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DEVELOPMENT AND MODELING OF A NON-INVASIVE OPTICAL SYSTEM

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Abstract

A noninvasive method of blood glucose measurement based on near-infrared spectroscopy and numerical modeling in MATLAB has been developed. It was found that the 900-1350 nm range provides optimal conditions for accurate analysis without skin puncture.
Keywords: infrared spectroscopy, non-invasive monitoring, glucose

Introduction

Diabetes is one of the most common chronic diseases affecting more than 500 million people worldwide, and it is predicted that the number of patients may exceed 1.3 billion by 2050 [1-2]. In Kazakhstan, the number of registered cases of diabetes reached 431,871 people by 2022 [3]. Effective treatment and prevention of complications require regular monitoring of glucose levels.

Modern invasive methods of monitoring are accompanied by discomfort and are not suitable for constant use. In this regard, there is an increasing interest in non-invasive approaches, in particular near-infrared spectroscopy (NIR), which has a high penetrating ability and sensitivity to changes in the optical properties of tissues. The present work is devoted to modeling the interaction of IR radiation with biotissues in order to estimate blood glucose concentration in a noninvasive way.

Experimental part. This paper deals with the development and testing of a mathematical model of a non-invasive optical system for determining blood glucose concentration. The Bouguer-Lambert-Bera law describing the exponential dependence of the intensity of optical radiation on the concentration of the absorbing substance was used as the basic principle of measurement.

$$I_{out} = I_0 \times exp\ (-k \times c \times L \times m) \tag{1.1}$$

where, I out - is the intensity of LED generating white light wave of visible spectrum at nominal voltage of 3.4 V; I_0 - intensity arising from the passage of light from the LED through the human skin; L - thickness of the measured layer of the biological medium (in our case it is the human skin); k - absorption coefficient; c - spectral range coefficient; m - biological object surface condition coefficient used specifically to screen out interference and create a median value throughout the measurement time [4].

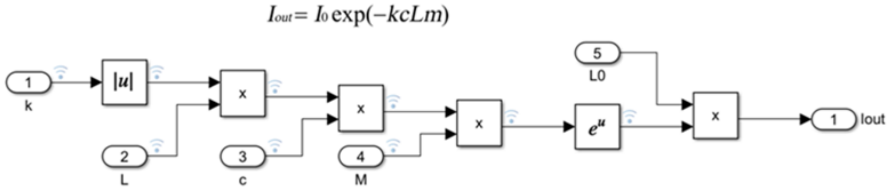

Figure 1: Block diagram of realization of the mathematical model of the Bouguer-Lambert-Bera law in MATLAB environment

A mathematical model of the relationship between wavelength, absorption coefficient and glucose concentration in biotissue was constructed. The experiments were carried out at wavelengths of 450, 900, 1045 and 1350 nm. It is shown that the chosen spectral ranges provide optimal sensitivity to changes in glucose level and minimal error in data reading.

Figure 2 shows a 3D plot, the dependence of the absorption coefficient A=-log10(T/100) on the infrared wavelength (X-axis), the percentage of light transmission through the organic material (Y-axis), and the absorption coefficient A (Z-axis and color scale).

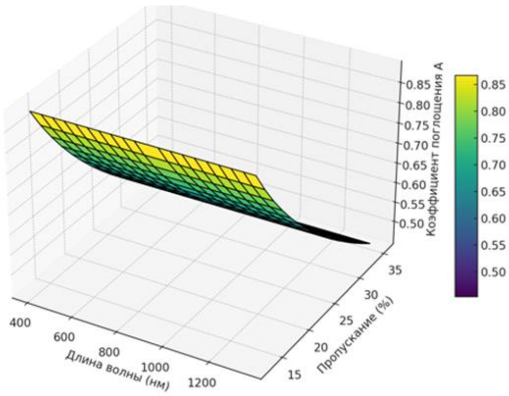

Figure 2. 3D-graph, dependence of absorption coefficient A=-log10(T/100)

Conclusions. The developed model based on the Bouguer-Lambert-Bera law allowed us to determine the quantitative relationship between the optical characteristics of tissue and blood glucose concentration. The most promising range for measurements turned out to be the interval 900-1350 nm, providing a stable optical response and high sensitivity. Experimental data confirmed the reliability of the proposed model, and MATLAB/Simulink demonstrated the efficiency of numerical modeling for noninvasive glucometric analysis

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РОЗРОБКА ТА МОДЕЛЮВАННЯ НЕІНВАЗИВНОЇ ОПТИЧНОЇ СИСТЕМИ

Анотація

Розроблено неінвазивний метод вимірювання рівня глюкози в крові на основі ближньої інфрачервоної спектроскопії та чисельного моделювання в середовищі MATLAB. Встановлено, що діапазон 900-1350 нм забезпечує оптимальні умови для точного аналізу без проколу шкіри.
Ключові слова: інфрачервона спектроскопія, неінвазивний моніторинг, глюкоза

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