Part A
Whisker Formation on Tin Plated Cu based Leadframes
Results and Conclusion
October 2004

Part B
Whisker Formation on Tin Plated FeNi42
Results and Conclusion
August 2004

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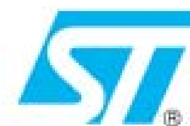

Part A
Whisker Formation on Tin Plated Cu based Leadframes

Results and Conclusion

October 2004

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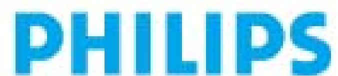
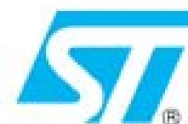
Part A

Content

- Introduction
- Experience E4
- Main cause whisker growth on Cu LF
- Countermeasures
- Conclusions

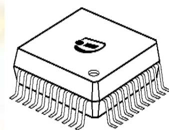


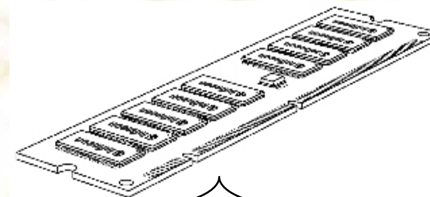


Introduction

Period of potential whisker growth

	storage conditions	service life conditions
FeNi42 L/F	no whisker growth	whisker see FeNi42 presentation
Cu-based L/F	whisker → countermeasure baking see this presentation	no whisker growth

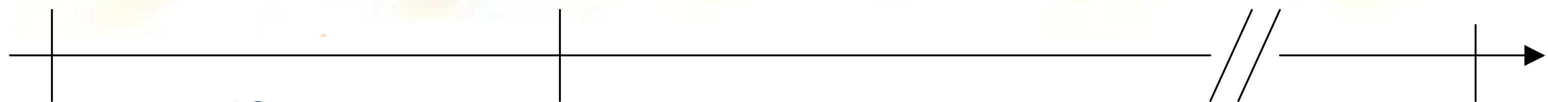




tin plating

board assembly/ soldering

product end of life



≤ 2 years

~ 15 years

Part A

Experience in Tin plating within E4

Electrolytes

Production line

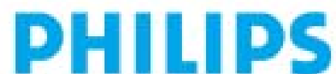
Shipley ST-200
Shipley ST 300
Schlötter Slototin40
Pyramid Pyra Tin Lux
Technic Technistan EP
OMG Reel Satin 2544 LF
Lucent Satin bright Tin

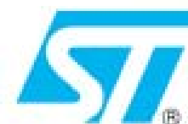
Lab scale

Shipley ST-150
Shipley ST-200
Shipley ST 300
Schlötter Slototin 40
Pyramid Pyra Tin Lux
Technic Technistan EP
OMG Reel Satin 2544 LF
Atotech HSM

Leadframe Material

ASTM / material number	Brand name / short notification	Composition
C14415	K 81 / CuSn0,15	0.1 Sn; <0.02 Ni/Zn
C18070	K 75 / CuCrSiTi	0.3 Cr; 0.35 Si; 0.07 Ti
C19210	K80 / CuFeP, KFC	0.1 Fe; 0.03 P
C18090	K62, CuSn1CrNiTi	0.6 Sn; 0.4 Ni; 0.3 Cr; 0.3 Ti
C19400	Olin 194, K 65 / CuFe2P	2.4 Fe; 0.12 Zn; 0,03 P
C50710	MF 202 / CuSn2ZnP	2.0 Sn; 0.2 Ni; 0,15 P; 0,15 Zn
C70250	Olin 7025, K 55 / CuNi3Si1Mg	3.0 Ni; 0.65 Si, 0.15 Mg; <1.0 Zn
C22000	MS10	CuZn10
	Alloy 42	FeNi42

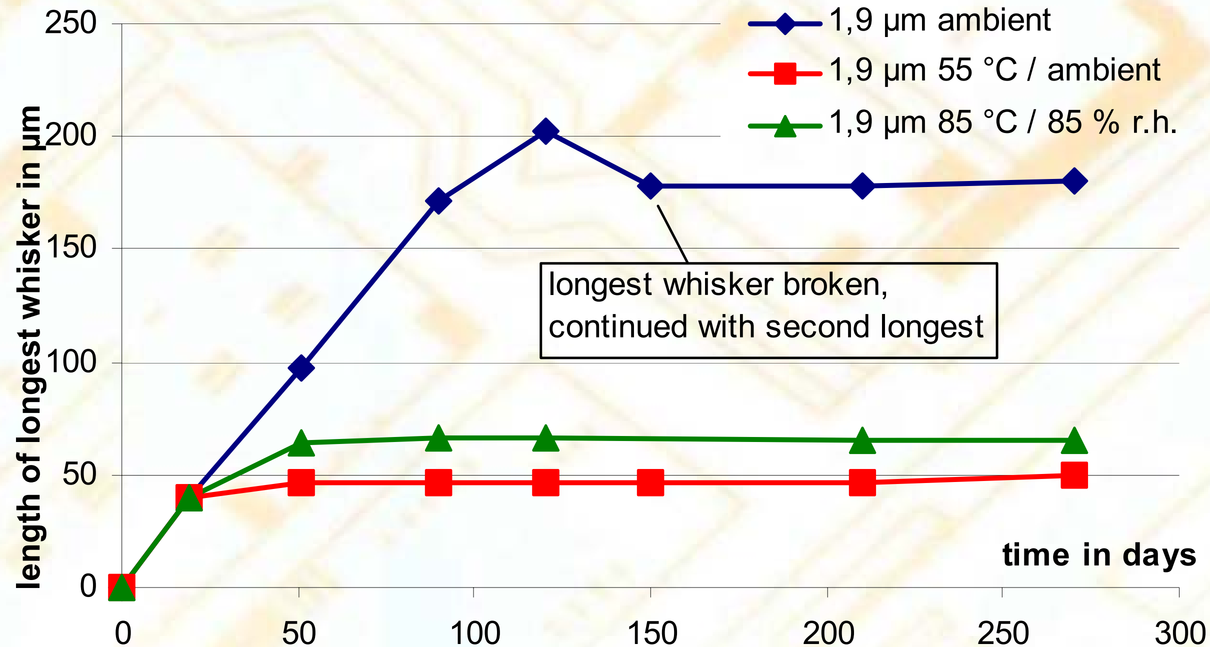




Part A

Storage conditions

- Test data showed that whiskers grow longest at room temperature
- Explanation: irregular intermetallic growth



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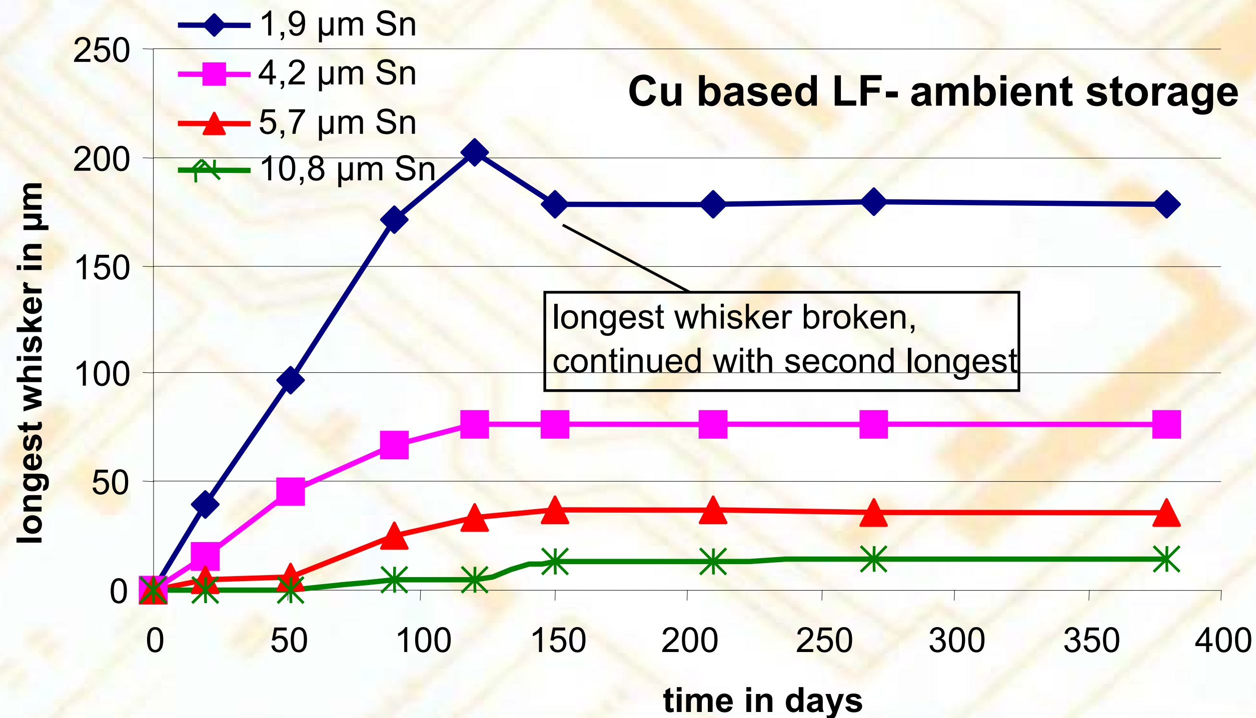
Part A

