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TEMPERATURE DEPENDENCE OF CHROMATICITY IN POLYMER-DISPERSED CHOLESTERIC LIQUID CRYSTAL: REFLECTION AND TRANSMISSION CHARACTERSTICS

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This paper continues our investigations of polymer-dispersed cholesteric liquid crystals (PDLC) composition and distant control of the temperature [1]. A comparison of the colour features of the reflected and transmitted light was made. A sample of NOA 65/ thermo-indicator/ carbon black was tested by heating to different temperatures and registration of the spectra in the wavelength range 380 – 780 nm. Colours were calculated in the standard CIE system. The results show an expansion of the maximal optical activity to temperatures lower than those for the pure PDLC.

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1. Introduction

Liquid crystals (LC) are highly anisotropic fluids that exist between the limits of the solid phase and the conventional isotropic liquid phase. Temperature measurements based on TCLC (termochromic cholesteric liquid crystals) exploit the property of some cholesteric liquid crystals (CLC) to reflect definite colours at specific temperatures. The colour change for the TCLC sensitivity ranges from clear at ambient temperature, through red as temperature increases and then to yellow, green, blue and violet before turning colourless (isotropic) again at a higher temperature. The colour-temperature deviation interval depends on the TCLC composition. These colour changes are repeatable and reversible, as long as the TCLCs [2] are not physically or chemically damaged. It makes TCLC applicable to temperature measurements in different areas like medicine, biophysics and the environment. In this case, we study the temperature behaviour of the polymer dispersed TCLC.

Molecular orientation in a CLC, with the general structural formula as in Fig. 1, shows a preferred axis labelled by a director. The molecular alignment within a layer is parallel, but the alignment in adjacent layers is rotated. The displacement is cumulative through successive layers so that the tip of the director traces out a helical path, “pitch” (Fig. 2). In CLC, the pitch exhibits extreme sensitivity to slight changes in temperature. This behaviour is used in our investigations in which we explore the CLC spectral response.

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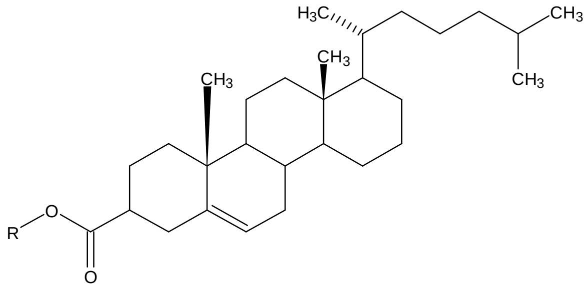

Fig. 1. General formula of a cholesteric liquid crystal. R = radical.

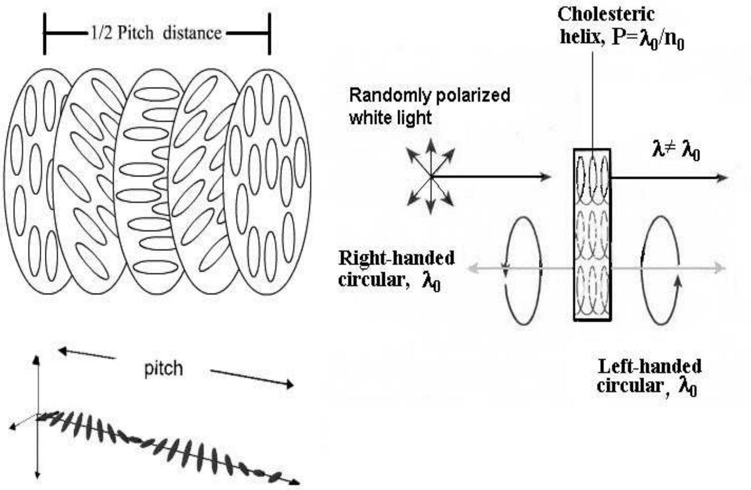

Fig. 2. Schematic diagram of the wavelength and pitch of CLC.

2. Materials and methods

Materials: The photopolymerizable mixture Norland Optical Adhesive NOA 65, manufactured by Norland Products, Inc., New Brunswick, N.J., contained 3,3-Bis-hydroxymethyl-4,4,4-trimercapto-butan-1-ol, 2,2-Bis-allyloxymethyl-butan-1-ol and 3-Isocyanato-1-isocyanatomethyl-3,5,5-trimethyl-cyclohexane [1]. The cholesteric liquid crystal thermo-indicator “Reachim”, Russia (K40Ch75I) was used. The PDLC consisted of 19% NOA 65, 80% cholesteric liquid crystal and fine carbon black. All components were mixed in an ultrasonic mixer, after shock temperature treatments.

