http://doi.org/10.35784/iapgos.7061

received: 12.01.2025 | revised: 25.02.2025 | accepted: 20.03.2025 | available online: 31.03.2025

METROLOGICAL FEATURE FOR DETERMINING THE CONCENTRATION OF CHOLESTEROL, TRIGLYCERIDES, AND PHOSPHOLIPIDS FOR PSORIASIS DETECTION

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Abstract. *The article is dedicated to the study of promising methods for determining the concentration of cholesterol, triglycerides, and phospholipids for the detection of psoriasis. It demonstrates that when interacting with cholesterol and triglycerides, the cholesteric-nematic mixture alters its spectral characteristics, in particular, which leads to a wavelength shift in the direction of the long-wavelength region. It is also shown that the liquid crystal mixture can serve as a sensitive element in an optical sensor for cholesterol and triglycerides and be one of the rapid diagnostic methods for detecting psoriasis.*

Keywords: psoriasis, liquid crystals, spectral shift, 5CB, BLO-61, diagnosis of bioobjects

CECHY METROLOGICZNE DO OKREŚLANIA STĘŻENIA CHOLESTEROLU, TRÓJGLICERYDÓW I FOSFOLIPIDÓW W CELU WYKRYWANIA ŁUSZCZYCY

Streszczenie. *Artykuł poświęcony jest badaniu obiecujących metod określania stężenia cholesterolu, trójglicerydów i fosfolipidów w celu wykrycia łuszczycy. Wykazano, że podczas interakcji z cholesterolem i trójglicerydami mieszanina cholesterol-nematyczna zmienia swoją charakterystykę spektralną, w szczególności powodując przesunięcie minimalnej długości fali w kierunku obszaru o dużej długości fali. Wykazano również, że mieszanina ciekłych kryształów może służyć jako element czujnikowy w optycznym czujniku cholesterolu i trójglicerydów i być jedną z szybkich metod diagnostycznych do wykrywania łuszczycy.*

Słowa kluczowe: łuszczyca, ciekłe kryształy, przesunięcie spektralne, 5CB, BLO-61, diagnostyka obiektów biologicznych

Introduction

Psoriasis is one of the most common chronic multifactorial skin diseases, which affects almost 3-4% of the world's population, and the proportion of patients with this disease in the system of skin diseases reaches 10-40% and tends to increase. Research [1, 5] has shown that in the blood plasma of patients with psoriasis, an increased concentration of cholesterol, triglycerides and phospholipids is much more often detected, therefore its determination in vitro is an urgent problem [2, 6].

Existing laboratory research methods require immunological analyzers and special training of personnel. We propose to use optical sensors for express analysis of cholesterol, triglycerides and phospholipids. The sensitive element of such a sensor is based on a cholesteric liquid crystal, which changes its spectral characteristics in the presence of these biological substances [13–15].

The structure of the liquid nematic crystal 5CB (4-octyl-4-cyanobiphenyl) is shown in Fig. 1.

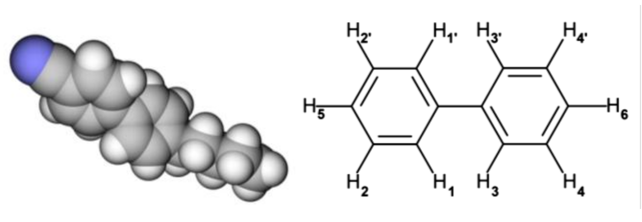

Fig. 1. Nematic liquid crystal 5CB (4 – octyl – 4 – cyanobiphenyl)

The change in the orientation of a liquid nematic crystal can be recorded by optical methods, such as a change in polarization, intensity, etc. This feature of the behavior of a liquid nematic crystal doped with biomolecules is the basis for the condition of creation of a sensitive element of the primary transducer of an optoelectronic sensor of cholesterol and other protein substances. The closeness of the chemical nature of nematic and cholesteric liquid crystals suggests the identity of the mechanism of their interaction with biological substances, and the presence of a supramolecular helical structure expands the methods of their detection.

1. Method

The optical properties of cholesteric liquid crystals contribute to their use as sensitive elements of primary transducers of biological sensors, which are used for the qualitative of determination of biological substances. As a result of contact with bioobjects, the optical characteristics of cholesteric liquid crystals change, which significantly expands the possibilities of identification and detection, and diagnosis of bioobjects.

Optical methods of forming an information signal are widely used in modern sensors. Such a signal will be formed due to selective transmission of optical radiation from an active medium that interacts with a gas, liquid, or solid. The creation of optoelectronic biosensors for the detection and quantitative analysis of biological substances is a task related to analysis of the effectiveness of drugs, the control of biological processes, etc.

