A liquid crystal optical sensor for monitoring acetone vapor in exhalation

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Exhaled air contains a large number of products of metabolism of the human body. Types of gases in this air and their concentration are related to human health, which can be used to detect certain diseases. Thus, the presence of acetone in exhalation is a gas marker of diabetes, methane - liver cirrhosis, CO - asthma, etc.

Traditionally, laboratory methods are used to determine the increased content of acetone bodies in human blood and urineю. It was found that the concentration of acetone in the blood has a strong correlation with the level of glucose in it. Diagnosis and monitoring of blood glucose and ketone bodies, which are currently used in clinical trials of patients with diabetes, includes blood tests. In patients with diabetes, the body produces an excess of ketones, including acetone, so it can be used as a biomarker to detect diabetes.

Therefore, respiratory analysis is important to ensure non-invasive and rapid screening and diagnosis of the disease. The advantages of respiratory analysis compared to traditional diagnostic methods include not only its non-invasiveness, but also painlessness and ease of sampling. It is known that the concentration of acetone in human exhalation is normally 0.8 ppm, and in patients with diabetes - 1.8 ppm. Therefore, monitoring the exhalation of volatile substances such as acetone is an urgent problem.

EXPERIMENT

We investigated the BLO-62 cholesterol liquid crystal and its mixture with the 5CB nematic as a sensitive medium of the acetone vapor optical sensor. The spectral characteristics of such a medium change during interaction with acetone vapor, and the minimum in the transmission spectrum is shifted to the long-wavelength region.

To measure the spectral characteristics and their change under the influence of acetone vapor is used, developed by us, the measuring device is described. The time dependence of the position of the minimum transmission was obtained by the accumulation of acetone vapor in an isolated chamber for a time from 0 to 1 min. After the acetone vapor enters the chamber, it is sorbed by the liquid crystalline substance, due to which the vapor concentration in the chamber decreases slightly. The sorption process lasts 1-3 s, after which the interaction of the pair with the LCD stops, as evidenced by the saturation region as a function of the minimum transmittance from the interaction time. Spectral characteristics were obtained on a USB-2000 spectrophotometer in the range of 200-1100 nm. The experimental results were processed using OriginPro 8 software. The obtained spectral dependences were approximated by Gaussian functions, which made it possible to determine the wavelength of the position of the minimum light transmission.

Figure 1 shows the spectral characteristics of the LCD mixture based on BLO-62 plus 5CB (1) and after exposure to acetone vapor with a concentration of 400Pmm. It is established that the mixture has a minimum transmittance of 550 nm at the wavelength. After interaction with acetone vapors, we observe a shift in the transmission of mines toward long waves. At a concentration of acetone vapor of 400 pmm min transmission in the investigated wavelength range disappears, as can be seen from Fig.1. Figure 2 shows the spectral characteristics of the LCD mixture before action (1) and after the action of an aqueous solution of acetone (2) and (3). Figure 3 shows the relaxation characteristics of the LCD mixture after interaction with acetone vapor. At a holding time of 24 hours after interaction with acetone vapor, transmission mines are observed at 520 nm.

The interaction of the cholesterol-nematic mixture with acetone vapors and aqueous acetone solution was studied. The different nature of the action of these substances on the cholestric spiral is shown. The obtained results can be used to create a sensitive element of the optical sensor.