Influence of Plating Thickness



- Observation of strong dependency on thickness may result in acceleration factor according to thickness
- Similar results available for 4 Cu-materials and 3 electrolytes

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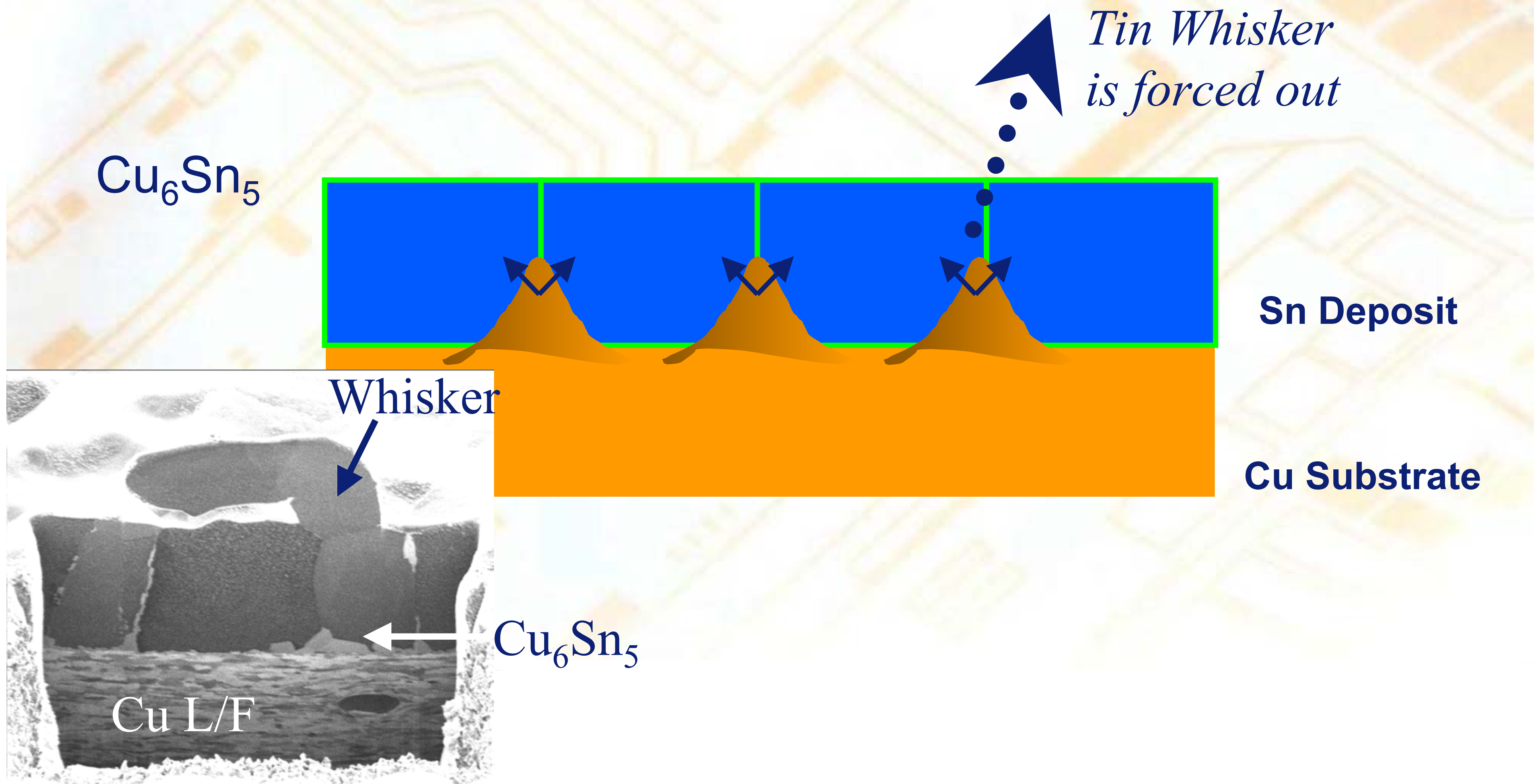
Part A

Whisker Mechanism on Cu based leadframes

Whiskers grow because of compressive stress in the plating which is caused by irregular growth of intermetallics



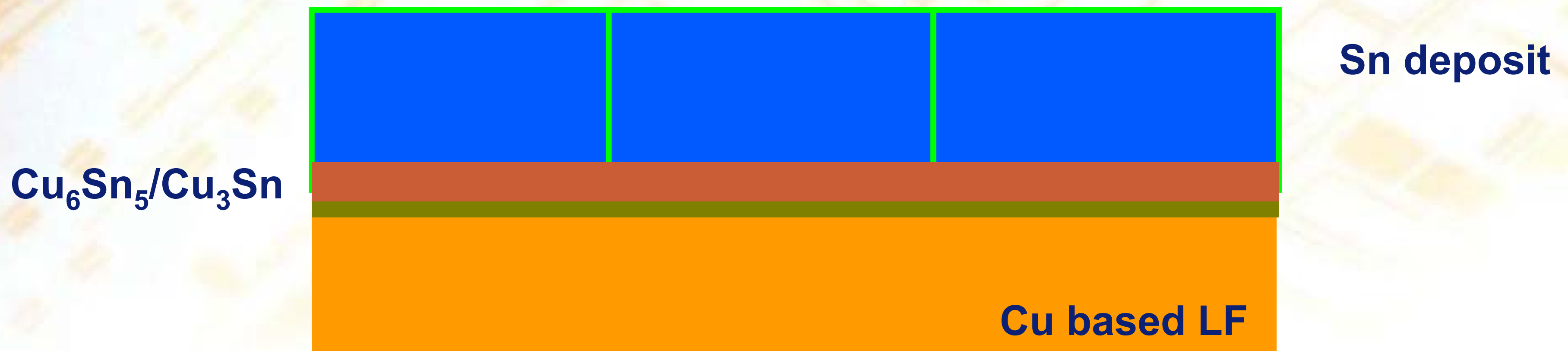
Part A

Protection by Postbake (1h, 150 °C)

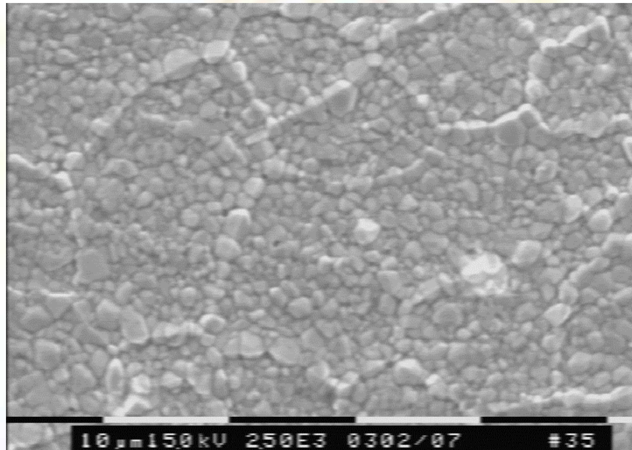
(Within 24 hours of plating)

- Because of higher temperature diffusion will shift from grain boundary to bulk diffusion and thus regular intermetallics
- Recrystallization of Sn
- Diffusion barrier for further intermetallic growth
- Annealing of stress
- Postbake does NOT change CTE mismatch!

No whisker!