The helical structure of cholesteric liquid crystals is sensitive to the influence of external factors, in particular biological substances. We propose to use cholesteric LC with a selective reflection band in the visible region of the spectrum as an indicator of the presence of biological substances. When contacting biological substances, the cholesteric-nematic mixture changes the position of the minimum transmission of optical radiation (Fig. 4, 5).

Also, the object of research was a reference solution of artificially synthesized triglycerides with a concentration of 2.5 mmol/L. The triglycerides we studied include unsaturated fatty acids – oleic, linoleic, and linolenic. Triglycerides enter the body with food or are synthesized in the liver. They accumulate in adipose tissue, being an energy reserve. An elevated level of triglycerides in blood serum is a marker of cardiovascular risk and atherosclerosis [4, 7, 16].

Therefore, monitoring the level of cholesterol, triglycerides, phospholipids in biological objects is a pressing problem. [9, 12] Today, many biosensors have been developed for quantitative and qualitative control of levels cholesterol's. Considerable attention is also paid to the development of optical sensors, where liquid crystalline substances are used to detect cholesterol – nematic liquid crystals, which change orientation from planar to homeotropic in the presence of molecules cholesterol's [3, 5, 10].

Propose to create an active environment by using cholesterol-nematic mixtures with further use in optical sensors for psoriasis disease control.

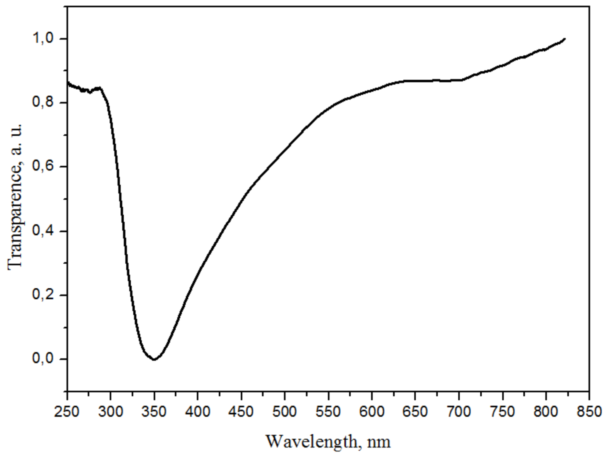

Fig. 2. Spectral characteristics of nematic liquid crystal 5CB

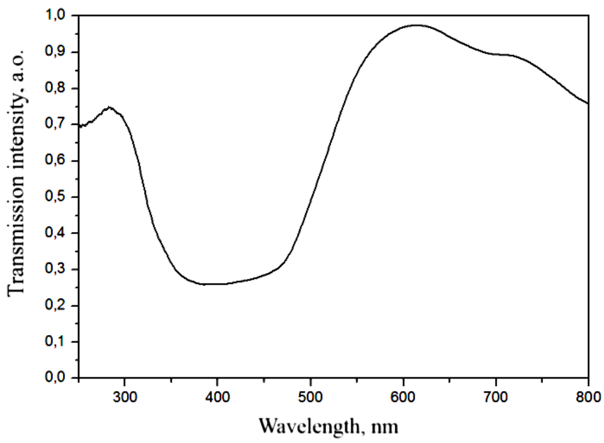

Fig. 3. Spectral characteristics of cholesteric liquid crystal

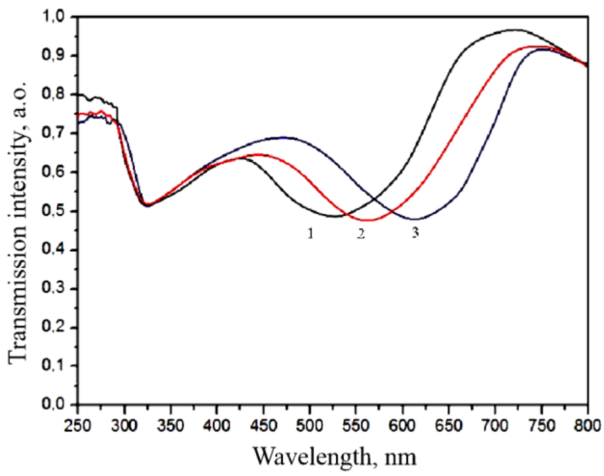

Fig. 4. Transmission spectrum of a mixture of cholesteric and nematic liquid crystal 1 – 5CB concentration 25%; 2 – 5CB concentration 30%; 3 – 5CB concentration 35%

2. Experimental part

We investigated the dependence of the change in the transmission spectra of mixtures of cholesteric liquid crystal BLO-61 and liquid nematic crystal 5CB on the cholesterol concentration in the range of 250–800 nm. The method of obtaining spectral characteristics and processing of experimental data is described in [7, 8].

The results of the studies show that at room temperature, the cholesterol content in 5CB does not significantly affect the transmission spectrum of the liquid crystal. This dependence is shown in Fig. 5.

