0	0	0	0	NM
BTU International	0	0	0	0	0	NM
Disco	2.7	0.9	0	0	0	-100.0
General Signal Thinfilm Company	0	0	0	0	0	NM
Kokusai Electric	32.3	29.3	32.8	42.7	56.9	15.2
Koyo Lindberg	1.9	1.3	0.8	1.1	0.8	-19.5
Semitherm	0	0	0	0	0	NM
Shinko Electric	4.0	1.9	2.3	1.9	3.3	-4.7
Silicon Valley Group	0	0	0	0	0	NM
Tempress	0	0	0	0	0	NM
Tokyo Electron Ltd.	45.0	34.3	41.5	75.1	129.9	30.4
Toyoko Kagaku	5.0	1.3	1.2	2.0	3.2	-10.6
Ulvac	5.6	5.8	7.3	8.2	11.7	20.2
Varian/TEL	0	0	0	0	0	NM
Total	110.6	82.8	92.4	137.9	211.7	17.6

(Continued)

Table 6-10 (Continued)
Each Company's Sales Revenue from Shipments of Vertical Tube LPCVD to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
European Market	11.8	13.4	29.0	45.8	86.0	64.3
ASM International	3.5	5.9	10.2	23.5	16.0	46.2
Bruce Technologies	0	0	0	0	2.7	NM
BTU International	1.0	0	0	0	0	-100.0
Disco	0	0	0	0	0	NM
General Signal Thinfilm Company	0	0	0	0	0	NM
Kokusai Electric	2.2	2.1	6.0	3.4	3.7	13.6
Koyo Lindberg	0	0	0	0	0	NM
Semitherm	0	0	0	0	11.4	NM
Shinko Electric	0	0	0	0	0	NM
Silicon Valley Group	2.7	2.4	6.3	11.3	26.6	77.2
Tempress	0	0.5	1.0	0	0	NM
Tokyo Electron Ltd.	0	0	0	0	25.6	NM
Toyoko Kagaku	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian/TEL	2.4	2.5	5.5	7.6	0	-100.0
Total	11.8	13.4	29.0	45.8	86.0	64.3
Asia/Pacific Market	37.1	38.2	71.9	137.8	294.9	67.9
ASM International	3.0	2.2	1.8	0	3.0	0
Bruce Technologies	0	0	0	0	0	NM
BTU International	0	0	0	0	0	NM
Disco	0	0	0	0	0	NM
General Signal Thinfilm Company	0	0	0	0	0	NM
Kokusai Electric	22.0	18.2	37.6	65.9	137.7	58.2
Koyo Lindberg	0	0	0	0	0	NM
Semitherm	0	0	0	0	1.7	NM
Shinko Electric	2.2	0	0	0.6	0	-100.0
Silicon Valley Group	1.9	1.6	0.9	0.6	0	-100.0
Tempress	0	0	0	0	0	NM
Tokyo Electron Ltd.	8.0	16.2	31.6	69.4	151.1	108.5
Toyoko Kagaku	0	0	0	1.3	1.4	NM
Ulvac	0	0	0	0	0	NM
Varian/TEL	0	0	0	0	0	NM
Total	37.1	38.2	71.9	137.8	294.9	67.9

(Continued)

Table 6-10 (Continued)
Each Company's Sales Revenue from Shipments of Vertical Tube LPCVD to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	187.9	154.9	230.8	392.3	733.2	40.5
ASM International	22.6	19.0	22.6	35.1	63.3	29.4
Bruce Technologies	0	0	0.5	3.2	10.0	NM
BTU International	4.5	0	0	0	0	-100.0
Disco	2.7	0.9	0	0	0	-100.0
General Signal Thinfilm Company	3.0	0	0	0	0	-100.0
Kokusai Electric	62.0	54.5	89.8	126.6	223.2	37.7
Koyo Lindberg	1.9	1.3	0.8	1.1	0.8	-19.5
Semitherm	1.5	0.5	2.5	3.2	27.4	106.8
Shinko Electric	6.2	1.9	2.3	2.5	3.3	-14.6
Silicon Valley Group	12.2	12.2	13.8	31.8	69.7	54.6
Tempress	0	1.4	1.9	0	0	NM
Tokyo Electron Ltd.	53.0	50.5	73.1	144.5	319.1	56.6
Toyoko Kagaku	5.0	1.3	1.2	3.9	4.6	-2.1
Ulvac	5.6	5.8	7.3	8.2	11.7	20.2
Varian/TEL	7.7	5.6	15.0	32.2	0	-100.0
Total	187.9	154.9	230.8	392.3	733.2	40.5

NM = Not meaningful
Note: Semitherm equipment is cross-functional and may be configured for diffusion.
Source: Dataquest (May 1996)

Table 6-11
Each Company's Sales Revenue from Shipments of Horizontal Tube PECVD to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	11.0	8.8	8.4	7.2	5.0	-17.9
ASM International	10.0	7.8	7.8	7.2	5.0	-15.9
Pacific Western	1.0	1.0	0.6	0	0	-100.0
Total	11.0	8.8	8.4	7.2	5.0	-17.9
Japanese Market	19.0	10.2	7.8	8.4	9.0	-17.0
ASM International	19.0	10.2	7.8	8.4	9.0	-17.0
Pacific Western	0	0	0	0	0	NM
Total	19.0	10.2	7.8	8.4	9.0	-17.0
European Market	4.0	5.7	6.6	9.8	12.9	34.0
ASM International	4.0	5.7	6.6	9.8	12.9	34.0
Pacific Western	0	0	0	0	0	NM
Total	4.0	5.7	6.6	9.8	12.9	34.0
Asia/Pacific Market	7.0	4.7	3.6	0.6	1.0	-38.5
ASM International	7.0	4.7	3.0	0.6	1.0	-38.5
Pacific Western	0	0	0.6	0	0	NM
Total	7.0	4.7	3.6	0.6	1.0	-38.5
Worldwide Market	41.0	29.4	26.4	26.0	27.9	-9.2
ASM International	40.0	28.4	25.2	26.0	27.9	-8.6
Pacific Western	1.0	1.0	1.2	0	0	-100.0
Total	41.0	29.4	26.4	26.0	27.9	-9.2

NM = Not meaningful
Source: Dataquest (May 1996)

Table 6-12
Top 10 Companies' Sales Revenue from Shipments of Nontube CVD to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	1	Applied Materials	413.9	849.9	105	47.1
2	2	Novellus Systems Inc.	190.2	340.2	79	18.9
3	3	Watkins-Johnson	122.4	202.0	65	11.2
4	4	Alcan/Canon/Quester (see note)	64.7	115.0	78	6.4
5	6	Tokyo Electron Ltd. (including joint ventures)	14.8	74.1	401	4.1
6	5	Genus	23.4	46.9	100	2.6
7	9	ASM International	8.0	45.3	466	2.5
8	13	Amaya	3.9	42.3	984	2.3
9	10	Ulvac	6.4	22.6	253	1.3
10	8	Lam Research	9.9	17.7	79	1.0
		North American Companies	759.8	1,456.7	92	80.8
		Japanese Companies	39.1	168.3	330	9.3
		European Countries	21.8	63.3	190	3.5
		Joint Venture Companies	64.7	115.0	78	6.4
		Identified Companies	885.4	1,803.3	104	100
		Other Companies	0	0	0	
		All Companies	885.4	1,803.3	104	

NM = Not meaningful

Notes: Figures for Alcan/Canon/Quester joint venture included in totals for Alcan Technology.

"Including joint ventures" indicates figures that include joint ventures.

Figures for "other companies" reflect estimates of unsurveyed market activity.

Source: Dataquest (May 1996)

Table 6-13
Sales Revenue from Shipments of Nontube CVD by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
North American Companies						
Americas Market	139.4	169.2	197.1	273.3	516.8	38.8
Japanese Market	131.8	92.4	120.6	192.2	335.8	26.3
European Market	49.7	49.7	96.1	121.6	211.5	43.6
Asia/Pacific Market	57.0	48.5	97.6	172.7	392.5	62.0
Worldwide Market	377.9	359.8	511.4	759.8	1,456.7	40.1
Japanese Companies						
Americas Market	4.2	3.0	1.6	0	11.2	27.9
Japanese Market	42.0	31.0	28.5	33.2	125.8	31.6
European Market	0	1.3	0.8	3.8	2.5	NM
Asia/Pacific Market	0	0	0	2.1	28.7	NM
Worldwide Market	46.2	35.3	30.9	39.1	168.3	38.2
European Companies						
Americas Market	5.9	2.5	2.1	0.5	6.6	2.8
Japanese Market	7.6	3.6	4.6	11.0	38.1	49.6
European Market	9.0	6.7	5.1	10.3	16.9	17.1
Asia/Pacific Market	1.0	0.6	1.0	0	1.7	14.2
Worldwide Market	23.5	13.4	12.8	21.8	63.3	28.1
Joint Venture Companies						
Americas Market	2.7	6.3	2.0	4.9	4.9	16.1
Japanese Market	21.4	19.0	19.8	25.9	58.7	28.7
European Market	0	0	0	2.3	4.3	NM
Asia/Pacific Market	2.7	3.2	8.3	31.6	47.2	104.5
Worldwide Market	26.8	28.5	30.1	64.7	115.0	43.9
Other Companies						
Americas Market	0	0	0	0	0	NM
Japanese Market	0	0	0	0	0	NM
European Market	0	0	0	0	0	NM
Asia/Pacific Market	0	0	0	0	0	NM
Worldwide Market	0	0	0	0	0	NM

(Continued)

Table 6-13 (Continued)
Sales Revenue from Shipments of Nontube CVD by Company Base into Each Region (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
All Companies						
Americas Market	152.2	181.0	202.8	278.7	539.6	37.2
Japanese Market	202.8	146.0	173.5	262.3	558.4	28.8
European Market	58.7	57.7	102.0	138.0	235.1	41.5
Asia/Pacific Market	60.7	52.3	106.9	206.4	470.1	66.8
Worldwide Market	474.4	437.0	585.2	885.4	1,803.3	39.6

NM = Not meaningful

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.

Source: Dataquest (May 1996)

Table 6-14
Sales Revenue from Shipments of Nontube CVD into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Americas Market						
North American Companies	197.1	273.3	516.8	97.2	98.1	95.8
Japanese Companies	1.6	0	11.2	0.8	0	2.1
European Companies	2.1	0.5	6.6	1.0	0.2	1.2
Joint Venture Companies	2.0	4.9	4.9	1.0	1.8	0.9
Identified Companies	202.8	278.7	539.6	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	202.8	278.7	539.6			
Japanese Market						
North American Companies	120.6	192.2	335.8	69.5	73.3	60.1
Japanese Companies	28.5	33.2	125.8	16.4	12.7	22.5
European Companies	4.6	11.0	38.1	2.7	4.2	6.8
Joint Venture Companies	19.8	25.9	58.7	11.4	9.9	10.5
Identified Companies	173.5	262.3	558.4	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	173.5	262.3	558.4			
European Market						
North American Companies	96.1	121.6	211.5	94.2	88.1	89.9
Japanese Companies	0.8	3.8	2.5	0.8	2.8	1.1
European Companies	5.1	10.3	16.9	5.0	7.5	7.2
Joint Venture Companies	0	2.3	4.3	0	1.7	1.8
Identified Companies	102.0	138.0	235.1	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	102.0	138.0	235.1			

(Continued)

Table 6-14 (Continued)
Sales Revenue from Shipments of Nontube CVD into Each Region by Company Base (End-User Sales Revenue in Millions of U.S. Dollars)

				Market Share (%)		
	1993	1994	1995	1993	1994	1995
Asia/Pacific Market						
North American Companies	97.6	172.7	392.5	91.3	83.7	83.5
Japanese Companies	0	2.1	28.7	0	1.0	6.1
European Companies	1.0	0	1.7	0.9	0	0.4
Joint Venture Companies	8.3	31.6	47.2	7.8	15.3	10.0
Identified Companies	106.9	206.4	470.1	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	106.9	206.4	470.1			
Worldwide Market						
North American Companies	511.4	759.8	1,456.7	87.4	85.8	80.8
Japanese Companies	30.9	39.1	168.3	5.3	4.4	9.3
European Companies	12.8	21.8	63.3	2.2	2.5	3.5
Joint Venture Companies	30.1	64.7	115.0	5.1	7.3	6.4
Identified Companies	585.2	885.4	1,803.3	100.0	100.0	100.0
Other Companies	0	0	0			
All Companies	585.2	885.4	1,803.3			

Note: Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 6-15
Each Company's Sales Revenue from Shipments of Atmospheric/Subatmospheric CVD to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	16.4	26.5	28.8	34.3	102.3	58.0
Alcan/Canon/Quester (see note)	2.7	6.3	2.0	4.9	4.9	16.1
Amaya	0	0	0	0	3.8	NM
Applied Materials	0	0	0	0	33.5	NM
General Signal Thinfilm Company	0.5	0	0	0	0	-100.0
Koyo Lindberg	0	0	0	0	0	NM
Toshiba	0	0	0	0	0	NM
Watkins-Johnson	13.2	20.2	26.8	29.4	60.0	46.0
Total	16.4	26.5	28.8	34.3	102.3	58.0
Japanese Market	52.9	35.3	37.0	57.1	134.8	26.4
Alcan/Canon/Quester (see note)	21.4	19.0	19.8	25.9	58.7	28.7
Amaya	12.3	6.3	5.4	3.9	30.7	25.7
Applied Materials	0	0	0	0	7.7	NM
General Signal Thinfilm Company	0	0	0	0	0	NM
Koyo Lindberg	0.6	0	0.5	0	0	-100.0
Toshiba	3.2	2.1	1.2	0.4	3.7	3.9
Watkins-Johnson	15.4	7.9	10.1	26.9	34.0	21.9
Total	52.9	35.3	37.0	57.1	134.8	26.4
European Market	4.9	3.4	13.7	18.2	43.2	72.3
Alcan/Canon/Quester (see note)	0	0	0	2.3	4.3	NM
Amaya	0	0	0	0	0	NM
Applied Materials	0	0	0	0	12.9	NM
General Signal Thinfilm Company	0	0	0	0	0	NM
Koyo Lindberg	0	0	0	0	0	NM
Toshiba	0	0	0	0	0	NM
Watkins-Johnson	4.9	3.4	13.7	15.9	26.0	51.8
Total	4.9	3.4	13.7	18.2	43.2	72.3
Asia/Pacific Market	17.7	16.7	23.9	81.8	144.7	69.1
Alcan/Canon/Quester (see note)	2.7	3.2	8.3	31.6	47.2	104.5
Amaya	0	0	0	0	7.8	NM
Applied Materials	0	0	0	0	7.7	NM
General Signal Thinfilm Company	0	0	0	0	0	NM
Koyo Lindberg	0	0	0	0	0	NM
Toshiba	0	0	0	0	0	NM
Watkins-Johnson	15.0	13.5	15.6	50.2	82.0	52.9
Total	17.7	16.7	23.9	81.8	144.7	69.1

(Continued)

Table 6-15 (Continued)
Each Company's Sales Revenue from Shipments of Atmospheric/Subatmospheric CVD to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	91.9	81.9	103.4	191.4	425.0	46.6
Alcan/Canon/Quester (see note)	26.8	28.5	30.1	64.7	115.0	43.9
Amaya	12.3	6.3	5.4	3.9	42.3	36.2
Applied Materials	0	0	0	0	61.9	NM
General Signal Thinfilm Company	0.5	0	0	0	0	-100.0
Koyo Lindberg	0.6	0	0.5	0	0	-100.0
Toshiba	3.2	2.1	1.2	0.4	3.7	3.9
Watkins-Johnson	48.5	45.0	66.2	122.4	202.0	42.9
Total	91.9	81.9	103.4	191.4	425.0	46.6

NM = Not meaningful

Note: Figures for Alcan/Canon/Quester joint venture are included in totals for Alcan Technology.