Methods: PDLC was obtained by photo-polymerisation induced phase separation (PIPS) [3,4,5] in two liquid crystal cells with 15 µm spacers. The first was a standard cell, used for measurements of transmitted light. The second cell, used in measurements of reflected light was completed with a transparent ITO covered glass as the top plate and a one-side metallized glass (mirror) as the base of the cell. The measurements were made using an Ocean Optics PC2000 UV-VIS fibre-optic micro-spectrometer, plus a high-sensitivity 2048-element linear CCD-array (spectral resolution approximately 8.5 nm), a 12 bit ADC and a halogen light source. The measurements of transmitted light through the sample were supplemented by measurements of the light reflected from the sample. The registered data was in the region 400-780 nm, with a 5 nm sampling step. We used a simple standard technique for the calculation of the colour features in the CIEXYZ system [6].

3. Results and discussion

The sample was tested in the temperature range 35 to 75 °C. The measurements were made under conditions of increasing and decreasing temperature. Reflected light was also measured in the cases of normal and inclined incidence. The colour feature changes were detected at the same temperature, which is why only the summarized results are presented. Fig. 3 shows the temperature dependence of the lightness, calculated in the CIEXYZ system. The results indicate that the changes are localized at the same temperature, and that they do not depend on the type of measurement of transmitted or reflected light.

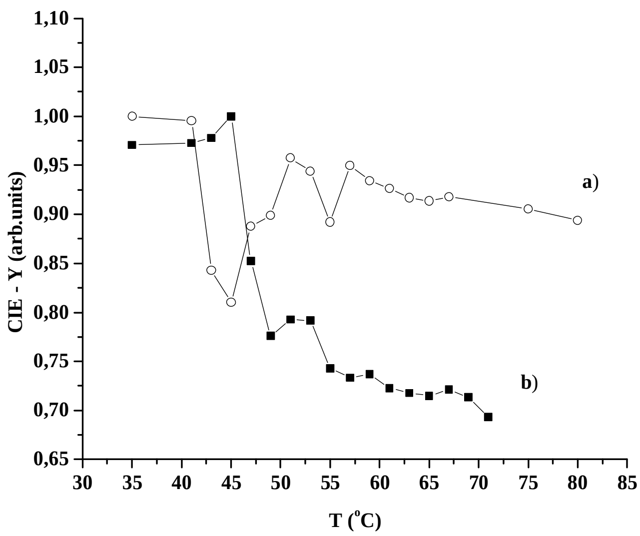

Fig. 3. Temperature dependences of the lightness CIE-Y a) - transmitted light, b) - reflected light.

The temperature dependences of the CIEXYZ chromaticity of the samples are presented in Fig. 4. Maximal deviation of the numerical coordinates with respect to white source coordinates occurs at 47 °C. The coordinates for the all temperatures in the measurements of transmitted light form a closed curve that starts and finishes at neighbouring positions. The coordinates also form a closed curve in the case of reflected light.

Changes in the colour of the measured light are given in Table 1. The colours are denoted in accordance with the coordinates of the white source. The lack of coincidence between complement colours in the case of transmission and reflection is due to the non-homogenous mixture.

Table 1. Colour deviations as as function of temperature. Tr = transmission; Refl. = Reflection.

	White source coordinates			Colour deviations in accordance to the white						
	x_w	y_w	T °C	35	43	45	47	49	51	57
Tr.	0.43643	0.46890		white	blue	purple	red	orange	green	white
Refl.	0.44021	0.47081		white	red	orange	green	cyan	blue	white

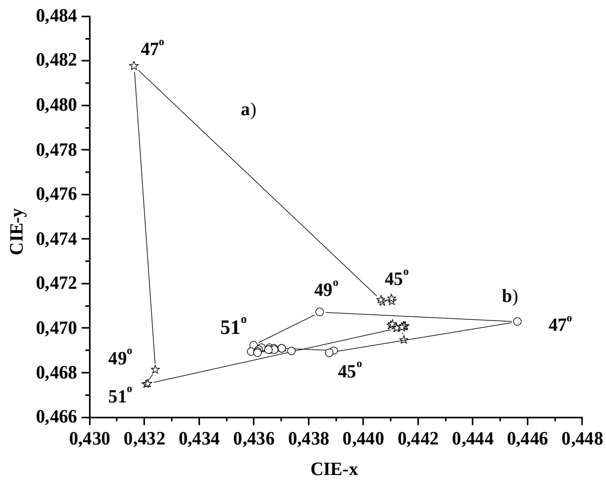

Fig. 4. Time dependence of chromaticity coordinates a) - reflected light, b) - transmitted light.

4. Conclusions

In this investigation, the behavior of polymer dispersed TCLC was studied under conditions of different temperatures and measurements of the transmitted and reflected light. As a result, colour features, presented in the standard CIEXYZ system, were obtained.

The conclusions can be summarized as follows:

- Chromaticity - the temperature relation shows the ability to create a precise thermometer based on PDLC, operating over a wide temperature range [7];

- the intensity variation of the transmitted and reflected light, measured in the visible region, means that precise measurement of temperature in the TCLC active range is possible.

Studies also demonstrate that the reflection mode of operation is more advantageous than the transmission one.

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