As can be seen from the figure, when the cholesterol concentration in BLO-61 changes from 0 to 5 wt.%, a sharp change in the wavelength of the minimum transmission is observed. However, with a further increase in the cholesterol concentration from 10 wt.%, this wavelength is practically unchanged.

At the same time, for BLO-61, the wavelength of the minimum transmission changes with increasing cholesterol concentration in the liquid crystal. When the cholesterol concentration in BLO-61 changes from 0 to 5 wt.%, a sharp change in the wavelength of the minimum transmission is observed. However, with further increases in cholesterol concentration, this wavelength remains practically unchanged.

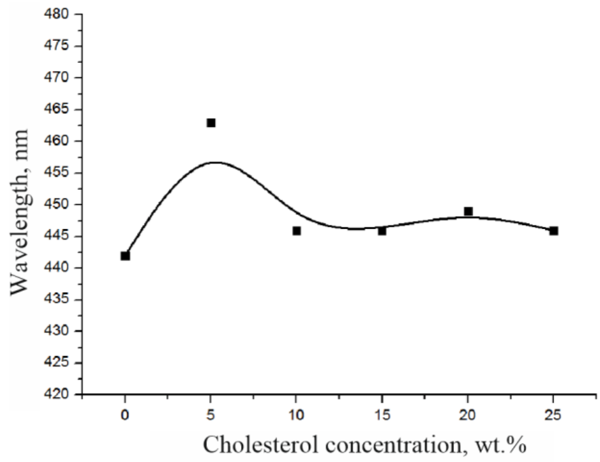

Fig. 5. Analysis of the wavelength dependence of the minimum transmission of cholesterol content in BLO-61

For further studies, cholesteric-nematic mixtures were created based on liquid cholesteric crystal (CLC) BLO-61 and liquid nematic crystal 5CB (20–40 wt. %) with a step of 5 wt.%.

The concentration level of NLC is determined in such a way as to obtain the maximum value of the reflection of the optical signal in the visible region. Experimental composites were obtained by heating the components to a temperature that is 5–7°C higher than the temperature of the phase transition to the isotropic state. Mixing of the mixture was carried out using a magnetic stirrer.

In the transmission spectra of the cholesteric-nematic mixture, two light transmission minima are observed, one of which, at a wavelength of 320 nm, corresponds to the intrinsic transmission minimum of the nematic liquid crystal. The position of the second minimum depends on the concentration of the liquid nematic crystal in the cholesteric-nematic mixture, in particular when the concentration of 5CB changes from 20 wt. % to 40 wt. % wavelength varies from 460 to 660 nm [8, 11].

Cholesterol was added to each of the formed CNS with concentrations from 0 to 5 wt%. The assessment of the independence of the value of the minimal transmittance of the nanocomposite from the content of cholesterol in it is presented in Fig. 6.

Analyzing the dependence of the minimum transmission wavelength on cholesterol concentration, as shown in Figure 2, it can be concluded that increasing the cholesterol concentration in the cholesteric-nematic mixture (CNM) from 0 to 5 wt.% causes a sharp shift transmission wavelength of the minimum toward the long-wavelength region.

Figure 7 presents the dependence of the minimum transmission wavelength of the developed nanocomposites on triglyceride concentration.

Analysis of the obtained dependencies shows that as the triglyceride concentration increases within the range of 0–5 wt.%, a sharp shift of the minimum transmission toward the long-wavelength region occurs.

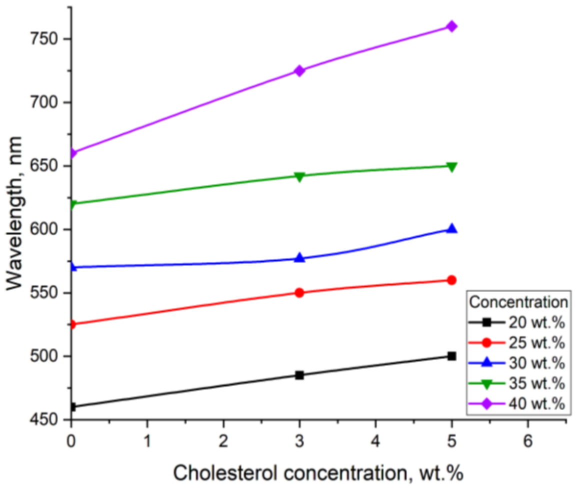

Fig. 6. The assessment of the independence of the value of the minimal transmittance of the nanocomposite from the content of cholesterol

