Development of the device for study of the skin characteristics

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Abstract. The skin is the largest organ of the human body that performs many specialized functions. The main kind of the skin study is histological analysis, so the development of non-invasive methods for investigating the characteristics of the skin is very important. For a more detailed study of the skin the combined infrared spectroscopy and bioimpedance method has been proposed so that to examine the structure of the skin in more detail.

1. Introduction

The skin is the largest organ of the human body and performs many specialized functions. It consists of three main layers - the epidermis, dermis and hypodermis. The skin acts as a barrier between the body and the environment and provides immune protection against the dangerous pathogens. Skin cancer is one of the most common types of cancer [1-3]. White-skinned people are more susceptible to this type of the disease, due to the low content of melanin in the skin, which performs the protective function [4]. The main type of the skin study is a histological analysis, so the development of non-invasive methods for investigating the characteristics of the skin seems to be relevant.

Infrared spectroscopy and bioimpedance analysis are non-invasive techniques which are widely used in various applications, ranging from the determination of the quality of wood samples, metal corrosion detection or to study tissue samples for medical diagnostics. In particular Halter et al. used bioimpedance method for detection of prostate cancer tissue [5]. The sensitivity in these cases ranged 81-95% and a specificity of 49-64%. However, in these studies micro-invasive electrodes were used, designed specifically to overcome the top layer of the skin.

Ewaga applied infrared spectroscopy for study urea and water content in the human skin, while Shuler et al. used the method for determining the oxygen content in the leg after acute injury [6, 7]. Authors have reached 70-98% accuracy in the differentiation of benign and malignant neoplasms. However, they excluded the case of melanoma from their study.

For a more detailed study of the skin it has been proposed to combine the two methods, and to develop the appropriate type of electrode. Such combination will provide more information on the state of the skin, than by using one of the methods. It is therefore necessary to develop a non-invasive device for fast and reliable studies of the skin characteristics.

2. Materials and methods

The main part of the device is bioimpedance spectrometer which measures the impedance of tissues in the frequency range 100 Hz - 100 kHz. As a main element, the bioimpedance spectrometer chip AD5933 is selected, which represents an impedance converter. For a more accurate and stable measurements, the Howland current source is selected. The main requirement to the current source is high output impedance as compared to the load resistance. Additional requirements are stability, load capacity and low sensitivity to the various components of the circuit. The study of the load characteristic of the current source is shown in Figure 1. As can be seen, the current source maintains a stable current value when the load changes from 100 ohms to 1 Mohm.

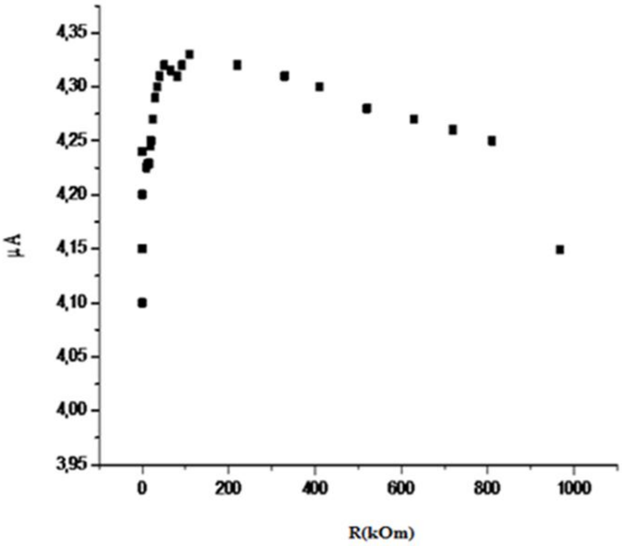

Figure 1. Load characteristics of the current source.

According to [8] the cell may be represented by an equivalent circuit, consisting of two resistors and one capacitor. The equivalent circuit has a characteristic frequency at which the phase reaches its peak.

$$\begin{cases} f = \dfrac{1}{2\pi c}\sqrt{\dfrac{R_1 + R_2}{R_1 R_2^2}} \\ \theta_{peak} = -arctn\left(\dfrac{1}{2}\sqrt{\dfrac{R_2^2}{R_1(R_1 + R_2)}}\right) \end{cases} \tag{1}$$

The calculated values are - the phase reaches its peak at θ_{peak} = -32,6 ° and frequency f = 100 kHz. Further, the equivalent circuit dependence on the frequency was measured in 30 frequency points in the frequency range 1 kHz-100 kHz. The result at each point is averaged over 50 measurements, which reduces errors. The measurement results are shown in Figure 2.

