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Spectroscopic and wireless sensor of hematocrit level

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Abstract

An optical method for hematocrit measurement has been presented. The sensor, designed and developed by authors, consists of spectroscopic set-up controlled by a microcontroller. Measurement results are sent via wireless module. Experiment has confirmed the ability of the sensor to determine the hematocrit with appropriate measurement accuracy.

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Keywords: hematocrit measurement; spectroscopy; blood analysis

1. Introduction

Nowadays, the necessity to gather information on a wide range of parameters appears crucial in many fields. It requires a high number of sensors to be connected in a single network to provide easy control and acquisition of measurement. Sensor networks are widely-used in medicine, structural health monitoring and telemedicine. Optical sensors are popular because of their advantages: small weight and size, as well as their immunity to environmental conditions, such as strong radiation. [1]

The blood hematocrit is routinely determined in the clinic by analysis of blood samples. There are several methods of measuring the HCT and hemoglobin. Unfortunately, almost all of them require either blood sampling or catheterization. Therefore, there is a great interest in optical measurement that would permit simultaneous analysis of multiple components (analytes) in whole blood without the need for conventional sample processing, such as centrifuging and adding reagents. There are few optical methods of the hematocrit measurement. Schmitt et al. [2] used the dual-wavelength near IR-photoplethysmography. Xu et al. applied optical coherence tomography for investigating the HCT value [3]. Enejder et al. [4] used Raman spectroscopy for simultaneous measurement of concentrations of multiple analytes in whole blood, including the hematocrit and hemoglobin. Iftimia et al. [5] demonstrated the use of the spectral domain low coherence interferometry to hematocrit measurement.

Our objective was to design a system for measuring blood parameters of patients at home. Daily monitoring of changes in the patient gives the possibility of better diagnosis and more rapid response to threats in the case of high risk groups. The development of cheap and versatile device makes it possible to prevent the recurrence of the disease early and effective treatment. Sensors of this type will also apply in the case of successful treatment of cancer. The usefulness of several optical method for measuring hematocrit in the whole blood were investigated, for example: Raman spectroscopy [6], optical coherent tomography [7] and low-coherent interferometry [8]. However, authors decided to implement optical spectroscopy in the designed sensor. The results presented in the paper shows the ability of the method for measuring blood parameters.

Nomenclature

HCT [%]	Hematocrit
V_b	Volume blood in the sample
V_e	Volume erythrocytes in the sample
$A^{880,570}$	Absorbance for wavelength 808 nm and 570 nm
$c_{880,570}$	Calibration coefficients

Hematocrit is the ratio of volume of blood to the volume of erythrocytes in whole blood (V_e). It is usually expressed as a percentage or as a fraction. [9]

$$HCT = \frac{V_e}{V_b} \quad (1)$$

The first figure shows the distribution of blood components in vitro. It can be seen that the blood can be approximately divided into: plasma and formed elements such as: erythrocytes, leukocytes, thrombocytes.

Analysis of literature and experimental studies help us to identified two wavelengths as useful for determining the absorbance of blood sample 570 nm and 880 nm. By the use of optical signals measured at this wavelengths and using equation (3) it is possible to estimate the hematocrit value.

$$HCT = \frac{c^{570} A^{570}}{c^{570} A^{570} + c^{880} A^{880}} \quad (2)$$

2. Sensor

Figure 2(a) shows a block diagram of develop system. The microcontroller is dedicated to control LED diode and to receive information from optic sensor by the use of analog to digital converter. The second microcontroller transmit information to ZigBee module. The value of hematocrit is send in wireless data transmission format to the host computer. Doctors have the access to the database covered with all patients' blood parameters.

In figure 2(b) block diagram of the optic sensor working in transition mode is shown. There is two LED sources of light 570 nm and 880 nm. Transmitted light through the blood sample is detected by the

detector and then the signal from photodiode are amplified. The measurement signal from the sensor is sampled in microcontroller A/D converter.