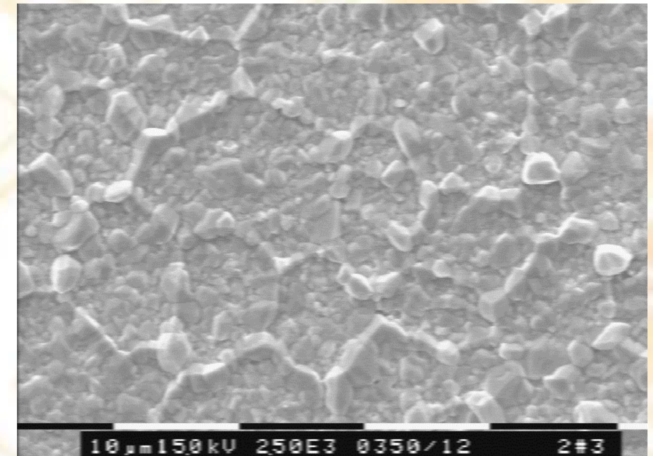
Morphology of the Intermetallics



1 h 150 °C

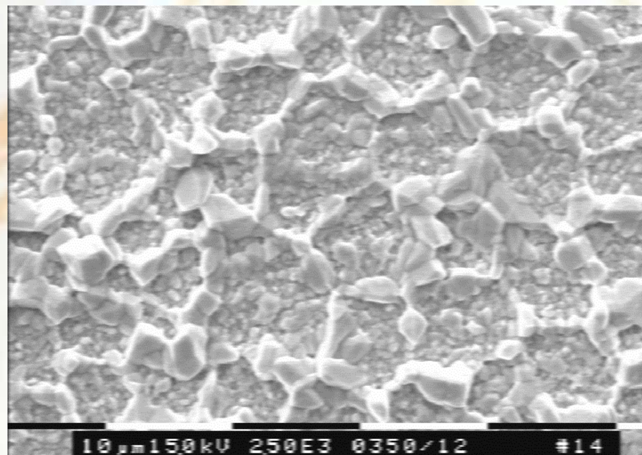
Bulk Diffusion

Recrystallization



4 h 125 °C

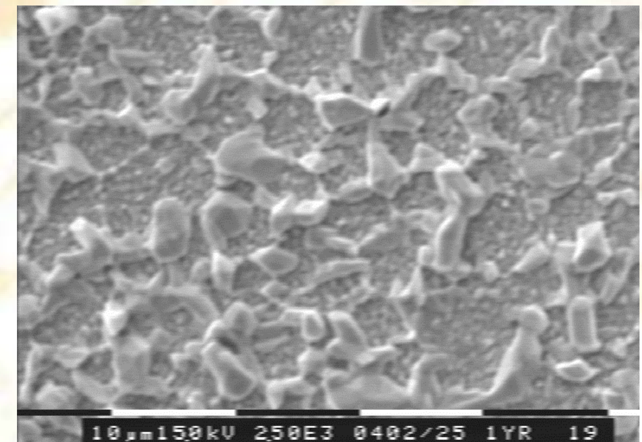
Same amount of intermetallics!



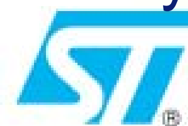
42 days 55 °C

Grain Boundary Diffusion

Less Recrystallization



1 year RT



Postbake Characteristics

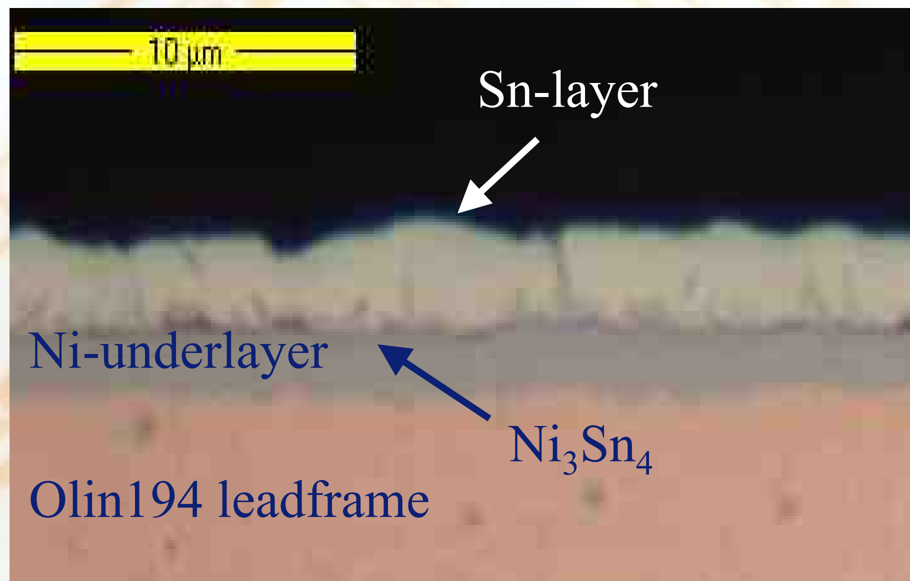
- Postbake results in double layer of Cu_3Sn and Cu_6Sn_5
- The average layer thickness of the resulting intermetallic is 0.7 Tm (+0.2/-0.3)
- Sn grain size 5 to 25 μm
- No additional intermetallic after 12 months storage at ambient

Protection by underlayer

Whisker on Cu

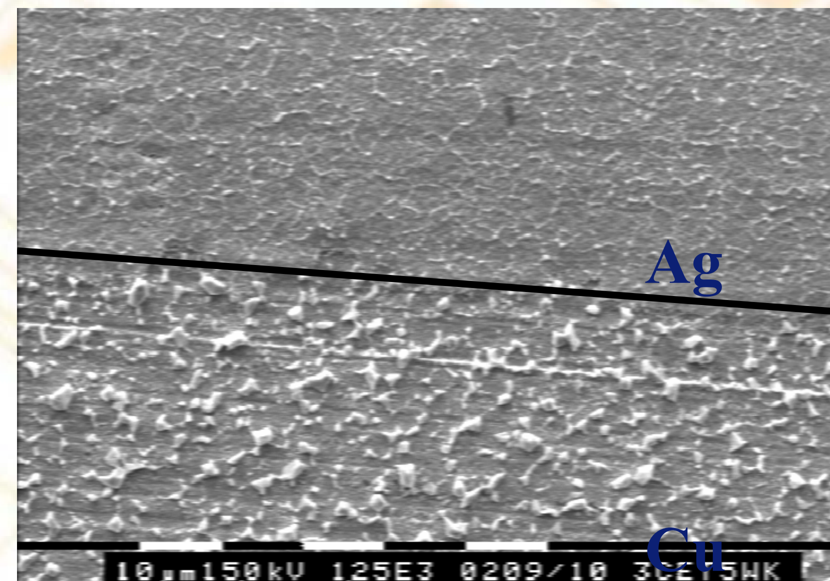
Changing underlayer results in other than Cu_6Sn_5 intermetallics, no stress build-up!

Ni underlayer:

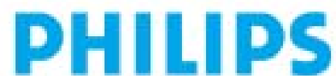


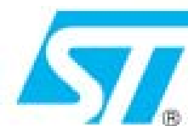
Cross-sectioned view of 5µm Sn on Cu-based leadframe with 2 µm Ni underlayer

Ag underlayer:



Surface after stripping Sn showing intermetallics: upper half Ag underlayer, lower half Cu substrate (5 weeks@R.T)