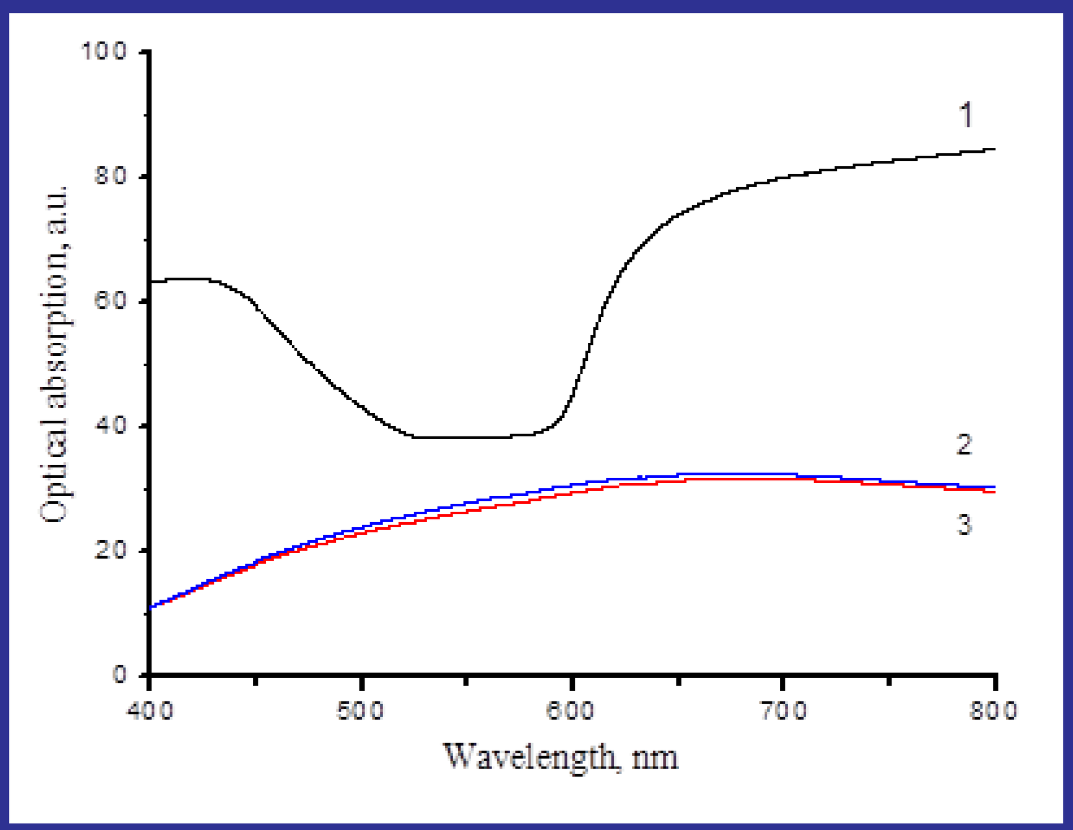


Fig.1. Spectral characteristics of the liquid crystal mixture based on BLO-62 + 5CB before (1) and after the action of (2,3) acetone vapor with a concentration of 400ppm