Source: Dataquest (May 1996)

Table 6-16
Each Company's Sales Revenue from Shipments of High-Density Plasma CVD to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	3.2	0.4	2.9	6.3	11.1	36.5
Anelva	0	0	0	0	0	NM
Applied Materials	0	0	0	0	2.7	NM
Fuji Electric	0	0	0	0	0	NM
Lam Research	0	0	2.9	6.3	8.0	NM
Oxford Instruments Inc.	0.5	0.4	0	0	0.4	-5.4
Sumitomo Metals	2.7	0	0	0	0	-100.0
Total	3.2	0.4	2.9	6.3	11.1	36.5
Japanese Market	3.8	4.0	7.8	0	1.6	-19.4
Anelva	3.8	0	0	0	0	-100.0
Applied Materials	0	0	0	0	0	NM
Fuji Electric	0	4.0	2.2	0	0	NM
Lam Research	0	0	0	0	1.6	NM
Oxford Instruments Inc.	0	0	0.4	0	0	NM
Sumitomo Metals	0	0	5.2	0	0	NM
Total	3.8	4.0	7.8	0	1.6	-19.4
European Market	1.0	0.4	2.0	2.4	0.4	-20.5
Anelva	0	0	0	0	0	NM
Applied Materials	0	0	0	0	0	NM
Fuji Electric	0	0	0	0	0	NM
Lam Research	0	0	1.3	1.6	0	NM
Oxford Instruments Inc.	1.0	0.4	0.7	0.8	0.4	-20.5
Sumitomo Metals	0	0	0	0	0	NM
Total	1.0	0.4	2.0	2.4	0.4	-20.5
Asia/Pacific Market	0	0	0	0	0	NM
Anelva	0	0	0	0	0	NM
Applied Materials	0	0	0	0	0	NM
Fuji Electric	0	0	0	0	0	NM
Lam Research	0	0	0	0	0	NM
Oxford Instruments Inc.	0	0	0	0	0	NM
Sumitomo Metals	0	0	0	0	0	NM
Total	0	0	0	0	0	NM

(Continued)

Table 6-16 (Continued)
Each Company's Sales Revenue from Shipments of High-Density Plasma CVD to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	8.0	4.8	12.7	8.7	13.1	13.1
Anelva	3.8	0	0	0	0	-100.0
Applied Materials	0	0	0	0	2.7	NM
Fuji Electric	0	4.0	2.2	0	0	NM
Lam Research	0	0	4.2	7.9	9.6	NM
Oxford Instruments Inc.	1.5	0.8	1.1	0.8	0.8	-14.5
Sumitomo Metals	2.7	0	5.2	0	0	-100.0
Total	8.0	4.8	12.7	8.7	13.1	13.1

NM = Not meaningful
Source: Dataquest (May 1996)

Table 6-17
Each Company's Sales Revenue from Shipments of Dedicated LPCVD Reactors to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	28.0	45.7	57.2	75.7	160.9	54.8
Anelva	0	0	0	0	0	NM
Applied Materials	12.0	27.3	38.2	51.7	93.4	67.0
BCT Spectrum	2.0	0	0	0	0	-100.0
Genus	6.8	5.2	4.2	0	0	-100.0
Lam Research	0	5.7	1.3	0	4.1	NM
Materials Research Corporation	0	1.6	0	0	2.5	NM
Novellus Systems Inc.	5.7	4.5	11.9	24.0	56.0	77.0
Tokyo Electron Ltd.	0	0	0	0	1.7	NM
Ulvac	1.5	1.4	1.6	0	3.2	20.8
Total	28.0	45.7	57.2	75.7	160.9	54.8
Japanese Market	37.6	36.0	43.1	75.4	184.5	48.8
Anelva	0	0	0	0.9	1.6	NM
Applied Materials	17.0	22.0	25.7	36.5	73.7	44.3
BCT Spectrum	0	0	0	0	0	NM
Genus	10.0	3.7	3.8	3.9	1.9	-34.0
Lam Research	0	0	0	0	0	NM
Materials Research Corporation	0	1.2	0	1.7	7.5	NM
Novellus Systems Inc.	0	1.1	4.9	13.3	26.5	NM
Tokyo Electron Ltd.	2.7	0	1.5	12.7	53.9	111.4
Ulvac	7.9	8.0	7.2	6.4	19.4	25.2
Total	37.6	36.0	43.1	75.4	184.5	48.8
European Market	6.8	16.3	19.8	29.9	32.8	48.2
Anelva	0	0	0	0	0	NM
Applied Materials	2.0	7.4	10.6	13.7	23.8	85.7
BCT Spectrum	0	0	0	0	0	NM
Genus	4.8	6.0	6.0	8.2	0	-100.0
Lam Research	0	1.6	1.3	2.0	4.0	NM
Materials Research Corporation	0	1.3	0	3.8	2.5	NM
Novellus Systems Inc.	0	0	1.1	2.2	2.5	NM
Tokyo Electron Ltd.	0	0	0	0	0	NM
Ulvac	0	0	0.8	0	0	NM
Total	6.8	16.3	19.8	29.9	32.8	48.2

(Continued)

Table 6-17 (Continued)
Each Company's Sales Revenue from Shipments of Dedicated LPCVD Reactors to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Asia/Pacific Market	11.0	12.3	27.2	37.1	131.1	85.8
Anelva	0	0	0	0	0	NM
Applied Materials	1.0	4.2	14.2	19.1	50.0	165.9
BCT Spectrum	0	0	0	0	0	NM
Genus	8.1	7.0	10.5	11.3	45.0	53.5
Lam Research	1.9	0	1.4	0	0	-100.0
Materials Research Corporation	0	0	0	0	2.4	NM
Novellus Systems Inc.	0	1.1	1.1	4.6	15.1	NM
Tokyo Electron Ltd.	0	0	0	2.1	18.5	NM
Ulvac	0	0	0	0	0	NM
Total	11.0	12.3	27.2	37.1	131.1	85.8
Worldwide Market	83.4	110.3	147.3	218.1	509.3	57.2
Anelva	0	0	0	0.9	1.7	NM
Applied Materials	32.0	60.9	88.7	121.0	240.9	65.6
BCT Spectrum	2.0	0	0	0	0	-100.0
Genus	29.7	21.9	24.5	23.4	46.9	12.1
Lam Research	1.9	7.3	4.0	2.0	8.1	43.7
Materials Research Corporation	0	4.1	0	5.5	14.9	NM
Novellus Systems Inc.	5.7	6.7	19.0	44.1	100.1	104.7
Tokyo Electron Ltd.	2.7	0	1.5	14.8	74.1	128.9
Ulvac	9.4	9.4	9.6	6.4	22.6	24.5
Total	83.4	110.3	147.3	218.1	509.3	57.2

NM = Not meaningful
Source: Dataquest (May 1996)

Table 6-18
Each Company's Sales Revenue from Shipments of Dedicated PECVD Reactors to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	104.6	108.4	113.9	162.4	265.3	26.2
Applied Materials	77.0	85.0	81.5	102.5	163.3	20.7
ASM International	0	0	0	0	4.8	NM
E.T. Electrotech	3.4	2.1	1.4	0	0.9	-28.3
Enya	0	0	0	0	0	NM
Japan Production Engineering	0	0	0	0	0	NM
Novellus Systems Inc.	23.0	20.5	28.8	59.4	95.8	42.9
Oxford Instruments Inc.	0	0	0.7	0.5	0.5	NM
Plasma & Materials Technologies	0	0	1.5	0	0	NM
Plasma-Therm	1.2	0.8	0	0	0	-100.0
Samco	0	0	0	0	0	NM
Total	104.6	108.4	113.9	162.4	265.3	26.2
Japanese Market	108.5	70.7	85.6	129.8	237.5	21.6
Applied Materials	63.4	41.0	58.2	73.2	125.2	18.5
ASM International	0	0	1.6	6.4	32.4	NM
E.T. Electrotech	7.6	3.6	2.2	4.2	5.1	-9.5
Enya	1.6	0.8	0	0	0	-100.0
Japan Production Engineering	5.6	3.2	2.2	3.1	4.1	-7.5
Novellus Systems Inc.	26.0	16.7	17.9	38.4	65.2	25.8
Oxford Instruments Inc.	0	0	0.4	0.4	0.6	NM
Plasma & Materials Technologies	0	0	0	0	0	NM
Plasma-Therm	0	0	0	0	0	NM
Samco	4.3	5.4	3.1	4.1	4.9	3.3
Total	108.5	70.7	85.6	129.8	237.5	21.6
European Market	46.0	37.6	66.5	87.5	158.8	36.3
Applied Materials	29.0	26.6	51.2	58.6	108.9	39.2
ASM International	0	0	0	1.6	6.4	NM
E.T. Electrotech	8.0	6.3	3.4	7.0	9.0	3.0
Enya	0	0	0	0	0	NM
Japan Production Engineering	0	0	0	0	0	NM
Novellus Systems Inc.	9.0	4.7	10.9	19.4	33.4	38.8
Oxford Instruments Inc.	0	0	1.0	0.9	1.1	NM
Plasma & Materials Technologies	0	0	0	0	0	NM
Plasma-Therm	0	0	0	0	0	NM
Samco	0	0	0	0	0	NM
Total	46.0	37.6	66.5	87.5	158.8	36.3

(Continued)

Table 6-18 (Continued)
Each Company's Sales Revenue from Shipments of Dedicated PECVD Reactors to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Asia/Pacific Market	32.0	23.3	55.8	87.5	194.4	57.0
Applied Materials	25.0	16.2	41.9	58.6	147.0	55.7
ASM International	0	0	0	0	1.7	NM
E.T. Electrotech	1.0	0.6	0.7	0	0	-100.0
Enya	0	0	0	0	0	NM
Japan Production Engineering	0	0	0	0	0	NM
Novellus Systems Inc.	6.0	6.5	12.9	28.9	45.7	66.1
Oxford Instruments Inc.	0	0	0.3	0	0	NM
Plasma & Materials Technologies	0	0	0	0	0	NM
Plasma-Therm	0	0	0	0	0	NM
Samco	0	0	0	0	0	NM
Total	32.0	23.3	55.8	87.5	194.4	57.0
Worldwide Market	291.1	240.0	321.8	467.2	855.9	30.9
Applied Materials	194.4	168.8	232.8	292.9	544.3	29.4
ASM International	0	0	1.6	8.0	45.3	NM
E.T. Electrotech	20.0	12.6	7.7	11.2	15.0	-6.9
Enya	1.6	0.8	0	0	0	-100.0
Japan Production Engineering	5.6	3.2	2.2	3.1	4.1	-7.5
Novellus Systems Inc.	64.0	48.4	70.5	146.1	240.1	39.2
Oxford Instruments Inc.	0	0	2.4	1.8	2.2	NM
Plasma & Materials Technologies	0	0	1.5	0	0	NM
Plasma-Therm	1.2	0.8	0	0	0	-100.0
Samco	4.3	5.4	3.1	4.1	4.9	3.3
Total	291.1	240.0	321.8	467.2	855.9	30.9

NM = Not meaningful
Source: Dataquest (May 1996)

Table 6-19
Top 10 Companies' Sales Revenue from Shipments of Sputtering to the World (End-User Revenue in Millions of U.S. Dollars)

1995 Rank	1994 Rank		1994 Revenue	1995 Revenue	Change (%)	Market Share (%)
1	1	Applied Materials	504.4	880.9	75	56.2
2	2	Varian (including joint ventures)	137.8	191.1	39	12.2
3	3	Anelva	134.7	158.5	18	10.1
4	4	Materials Research Corporation	119.0	155.0	30	9.9
5	5	Ulvac	54.3	80.4	48	5.1
6	6	E.T. Electrotech	28.5	53.6	88	3.4
7	7	CVC Products	7.7	22.8	196	1.5
8	9	Sputtered Films	7.0	8.0	14	0.5
9	8	Novellus Systems Inc.	7.2	5.0	-31	0.3
10	10	Denton Vacuum	4.0	4.5	13	0.3
		North American Companies	672.5	1,179.9	66	71.4
		Japanese Companies	310.5	395.5	27	25.2
		European Countries	28.5	53.6	88	3.4
		Joint Venture Companies	0	0	0	0
		Identified Companies	1,011.5	1,566.5	55	100.0
		Other Companies	0	0	0	
		All Companies	1,011.5	1,566.5	55	

NM = Not meaningful
Note: "Including joint ventures" indicates figures that include joint ventures.
Figures for "other companies" reflect estimates of unsurveyed market activity.
Source: Dataquest (May 1996)

Table 6-20
Each Company's Sales Revenue from Shipments of Sputtering to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	108.8	152.4	221.7	369.5	509.1	47.1
Advanced Film Technology Inc.	0	0	0	0	0	NM
Anelva	20.8	23.7	34.2	33.4	16.4	-5.8
Applied Materials	13.6	41.6	94.7	196.7	299.5	116.6
CHA Industries	0.4	0.2	0	1.1	2.3	54.9
CPA	2.0	1.0	0	0	0	-100.0
CVC Products	4.5	4.0	5.3	6.4	21.1	47.1
Denton Vacuum	1.4	1.0	2.0	2.5	2.9	20.0
E.T. Electrotech	3.0	1.2	0	5.3	6.9	23.1
Innotec	0.2	0	0	0	0	-100.0
Ion Tech	0.2	0.1	0	0	0	-100.0
Kurt J. Lesker	0.2	0.4	2.0	1.7	2.8	93.4
Leybold-Heraeus	1.0	0	0	0	0	-100.0
Materials Research Corporation	30.0	55.6	38.2	78.5	69.0	23.1
Novellus Systems Inc.	1.8	2.4	4.8	7.2	5.0	29.1
Shibaura Engineering Works	0	0	0	0	0	NM
Shinko Seiki	0	0	0	0	0	NM
Sputtered Films	2.0	2.3	5.9	7.0	8.0	41.4
Ulvac	2.2	2.5	2.3	0	3.2	9.8
Varian	25.5	16.4	32.3	29.7	72.1	29.7
Total	108.8	152.4	221.7	369.5	509.1	47.1
Japanese Market	209.1	148.6	199.9	319.4	509.0	24.9
Advanced Film Technology Inc.	0.8	0	0	0	0	-100.0
Anelva	80.0	52.2	41.4	72.8	122.4	11.2
Applied Materials	19.5	36.4	74.8	147.3	255.5	90.2
CHA Industries	0	0	0	0	0	NM
CPA	0	0	0	0	0	NM
CVC Products	0.5	0	1.0	0.5	0.5	0
Denton Vacuum	0	0	0	0	0	NM
E.T. Electrotech	0	0	0	8.8	5.6	NM
Innotec	0	0	0	0	0	NM
Ion Tech	0	0	0	0	0	NM
Kurt J. Lesker	0	0	0	0	0	NM
Leybold-Heraeus	0	0	0	0	0	NM
Materials Research Corporation	34.0	10.3	29.8	16.7	36.5	1.8
Novellus Systems Inc.	0	0	0	0	0	NM

(Continued)

Table 6-20 (Continued)
Each Company's Sales Revenue from Shipments of Sputtering to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Shibaura Engineering Works	2.6	4.4	0	0	0	-100.0
Shinko Seiki	0.4	1.4	0.9	2.5	1.1	27.7
Sputtered Films	0	0	0	0	0	NM
Ulvac	43.1	35.0	45.0	54.3	77.2	15.7
Varian	28.2	8.9	7.0	16.5	10.3	-22.3
Total	209.1	148.6	199.9	319.4	509.0	24.9
European Market	38.6	57.9	71.1	109.1	182.1	47.4
Advanced Film Technology Inc.	0	0	0	0	0	NM
Anelva	3.7	0	2.7	19.3	0	-100.0
Applied Materials	1.8	21.6	29.9	55.5	96.9	170.9
CHA Industries	0	0	0	0	0	NM
CPA	0	0	0	0	0	NM
CVC Products	0.5	0.5	0.6	0.8	1.2	24.5
Denton Vacuum	0	0	0	0	0	NM
E.T. Electrotech	8.0	6.0	9.1	14.4	41.1	50.6
Innotec	0	0	0	0	0	NM
Ion Tech	0	0	0	0	0	NM
Kurt J. Lesker	0.8	0.4	0.4	0.8	0.1	-40.5
Leybold-Heraeus	2.6	0	0	0	0	-100.0
Materials Research Corporation	8.5	16.5	22.2	16.7	31.5	38.7
Novellus Systems Inc.	0	0	0	0	0	NM
Shibaura Engineering Works	0	0	0	0	0	NM
Shinko Seiki	0	0	0	0	0	NM
Sputtered Films	0	0	0	0	0	NM
Ulvac	0	0	0	0	0	NM
Varian	12.7	12.9	6.2	1.6	11.3	-2.9
Total	38.6	57.9	71.1	109.1	182.1	47.4
Asia/Pacific Market	68.7	87.5	91.5	213.5	366.3	52.0
Advanced Film Technology Inc.	0	0	0	0	0	NM
Anelva	10.0	5.9	0	9.2	19.8	18.6
Applied Materials	17.4	25.2	49.9	104.9	229.0	90.5
CHA Industries	0.3	0	0.2	0.6	0	-100.0
CPA	0	0	0	0	0	NM
CVC Products	1.5	1.5	0	0	0	-100.0
Denton Vacuum	0.4	0	1.0	1.5	1.6	41.4

(Continued)