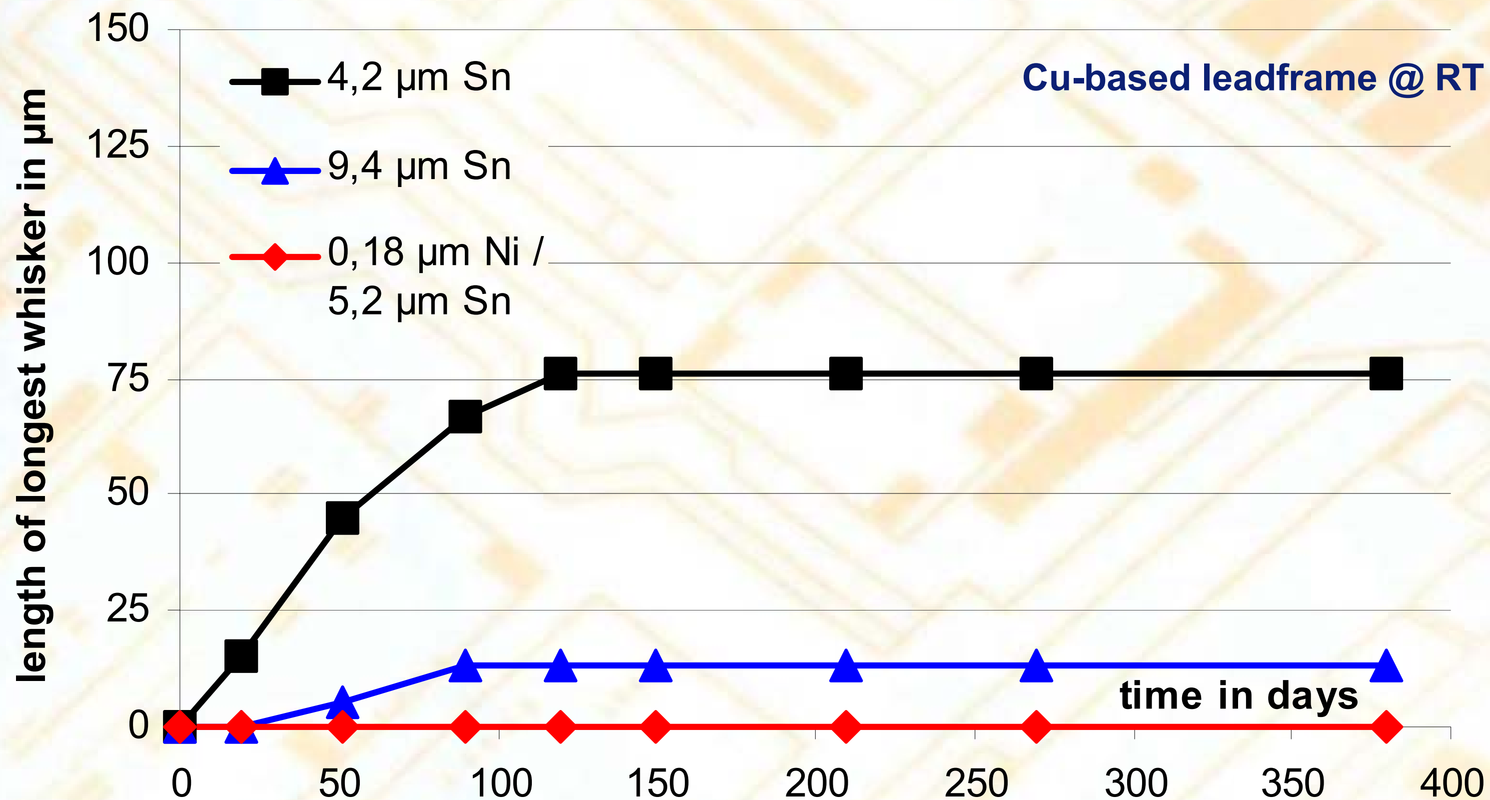




Part A

Protection by underlayer

Whisker on Cu



Sn-plating on Cu-base-material is prone to whiskers.

Ni-underlayer will eliminate whisker risk.

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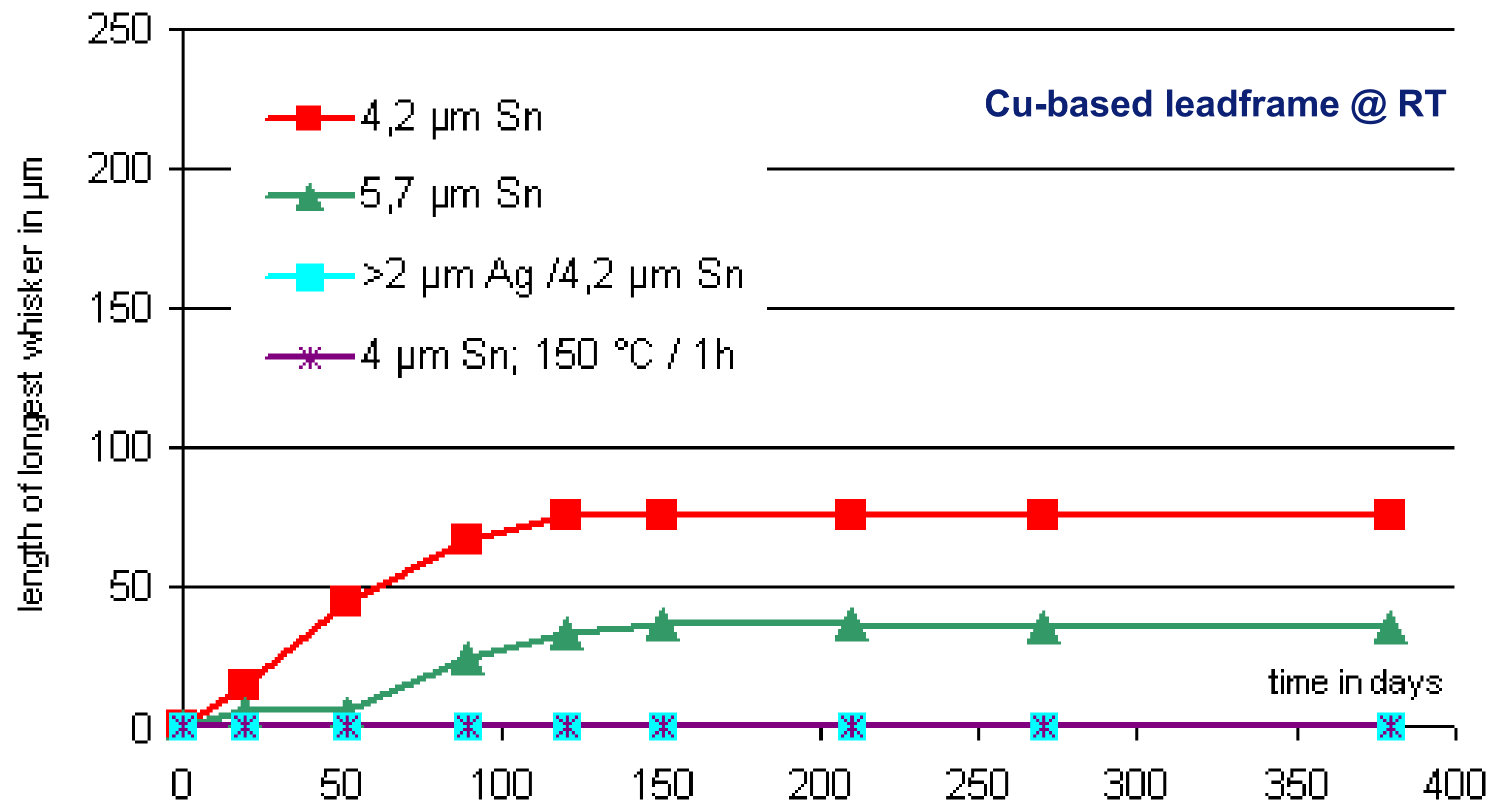
Protection by underlayer

Part A

Whisker on Cu



Sn-plating on Cu-base-material is prone to whiskers.

Ag-underlayer will eliminate whisker risk.

A bake process will eliminate whisker risk.

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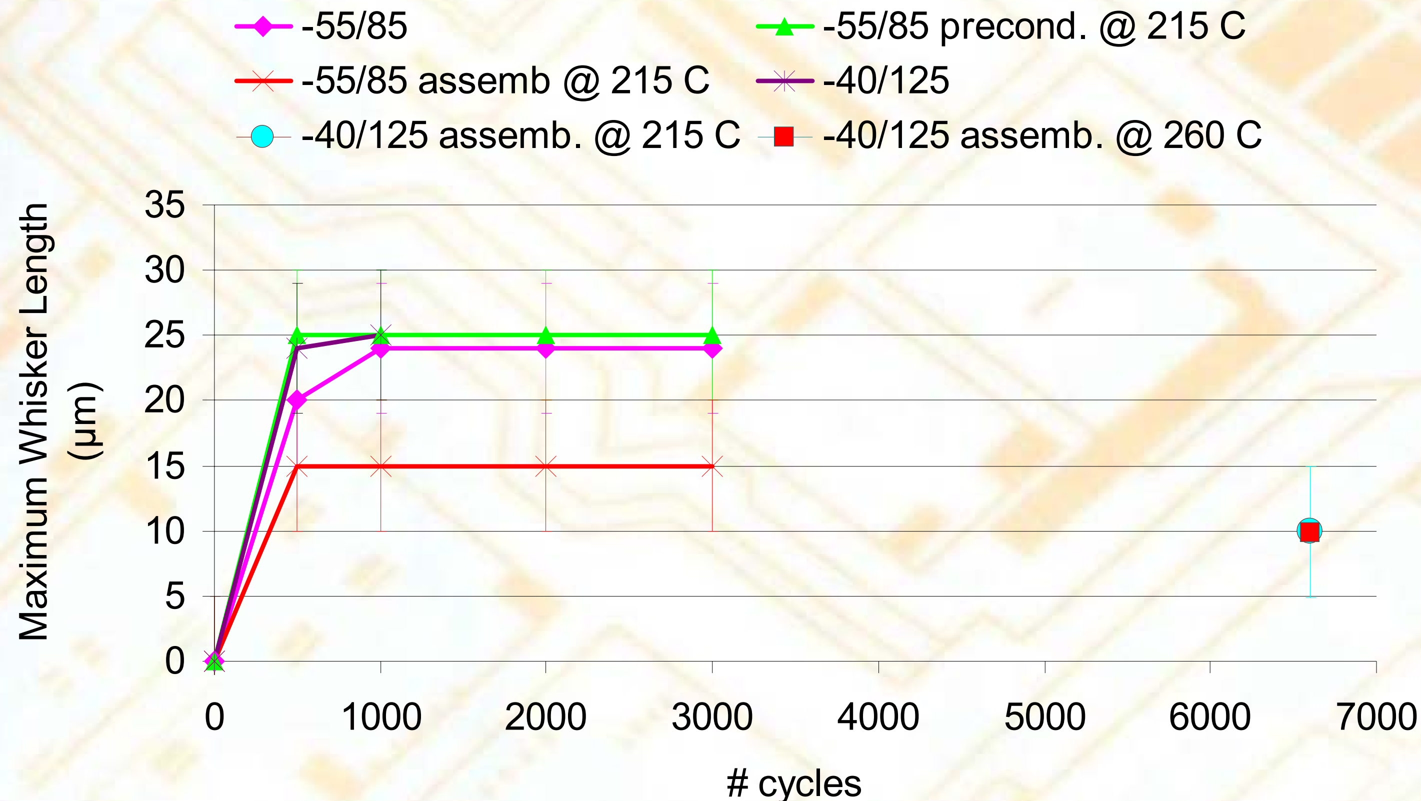
Part A