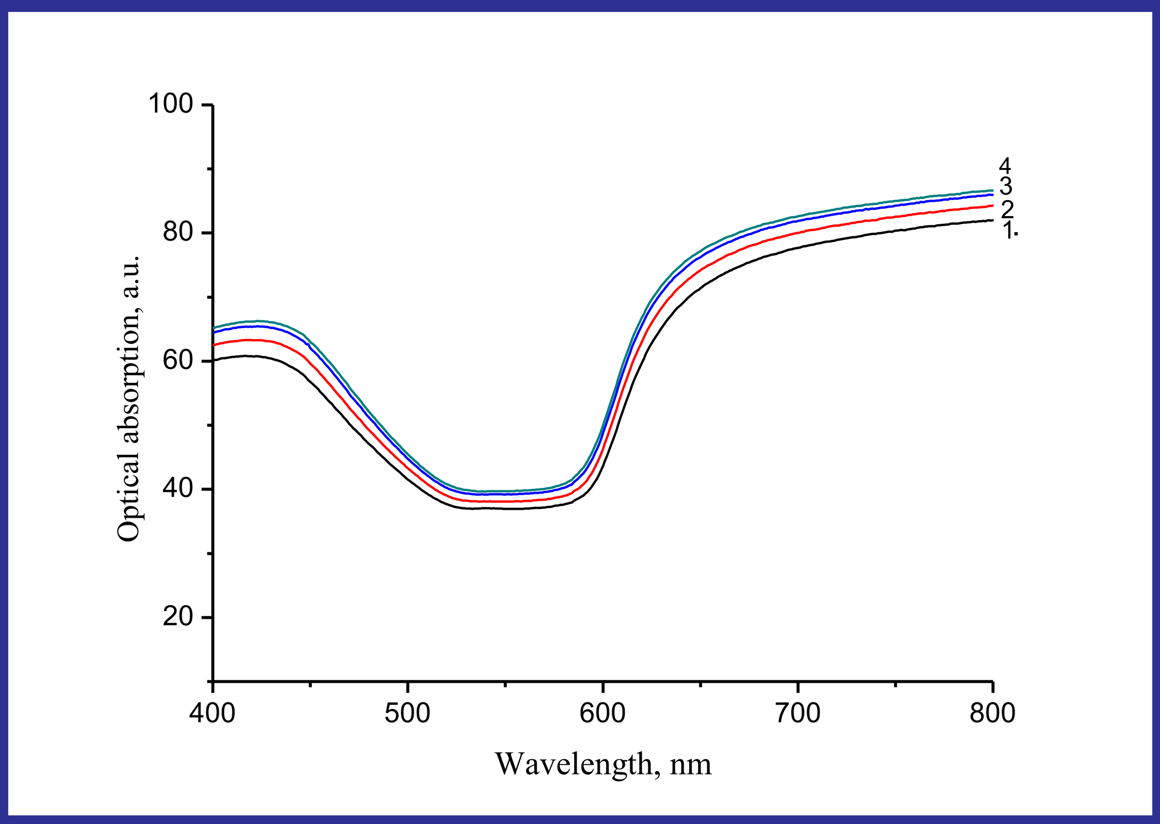
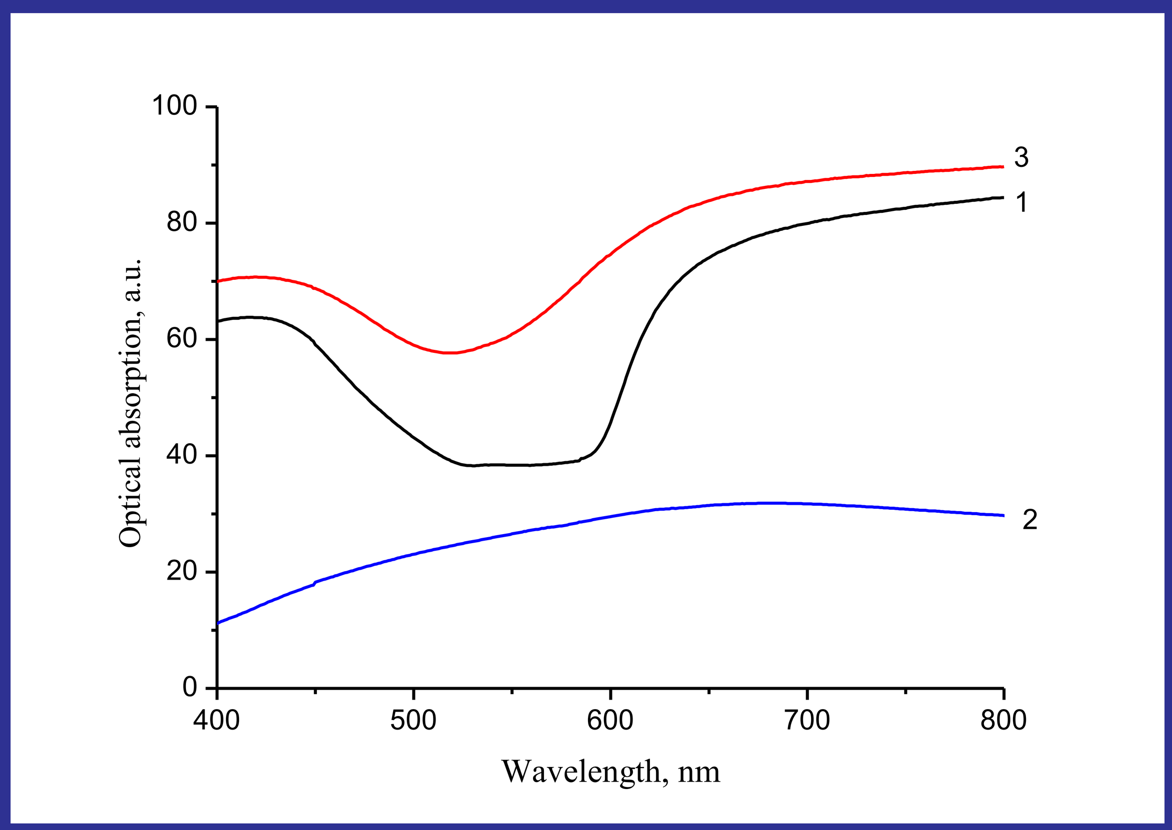


Fig.2. Spectral characteristics of the liquid crystalline mixture before exposure (1) and after exposure 0.02 ml (2), 0.04 ml (3) and 1 ml (4) of 2% aqueous acetone solution



Relaxation characteristics of the liquid crystalline mixture after interaction with acetone vapor:
1 - to exposure to acetone vapor
2 - after exposure to acetone vapor
3 - after 24 hours