Table 6-20 (Continued)
Each Company's Sales Revenue from Shipments of Sputtering to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
E.T. Electrotech	1.0	0	0.8	0	0	-100.0
Innotec	0.5	0.4	0	0	0	-100.0
Ion Tech	0	0	0	0	0	NM
Kurt J. Lesker	0	0	0	0.2	0.5	NM
Leybold-Heraeus	0.8	0	0	0	0	-100.0
Materials Research Corporation	12.0	20.5	6.3	7.1	18.0	10.7
Novellus Systems Inc.	0	0	0	0	0	NM
Shibaura Engineering Works	0	0	0	0	0	NM
Shinko Seiki	0	0	0	0	0	NM
Sputtered Films	0.3	0.4	0	0	0	-100.0
Ulvac	0	0	0	0	0	NM
Varian	24.5	33.6	33.3	90.0	97.4	41.2
Total	68.7	87.5	91.5	213.5	366.3	52.0
Worldwide Market	425.2	446.4	584.2	1,011.5	1,566.5	38.5
Advanced Film Technology Inc.	0.8	0	0	0	0	-100.0
Anelva	114.5	81.8	78.3	134.7	158.5	8.5
Applied Materials	52.3	124.8	249.3	504.4	880.9	102.6
CHA Industries	0.7	0.2	0.2	1.7	2.3	34.6
CPA	2.0	1.0	0	0	0	-100.0
CVC Products	7.0	6.0	6.9	7.7	22.8	34.3
Denton Vacuum	1.8	1.0	3.0	4.0	4.5	25.7
E.T. Electrotech	12.0	7.2	9.9	28.5	53.6	45.4
Innotec	0.7	0.4	0	0	0	-100.0
Ion Tech	0.2	0.1	0	0	0	-100.0
Kurt J. Lesker	1.0	0.8	2.4	2.7	3.4	35.8
Leybold-Heraeus	4.4	0	0	0	0	-100.0
Materials Research Corporation	84.5	102.9	96.5	119.0	155.0	16.4
Novellus Systems Inc.	1.8	2.4	4.8	7.2	5.0	29.1
Shibaura Engineering Works	2.6	4.4	0	0	0	-100.0
Shinko Seiki	0.4	1.4	0.9	2.5	1.1	27.7
Sputtered Films	2.3	2.7	5.9	7.0	8.0	36.6
Ulvac	45.3	37.5	47.3	54.3	80.4	15.4
Varian	90.9	71.8	78.8	137.8	191.1	20.4
Total	425.2	446.4	584.2	1,011.5	1,566.5	38.5

NM = Not meaningful
Source: Dataquest (May 1996)

Table 6-21
Each Company's Sales Revenue from Shipments of Silicon Epitaxy to the World
(End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Americas Market	25.2	26.8	31.6	43.5	88.5	36.9
Applied Materials	7.0	5.5	6.5	12.5	38.3	52.9
ASM International	15.0	19.2	20.0	22.1	31.7	20.6
Concept Systems Design	0.4	0	0.4	3.5	9.7	121.9
Kokusai Electric	0	0	0	0	0	NM
LPE	0	0	0	0	0	NM
Moore Epitaxial Inc.	2.8	2.1	4.7	5.4	8.8	33.0
Toshiba	0	0	0	0	0	NM
Total	25.2	26.8	31.6	43.5	88.5	36.9
Japanese Market	46.1	46.3	25.4	32.2	62.5	7.9
Applied Materials	20.0	14.9	8.8	15.4	29.8	10.5
ASM International	7.2	7.2	6.0	7.5	10.4	9.6
Concept Systems Design	0	1.6	0.8	0	0	NM
Kokusai Electric	5.9	11.1	4.6	0.8	8.1	8.2
LPE	0	0	0	0	0	NM
Moore Epitaxial Inc.	0.5	2.0	0.7	1.3	0.9	14.2
Toshiba	12.5	9.5	4.5	7.2	13.3	1.6
Total	46.1	46.3	25.4	32.2	62.5	7.9
European Market	11.0	6.9	20.9	29.9	44.1	41.5
Applied Materials	3.0	0.9	5.3	10.8	22.3	65.1
ASM International	5.5	3.6	10.2	8.5	9.9	15.8
Concept Systems Design	0	0	2.0	2.7	2.5	NM
Kokusai Electric	0	0	0	0	0	NM
LPE	2.5	2.0	3.0	2.9	4.1	13.2
Moore Epitaxial Inc.	0	0.4	0.4	5.0	4.0	NM
Toshiba	0	0	0	0	1.3	NM
Total	11.0	6.9	20.9	29.9	44.1	41.5
Asia/Pacific Market	6.7	4.0	4.7	8.5	11.7	15.0
Applied Materials	2.0	1.7	1.3	2.8	1.6	-5.4
ASM International	2.2	1.2	2.4	2.4	5.0	22.8
Concept Systems Design	0	0	0	2.3	1.7	NM
Kokusai Electric	0	0	0	0	0	NM
LPE	2.5	1.1	1.0	1.0	2.0	-5.4
Moore Epitaxial Inc.	0	0	0	0	0	NM
Toshiba	0	0	0	0	1.4	NM
Total	6.7	4.0	4.7	8.5	11.7	15.0

(Continued)

Table 6-21 (Continued)
Each Company's Sales Revenue from Shipments of Silicon Epitaxy to the World (End-User Sales Revenue in Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Worldwide Market	89.0	84.0	82.6	114.1	206.7	23.5
Applied Materials	32.0	23.0	21.9	41.5	92.0	30.2
ASM International	29.9	31.2	38.6	40.5	57.0	17.5
Concept Systems Design	0.4	1.6	3.2	8.5	13.9	142.8
Kokusai Electric	5.9	11.1	4.6	0.8	8.1	8.2
LPE	5.0	3.1	4.0	3.9	6.1	5.1
Moore Epitaxial Inc.	3.3	4.5	5.8	11.7	13.6	42.5
Toshiba	12.5	9.5	4.5	7.2	16.0	6.4
Total	89.0	84.0	82.6	114.1	206.7	23.5

NM = Not meaningful
Source: Dataquest (May 1996)

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Market
Analysis

Semiconductor Equipment, Manufacturing, and
Materials Worldwide

Market Analysis

A Market Perspective on the SIA Lithography Road Map

Abstract: *This article will review the 1994 Semiconductor Industry Association (SIA) lithography road map. We offer a perspective on the market dynamics that will strongly influence the milestones along the road map, and on the evolution of this critical technology. Our goal is to share with the reader a viewpoint that incorporates the market forces in adoption and proliferation of this critical technology.*
By Nâder Pakdaman

Introduction

According to the German writer Heinrich Böll, "Too many things happen in the foreground, and we do not know anything about what happens in the background." We believe that Böll's statement would correctly describe events in the evolution of technology if the market vector is taken out of a technology road map. Without an understanding of the market, every event and opinion could propose a valid alternative—and this spells chaos. Therefore, from our perspective, the market is the parameter that will dominate the course of events, and it offers the canvas that history will be painted upon. The dynamics of the interaction between the market and the technical demands of the industry are the driving forces of technology.

The history of lithography is a perfect example of how the technical demands of the industry along with the market's need for cost-effective manufacturing have shaped the technology. History also teaches us that the past is not a perfect guiding light to the future. For lithography, many of the "correct" beliefs of the past did not bear truth for the future. For example, it was believed in the late 1970s that optical lithography will not be able to process below 1 micron. Later in the 1980s the "final" limit was set at 0.5 microns. We know now optical lithography has shown the potential to

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expose critical device layers below 0.25 microns. Recent work in research laboratories suggests that this capability could be extended to 0.18 microns.

The goal of this article is to offer an insight into evolution of lithography technology by using the recently published 1994 Semiconductor Industry Association (SIA) Technology Roadmap as the background for our discussion. We will offer our perspective on the market conditions that will be a determining factor in adoption and success of the technologies discussed in the SIA Roadmap. Here we will focus on the near-term future of lithography, namely the optical technology. Our goal is to continue this discussion throughout 1996 on the latter subject.

The SIA Roadmap

Table 1 shows the technical demands for lithography technology, as outlined by the SIA. The major change form the 1993 version is that the die sizes for microprocessors predicted in the previous version were believed to follow a faster growth rate than shown here. The SIA Roadmap is shown in Figure 1. For further discussion on the technology road map, the reader may also choose to refer to a recent publication of Dataquest (Semiconductor Equipment Road Map, SEMM-WW-FR-9401).

The major underlying assumption embedded throughout the SIA Roadmap is its adherence to Moore's Law, which states that since the early 1970s the device count per chip quadruples every three years. It is believed that the industry must adhere to Moore's Law for it to continue its rather high (when compared to other large-scale industries) rate of growth.

Moore's Law is an important barometer of the industry's demand for improved performance. However, as Dr. Gordon Moore has repeatedly said, this law is not a natural law. His analysis shows that, in the early 1970s, after the first several generations of integrated circuit implementations, the "smarts" for circuit design (or how to "pack" the devices with the most efficient use of the silicon real estate) as a means for staying on the law's curve were exhausted. Therefore it has been the ability to make the devices smaller that has kept the industry on the law's curve. There is no reason to believe that the industry may not find other means to become "smart" again in designing ICs. However, today and for the foreseeable future, the industry has to outperform its own record on the fab floor. Therefore the focus has been on manufacturing technology.

SEMATECH Manufacturing Productivity Study

Recent reports from SEMATECH propose that the industry has managed to continuously improve its productivity by lowering the cost of manufacturing 25 to 30 percent each year. The contributions have been made by shrinking device features and using larger wafer sizes, along with making improvements in yield and tool use. Figure 2, from a SEMATECH study, shows the factors that have sustained the lowered manufacturing cost, along with their relative contributions. This figure may be seen as an extension of Moore's Law, as it goes beyond device count into other realms of manufacturing technology.

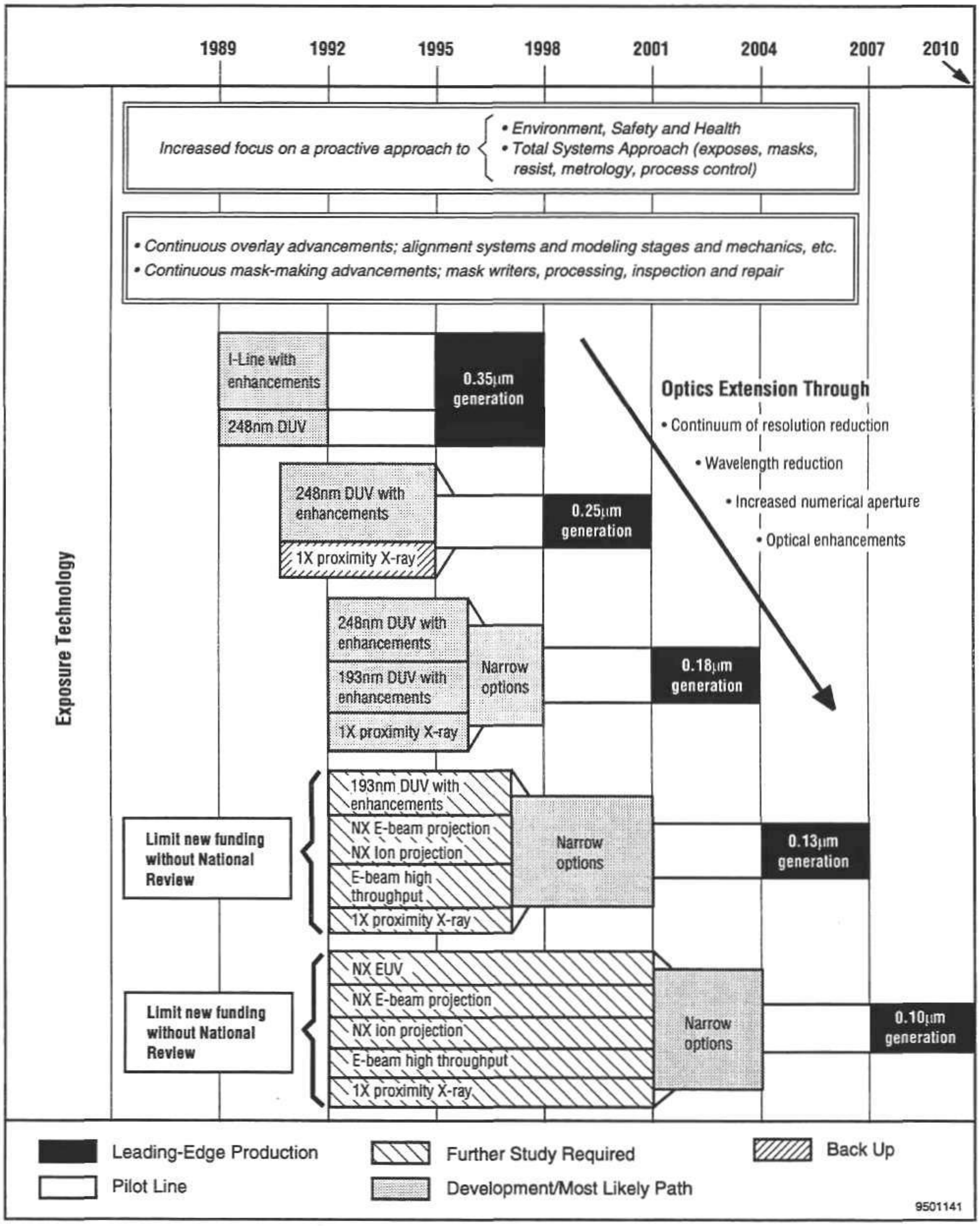
This study showed that, although the share of contributions from feature size shrinks and equipment productivity has increased, yield and wafer

Table 1
Critical Level Lithography Requirements

	1995—0.35µm	1998—0.25µm	2001—0.18µm	2004—0.13µm	2007—0.10µm	2010—0.07µm
Function						
DRAM (Bits)	64M	256M	1G	4G	16G	64G
Microprocessor (Logic Transistors /cm^2)	4M	7M	13M	25M	50M	90M
ASIC (Transistors/cm^2 Auto Layout)[1]	2M	4M	7M	12M	25M	40M
Resolution (µm)	0.35	0.25	0.18	0.13	0.10	0.07
Gate CD Control at Post Etch (nm)	35	25	18	13	10	7
Overlay (nm)	100	75	50	40	30	20
Chip Size						
DRAM (mm^2)	190	280	420	640	960	1,400
Microprocessor (mm^2)	250	300	360	430	520	620
DRAM (mm x mm)	10 x 20	12 x 24	15 x 30	18 x 36	22 x 44	28 x 50
Microprocessor (mm x mm)	16 x 16	18 x 18	19 x 19	21 x 21	23 x 23	25 x 25
Minimum Field Size						
Number of DRAM/Field	2	2	1	1	1	1
(mm x mm)	22 x 22	26 x 26	26 x 30	26 x 36	26 x 44	28 x 50
(mm^2)	484	676	780	936	1,144	1,400
Depth of Focus (Usable) (µm) (Full Field/ ±10 Percent Exposure)	1.0	0.8[2]	0.7[2]	TBD	TBD	TBD
Minimum Mask Count	18	20	20	22	22	24
Defect Density, Lithography Only (per Layer/m^2 at Defect Size µm)	690 at 0.12	320 at 0.08	135 at 0.06	TBD	TBD	TBD
Market Size (Inches) (Quartz)	6x6	6x6	6x6 Next Size	Next Size	Next Size	Next Size

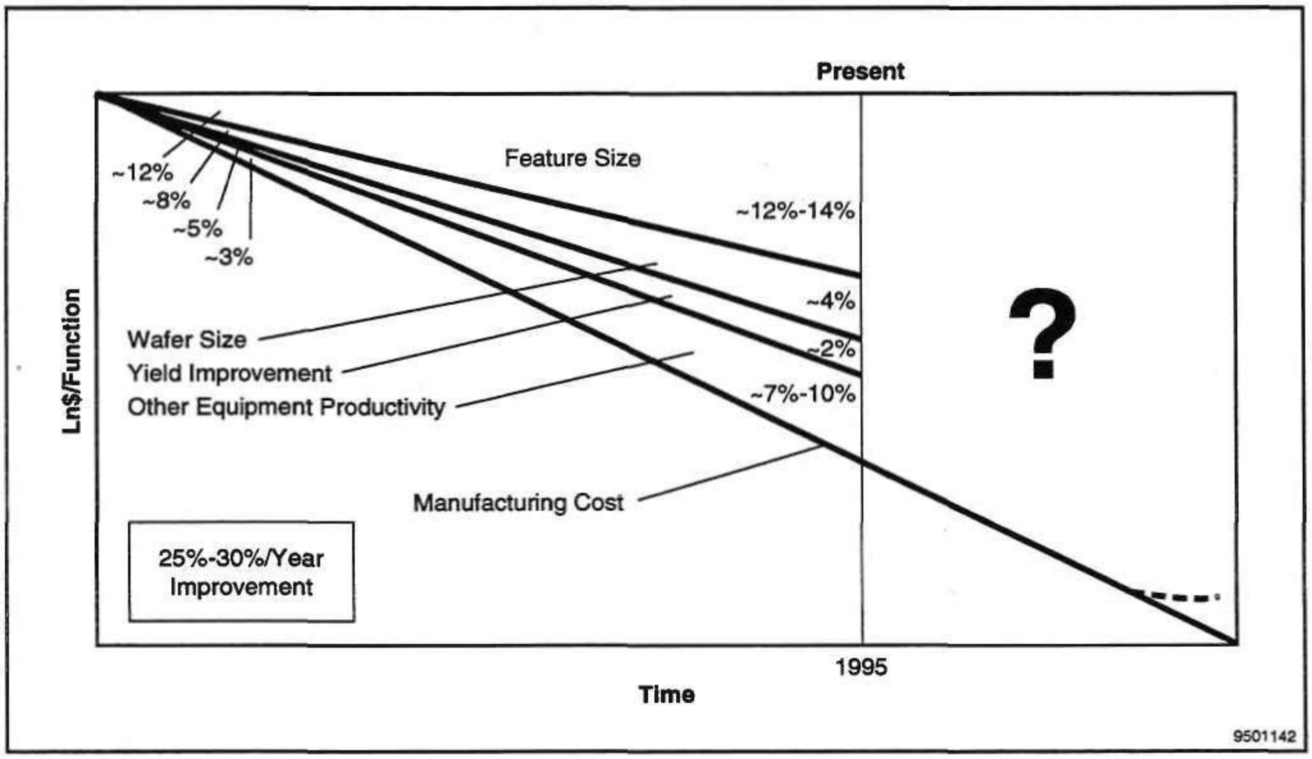
TBD = To be determined
[1]ASIC will use maximum available field size.
[2]Assumes advanced techniques to maximize the usable depth of focus. Further analysis is needed.
Source: SIA, The National Technology Roadmap for Semiconductors (1994)

Figure 1
Critical Level Exposure Technology Potential Solutions Roadmap



Source: SIA, The National Technology Roadmap for Semiconductors (1994)

Figure 2
Keeping the Productivity Engine on Track



Source: SEMATECH (SEMI Industry Strategy Symposium, January 1994, Pebble Beach, California)

size seem to be increasingly playing a smaller role. This may be because yield improvements have almost increased to a point of perfection, and die sizes have increased to compensate for the increases in wafer diameter. As the figure shows, SEMATECH views the future with a question mark. Will we fall off the curve? And if so, when?