Cu Leadframes and Temperature Cycling



- Small whiskers can occur due to limited mismatch of CTE
- Postbake does NOT change this mismatch

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Test Results

Part A

Test condition	Preconditioning	Non postbaked Cu leadframes		Postbaked Cu leadframe	
		Max. Whisker Length (µm)	Time (h)/ # Cycles	Max. Whisker Length (µm)	Time (h)/ # Cycles
20-25 °C, 30-80 % r.h.	-	~ 90	> 5000	<10	~ 8000
20-25 °C, 30-80 % r.h.	simulated reflow @ 215 °C	0	> 8000	0	~ 6000
20-25 °C, 30-80 % r.h.	simulated reflow @ 260 °C	-	-	0	~ 6000
20-25 °C, 30-80 % r.h.	assembly @ 215 °C	0	> 8000	0	~ 6000
20-25 °C, 30-80 % r.h.	assembly @ 260 °C	0	> 8000	0	~ 3000
20-25 °C, 30-80 % r.h. with 5 V bias applied	assembly @ 215 °C	-	-	0	~ 5000
55 °C/85% r.h	-	~ 60	> 5000	< 10	~ 4500
60 °C/93% r.h	-	-	-	0*	~ 4000
60 °C/93% r.h	simulated reflow @ 215 °C	-	-	0*	~ 6000
60 °C/93% r.h	simulated reflow @ 260 °C	-	-	0*	~ 6000
60 °C/93% r.h	assembly @ 215 °C	-	-	0	~ 5000
60 °C/93% r.h	assembly @ 260 °C	-	-	0	~ 5000
55 °C/85% r.h	assembly @ 260 °C	0	~ 5000	-	-
60 °C/93% r.h with 5 V bias applied	assembly @ 215 °C	~ 30	~ 1000	0	~ 4000
-40 °C/125 °C, TST, >7' dwell	-	~ 30	1000	~ 30	1000
-55 °C/85 °C, TST, 10' dwell	-	~ 30	1000	~ 25	1000
-55 °C/85 °C, TST, 10' dwell	simulated reflow @ 215 °C	-	-	~ 30	3000
-55 °C/85 °C, TST, 10' dwell	simulated reflow @ 260 °C	-	-	~ 30	3000
-55 °C/85 °C, TST, 10' dwell	assembly @ 215 °C	-	-	~ 15	3000
-55 °C/85 °C, TST, 10' dwell	assembly @ 260 °C	-	-	~ 15	3000
-40 °C/125 °C, TST, 20' dwell	assembly @ 215 °C	< 10	~ 6600	-	-
-40 °C/125 °C, TST, 20' dwell	assembly @ 260 °C	< 10	~ 6600	-	-

* whiskers found after severe corrosion and exceeding 3000 h test time.

Part A

NEMI DoE3 Test results 60°C/93%RH

60C/93RH STORAGE
6000 HRS INSPECTION

Finishes Ranked by Max. Whisker Length
Isothermal Storage 6000hrs

Substrate	Plating	Max.Whisker Length
CDA194	Matte Sn/2-3Bi	360
CDA194	Matte Sn	270
Cu 7025	Matte Sn	200
CDA194	150C 1hr Matte Sn	160
CDA194	Hot-dipped Sn	150
CDA194	Matte Sn/2-3Cu	150
CDA194	245C reflow Matte Sn	110
CDA194	Matte Sn 3 - 5um	110
CDA194	Sn/2-4Ag	100
CDA194	SnPb	75*

*on areas with no Pb

DOE3 Test Results Update
August 2004
Peter Bush, SUNY at Buffalo

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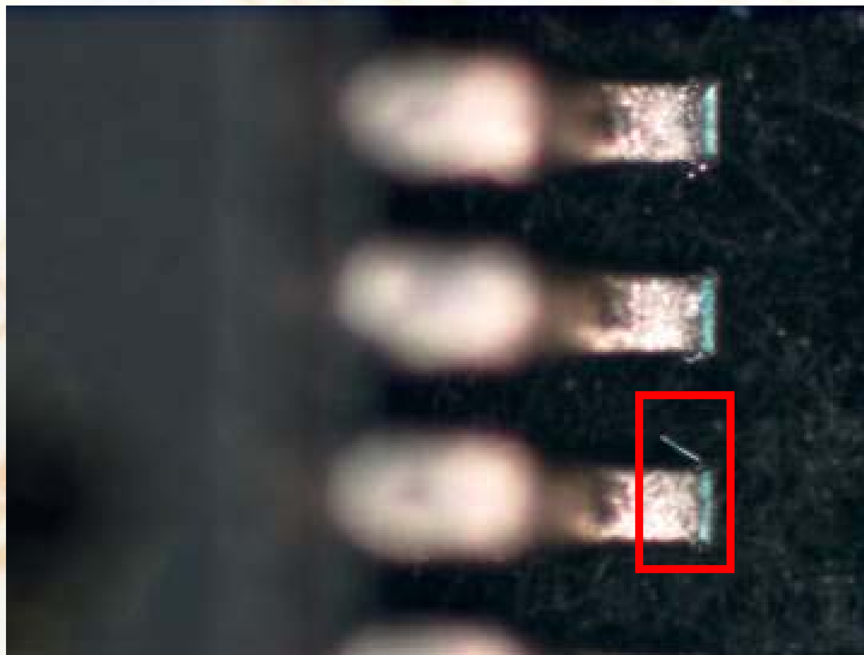
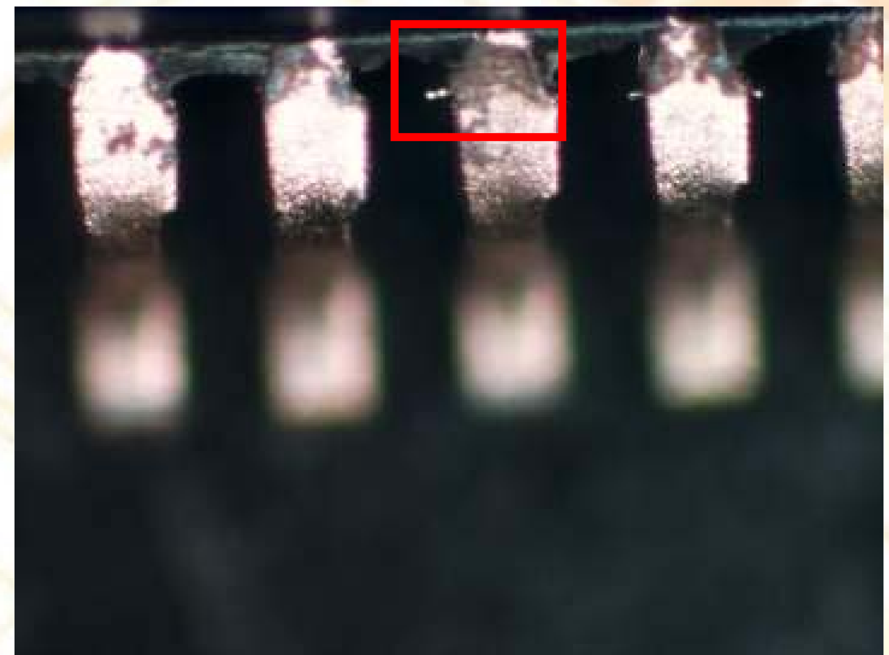
Part A