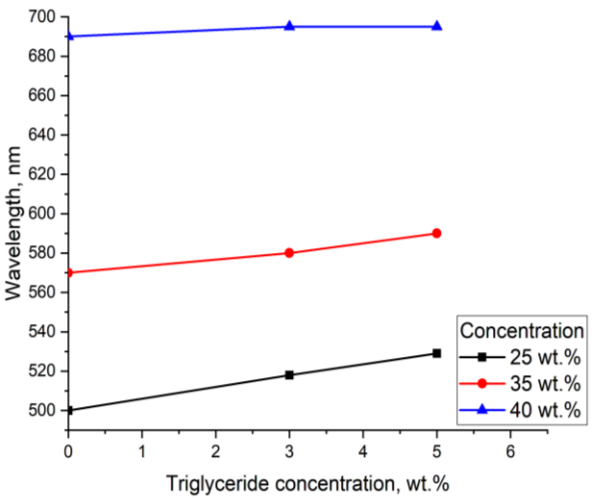

Fig. 7. The assessment of the independence of the value of the minimal transmittance of the nanocomposite from the content of triglyceride

3. Experimental results and their discussion

The properties of the nanocomposites were evaluated using the spectral sensitivity coefficient S, which is determined by the following equation:

$$S = \Delta\lambda / \Delta C \quad (1)$$

where $\Delta\lambda$ is the change of the wavelength of the minimum transmission of the cholesteric-nematic mixture (CNM) as a function of cholesterol content in the CNM (in nm), and ΔC is the change in the concentration of cholesterol and triglycerides (in %).

When the cholesterol concentration increases from 0 to 5 wt.%, a linear region is observed in Figure 1. The spectral sensitivity coefficient is 4.2 nm/%.

Analysis of the dependence of the spectral sensitivity coefficient on the triglyceride concentration (Figure 2) shows that, in the concentration range of 0–5% triglycerides, for mixtures with a 25% 5CB concentration, it is 3.5 nm/%. For a 35% 5CB concentration in the range of 0–10%, it is 4 nm/%.

For mixtures of nematic liquid crystal with cholesterol, with increasing cholesterol concentration, a shift of the optical minimum transmission to the range of longer wavelengths (~from 320 to 370 nm) is observed. This can be explained by the fact that groups with atoms with an unshared pair of electrons (for example, the -OH group, which is part of cholesterol) enter into p-π conjugation with multiple bonds. The carbon of the nitrile group (-C≡N) in the 5CB composition is electrophilic (there is a partial positive effective charge on the carbon atom), therefore, prone to nucleophilic addition reactions. Electrophiles are able to react with compounds that have an unshared pair of electrons. Thus, it is possible to assume some interaction between cholesterol and 5CB molecules, as a result of which the liquid crystal molecules can change their spatial characteristics (structure, orientation, optical conformation, etc.), and this, in turn, directly affects the position of the light transmission minimum.

To interact with weak nucleophiles, in particular ROH alcohols, the nitrile group requires additional activation – protonation. The reaction scheme of nucleophilic addition has the form shown in Fig. 8.

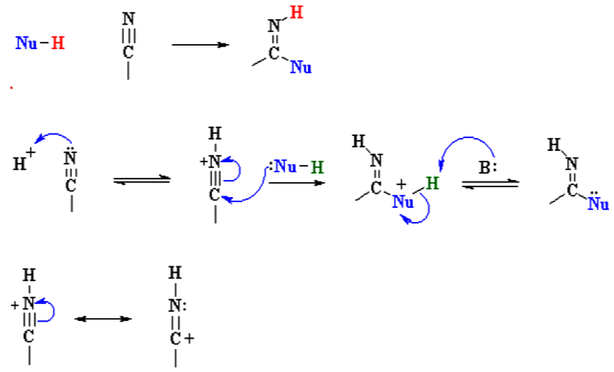

Fig. 8. Scheme of nucleophilic addition.

In [2, 9], the nature of the interaction of the liquid nematic crystal 5CB with cholic acid, which is a product of cholesterol oxidation, was analyzed, and the mechanism of the formation of complexes between the molecules of the liquid crystal and cholic acid molecules was shown.

Based on the analysis of the mechanisms of interaction between the nematic liquid crystal and cholesterol molecules, it can be argued that in the final version this process will lead to an increase in the step of the cholesteric-nematic mixture.

4. Conclusion

When interacting with cholesterol and triglycerides, the cholesteric-nematic mixture (CNM) demonstrates a notable alteration in its spectral characteristics. Specifically, this interaction induces a shift in the minimum transmission wavelength, moving it toward the spectrum long wavelength region. This phenomenon reflects the sensitivity of CNM to these biomolecules and highlights its potential for scientific and medical applications.

Studies have revealed that CNM holds significant promise as a responsive material in the development of optical sensors designed to detect cholesterol and triglycerides. Such sensors could enable rapid, non-invasive diagnostic methods by leveraging the CNM's ability to detect subtle biochemical changes. In particular, this approach has been identified as a potentially valuable tool for the early detection and monitoring of psoriasis, offering a swift and efficient means of diagnosis through the analysis of biochemical markers.

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