One may answer these questions with another question. What has prevented the industry from falling off the improving productivity trend curve in the past? If we cannot find somewhat similar scenarios unfolding today that would increase manufacturing productivity at the rate that would satisfy Moore's Law, then two options exist:

- Manufacturing productivity would not enjoy the historical rate of increase it has enjoyed, and the industry will diverge (negatively) from the curve
- Or, we will have to adhere to the rather aggressive plan outlined by the SIA in Figure 1

We believe that the first option will not impose itself on the industry for at least well into the first decade of the next century. Our discussion that follows will further elaborate on this.

On the second option, we must first understand some of the underpinning definitions and assumptions of the SIA Technical Working Group (TWG). We summarize these points in the road map as:

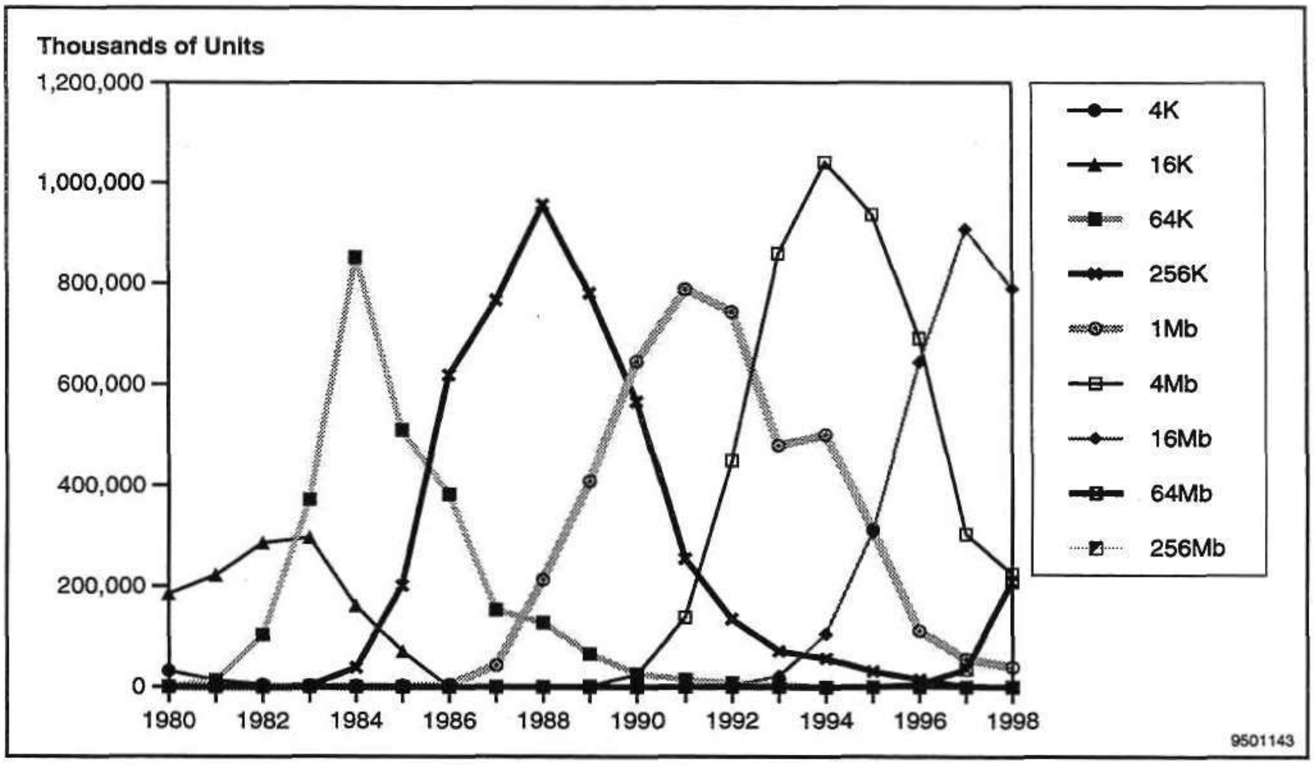
- The "safe margin" factor
- Snapshot view of the Roadmap
- The Roadmap and the market

The SIA Roadmap and the "Safe Margin"

In Figure 1, SIA's Roadmap shows the onset of a capable technology with "pilot line" production. For example 0.25-micron technology should be available in 1995. Or, by 1998, the industry should have 0.18-micron lithography capability. However, to many players in the industry, pilot production may be perceived as a stage in the product cycle that would immediately lead into volume production. On the other hand, according to Figure 3, the ramp-up for volume production of the 0.35-micron technology (the 64Mb DRAM) will begin in 1997, with 64Mb pilot production preceding it in 1996, whereas the SIA Roadmap calls for 0.35-micron pilot lines in 1992. Along the same definitions, the SIA calls "leading-edge production" as the step in the product cycle that will immediately precede volume production. Every generation of technology will have a three-year "pilot line" followed by three-year "leading-edge production."

The reason for this difference in semantics is that SIA, by definition of its charter for the Roadmap, assumes that technical capability should exist five

Figure 3
Annual DRAM Production



Source: Dataquest (March 1995)

to seven years preceding volume production. This "safe margin" is to ensure the availability (and proven capability) of a given technology.

The Roadmap Is a Snapshot

The other, and perhaps less appreciated, point that must be understood about the SIA Roadmap is its underlying methodology. The TWG looks at the needs of the industry with a snapshot view of what technologies are available today, and how far they may be extended. The Roadmap is not meant as a prescription for tomorrow's alternatives, but as an overview of what needs to be done if we had the same capabilities of today in addressing tomorrow's needs.

The Roadmap and the Market

The SIA, because of its charter, also does not include market conditions in its Roadmap. It is our belief that, without this facet of the industry, increases in manufacturing productivity could have not taken place. The difference lies in the response to this question: Does technology drive the market, or does the market drive technology?

Dataquest Perspective

Because our focus for this article is on the optical portion of the Roadmap, we will discuss the SIA's view from 1995 to 2001. The SIA Roadmap calls for a three-year period for the implementation of the next technology generation. This is the period that the SIA uses going from what it terms "pilot production" of one device generation to the next.

Therefore, according to the Roadmap, in the seven-year period preceding the year 2002, 0.35-micron technology will be developed with i-line and deep-UV exposure tools and 0.18 devices with deep-UV (248nm and/or 193nm) systems and/or proximity X-ray tools. The 0.25-micron, 248nm deep-UV and proximity X-ray are the primary candidates for the interim device generation. In short, very drastic enhancements coupled with revolutionary technology shifts are needed to adhere to Moore's Law. This technology road map must be cost-effective to adhere to the cost-performance requirements outlined by SEMATECH.

Market-Driven Evolution of Technology

What the Roadmap does not show is that even the most revolutionary changes in lithography have taken place on a gradual basis. Roadblocks have existed at every step. Most, if not all, of the time these roadblocks have been overcome by investments directed at the most cost-effective approach(es). For example, when optical steppers were first considered to address and alleviate the limitations of projection aligners as the exposure tool, it was believed that optical lithography would have a much shorter lifetime and massive investments were being made in nonoptical alternatives. Those other alternatives have yet to be deployed in volume manufacturing. The market has continued to invest in optical technology because it is the most cost-effective technical alternative in manufacturing.

Because of this sheer momentum we believe that the industry will most probably continue to develop optical technology as far as it can push the envelope. According to the SIA Roadmap, 0.13-micron devices may be exposed with 193nm deep-UV exposure tools. Our viewpoint does not exclude the use of other alternatives in volume production. However, the measuring stick will be the optical systems.

The embedded "snapshot" viewpoint in the Roadmap does not account for investment patterns, both by the manufacturers and the suppliers. Therefore it reverts to a rather linear outlook in technology development. Technology investments can and have only taken place when the capital has become available by favorable market conditions. The return on investment governs the equipment and material suppliers' decision on the direction, level, and timing of their investments.

Technology Cost Performance—Deep-UV versus i-Line

Lithography historically has managed to respond to the technical innovations needed to ensure more advanced and yet cost-effective manufacturing capability. Therefore, the physical law of the "path of least action" also holds true in the technology development field. This law dictates that the industry (supplier and user) will continue to incrementally develop mature technologies to minimize cost. Better performance or potential cost benefit of a technology in manufacturing do not guarantee the use and proliferation of that technology. For example, deep-UV step and scan systems have been on the market since 1989. It is only recently that all the players in the lithography market have declared their strategies in introducing their version of the step and scan deep-UV system. Along with these announcements we also see aggressive, yet incremental, plans by the same stepper suppliers to further develop and enhance the i-line exposure tools. The exposure enhancements techniques, along with improvements in the mask and photoresist used for i-line lithography, have proven that i-line systems may even be used for the critical layers below 0.35-micron device generations. This may be extended to 0.25 microns, contrary to the current SIA Roadmap.

The bottom line is cost. The resiliency of an "old" technology in lithography lies in the cost/performance ratio. We believe that deep-UV technology (exposure tool, photoresist, and mask) performance (yield and throughput) will have to displace i-line on a cost basis also. This holds true for the migration from 248nm to 193nm, and for the postoptical period. However, this will by no means be a smooth ride. Technical capabilities will not be developed along a smooth curve. The markets that generate the revenue needed to make the investment in R&D of new technologies also will not scale linearly.

Market Forecast

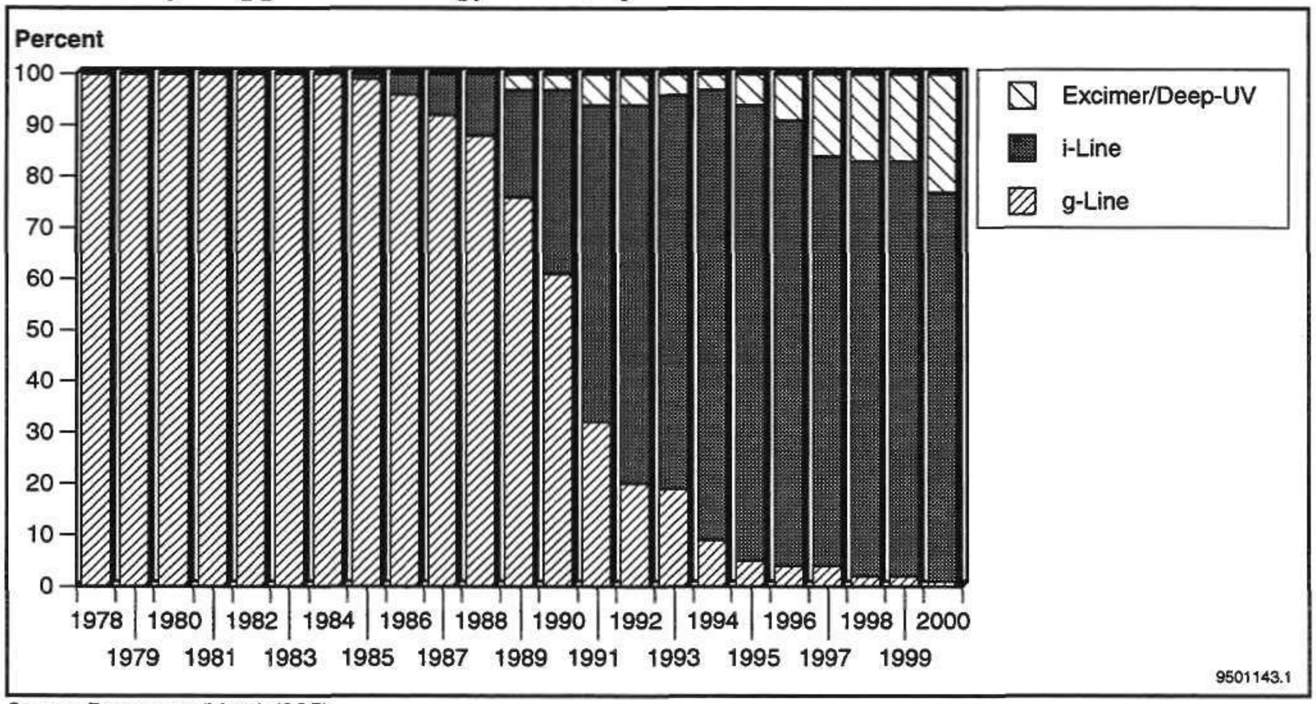
Figure 4 shows the preliminary estimates for the stepper market to the year 2000. We believe that many manufacturers in 1997 and 1998 will ramp up to volume production using i-line steppers for the critical mask layers. This by no means excludes the deep-UV systems. Cost performance of deep-UV technology could be different for each manufacturer, depending on device type and level of understanding deep-UV processing for volume manufacturing. I-line will challenge, and may even dominate, deep-UV steppers used for the critical geometries of the 0.35-micron devices.

Dataquest Conclusions

The more things change, the more they remain the same?

It is not the role of SEMATECH or the SIA to outline the course of technology development beyond their announced charters. Market conditions and ensuing investment patterns eventually will have to respond to the technical demands outlined by the industry consortia. We believe that the

Figure 4
Preliminary Stepper Technology Share, by Unit



Source: Dataquest (March 1995)

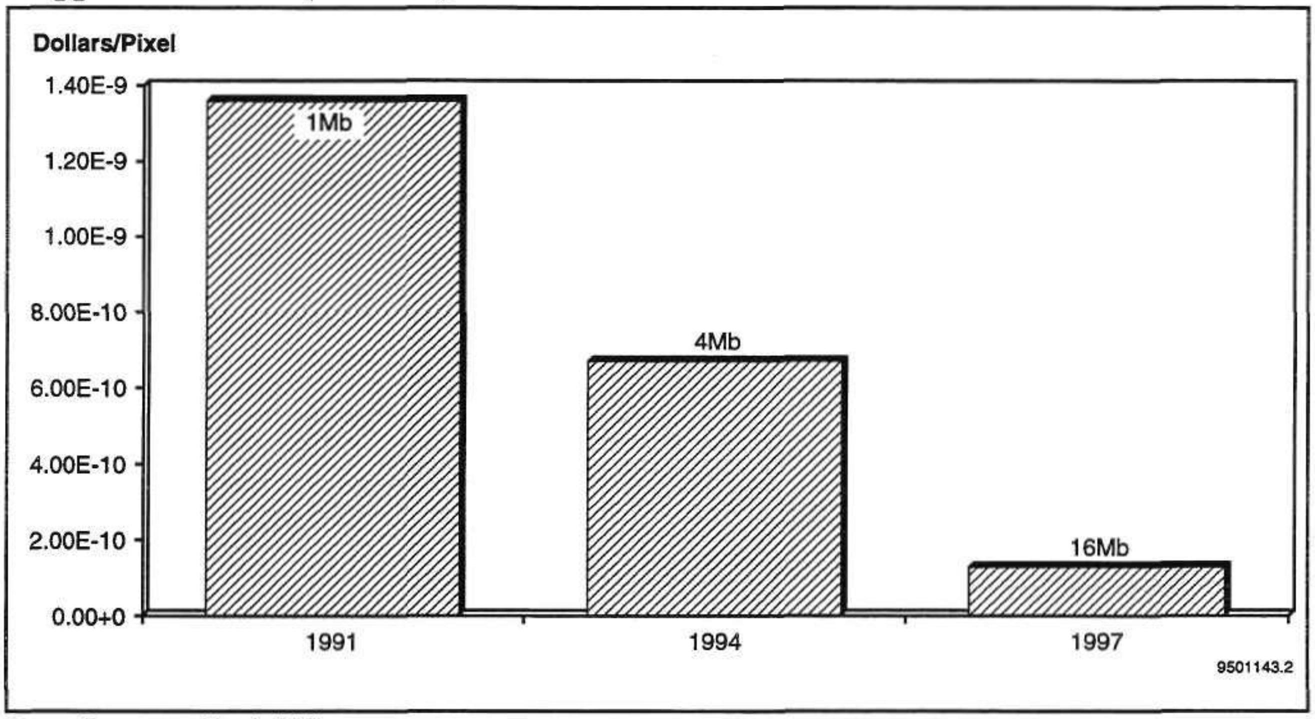
industry will find the means to remain on course with Moore's Law well into latter parts of the first decade of the next century.