60 °C/93 %RH Corrosion



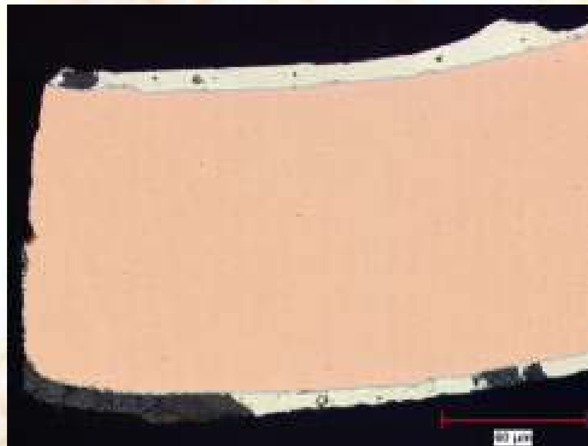
Toe area of QFP after > 3000 h 60 °C/93%RH



Shoulder area of QFP after > 3000 h 60 °C/93%RH

Part A

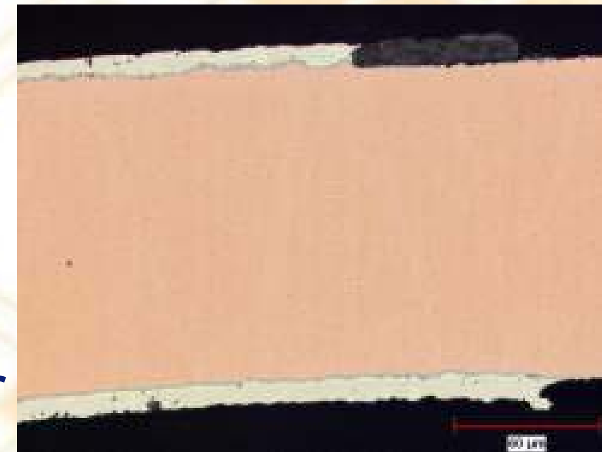
60 °C/93 %RH X-sections

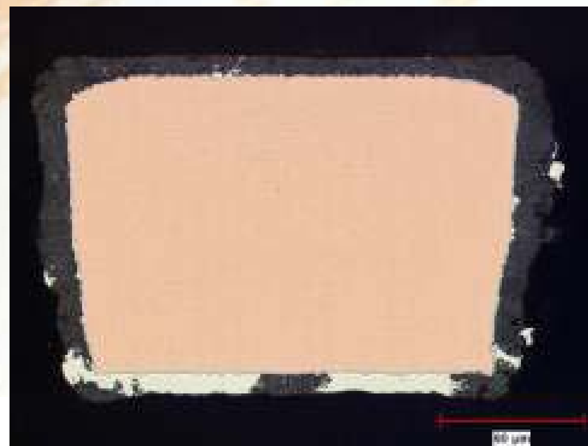


Parallel cross-sections after aging > 3000h

Foot

Shoulder





Perpendicular cross-sections on foot area after aging > 3000h

Part A

Conclusions

- Compressive stress is the driving force in pure tin layers (without compressive stress no whiskers).
- Whisker growth on Copper leadframes is mainly caused by large, irregular intermetallic Cu_6Sn_5 growth at interface substrate / plating layer.
- Storage in ambient atmosphere produces longest whiskers on copper leadframe (compared to all other tested storage conditions).
- The thicker the Sn-layer the shorter is the whisker.
- Countermeasures are postbake, Ni-, Ag-underlayer.
- Postbake 1h, 150°C is performed after plating.
- Temperature cycling may cause a maximum whisker length of 30 µm on Cu leadframes.
- Maximum specified whisker length is 50 µm for accelerated tests.
- After 2 years storage at ambient and/or soldering on board matt tin plated Cu-L/F, with above mentioned countermeasures, does not show evidence of whiskers.

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Part B
Whisker Formation on Tin Plated FeNi42

Results and Conclusion

August 2004

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Part B

Outline

- Introduction
- Experimental procedure and inspection
- Results
- Summary and Conclusions

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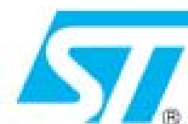
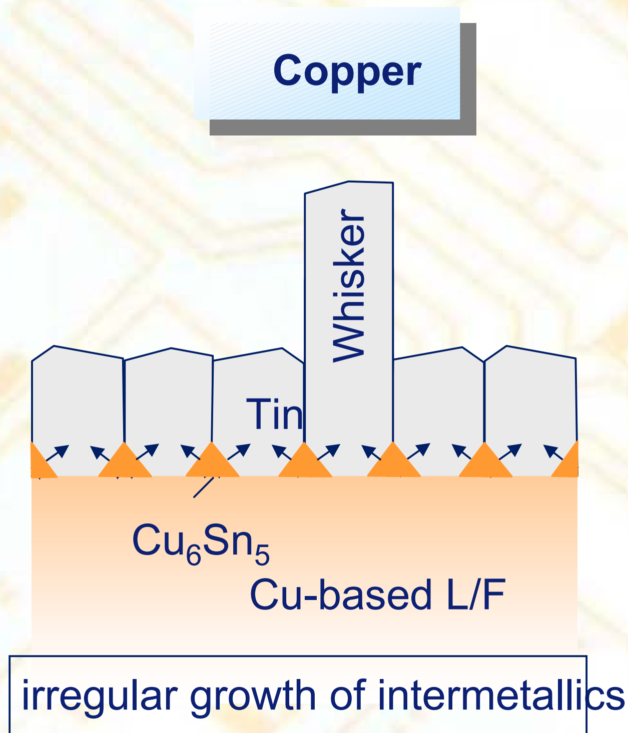
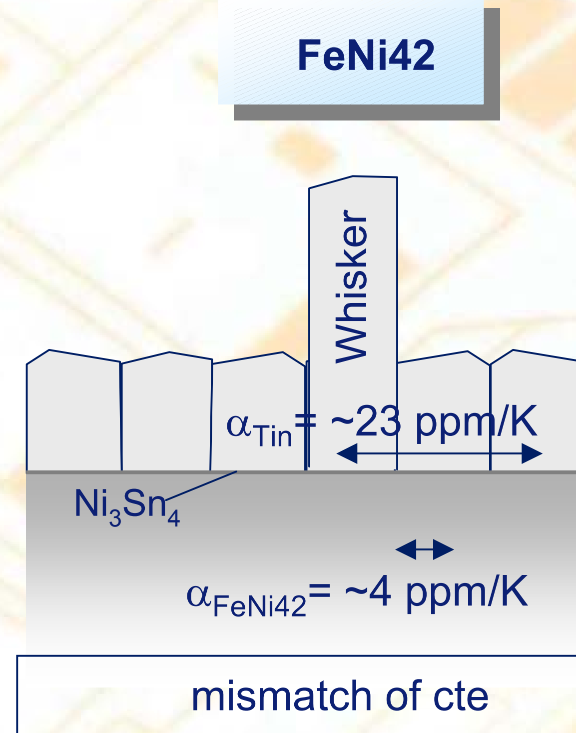


Introduction

Major mechanism and conditions for whisker formation



isothermal storage at moderate temperature



thermal cycling

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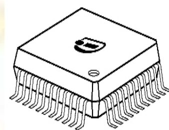
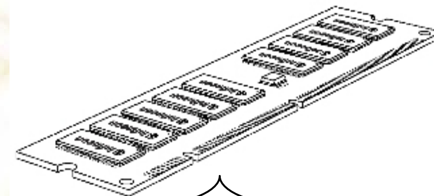
Introduction

Part B

Period of potential whisker growth

	storage conditions	service life conditions
FeNi42 L/F	no whisker growth	whisker see this presentation
Cu-based L/F	whisker → countermeasure baking	no whisker growth