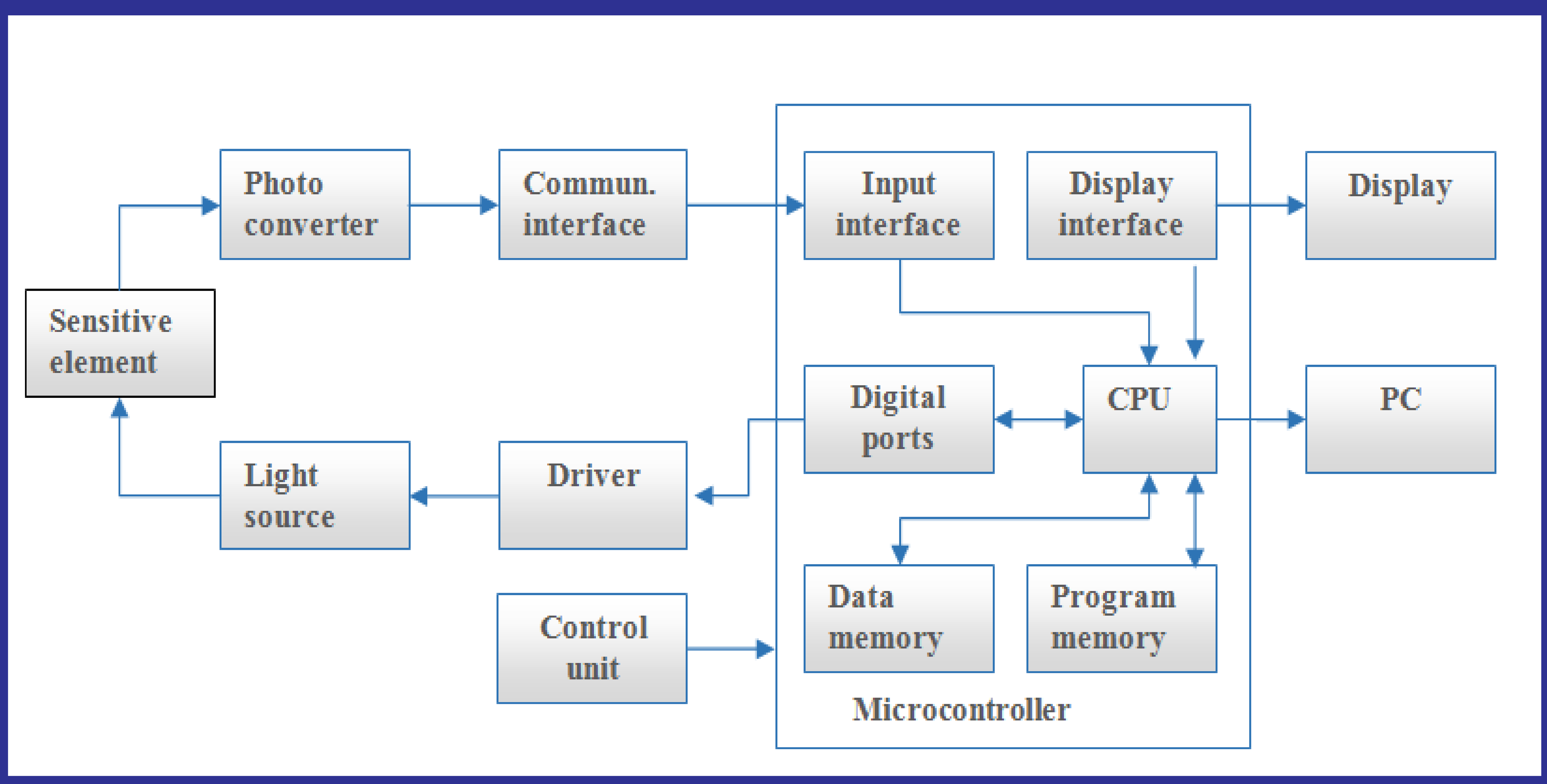


Fig.4. The generalized structure of the sensor circuit.

Based on the research results of the spectral characteristics of aqueous solutions of amino acids in the liquid crystal substance developed basic approaches for developing optical sensors (Fig. 4). The Arduino Nano microcontroller platform, RGB LED, and highly sensitive integrated photo converter TCS3400 were used to uild the experimental sample. The use of modern software-controlled tools, in particular PSoC systems of the 5LP Family Cypress family [3] , will significantly expand the functionality and accuracy of the touch device.

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