The industry may have to revisit some of the areas that it believes it has exhausted in its quest for increased productivity. Yield curves are maturing at a very fast rate. New and rather revolutionary yield-enhancement strategies have only recently been incorporated on the fab floor. By our estimate, the impact on productivity from yield may grow. Product cycles of different device types may be overlapped to increase tool use of leading-edge technologies. Along with increases in tool use and yield enhancement, new strategies in product developments and shorter cycles from prototype to manufacturing may soon be realized. We are already seeing some of these trends in the microprocessor arena. Adoption of larger wafer diameter may also become more aggressive and common if the needed investments could be justified by the suppliers and users.

More on Mix and Match

Strategically significant trends have emerged in manufacturing in the past several years that will play an important role in productivity enhancements of the future. Among them is the ongoing acceptance and proliferation of mix and match of critical- to high-throughput stepper systems on the fab floor. This trend has been accelerated by the continuing increases in the throughputs of systems (both critical and noncritical). Mix and match lithography has just begun to impact the productivity picture. Although every fab cost model incorporates this important strategy in its cost structure, we believe the full potential has yet to be realized. Figure 5 shows the importance of mix and match strategies in reducing costs. The figures and assumptions behind Figure 5 appeared in the Dataquest's Semiconductor Equipment Road Map (SEMM-WW-FR-9401). The estimates

Figure 5
Stepper Cost Factor (Estimate)



Source: Dataquest (March 1995)

used to generate this chart were based on rather low and "conservative" figures for the throughput of the critical and non-critical steppers.

Showstoppers

What conditions and events may derail the industry from the productivity curve? The semiconductor industry is in a state of flux. This translates into uncharted market conditions for technology development. The manufacturers that defined and led technology development for several decades with massive investments in R&D—and spurred the technical and market growth of the suppliers—have more or less relinquished that role. With the lower government and research investments in the post-Cold War era, semiconductor research in the United States is redefining itself. The weak Japanese economy of the past several years has also slowed the pace of advanced research. Perhaps this could translate into new opportunities for a new generation of players, or it may spell warning signs for staying on the productivity curve. However, we believe that the needs of the exponential growth of information technology will find the means to address the voracious growth for advanced development of cost-effective technology.

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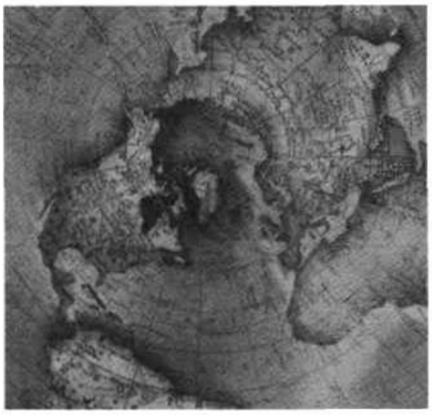

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1995 Korean Wafer Fab Equipment Market and Outlook

Focus Report

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Chapter 1
Executive Summary

For the most part, the Korean and rest of Asia/Pacific markets are microcosms of the worldwide wafer fab equipment market. The exceptions, when comparing segment emphasis with other regions of the world, are that the Asia/Pacific fabs tend to favor factory automation systems while not encompassing in-line process control techniques and tools as much.

Because this report provides a more detailed look at a regional or account-driven market share, there are notable instances where various companies are shown to have better positions in some markets. The strongest market share position in Korea is a direct manufacturing presence, and it means a great deal in Korean market share. Cases where companies have had better than average success in Korea because of their direct presence include Kokusai Electric Co. Ltd., Varian Associates Inc., and, to a lesser extent, Applied Materials Inc..

The often erratic but long-term high growth in semiconductor capital spending for the Asia/Pacific region translated to very strong years in 1994 and 1995 for wafer fab equipment consumption before moderating in 1996. Dataquest is expecting a major contraction in the region in 1997 and a slow 1998 before resumption of growth in 1999. Longer term, we expect Asia/Pacific to exhibit the most aggressive growth of any region, with an average annual growth rate for wafer fab equipment of 16.7 percent from 1995 through 2001.

The Korean companies as a group maintain more than half of the capital spending by Asia/Pacific companies in total. Although on a downward trend recently, Korean companies are expected to gain share slightly of the Asia/Pacific company spending in 1997.

In 1994, Korea consumed about two-thirds of all wafer fab equipment but accounted only for a little over 40 percent of all capital spending in the region. This large difference can be explained by the investment in the test and assembly plants throughout Asia, which are concentrated in Taiwan and Malaysia. In 1995, the foundry investment drove more front-end manufacturing facilities and consumed more wafer fab equipment. This shifted the wafer fab equipment market slightly away from Korea even though Korean capital spending share increased. In the longer term, we would expect that Korea would consume less than half of the wafer fab equipment shipped into the Asia/Pacific region by the turn of the decade.

Chapter 2

Korean Wafer Fab Equipment Market Review and Outlook

The often erratic but long-term high growth in semiconductor capital spending for the Asia/Pacific region translated to very strong years in 1994 and 1995 for wafer fab equipment consumption before moderating during 1996. Dataquest is expecting a major contraction in the region during 1997 and a slow 1998 before resumption of growth during 1999. Longer term, we expect Asia/Pacific to exhibit the most aggressive growth of any region, with an average annual growth rate for wafer fab equipment of 16.7 percent from 1995 through 2001 (see Table 2-1).

Asia/Pacific Spending Review

Spending in the Asia/Pacific region during 1995 came primarily from two areas, DRAMs and foundry capacity. In 1995 and early 1996, the Korean conglomerates continued their relentless DRAM capacity expansion plans. However, the tide has turned in the DRAM area, and Dataquest is forecasting the Asia/Pacific region to be hit hardest in 1997, with a 30 percent decline in wafer fab equipment consumption.

The real story of interest in 1995 and 1996 is the new Taiwanese players. Vanguard International Semiconductor Corporation will be brought on its new DRAM fab late in 1995, and PowerChip Semiconductor Corporation and Nan Ya Technology Corporation, among others, brought new DRAM capacity on in early 1996. All of these are targeted at 16Mb DRAM running 200mm wafers. Current players such as Texas Instruments-Acer Inc. and Mosel Vitelic Inc. also increased their spending with new projects. But the tide has turned quickly, likely accelerated by the fact that the Taiwanese stock market is very close to the U.S. stock market in its reaction to bad news. Many companies in DRAM are now cutting back feverishly to save near-term profitability.

Table 2-1
Wafer Fab Equipment Market and Forecast, 1994-2001 (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1995-2001
Total Wafer Fab Equipment	10,787	19,010	21,245	17,439	18,386	23,976	33,477	40,988	13.7
Percentage Growth	57.1	76.2	11.8	-17.9	5.4	30.4	39.6	22.4	
Americas	3,190	5,332	6,154	5,728	6,439	8,062	10,451	12,197	15.0
Percentage Growth	50.6	67.1	15.4	-6.9	12.4	25.2	29.6	16.7	
Japan	3,661	6,157	6,263	5,129	5,614	7,253	9,739	10,803	9.8
Percentage Growth	49.4	68.2	1.7	-18.1	9.5	29.2	34.3	10.9	
Europe, Middle East, and Africa	1,370	2,313	2,623	2,243	2,223	2,946	3,862	4,691	12.5
Percentage Growth	38.6	68.8	13.4	-14.5	-0.9	32.5	31.1	21.5	
Asia/Pacific	2,567	5,208	6,205	4,339	4,110	5,716	9,425	13,298	16.7
Percentage Growth	95.7	102.9	19.1	-30.1	-5.3	39.1	64.9	41.1	

Source: Dataquest (January 1997)

However, Taiwanese chip companies Taiwan Semiconductor Mfg. Co., Macronix International Co. Ltd., and United Microelectronics Corporation, along with Chartered Semiconductor Mfg. Pte. Ltd. in Singapore and Submicron Technology PCL in Thailand, continue with their planned projects in expansion of foundry capacity. Anam Semiconductor Corporation, with its new foundry fab in Korea, is part of what we believe will be several new entries into this business. The reason for the continued interest in spending capital in this area comes from the fact that the core business is dependent on logic and PC unit demand rather than DRAM. Further, Dataquest estimates that only about 32 percent of the contracted manufacturing of semiconductors originates from fabless companies. The remainder is from integrated device manufacturers (IDMs) that wish to place manufacturing lower-value-added products away from their own facilities in order to maximize resources and cost, to reduce investment risks using foundries as an extension of their own capacity, or to use the more advanced technology of foundries (in some cases) as a growth strategy. We do expect investment in the foundry arena to cool over the next couple of years, as even this sector is trying to absorb oversupply.

As shown in Table 2-2, even with the large investment by dedicated foundries, the Korean companies as a group maintain more than half the capital spending by Asian companies in total. With the introduction of Anam in the foundry industry, along with a recent strategic upgrade-type investment focus on the foundry sector and in fabs located outside Korea by the "big three" Korean companies, Korean companies are expected to gain share of the Asia/Pacific company spending slightly during 1997.

However, because Korean companies are beginning to spend outside Korea, and several foreign multinationals are investing in capacity within the Asia/Pacific region, it is more important to look at where money is being spent to give indications of where wafer fab equipment will be consumed. Table 2-3 is a summary of spending patterns within the Asia/Pacific region.

Table 2-2
Summary of Asia/Pacific Company Capital Spending, 1994 to 1997 (Millions of U.S. Dollars)

Company	1994	1995	Projected 1996	Estimated 1997
Korean Companies	2,540	5,781	7,205	6,191
LG Semicon	800	2,258	2,748	2,248
Hyundai	700	1,492	2,124	1,748
Korea Electronics Co.	20	64	80	72
Samsung	1,000	1,947	2,248	1,873
Other Korean Companies	20	20	5	250
Other Asia/Pacific Companies	1,418	3,423	5,774	4,709
Total Asia/Pacific Companies	3,958	9,204	12,979	10,900
Korean Company Percentage	64.2	62.8	55.5	56.8

Source: Dataquest (January 1997)

Table 2-3
Summary of Asia/Pacific Region Capital Spending and Wafer Fab Equipment, 1994 to 1997 (Millions of U.S. Dollars)

	1994	1995	Projected 1996	Estimated 1997
Korean Company Capital Spending	2,540	5,781	7,205	6,191
Capital Spending within Korea	2,375	5,457	6,840	5,319
Capital Spending within Asia/Pacific	5,720	12,194	15,405	11,205
Korean Percentage of Asia/Pacific Spending	41.5	44.8	44.4	47.5
Wafer Fab Equipment into Korea	1,703	3,141	3,600	2,600
Wafer Fab Equipment into Asia/Pacific	2,567	5,208	6,205	4,339
Korean Percentage of Asia/Pacific Wafer Fab Equipment	66.3	60.3	58.0*	60.0*

*Forecast
Source: Dataquest (January 1997)

The first issue that raises a question is the large difference in the Korean share of capital spending and wafer fab equipment. In 1994, Korea consumed about two-thirds of all wafer fab equipment, but accounted for only a little over 40 percent of all capital spending in the region. This large difference can be explained by the investment in the test and assembly plants throughout Asia, which are concentrated in Taiwan and Malaysia. This investment is represented in semiconductor capital spending but is not counted as part of wafer fab equipment, which is a front-end equipment market.

Worldwide capital spending in 1994 totaled $22.1 billion, of which Dataquest estimates that about 15 percent, or just over $3 billion, was spent on test and assembly facilities. It is reasonable to assume that perhaps two-thirds, or $2 billion, of this spending went into the Asia/Pacific region and can account for the entire difference noted.

During 1995, the foundry investment drove more front-end manufacturing facilities and consumed more wafer fab equipment. This shifted the wafer fab equipment market slightly away from Korea even though Korean capital spending share increased. For 1996, we expect this general trend to have continued. In 1997, we believe that the additional foundry investment by the Korean companies within Korea will increase the Korean share of both capital spending and wafer fab equipment. In the longer term, we would expect that Korea would consume less than half of the wafer fab equipment shipped into the Asia/Pacific region by the turn of the decade.

Equipment Segment and Market Share Trends in Korea

Chapter 3 contains tables that specify the detailed segmented market share of each wafer fab equipment supplier within Korea and the rest of the Asia/Pacific region. Appendix A contains the same information sorted as an alphabetic listing of suppliers.

For the most part, the Korean and rest of Asia/Pacific markets are microcosms of the worldwide wafer fab equipment market. The exceptions, comparing segment emphasis with other regions of the world, are that the Asia/Pacific fabs tend to favor factory automation systems while not encompassing in-line process control techniques and tools as much.

Because this report provides a more detailed look at a regional or account-driven market share, there are notable instances where various companies are shown to have better positions in some markets. Examples of this include:

- Although the stepper market in Korea holds share fairly close to the worldwide market, with Nikon Corporation and Canon Inc. dominant, ASM Lithography NV's strong position in Taiwan places it in the No. 2 spot behind Nikon in the rest of Asia/Pacific market.
- Very clear market splits occur in the E-beam maskmaking lithography market, where Etec Systems Inc. has the Korean market, but Hitachi systems are preferred elsewhere in Asia/Pacific.
- The automated clean station market is dominated in Asia by the Japanese supplier, where Sugai has the lead in Korea, but the rest of Asia/Pacific is a more balanced competitive environment.
- Direct manufacturing presence means a great deal in Korea. Cases where companies have had better than average success in Korea because of their direct presence include Kokusai in tube furnace systems, Varian in sputtering and, particularly, in implant, and, to a lesser extent, Applied Materials in etch and CVD systems.

Chapter 3
1995 Wafer Fab Equipment Segment Market Share Tables for Korea and Rest of Asia/Pacific

Tables 3-1 through 3-11 show the market share of wafer fab equipment suppliers within Korea and the rest of the Asia/Pacific region.