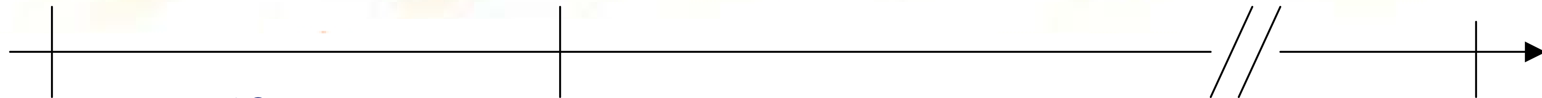




tin plating

board assembly/ soldering

product end of life



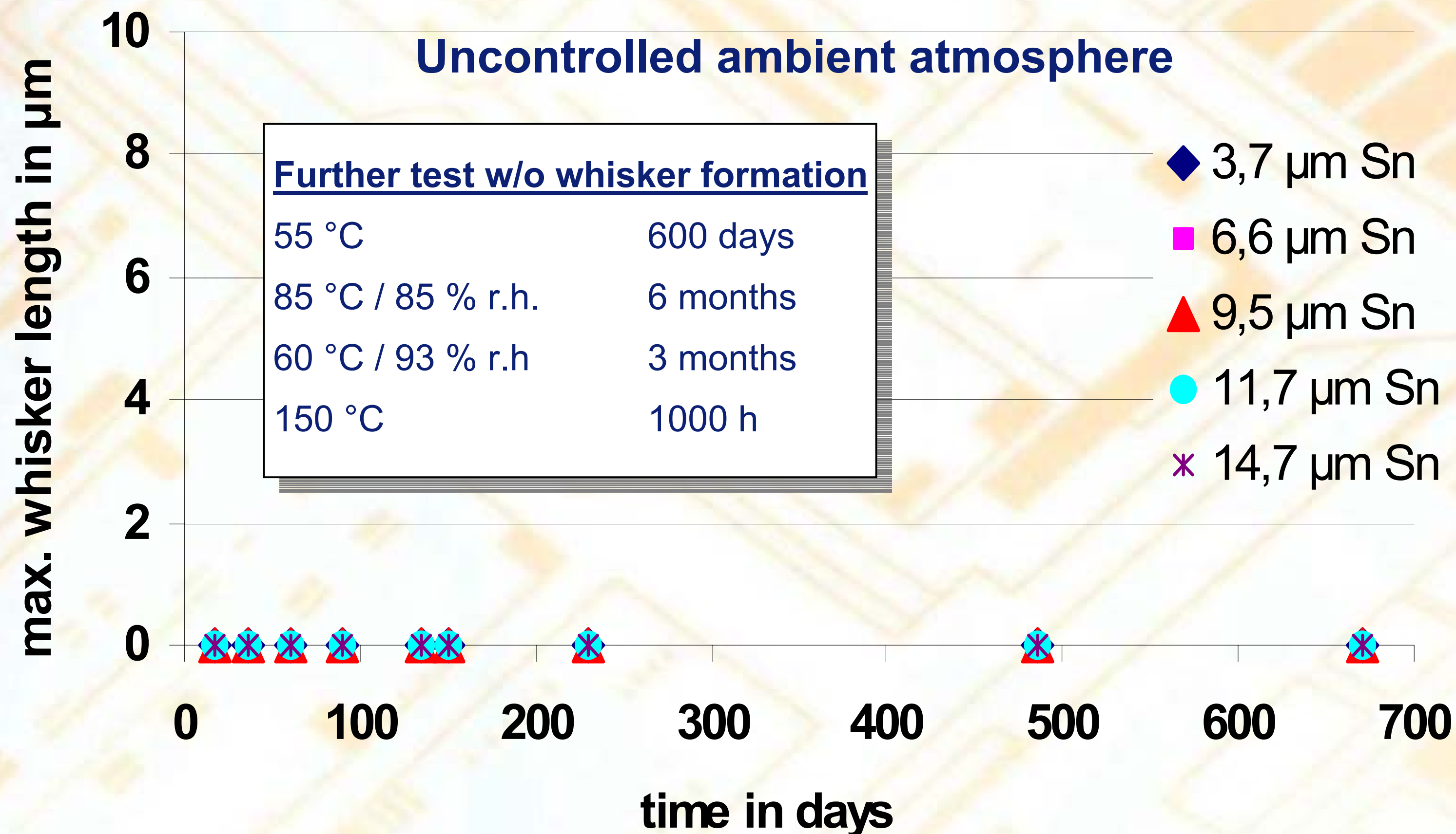
≤ 2 years

≤ 15 years

Part B

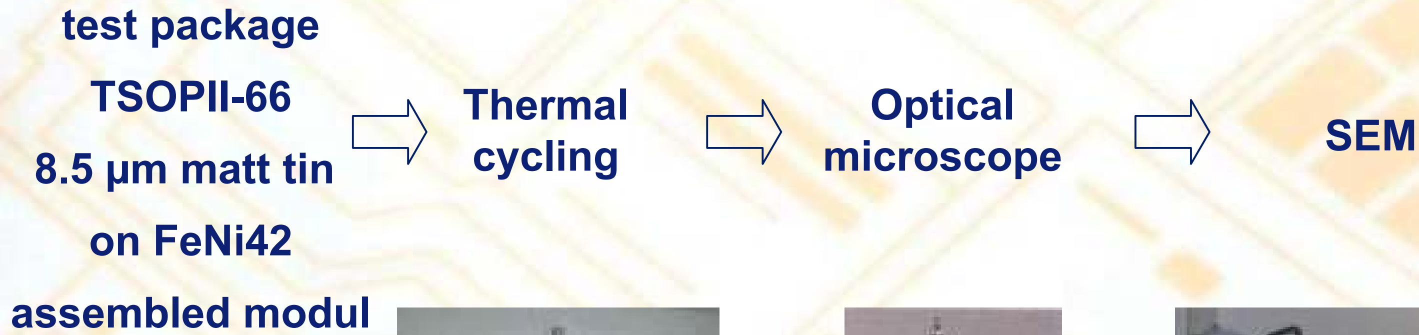
Whisker on FeNi42 leadframes

Isothermal storage of tin plated FeNi42



Isothermal storage does not result in whisker formation for matt Sn plated FeNi42 based components

Experimental procedure and inspection



test package

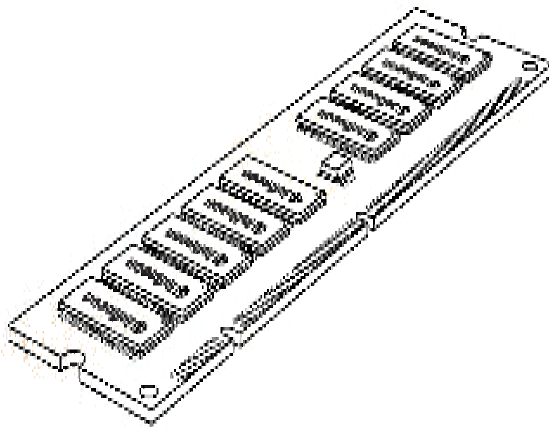
TSOPII-66

8.5 µm matt tin

on FeNi42

assembled modul

Thermal cycling → Optical microscope → SEM



5 components per test condition and read number of cycles for readout (5 data per 330 leads)

identify longest whisker per component

- overview photo
- photo of longest whisker per package
- length measurement

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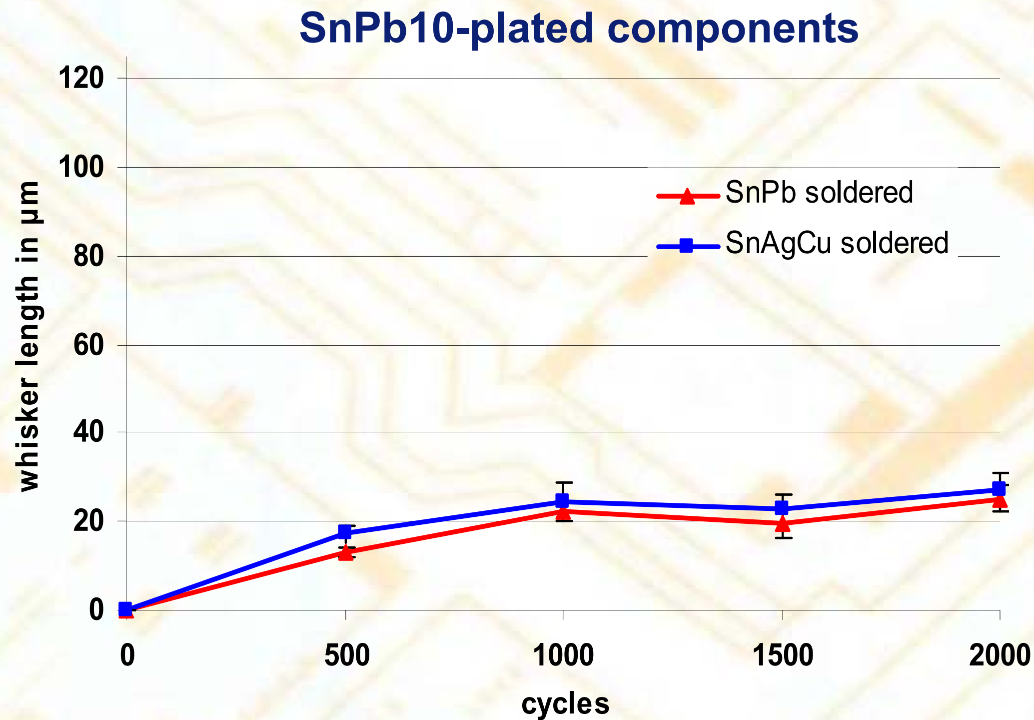
Part B