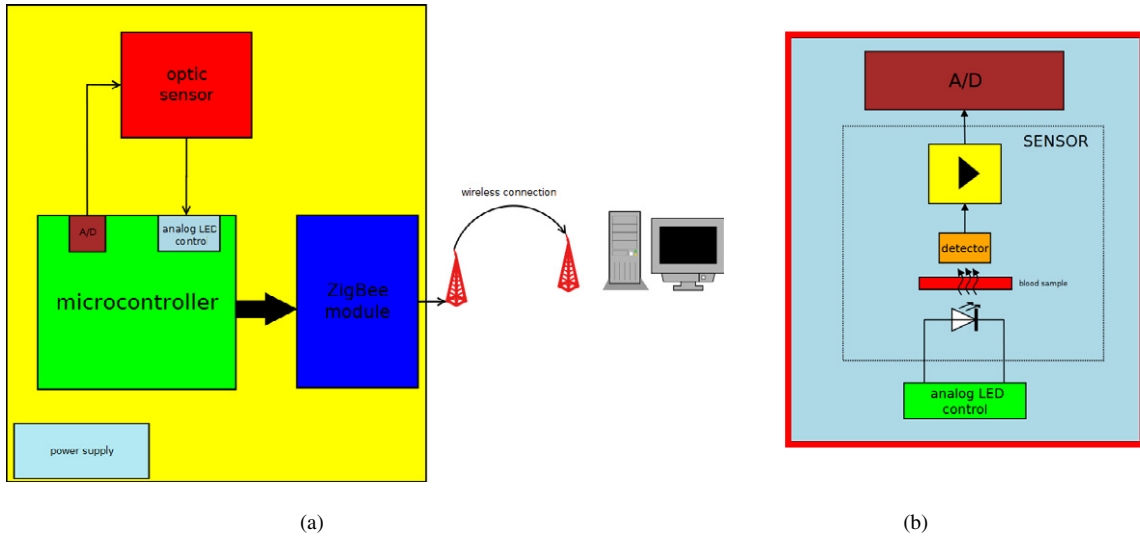


Fig. 2. (a) block diagram of the wireless measurement system; (b) block diagram of the optic sensor.

3. Measurement

In order to find out whether designed sensor sufficient accuracy to monitoring of blood hematocrit, a serie of measurements was carried out. During experimental work authors used the whole human blood for tests. Set of 2 ml blood samples with various hematocrit levels were investigated by the sensor. Moreover, the hematocrit level of each blood sample was independently measured by standard laboratory diagnostic method. Samples were obtained from rather healthy volunteers and therefore the measurement range of the hematocrit level was limited to the range from 30 to 50%. This range was broad enough to assess resolution and accuracy of the measurement system.

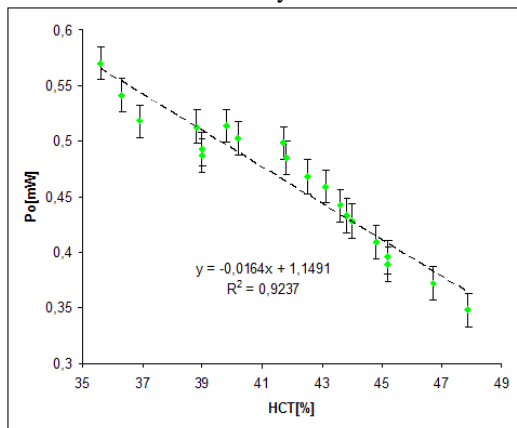


Fig.3. Characteristic of sensor response.

With the use of developed sensor the hematocrit value of numerous blood sample was measured. Measurement results with estimated measurement uncertainties are presented in Figure 3. Based on this data the determination coefficient was calculated. Obtained value is $R^2=0.923$.

It can be noted from figure 3 that the measurement system have very good sensitivity. System accuracy is less than 1.5%, which is a satisfying result.

4. Conclusion

Our motivation was to design the system for measuring human blood parameters of patients, who are sick or elder and are not able to control this parameter in the ambulatory. The investigation of spectroscopic method confirms its ability for the hematocrit control in appropriate measurement range with sufficient accuracy. The analysis of the preliminary results have showed that the measurement system based on the spectroscopic measurement is the most accurate solution. The designed system is cheap and accurate. Furthermore, it is easy to use what make it possible to apply this system in practice. The downside of this system is undoubtedly the measurement speed because one measurement takes from 30 to 60 sec. One can increase the speed of the system, reducing the acquisition time, unfortunately, these results in a decrease in accuracy. The presented preliminary results can be the base for building sensor ready for practical applications.

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