Table 3-1
Sales Revenue from Shipments of Wafer Fab Equipment into Asia/Pacific by Company Base, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Americas Companies						
Lithography	23.6	44.1	12.8	17.4	36.4	61.5
Resist Processing (Track)	8.9	29.5	5.8	28.7	14.7	58.2
Etch and Clean	181.5	401.1	120.5	280.8	302.0	681.9
Deposition	225.3	467.6	150.6	259.2	375.9	726.8
Thermal Nondeposition	3.6	3.4	5.9	11.8	9.5	15.2
Ion Implantation	84.4	154.9	45.6	106.4	130.0	261.3
Process Control	87.4	149.1	55.5	106.2	142.9	255.3
Factory Automation	-	-	-	-	-	-
Other Wafer Fab Equipment	2.8	4.1	0.7	8.4	3.5	12.5
Wafer Fab Equipment	617.5	1,253.8	397.4	818.8	1,014.9	2,072.6
Japanese Companies						
Lithography	267.4	467.1	93.1	227.7	360.4	694.7
Resist Processing (Track)	126.4	174.5	41.6	158.8	168.0	333.3
Etch and Clean	231.5	359.6	91.8	284.5	323.3	644.0
Deposition	113.0	238.2	42.7	121.4	155.7	359.6
Thermal Nondeposition	95.4	139.2	25.5	77.6	120.9	216.8
Ion Implantation	-	-	7.6	9.9	7.6	9.9
Process Control	36.2	76.8	22.1	74.1	58.2	150.8
Factory Automation	-	-	-	-	-	-
Other Wafer Fab Equipment	-	-	-	-	-	-
Wafer Fab Equipment	869.9	1,455.3	324.3	954.0	1,194.2	2,409.3
European Companies						
Lithography	11.1	64.0	52.2	100.2	63.3	164.2
Resist Processing (Track)	0.3	0.2	1.7	5.0	2.0	5.2
Etch and Clean	-	-	-	2.1	-	2.1
Deposition	0.3	4.0	3.7	8.7	4.0	12.7
Thermal Nondeposition	-	2.7	2.6	8.0	2.6	10.7
Ion Implantation	-	-	-	-	-	-
Process Control	10.0	8.2	0.9	2.7	10.9	10.9
Factory Automation	-	-	-	-	-	-

Table 3-1 (Continued)
Sales Revenue from Shipments of Wafer Fab Equipment into Asia/Pacific by Company Base, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Other Wafer Fab Equipment	-	-	-	-	-	-
Wafer Fab Equipment	21.7	79.1	61.1	126.7	82.7	205.8
Joint-Venture Companies						
Lithography	-	-	-	-	-	-
Resist Processing (Track)	-	-	-	-	-	-
Etch and Clean	6.9	21.0	-	0.8	6.9	21.7
Deposition	31.6	39.2	-	8.0	31.6	47.2
Thermal Nondeposition	-	-	-	-	-	-
Ion Implantation	-	-	-	-	-	-
Process Control	-	-	-	-	-	-
Factory Automation	-	-	-	-	-	-
Other Wafer Fab Equipment	-	-	-	-	-	-
Wafer Fab Equipment	38.5	60.1	-	8.8	38.5	68.9
Other Companies						
Lithography	-	-	-	-	-	-
Resist Processing (Track)	-	-	-	-	-	-
Etch and Clean	-	-	-	-	-	-
Deposition	6.0	8.0	9.0	12.0	15.0	20.0
Thermal Nondeposition	-	-	-	-	-	-
Ion Implantation	-	-	-	-	-	-
Process Control	18.3	29.0	10.1	18.1	28.4	47.1
Factory Automation	96.0	186.0	47.0	98.0	143.0	284.0
Other Wafer Fab Equipment	35.0	70.0	15.0	30.0	50.0	100.0
Wafer Fab Equipment	155.3	293.0	81.1	158.1	236.4	451.1
All Companies						
Lithography	302.1	575.2	158.1	345.3	460.1	920.5
Resist Processing (Track)	135.6	204.2	49.1	192.5	184.7	396.7
Etch and Clean	420.0	781.6	212.2	568.1	632.2	1,349.7
Deposition	376.2	757.0	206.0	409.3	582.2	1,166.3
Thermal Nondeposition	99.0	145.3	34.0	97.3	133.0	242.7
Ion Implantation	84.4	154.9	53.2	116.3	137.6	271.2
Process Control	151.8	263.1	88.6	201.0	240.4	464.1
Factory Automation	96.0	186.0	47.0	98.0	143.0	284.0
Other Wafer Fab Equipment	37.8	74.1	15.7	38.4	53.5	112.5
Wafer Fab Equipment	1,702.9	3,141.4	863.8	2,066.3	2,566.7	5,207.7

Note: Figures for "other companies" reflect Dataquest estimates of unsurveyed market activity.
Source: Dataquest (February 1997)

Table 3-2
Sales Revenue from Shipments of Wafer Fab Equipment into Asia/Pacific by Equipment Segment, 1994 to 1995 (User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Lithography						
Americas Companies	23.6	44.1	12.8	17.4	36.4	61.5
Japanese Companies	267.4	467.1	93.1	227.7	360.4	694.7
European Companies	11.1	64.0	52.2	100.2	63.3	164.2
Joint-Venture Companies	-	-	-	-	-	-
Other Companies	-	-	-	-	-	-
All Companies	302.1	575.2	158.1	345.3	460.1	920.5
Resist Processing (Track)						
Americas Companies	8.9	29.5	5.8	28.7	14.7	58.2
Japanese Companies	126.4	174.5	41.6	158.8	168.0	333.3
European Companies	0.3	0.2	1.7	5.0	2.0	5.2
Joint-Venture Companies	-	-	-	-	-	-
Other Companies	-	-	-	-	-	-
All Companies	135.6	204.2	49.1	192.5	184.7	396.7
Etch and Clean						
Americas Companies	181.5	401.1	120.5	280.8	302.0	681.9
Japanese Companies	231.5	359.6	91.8	284.5	323.3	644.0
European Companies	-	-	-	2.1	-	2.1
Joint-Venture Companies	6.9	21.0	-	0.8	6.9	21.7
Other Companies	-	-	-	-	-	-
All Companies	420.0	781.6	212.2	568.1	632.2	1,349.7
Deposition						
Americas Companies	225.3	467.6	150.6	259.2	375.9	726.8
Japanese Companies	113.0	238.2	42.7	121.4	155.7	359.6
European Companies	0.3	4.0	3.7	8.7	4.0	12.7
Joint-Venture Companies	31.6	39.2	-	8.0	31.6	47.2
Other Companies	6.0	8.0	9.0	12.0	15.0	20.0
All Companies	376.2	757.0	206.0	409.3	582.2	1,166.3
Thermal Nondeposition						
Americas Companies	3.6	3.4	5.9	11.8	9.5	15.2
Japanese Companies	95.4	139.2	25.5	77.6	120.9	216.8
European Companies	-	2.7	2.6	8.0	2.6	10.7
Joint-Venture Companies	-	-	-	-	-	-
Other Companies	-	-	-	-	-	-
All Companies	99.0	145.3	34.0	97.3	133.0	242.7

Table 3-2 (Continued)
Sales Revenue from Shipments of Wafer Fab Equipment into Asia/Pacific by Equipment Segment, 1994 to 1995 (User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Ion Implantation						
Americas Companies	84.4	154.9	45.6	106.4	130.0	261.3
Japanese Companies	-	-	7.6	9.9	7.6	9.9
European Companies	-	-	-	-	-	-
Joint-Venture Companies	-	-	-	-	-	-
Other Companies	-	-	-	-	-	-
All Companies	84.4	154.9	53.2	116.3	137.6	271.2
Process Control						
Americas Companies	87.4	149.1	55.5	106.2	142.9	255.3
Japanese Companies	36.2	76.8	22.1	74.1	58.2	150.8
European Companies	10.0	8.2	0.9	2.7	10.9	10.9
Joint-Venture Companies	-	-	-	-	-	-
Other Companies	18.3	29.0	10.1	18.1	28.4	47.1
All Companies	151.8	263.1	88.6	201.0	240.4	464.1
Factory Automation						
Americas Companies	-	-	-	-	-	-
Japanese Companies	-	-	-	-	-	-
European Companies	-	-	-	-	-	-
Joint-Venture Companies	-	-	-	-	-	-
Other Companies	96.0	186.0	47.0	98.0	143.0	284.0
All Companies	96.0	186.0	47.0	98.0	143.0	284.0
Other Wafer Fab Equipment						
Americas Companies	2.8	4.1	0.7	8.4	3.5	12.5
Japanese Companies	-	-	-	-	-	-
European Companies	-	-	-	-	-	-
Joint-Venture Companies	-	-	-	-	-	-
Other Companies	35.0	70.0	15.0	30.0	50.0	100.0
All Companies	37.8	74.1	15.7	38.4	53.5	112.5
Wafer Fab Equipment						
Americas Companies	617.5	1,253.8	397.4	818.8	1,014.9	2,072.6
Japanese Companies	869.9	1,455.3	324.3	954.0	1,194.2	2,409.3
European Companies	21.7	79.1	61.1	126.7	82.7	205.8
Joint-Venture Companies	38.5	60.1	-	8.8	38.5	68.9
Other Companies	155.3	293.0	81.1	158.1	236.4	451.1
All Companies	1,702.9	3,141.4	863.8	2,066.3	2,566.7	5,207.7

Note: Figures for "other companies" reflect Dataquest estimates of unsurveyed market activity.
Source: Dataquest (February 1997)

Table 3-3
Individual Company Sales Revenue from Shipments of Lithography Equipment into Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Contact/Proximity						
Canon	-	-	0.5	0.5	0.5	0.5
Karl Suss	1.5	2.2	3.9	7.5	5.4	9.7
Total	1.5	2.2	4.4	8.0	5.9	10.2
Projection Aligners						
Silicon Valley Group	-	-	2.6	1.4	2.6	1.4
Total	-	-	2.6	1.4	2.6	1.4
Steppers						
ASM Lithography	9.6	61.8	45.5	92.0	55.1	153.8
Canon	50.6	142.2	33.7	67.1	84.3	209.3
Integrated Solutions	-	-	-	3.3	-	3.3
Nikon	214.3	324.9	50.7	153.1	265.0	478.0
Silicon Valley Group	3.8	8.4	-	-	3.8	8.4
Ultratech	10.3	25.7	7.3	12.7	17.6	38.4
Total	288.6	563.0	137.2	328.2	425.8	891.2
Direct-Write E-Beam Lithography						
Hitachi	2.5	-	2.5	-	5.0	-
Leica	-	-	-	0.7	-	0.7
Total	2.5	-	2.5	0.7	5.0	0.7
E-Beam Maskmaking Lithography						
Etec	9.5	10.0	-	-	9.5	10.0
Hitachi	-	-	5.7	6.9	5.7	6.9
Jenoptik	-	-	2.8	-	2.8	-
Total	9.5	10.0	8.5	6.9	18.0	16.9
Optical Maskmaking Lithography						
Etec	-	-	2.9	-	2.9	-
Total	-	-	2.9	-	2.9	-

Note: Totals report sum of Dataquest estimates for individual companies; figures exclude estimates of unsurveyed market activity.
Source: Dataquest (February 1997)

Table 3-4
Individual Company Shipments of Steppers into Asia/Pacific, 1994 to 1995 (Units)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
ASM Lithography	3	17	20	24	23	41
Canon	24	52	16	26	40	78
Integrated Solutions	-	-	-	2	-	2
Nikon	90	108	20	54	110	162
Silicon Valley Group	1	2	-	-	1	2
Ultratech	10	18	6	10	16	28
Total	128	197	62	116	190	313

Note: Totals report sum of Dataquest estimates for individual companies; figures exclude estimates of unsurveyed market activity.
Source: Dataquest (February 1997)

Table 3-5
Individual Company Sales Revenue from Shipments of Track Equipment into Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Dainippon Screen	26.3	24.7	8.9	8.2	35.2	32.9
Fairchild Convac	0.3	0.2	1.7	5.0	2.0	5.2
FSI International	6.8	24.5	-	-	6.8	24.5
Integrated Solutions	-	-	-	0.7	-	0.7
Semiconductor Systems	-	-	0.8	-	0.8	-
Silicon Valley Group	2.1	5.0	5.0	28.0	7.1	33.0
Tazmo	3.5	5.1	-	-	3.5	5.1
Tokyo Electron Ltd.	96.6	144.7	32.7	150.6	129.3	295.4
Total	135.6	204.2	49.1	192.5	184.7	396.7

Note: Totals report sum of Dataquest estimates for individual companies; figures exclude estimates of unsurveyed market activity.
Source: Dataquest (February 1997)

Table 3-6
Individual Company Sales Revenue from Shipments of Etch and Clean Equipment into Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Auto Wet Stations						
CFM Technology	2.3	1.3	-	-	2.3	1.3
Dainippon Screen	42.5	11.7	12.9	33.2	55.4	45.0
Dan Science Co. Ltd.	-	-	2.2	4.0	2.2	4.0
Kaijo Denki	11.8	41.2	5.8	28.6	17.6	69.8
Maruwa	0.6	0.3	1.0	1.8	1.6	2.1
Sankyo Engineering	19.2	0.9	5.0	16.7	24.2	17.6
Santa Clara Plastics	-	-	2.6	-	2.6	-
Sugai	17.7	80.9	1.8	29.7	19.5	110.6
Toho Kasei	-	-	1.3	2.1	1.3	2.1
Tokyo Electron Ltd.	4.2	41.9	4.8	24.3	9.0	66.2
Total	98.2	178.2	37.4	140.4	135.7	318.6
Spray Processors						
Dainippon Screen	-	-	0.4	-	0.4	-
FSI International	0.4	-	3.8	6.2	4.2	6.2
Semitool (Including Semitherm)	0.5	0.9	1.4	1.6	1.9	2.5
Total	0.9	0.9	5.6	7.8	6.5	8.7
Vapor Phase Clean						
FSI International	2.0	0.2	0.7	3.8	2.7	4.0
Total	2.0	0.2	0.7	3.8	2.7	4.0
Post-CMP Clean						
Dainippon Screen	-	-	-	0.7	-	0.7
FSI International	0.5	-	0.3	-	0.8	-
IPEC/Planar	-	1.5	1.0	-	1.0	1.5
OnTrak Systems	-	0.8	0.4	1.1	0.4	1.9
Total	0.5	2.3	1.7	1.8	2.2	4.1
Other Clean Process						
Dainippon Screen	10.3	13.9	4.0	20.7	14.3	34.7
Dan Science Co. Ltd.	-	1.4	0.4	0.5	0.4	1.9
ET Systems Engineering	-	-	-	0.4	-	0.4
FSI International	-	-	0.3	-	0.3	-
IPEC/Planar	-	1.2	-	-	-	1.2
Maruwa	-	-	0.6	0.4	0.6	0.4
Semitool (Including Semitherm)	0.3	0.4	0.3	1.3	0.6	1.7
SubMicron Systems Inc.	-	-	1.9	3.1	1.9	3.1
Sugai	-	-	0.1	0.3	0.1	0.3
Toho Kasei	-	-	-	2.1	-	2.1
Toyoko Kagaku	-	-	0.8	1.1	0.8	1.1
Verteq	0	0.1	0.7	1.2	0.7	1.3

Table 3-6 (Continued)
Individual Company Sales Revenue from Shipments of Etch and Clean Equipment into Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Total	10.6	17.0	9.1	31.2	19.8	48.2
Chemical Mechanical Polishing						
IPEC/Planar	0.7	3.5	0.9	5.0	1.6	8.5
Strasbaugh	-	0.5	-	-	-	0.5
Total	0.7	4.0	0.9	5.0	1.6	9.0
Dry Strip						
Alcan Technology	6.9	21.0	-	0.8	6.9	21.7
Fusion Semiconductor Systems	2.3	3.8	1.1	1.8	3.4	5.6
GaSonics	6.2	9.3	2.6	4.5	8.8	13.9
Hitachi	-	1.7	1.2	1.0	1.2	2.7
Matrix Integrated Systems	0.8	1.2	0.7	1.1	1.5	2.3
Mattson Technologies	1.1	6.9	1.4	9.4	2.5	16.3
MC Electronics	11.9	18.0	-	2.9	11.9	20.9
Plasma Systems	18.1	19.2	8.8	18.5	26.9	37.7
Sumitomo Metals	-	-	-	3.0	-	3.0
Tegal	-	-	0.7	0.5	0.7	0.5
Tokyo Ohka Kogyo	-	-	-	1.2	-	1.2
Total	47.3	81.0	16.5	44.8	63.8	125.8
Low-Density Etch						
Anelva	-	0.3	-	0.0	-	0.4
Applied Materials	88.6	199.7	40.4	124.8	129.0	324.5
E.T. Electrotech	-	-	-	2.1	-	2.1
GaSonics	0.3	-	0.3	-	0.6	-
Lam Research	34.8	87.4	42.6	85.5	77.4	172.9
Matrix Integrated Systems	0.7	1.0	0.5	0.7	1.2	1.7
Plasma Systems	-	-	-	1.1	-	1.1
Tegal	-	-	8.9	5.3	8.9	5.3
Tokyo Electron Ltd.	60.0	66.5	27.4	76.3	87.4	142.8
Total	184.4	354.9	120.1	295.8	304.5	650.7
High-Density Etch						
Anelva	-	-	1.3	-	1.3	-
Applied Materials	-	21.2	-	5.6	-	26.8
Hitachi	32.5	58.6	11.8	10.7	44.3	69.2
Lam Research	36.6	58.2	7.0	14.2	43.6	72.4
Plasma and Materials Technologies	3.4	2.0	-	-	3.4	2.0
Sumitomo Metals	2.9	3.1	-	3.1	2.9	6.2
Tegal	-	-	-	4.0	-	4.0
Total	75.4	143.0	20.1	37.6	95.5	180.6

Note: Totals report sum of Dataquest estimates for individual companies; figures exclude estimates of unsurveyed market activity.
Source: Dataquest (February 1997)