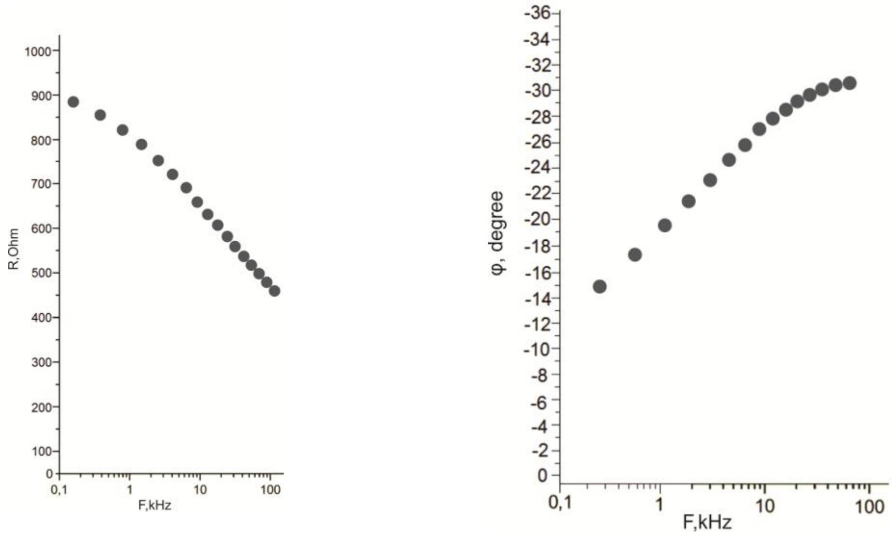

Figure 2. Dependence of module and phase angle on frequency

As seen from the graph, the maximum phase value = -32.6 ° is reached at 100 kHz. The result matches the calculated data. It follows that the device can measure the resistance of the tissue in the frequency range 1 kHz-100 kHz.

Oxygen content in the skin is the important factor, determining the correct cell metabolism. For controlling the oxygen content in the skin the method using two light sources with a wavelengths of 660 and 1300 nm is selected.

The device consists of the receiving part, optical converter and the system for collecting and processing data. The main control element is a microcontroller Atmega16. The signal is processed by a 10-bit ADC. Each LED is controlled via a multiplexer. The main objective is to select the AC signal with the exception of its DC component. This task is performed by using an operational amplifier. As smoothing filter the moving window is used.

The sensor is a cylinder. In the middle of the sensor are two light emitting diodes with a wavelength of 660 and 1300 nm, and a photodiode. Along the edges two electrodes for bioimpedance analysis situated.

Before measurement the skin was wiped with saline for 1 minute. First measurement was done with normal blood flow. Then, rubber band was imposed on the forearm for 1 minute. This was followed by a second measurement. Further measurements were taken every 30 seconds, until the full restoration of blood flow.

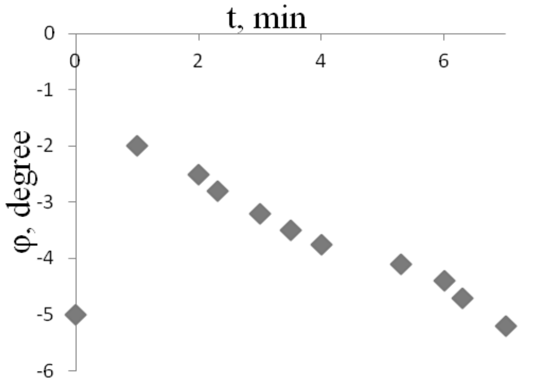

Figure 3. The dependence of the phase angle on the blood flow

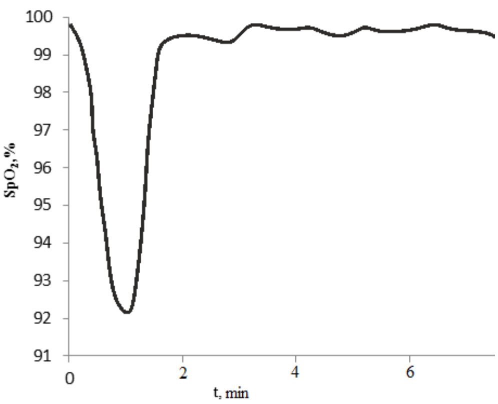

Figure 4. Oxygen saturation curve

3. Results and discussions

During hypoxia there is a lack of oxygen in the cells, which are not able to provide enough energy to the ionic channels and pumps. Since water molecules easily penetrate through the membrane, the interior of the cell contains a larger amount of water which leads to an increase in size, occupying more space in the extracellular space. Consequently, the current in the extracellular space becomes limited and the resistance at low frequency increases, which reduces the phase angle (Fig.4.).

From Figure 3. it is clear that approximately in the first minute there is a reduction of oxygen saturation in cells.

4. Summary

Combining the two methods made it possible to improve the reliability of measurements using non-invasive methods, as confirmed by the measurements. In the future, it is expected to carry out studies for the diagnosis of malignant tumors of the skin.

Acknowledgements

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