Whisker on FeNi42

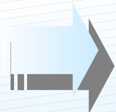
Temperature cycling after board assembly



-40 °C / +85 °C,

5 K/min,

30 min dwell



- SnPb plating shows whiskers after TC testing
- No difference between SnAgCu and SnPbAg soldering

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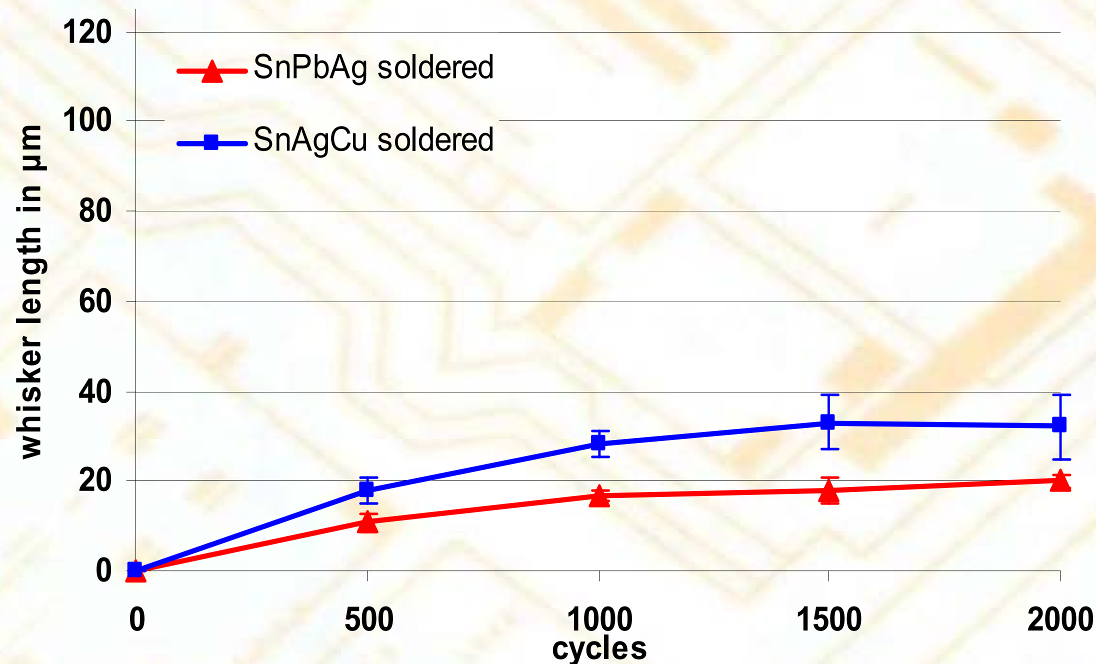
Whisker on FeNi42

Temperature cycling after board assembly



-40 °C / +85 °C,
5 K/min,
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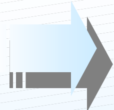

- Sn-plated components show whisker of similar size as SnPb plated components
- Little difference between SnAgCu and SnPbAg soldering

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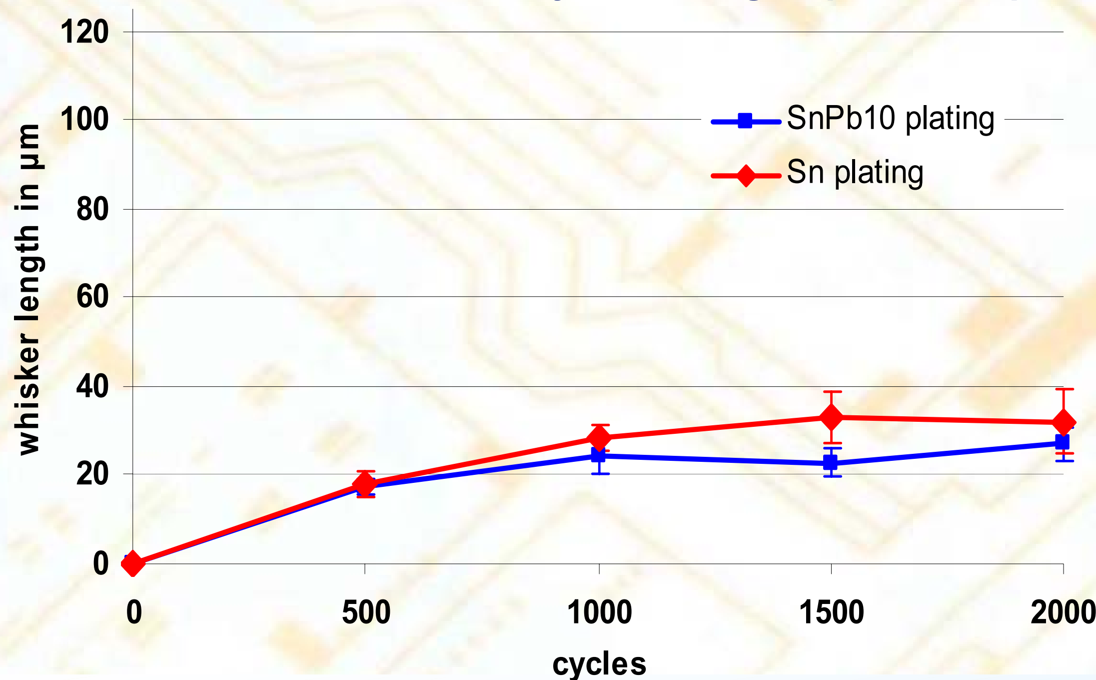
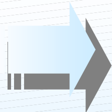
Whisker on FeNi42

Temperature cycling after board assembly



-40 °C / +85 °C,
5 K/min,
30 min dwell



- SnPb plating shows whiskers of similar size as Sn-plated components

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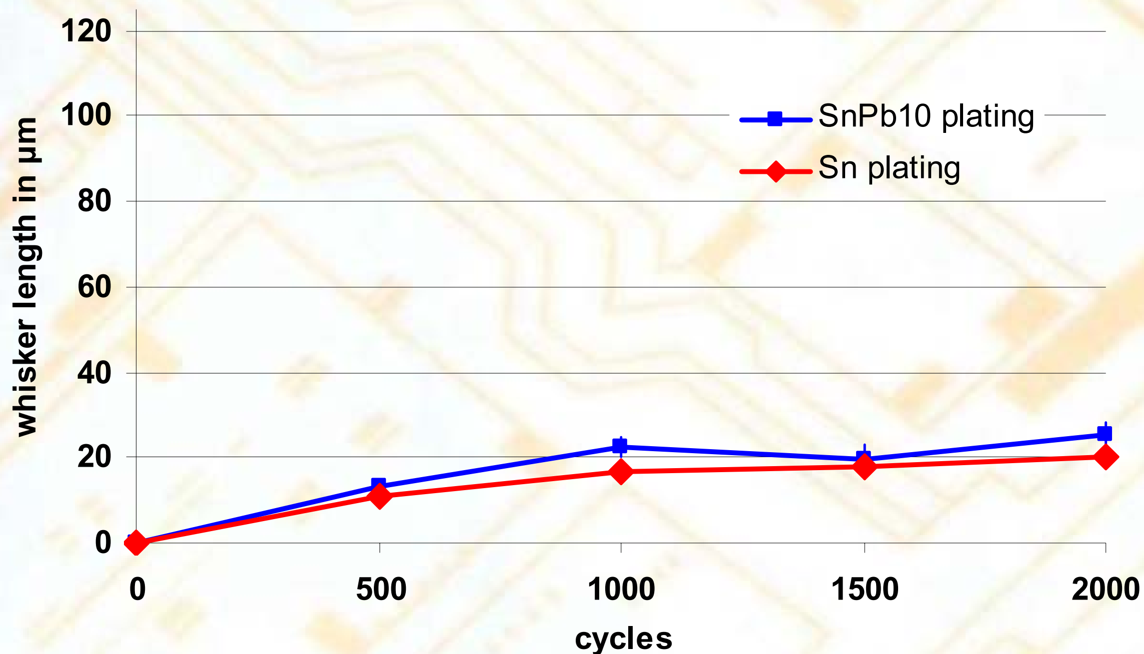
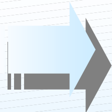
Part B

Whisker on FeNi42

Temperature cycling after board assembly



-40 °C / +85 °C,
5 K/min,
30 min dwell



- SnPb plating shows whiskers of similar size as Sn-plated components

PHILIPS · freescale semiconductor (Launched by Motorola) · ST · Infineon technologies

Summary and conclusions

- Whisker length after board assembly equal for Sn-plated and SnPb10 plated components
- Little influence of solder paste type and respective process for board assembly

➡ Whisker risk for Sn-plated components equal to actual SnPb standard plated components