Table 3-7
Individual Company Sales Revenue from Shipments of Deposition Equipment into Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Horizontal Tube LPCVD						
Silicon Valley Group	-	-	0.3	0.8	0.3	0.8
Total	-	-	0.3	0.8	0.3	0.8
Vertical Tube LPCVD						
ASM International	-	2.0	-	1.0	-	3.0
Kokusai Electric	64.0	126.3	1.9	11.5	65.9	137.7
Semitherm	-	1.7	-	-	-	1.7
Shinko Electric	-	-	0.6	-	0.6	-
Silicon Valley Group	-	-	0.6	-	0.6	-
Tokyo Electron Ltd.	46.9	90.7	22.5	60.4	69.4	151.1
Toyoko Kagaku	-	-	1.3	1.4	1.3	1.4
Total	110.9	220.6	26.9	74.3	137.8	294.9
Horizontal Tube PECVD						
ASM International	0.3	0.3	0.3	0.7	0.6	1.0
Total	0.3	0.3	0.3	0.7	0.6	1.0
Atmospheric/Subatmospheric Pressure CVD						
Alcan Technology (Including Quester)	31.6	39.2	-	8.0	31.6	47.2
Amaya	-	2.6	-	5.2	-	7.8
Applied Materials	-	-	-	7.7	-	7.7
Watkins-Johnson	33.0	48.0	17.2	34.0	50.2	82.0
Total	64.6	89.7	17.2	54.9	81.8	144.7
Dedicated LPCVD Reactors						
Anelva	-	-	-	0	-	0
Applied Materials	15.2	33.3	3.9	16.7	19.1	50.0
Genus	10.0	45.0	1.3	-	11.3	45.0
Materials Research Corporation	-	-	-	2.4	-	2.4
Novellus Systems Inc.	4.6	8.9	-	6.2	4.6	15.1
Tokyo Electron Ltd.	2.1	15.7	-	2.9	2.1	18.5
Total	31.9	102.9	5.2	28.2	37.1	131.1
Dedicated PECVD Reactors						
Applied Materials	45.1	98.0	13.5	49.0	58.6	147.0
ASM International	-	1.7	-	-	-	1.7
Novellus Systems Inc.	17.1	31.9	11.8	13.8	28.9	45.7
Total	62.2	131.6	25.3	62.8	87.5	194.4

Table 3-7 (Continued)
Individual Company Sales Revenue from Shipments of Deposition Equipment into Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Sputtering						
Anelva	-	0.1	9.2	19.7	9.2	19.8
Applied Materials	54.0	112.8	50.9	116.3	104.9	229.0
CHA Industries	0.6	-	-	-	0.6	-
Denton Vacuum	-	-	1.5	1.6	1.5	1.6
Kurt J. Lesker	-	0.5	0.2	-	0.2	0.5
Materials Research Corporation	-	-	7.1	18.0	7.1	18.0
Varian	43.4	86.4	46.6	11.0	90.0	97.4
Total	98.0	199.8	115.5	166.5	213.5	366.3
Silicon Epitaxy						
Applied Materials	-	-	2.8	1.6	2.8	1.6
ASM International	-	-	2.4	5.0	2.4	5.0
Concept Systems Design	2.3	1.2	-	0.5	2.3	1.7
LPE	-	-	1.0	2.0	1.0	2.0
Toshiba	-	1.4	-	-	-	1.4
Total	2.3	2.6	6.2	9.1	8.5	11.7

Note: Totals report sum of Dataquest estimates for individual companies; figures exclude estimates of unsurveyed market activity.
Source: Dataquest (February 1997)

Table 3-8
Individual Company Sales Revenue from Shipments of Thermal Nondeposition Equipment into Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Diffusion						
ASM International	-	1.0	-	-	-	1.0
Kokusai Electric	55.7	106.9	3.4	17.9	59.1	124.8
Koyo Lindberg	1.1	2.7	1.0	2.4	2.1	5.1
Pacific Western	-	-	0.3	0.3	0.3	0.3
Shinko Electric	-	-	2.7	2.6	2.7	2.6
Silicon Valley Group	0.6	1.0	0.6	1.4	1.2	2.4
Tokyo Electron Ltd.	38.6	29.7	18.4	54.6	57.0	84.3
Total	96.0	141.2	26.4	79.3	122.4	220.5
Rapid Thermal Processing						
AET Thermal	-	0.1	-	-	-	0.1
AG Associates	3.0	1.3	5.0	7.8	8.0	9.1
Applied Materials	-	-	-	2.3	-	2.3
AST Electronic GmbH	-	1.6	1.7	6.7	1.7	8.3
High Temperature Engineering	-	1.1	-	-	-	1.1
Jipelec	-	-	0.9	1.3	0.9	1.3
Total	3.0	4.1	7.6	18.1	10.6	22.2

Note: Totals report sum of Dataquest estimates for individual companies; figures exclude estimates of unsurveyed market activity.
Source: Dataquest (February 1997)

Table 3-9
Individual Company Sales Revenue from Shipments of Ion Implanters into Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Medium-Current Implanter						
Eaton	-	3.7	-	3.7	-	7.4
Nissin Electric	-	-	7.6	9.9	7.6	9.9
Varian	25.7	50.4	10.4	33.4	36.1	83.8
Total	25.7	54.1	18.0	47.0	43.7	101.1
High-Current Implanter						
Applied Materials	-	2.7	2.9	5.4	2.9	8.1
Eaton	2.2	13.0	30.6	52.8	32.8	65.8
Varian	37.1	46.3	1.7	7.3	38.8	53.6
Total	39.3	62.0	35.2	65.5	74.5	127.5
High-Voltage Implanter						
Eaton	-	13.2	-	3.8	-	17.0
Genus	19.4	25.6	-	-	19.4	25.6
Total	19.4	38.8	-	3.8	19.4	42.6

Note: Totals report sum of Dataquest estimates for individual companies; figures exclude estimates of unsurveyed market activity.
Source: Dataquest (February 1997)

Table 3-10
Individual Company Shipments of Ion Implanters into Asia/Pacific, 1994 to 1995 (Units)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Medium-Current Implanter						
Eaton	-	2	-	3	-	5
Nissin Electric	-	-	5	5	5	5
Varian	15	26	6	18	21	44
Total	15	28	11	26	26	54
High-Current Implanter						
Applied Materials	-	1	1	2	1	3
Eaton	1	6	14	23	15	29
Varian	17	20	1	3	18	23
Total	18	27	16	28	34	55
High-Voltage Implanter						
Eaton	-	4	-	1	-	5
Genus	6	8	-	-	6	8
Total	6	12	-	1	6	13

Note: Totals report sum of Dataquest estimates for individual companies; figures exclude estimates of unsurveyed market activity.
Source: Dataquest (February 1997)

Table 3-11
Individual Company Sales Revenue from Shipments of Process Control Equipment into Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Optical Metrology						
Biorad	1.9	1.4	-	0.9	1.9	2.2
Hitachi	2.6	0.9	-	-	2.6	0.9
IVS Inc.	0.9	0.9	-	-	0.9	0.9
KLA Instruments	4.2	6.8	2.0	-	6.2	6.8
Leica	0.2	0.1	-	-	0.2	0.1
Optical Specialties Inc.	1.9	10.2	1.2	1.2	3.1	11.4
Total	11.5	20.2	3.2	2.1	14.8	22.2
CD SEM						
Hitachi	9.8	41.2	19.7	47.7	29.5	88.9
Holon	7.9	5.1	-	-	7.9	5.1
JEOL	1.6	-	0.7	-	2.3	-
Opal	-	1.2	5.1	4.0	5.1	5.2
Total	19.3	47.5	25.5	51.7	44.8	99.2
Thin-Film Measurement						
Dainippon Screen	-	0.2	0.5	0.5	0.5	0.7
Leica	0.3	0.2	-	0.2	0.3	0.4
Nanometrics	0.6	1.2	0.5	0.6	1.1	1.8
Rudolph Research	3.0	5.4	1.0	3.3	4.0	8.7
Tencor Instruments	9.9	6.6	-	8.3	9.9	14.9
Thermawave	4.4	15.3	1.5	3.1	5.9	18.4
Total	18.2	28.9	3.5	16.0	21.7	44.9
Auto Patterned Detection						
Hitachi	-	6.5	-	10.6	-	17.1
Inspex	11.6	13.8	1.5	3.1	13.1	16.9
KLA Instruments	33.4	51.7	16.4	45.3	49.8	97.0
Optical Specialties Inc.	-	3.4	-	-	-	3.4
Tencor Instruments	5.2	7.9	2.1	5.0	7.3	12.9
Total	50.2	83.3	20.0	64.0	70.2	147.3
Auto Review and Classification						
Amray	-	3.6	-	-	-	3.6
Hitachi	2.5	2.7	-	-	2.5	2.7
Inspex	6.2	8.5	0.3	0.7	6.5	9.2
JEOL	3.8	14.4	1.0	8.5	4.7	22.9
Leica	1.8	2.6	0.7	1.7	2.5	4.3
Seiko	-	2.0	-	-	-	2.0
Ultrapointe	0.3	0.4	-	-	0.3	0.4
Total	14.6	34.2	2.0	10.8	16.5	45.0

Table 3-11 (Continued)
Individual Company Sales Revenue from Shipments of Process Control Equipment into Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Manual Detection and Review						
Lasertec Corporation	0.5	0.7	0.3	0.2	0.7	1.0
Leica	7.7	5.3	0.2	0.8	7.9	6.1
Nidek	2.8	-	-	-	2.8	-
Nikon	3.7	0.6	-	6.5	3.7	7.2
Total	14.7	6.7	0.5	7.5	15.1	14.2
Auto Unpatterned Detection						
ADE Corporation	-	-	1.1	2.6	1.1	2.6
Hitachi	1.1	2.4	-	-	1.1	2.4
Tencor Instruments	4.1	7.8	3.8	8.6	7.9	16.4
Total	5.1	10.2	4.9	11.2	10.1	21.4
Other Process Control						
ADE Corporation	-	-	2.9	10.1	2.9	10.1
KLA Instruments	-	-	1.9	2.5	1.9	2.5
Tencor Instruments	-	3.1	14.0	7.0	14.0	10.1
Total	-	3.1	18.8	19.6	18.8	22.7

Notes: Totals report sum of Dataquest estimates for individual companies; figures exclude estimates of unsurveyed market activity.
Auto Patterned Detection encompasses automated patterned wafer defect and particle detection systems; KLA and Tencor figures may include auto review systems.
Auto Review and Classification encompasses automated patterned wafer defect review and classification systems.
Manual Detection and Review encompasses operator-based patterned wafer defect and particle detection systems.
Auto Unpatterned Detection encompasses automated unpatterned wafer defect and particle detection systems.
Source: Dataquest (February 1997)

Appendix A
Alphabetic Listing of Wafer Fab Equipment Suppliers

Table A-1 lists wafer fab equipment suppliers.

Table A-1
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
ADE Corporation						
Auto Unpatterned Detection	-	-	1.1	2.6	1.1	2.6
Other Process Control	-	-	2.9	10.1	2.9	10.1
Wafer Fab Equipment	-	-	4.0	12.7	4.0	12.7
AET Thermal						
Rapid Thermal Processing	-	0.1	-	-	-	0.1
Wafer Fab Equipment	-	0.1	-	-	-	0.1
AG Associates						
Rapid Thermal Processing	3.0	1.3	5.0	7.8	8.0	9.1
Wafer Fab Equipment	3.0	1.3	5.0	7.8	8.0	9.1
Alcan Technology						
Dry Strip	6.9	21.0	-	0.8	6.9	21.7
Atmospheric/Subatmospheric Pressure CVD	31.6	39.2	-	8.0	31.6	47.2
Wafer Fab Equipment	38.5	60.1	-	8.8	38.5	68.9
Amaya						
Atmospheric/Subatmospheric Pressure CVD	-	2.6	-	5.2	-	7.8
Wafer Fab Equipment	-	2.6	-	5.2	-	7.8
Amray						
Auto Review and Classification	-	3.6	-	-	-	3.6
Wafer Fab Equipment	-	3.6	-	-	-	3.6
Anelva						
Dry Etch	-	0.3	1.3	0	1.3	0.4
Dedicated LPCVD Reactors	-	-	-	0	-	0
Sputtering	-	0.1	9.2	19.7	9.2	19.8
Other Deposition	-	1.5	-	-	-	1.5
Wafer Fab Equipment	-	1.9	10.5	19.7	10.5	21.7
Applied Materials						
Dry Etch	88.6	220.9	40.4	130.5	129.0	351.4
Dedicated LPCVD Reactors	15.2	33.3	3.9	16.7	19.1	50.0
Dedicated PECVD Reactors	45.1	98.0	13.5	49.0	58.6	147.0
Atmospheric/Subatmospheric Pressure CVD	-	-	-	7.7	-	7.7

Table A-1 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Sputtering	54.0	112.8	50.9	116.3	104.9	229.0
Silicon Epitaxy	-	-	2.8	1.6	2.8	1.6
Rapid Thermal Processing	-	-	-	2.3	-	2.3
High-Current Implanter	-	2.7	2.9	5.4	2.9	8.1
Wafer Fab Equipment	202.9	467.6	114.4	329.5	317.3	797.1
ASM International						
Vertical Tube LPCVD	-	2.0	-	1.0	-	3.0
Horizontal Tube PECVD	0.3	0.3	0.3	0.7	0.6	1.0
Dedicated PECVD Reactors	-	1.7	-	-	-	1.7
Silicon Epitaxy	-	-	2.4	5.0	2.4	5.0
Vertical Diffusion	-	1.0	-	-	-	1.0
Wafer Fab Equipment	0.3	5.0	2.7	6.7	3.0	11.7
ASM Lithography						
Steppers	9.6	61.8	45.5	92.0	55.1	153.8
Wafer Fab Equipment	9.6	61.8	45.5	92.0	55.1	153.8
AST Electronic GmbH						
Rapid Thermal Processing	-	1.6	1.7	6.7	1.7	8.3
Wafer Fab Equipment	-	1.6	1.7	6.7	1.7	8.3
Biorad						
Optical Metrology	1.9	1.4	-	0.9	1.9	2.2
Wafer Fab Equipment	1.9	1.4	-	0.9	1.9	2.2
Canon						
Contact/Proximity	-	-	0.5	0.5	0.5	0.5
Steppers	50.6	142.2	33.7	67.1	84.3	209.3
Wafer Fab Equipment	50.6	142.2	34.2	67.6	84.8	209.8
CFM Technology						
Auto Wet Stations	2.3	1.3	-	-	2.3	1.3
Wafer Fab Equipment	2.3	1.3	-	-	2.3	1.3
CHA Industries						
Sputtering	0.6	-	-	-	0.6	-
Wafer Fab Equipment	0.6	-	-	-	0.6	-
Concept Systems Design						
Silicon Epitaxy	2.3	1.2	-	0.5	2.3	1.7
Wafer Fab Equipment	2.3	1.2	-	0.5	2.3	1.7
Dainippon Screen						
Resist Processing (Track)	26.3	24.7	8.9	8.2	35.2	32.9
Auto Wet Stations	42.5	11.7	12.9	33.2	55.4	45.0
Spray Processors	-	-	0.4	-	0.4	-

Table A-1 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Post-CMP Clean	-	-	-	0.7	-	0.7
Other Clean Process	10.3	13.9	4.0	20.7	14.3	34.7
Thin-Film Measurement	-	0.2	0.5	0.5	0.5	0.7
Wafer Fab Equipment	79.1	50.5	26.8	63.4	105.8	113.9
Dan Science Co. Ltd.						
Auto Wet Stations	-	-	2.2	4.0	2.2	4.0
Other Clean Process	-	1.4	0.4	0.5	0.4	1.9
Wafer Fab Equipment	-	1.4	2.6	4.5	2.6	5.9
Denton Vacuum						
Sputtering	-	-	1.5	1.6	1.5	1.6
Wafer Fab Equipment	-	-	1.5	1.6	1.5	1.6
E.T. Electrotech						
Dry Etch	-	-	-	2.1	-	2.1
Wafer Fab Equipment	-	-	-	2.1	-	2.1
Eaton						
Medium-Current Implanter	-	3.7	-	3.7	-	7.4
High-Current Implanter	2.2	13.0	30.6	52.8	32.8	65.8
High-Voltage Implanter	-	13.2	-	3.8	-	17.0
Wafer Fab Equipment	2.2	29.9	30.6	60.3	32.8	90.2
ET Systems Engineering						
Other Clean Process	-	-	-	0.4	-	0.4
Wafer Fab Equipment	-	-	-	0.4	-	0.4
Etec						
Maskmaking Lithography	9.5	10.0	2.9	-	12.4	10.0
Wafer Fab Equipment	9.5	10.0	2.9	-	12.4	10.0
Fairchild Convac						
Resist Processing (Track)	0.3	0.2	1.7	5.0	2.0	5.2
Wafer Fab Equipment	0.3	0.2	1.7	5.0	2.0	5.2
FSI International						
Resist Processing (Track)	6.8	24.5	-	-	6.8	24.5
Spray Processors	0.4	-	3.8	6.2	4.2	6.2
Vapor Phase Clean	2.0	0.2	0.7	3.8	2.7	4.0
Post-CMP Clean	0.5	-	0.3	-	0.8	-
Other Clean Process	-	-	0.3	-	0.3	-
Wafer Fab Equipment	9.7	24.7	5.1	10.0	14.8	34.7
Fusion Semiconductor Systems						
Dry Strip	2.3	3.8	1.1	1.8	3.4	5.6
Other Wafer Fab Equipment	2.8	4.1	0.7	1.3	3.5	5.4

Table A-1 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Wafer Fab Equipment	5.1	7.9	1.8	3.1	6.9	11.0
GaSonics						
Dry Strip	6.2	9.3	2.6	4.5	8.8	13.9
Dry Etch	0.3	-	0.3	-	0.6	-
Wafer Fab Equipment	6.5	9.3	2.9	4.5	9.4	13.9
Genus						
Dedicated LPCVD Reactors	10.0	45.0	1.3	-	11.3	45.0
High-Voltage Implanter	19.4	25.6	-	-	19.4	25.6
Wafer Fab Equipment	29.4	70.6	1.3	-	30.7	70.6
High Temperature Engineering						
Rapid Thermal Processing	-	1.1	-	-	-	1.1
Wafer Fab Equipment	-	1.1	-	-	-	1.1
Hitachi						
Direct-Write Lithography	2.5	-	2.5	-	5.0	-
Maskmaking Lithography	-	-	5.7	6.9	5.7	6.9
Dry Strip	-	1.7	1.2	1.0	1.2	2.7
Dry Etch	32.5	58.6	11.8	10.7	44.3	69.2
Optical Metrology	2.6	0.9	-	-	2.6	0.9
CD SEM	9.8	41.2	19.7	47.7	29.5	88.9
Auto Patterned Detection	-	6.5	-	10.6	-	17.1
Auto Review and Classification	2.5	2.7	-	-	2.5	2.7
Auto Unpatterned Detection	1.1	2.4	-	-	1.1	2.4
Wafer Fab Equipment	50.9	114.0	40.9	77.0	91.7	190.9
Holon						
CD SEM	7.9	5.1	-	-	7.9	5.1
Wafer Fab Equipment	7.9	5.1	-	-	7.9	5.1
Inspex						
Auto Patterned Detection	11.6	13.8	1.5	3.1	13.1	16.9
Auto Review and Classification	6.2	8.5	0.3	0.7	6.5	9.2
Wafer Fab Equipment	17.8	22.3	1.8	3.8	19.6	26.1
Integrated Solutions						
Steppers	-	-	-	3.3	-	3.3
Resist Processing (Track)	-	-	-	0.7	-	0.7
Other Wafer Fab Equipment	-	-	-	7.1	-	7.1
Wafer Fab Equipment	-	-	-	11.1	-	11.1
IPEC/Planar						
Post-CMP Clean	-	1.5	1.0	-	1.0	1.5
Other Clean Process	-	1.2	-	-	-	1.2
Chemical Mechanical Polishing	0.7	3.5	0.9	5.0	1.6	8.5

Table A-1 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Wafer Fab Equipment	0.7	6.2	1.9	5.0	2.6	11.2
IVS Inc.						
Optical Metrology	0.9	0.9	-	-	0.9	0.9
Wafer Fab Equipment	0.9	0.9	-	-	0.9	0.9
Jenoptik						
Maskmaking Lithography	-	-	2.8	-	2.8	-
Wafer Fab Equipment	-	-	2.8	-	2.8	-
JEOL						
CD SEM	1.6	-	0.7	-	2.3	-
Auto Review and Classification	3.8	14.4	1.0	8.5	4.7	22.9
Wafer Fab Equipment	5.4	14.4	1.7	8.5	7.0	22.9
Jipelec						
Rapid Thermal Processing	-	-	0.9	1.3	0.9	1.3
Wafer Fab Equipment	-	-	0.9	1.3	0.9	1.3
Kaijo Denki						
Auto Wet Stations	11.8	41.2	5.8	28.6	17.6	69.8
Wafer Fab Equipment	11.8	41.2	5.8	28.6	17.6	69.8
KLA Instruments						
Optical Metrology	4.2	6.8	2.0	-	6.2	6.8
Auto Patterned Detection	33.4	51.7	16.4	45.3	49.8	97.0
Other Process Control	-	-	1.9	2.5	1.9	2.5
Wafer Fab Equipment	37.5	58.5	20.4	47.8	57.9	106.3
Kokusai Electric						
Vertical Tube LPCVD	64.0	126.3	1.9	11.5	65.9	137.7
Vertical Diffusion	55.7	106.9	3.4	17.9	59.1	124.8
Wafer Fab Equipment	119.7	233.2	5.4	29.4	125.0	262.6
Koyo Lindberg						
Vertical Diffusion	1.1	2.7	1.0	2.4	2.1	5.1
Wafer Fab Equipment	1.1	2.7	1.0	2.4	2.1	5.1
Lam Research						
Dry Etch	71.4	145.6	49.6	99.7	121.0	245.3
Wafer Fab Equipment	71.4	145.6	49.6	99.7	121.0	245.3
Lasertec Corporation						
Manual Detection and Review	0.5	0.7	0.3	0.2	0.7	1.0
Wafer Fab Equipment	0.5	0.7	0.3	0.2	0.7	1.0
Leica						
Direct-Write Lithography	-	-	-	0.7	-	0.7
Optical Metrology	0.2	0.1	-	-	0.2	0.1

Table A-1 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Thin-Film Measurement	0.3	0.2	-	0.2	0.3	0.4
Auto Review and Classification	1.8	2.6	0.7	1.7	2.5	4.3
Manual Detection and Review	7.7	5.3	0.2	0.8	7.9	6.1
Wafer Fab Equipment	10.0	8.2	0.9	3.4	10.9	11.6
Kurt J. Lesker						
Sputtering	-	0.5	0.2	-	0.2	0.5
Wafer Fab Equipment	-	0.5	0.2	-	0.2	0.5
LPE						
Silicon Epitaxy	-	-	1.0	2.0	1.0	2.0
Wafer Fab Equipment	-	-	1.0	2.0	1.0	2.0
Maruwa						
Auto Wet Stations	0.6	0.3	1.0	1.8	1.6	2.1
Other Clean Process	-	-	0.6	0.4	0.6	0.4
Wafer Fab Equipment	0.6	0.3	1.6	2.2	2.2	2.5
Materials Research Corporation						
Dedicated LPCVD Reactors	-	-	-	2.4	-	2.4
Sputtering	-	-	7.1	18.0	7.1	18.0
Wafer Fab Equipment	-	-	7.1	20.4	7.1	20.4
Matrix Integrated Systems						
Dry Strip	0.8	1.2	0.7	1.1	1.5	2.3
Dry Etch	0.7	1.0	0.5	0.7	1.2	1.7
Wafer Fab Equipment	1.5	2.2	1.2	1.8	2.7	4.0
Mattson Technologies						
Dry Strip	1.1	6.9	1.4	9.4	2.5	16.3
Wafer Fab Equipment	1.1	6.9	1.4	9.4	2.5	16.3
MC Electronics						
Dry Strip	11.9	18.0	-	2.9	11.9	20.9
Wafer Fab Equipment	11.9	18.0	-	2.9	11.9	20.9
Nanometrics						
Thin-Film Measurement	0.6	1.2	0.5	0.6	1.1	1.8
Wafer Fab Equipment	0.6	1.2	0.5	0.6	1.1	1.8
Nidek						
Manual Detection and Review	2.8	-	-	-	2.8	-
Wafer Fab Equipment	2.8	-	-	-	2.8	-
Nikon						
Steppers	214.3	324.9	50.7	153.1	265.0	478.0
Manual Detection and Review	3.7	0.6	-	6.5	3.7	7.2
Wafer Fab Equipment	218.0	325.5	50.7	159.7	268.7	485.2

Table A-1 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Nissin Electric						
Medium-Current Implanter	-	-	7.6	9.9	7.6	9.9
Wafer Fab Equipment	-	-	7.6	9.9	7.6	9.9
Novellus Systems Inc.						
Dedicated LPCVD Reactors	4.6	8.9	-	6.2	4.6	15.1
Dedicated PECVD Reactors	17.1	31.9	11.8	13.8	28.9	45.7
Wafer Fab Equipment	21.7	40.8	11.8	20.0	33.5	60.8
OnTrak Systems						
Post-CMP Clean	-	0.8	0.4	1.1	0.4	1.9
Wafer Fab Equipment	-	0.8	0.4	1.1	0.4	1.9
Opal						
CD SEM	-	1.2	5.1	4.0	5.1	5.2
Wafer Fab Equipment	-	1.2	5.1	4.0	5.1	5.2
Optical Specialties Inc.						
Optical Metrology	1.9	10.2	1.2	1.2	3.1	11.4
Auto Patterned Detection	-	3.4	-	-	-	3.4
Wafer Fab Equipment	1.9	13.6	1.2	1.2	3.1	14.8
Pacific Western						
Horizontal Diffusion	-	-	0.3	0.3	0.3	0.3
Wafer Fab Equipment	-	-	0.3	0.3	0.3	0.3
Plasma and Materials Technologies						
Dry Etch	3.4	2.0	-	-	3.4	2.0
Wafer Fab Equipment	3.4	2.0	-	-	3.4	2.0
Plasma Systems						
Dry Strip	18.1	19.2	8.8	18.5	26.9	37.7
Dry Etch	-	-	-	1.1	-	1.1
Wafer Fab Equipment	18.1	19.2	8.8	19.6	26.9	38.8
Rudolph Research						
Thin-Film Measurement	3.0	5.4	1.0	3.3	4.0	8.7
Wafer Fab Equipment	3.0	5.4	1.0	3.3	4.0	8.7
Sankyo Engineering						
Auto Wet Stations	19.2	0.9	5.0	16.7	24.2	17.6
Wafer Fab Equipment	19.2	0.9	5.0	16.7	24.2	17.6
Santa Clara Plastics						
Auto Wet Stations	-	-	2.6	-	2.6	-
Wafer Fab Equipment	-	-	2.6	-	2.6	-

Table A-1 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Seiko						
Auto Review and Classification	-	2.0	-	-	-	2.0
Wafer Fab Equipment	-	2.0	-	-	-	2.0
Semiconductor Systems						
Resist Processing (Track)	-	-	0.8	-	0.8	-
Wafer Fab Equipment	-	-	0.8	-	0.8	-
Semitool (Including Semitherm)						
Spray Processors	0.5	0.9	1.4	1.6	1.9	2.5
Other Clean Process	0.3	0.4	0.3	1.3	0.6	1.7
Vertical Tube LPCVD	-	1.7	-	-	-	1.7
Wafer Fab Equipment	0.8	3.0	1.7	2.9	2.5	5.9
Shinko Electric						
Vertical Tube LPCVD	-	-	0.6	-	0.6	-
Vertical Diffusion	-	-	2.7	2.6	2.7	2.6
Wafer Fab Equipment	-	-	3.3	2.6	3.3	2.6
Silicon Valley Group						
Projection Aligners	-	-	2.6	1.4	2.6	1.4
Steppers	3.8	8.4	-	-	3.8	8.4
Resist Processing (Track)	2.1	5.0	5.0	28.0	7.1	33.0
Horizontal Tube LPCVD	-	-	0.3	0.8	0.3	0.8
Vertical Tube LPCVD	-	-	0.6	-	0.6	-
Vertical Diffusion	-	1.0	-	-	-	1.0
Horizontal Diffusion	0.6	-	0.6	1.4	1.2	1.4
Wafer Fab Equipment	6.5	14.4	9.1	31.6	15.6	46.0
Strasbaugh						
Chemical Mechanical Polishing	-	0.5	-	-	-	0.5
Wafer Fab Equipment	-	0.5	-	-	-	0.5
SubMicron Systems Inc.						
Other Clean Process	-	-	1.9	3.1	1.9	3.1
Wafer Fab Equipment	-	-	1.9	3.1	1.9	3.1
Sugai						
Auto Wet Stations	17.7	80.9	1.8	29.7	19.5	110.6
Other Clean Process	-	-	0.1	0.3	0.1	0.3
Wafer Fab Equipment	17.7	80.9	2.0	30.0	19.6	110.9
Sumitomo Metals						
Dry Strip	-	-	-	3.0	-	3.0
Dry Etch	2.9	3.1	-	3.1	2.9	6.2
Wafer Fab Equipment	2.9	3.1	-	6.1	2.9	9.2

Table A-1 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Karl Suss						
Contact/Proximity	1.5	2.2	3.9	7.5	5.4	9.7
Wafer Fab Equipment	1.5	2.2	3.9	7.5	5.4	9.7
Tazmo						
Resist Processing (Track)	3.5	5.1	-	-	3.5	5.1
Wafer Fab Equipment	3.5	5.1	-	-	3.5	5.1
Tegal						
Dry Strip	-	-	0.7	0.5	0.7	0.5
Dry Etch	-	-	8.9	9.3	8.9	9.3
Wafer Fab Equipment	-	-	9.6	9.8	9.6	9.8
Tencor Instruments						
Thin-Film Measurement	9.9	6.6	-	8.3	9.9	14.9
Auto Patterned Detection	5.2	7.9	2.1	5.0	7.3	12.9
Auto Unpatterned Detection	4.1	7.8	3.8	8.6	7.9	16.4
Other Process Control	-	3.1	14.0	7.0	14.0	10.1
Wafer Fab Equipment	19.2	25.4	19.9	28.8	39.1	54.2
Thermawave						
Thin-Film Measurement	4.4	15.3	1.5	3.1	5.9	18.4
Wafer Fab Equipment	4.4	15.3	1.5	3.1	5.9	18.4
Toho Kasei						
Auto Wet Stations	-	-	1.3	2.1	1.3	2.1
Other Clean Process	-	-	-	2.1	-	2.1
Wafer Fab Equipment	-	-	1.3	4.2	1.3	4.2
Tokyo Electron Ltd.						
Resist Processing (Track)	96.6	144.7	32.7	150.6	129.3	295.4
Auto Wet Stations	4.2	41.9	4.8	24.3	9.0	66.2
Dry Etch	60.0	66.5	27.4	76.3	87.4	142.8
Vertical Tube LPCVD	46.9	90.7	22.5	60.4	69.4	151.1
Dedicated LPCVD Reactors	2.1	15.7	-	2.9	2.1	18.5
Vertical Diffusion	38.6	29.7	18.4	54.6	57.0	84.3
Wafer Fab Equipment	248.4	389.2	105.8	369.1	354.2	758.3
Tokyo Ohka Kogyo						
Dry Strip	-	-	-	1.2	-	1.2
Wafer Fab Equipment	-	-	-	1.2	-	1.2
Toshiba						
Silicon Epitaxy	-	1.4	-	-	-	1.4
Wafer Fab Equipment	-	1.4	-	-	-	1.4

Table A-1 (Continued)
Detailed Company Sales Revenue from Shipments of Wafer Fab Equipment to Asia/Pacific, 1994 to 1995 (End-User Sales Revenue in Millions of U.S. Dollars)

	Korea		Other Asia/Pacific		Asia/Pacific	
	1994	1995	1994	1995	1994	1995
Toyoko Kagaku						
Other Clean Process	-	-	0.8	1.1	0.8	1.1
Vertical Tube LPCVD	-	-	1.3	1.4	1.3	1.4
Wafer Fab Equipment	-	-	2.1	2.5	2.1	2.5
Ultrapointe						
Auto Review and Classification	0.3	0.4	-	-	0.3	0.4
Wafer Fab Equipment	0.3	0.4	-	-	0.3	0.4
Ultratech						
Steppers	10.3	25.7	7.3	12.7	17.6	38.4
Wafer Fab Equipment	10.3	25.7	7.3	12.7	17.6	38.4
Varian						
Sputtering	43.4	86.4	46.6	11.0	90.0	97.4
Medium-Current Implanter	25.7	50.4	10.4	33.4	36.1	83.8
High-Current Implanter	37.1	46.3	1.7	7.3	38.8	53.6
Wafer Fab Equipment	106.2	183.1	58.7	51.7	164.9	234.8
Verteq						
Other Clean Process	0	0.1	0.7	1.2	0.7	1.3
Wafer Fab Equipment	0	0.1	0.7	1.2	0.7	1.3
Watkins-Johnson						
Atmospheric/Subatmospheric Pressure CVD	33.0	48.0	17.2	34.0	50.2	82.0
Wafer Fab Equipment	33.0	48.0	17.2	34.0	50.2	82.0
Surveyed Companies						
Wafer Fab Equipment	1,547.6	2,848.4	782.7	1,908.2	2,330.3	4,756.6
Other Companies						
Wafer Fab Equipment	155.3	293.0	81.1	158.1	236.4	451.1
All Companies						
Wafer Fab Equipment	1,702.9	3,141.4	863.8	2,066.3	2,566.7	5,207.7

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