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Optical Properties in Polymer Stabilized Liquid Crystal Indicator Used in the Thermometry*

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Abstract. Extending the temperature range of the ordinary thermo indicator by mixture of TLC and PMMA we achieved a better spectral sensitivity in a wider temperature range. We observed modulation of the intensity of the transmitted monochromatic light in accordance with the temperature changes. Also that sensor could be used like an 'on-off' fire alarm detector.

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1 Introduction

Liquid crystals (LC) are highly anisotropic fluids intermediate between solid phase and the conventional isotropic liquid phase. Temperature measurements based on thermochromic liquid crystal (TLC) exploit the property of some cholesteric liquid crystals (ChLC) to reflect definite colours at specific temperatures. The colour-temperature deviation interval depends on the TLC composition. These colour changes are reproducible and reversible as long as the TLC's [1] are not physically or chemically damaged.

Molecular axis in a ChLC, with general structural formula (Figure 1), shows a preferred orientation labelled as 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 pitch — P (Figure 2).

In ChLC the pitch exhibits extreme sensitivity to slight changes in temperature. This behaviour is used in our investigations. We explore the LC spectral

*his work is dedicated Professor Alexander Derzhanski, Dsci Corresponding Member of the Bulgarian Academy of Sciences; on the occasion of his 70th anniversary.

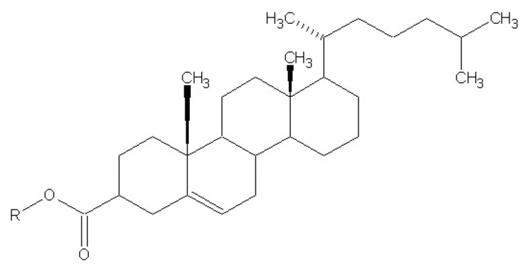

Figure 1. General formula of cholesteric liquid crystal.

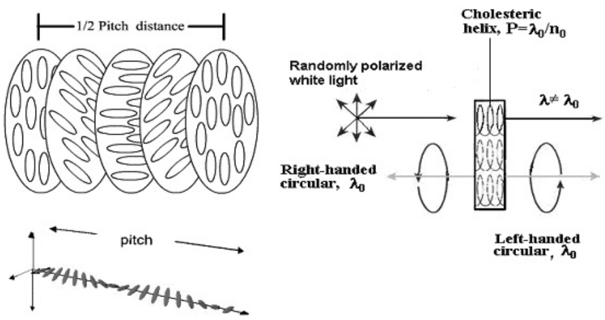

Figure 2. Schematic presentation of the wavelength and pitch of ChLC's.

response, where make use of polymer-dispersed liquid crystals (PDLC) for thermometry, which is very important for determination of refractive index of bulk PDLC. The purpose of this work is by mixture of thermo indicator (TI) and ChLC to extend the temperature region in order to obtain more sensitive thermometer.

2 Materials and Methods

Materials: Polymethylmethacrylate (PMMA), L-α-phosphatidylcholine Soybean lecithin (Sigma) and LC thermoindicator "Reachim" — Russia (Cr–40°C–Ch–75°C–I) was mixed by means of an ultrasonic mixer. We produced and investigated two structures with different polymer quantity. The first structure is 4% PMMA–polymer stabilized liquid crystal (PSLC) [2] and the second is 50% PMMA–PDLC [3] (Figure 3).

The spectral response of three samples: TLC – pure, PSLC and PDLC were investigated at a set-up shown in Figure 4.

Methods: PSLC and PDLC obtained by solvent induced phase separation. The temperature dependence was investigated by the spectral-polarization

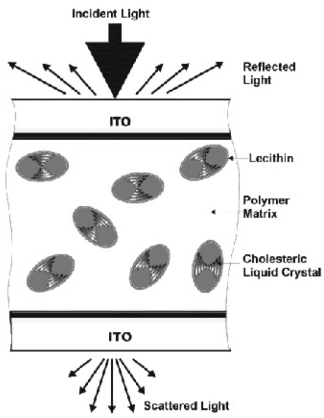

Figure 3. Cross-sectional of PDLC thin film prepared like LC cell.

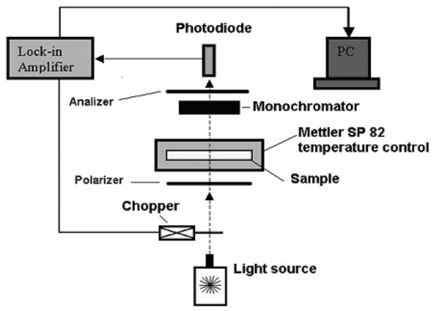

Figure 4. The set-up for spectral – polarization experiment .

method [4]. The set-up is sketched out in Figure 4.

When the illumination wavelength is equal to the pitch length, the crystal acts as a Bragg grating and locks a large fraction of the incident intensity. The light passes through the crystal at different wavelengths. Molecular organization of PDLC causes an intensity modulation because the polarizers are adjusted at 45°. So, the spectral response looks as alternative regions with light intensity modulation followed by regions without modulations.

3 Results and Discussion

The results of measured spectral response at two different temperatures are shown in Figure 5. The measurements at 40°C without polarizer (base curve) and with polarizers are illustrated in the inset. The latter illustrates how intensity modulation increases when polarizers are used. The regions without modulations are separated by spectral distance $\Delta\lambda$, which holds [5]

$$k\Delta\lambda = nP \tag{1}$$

(k is the integer number, n is the refractive index). To verify the 'spectral distance — temperature' relation the spectral response was measured at different temperatures. As we expected, $\Delta\lambda$ increases with temperature raise because P increases (see Figure 5 — the spectral response at 50°C). Unfortunately, the modulation and the spectral distance were not so clear as those at 40°C. This is probably due to some disorder of the system. To achieve high temperature sensitivity (in the range $\delta\Lambda$, see Figure 5) we need molecular alignments in the whole LC volume. In this case the sample will act as a precise Fabri-Perot interferometer in a wider temperature range, where the ChLC dominates.

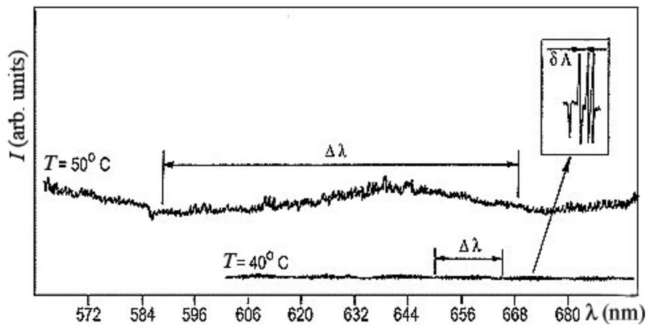

Figure 5. Spectral response of PSLC and PDLC.

The spectral response was measured in the active range of TLC for two wavelengths. As we expected, the transmission of the green light ($\lambda_1 = 530$ nm) sharply decreases near the active range (at 69°C) (Figure 6). The same was observed for the red light ($\lambda_2 = 630$ nm) at 76°C. This behaviour shows the possibility of precise measurement of temperature in the active range 69–76°C controlling the intensity of transmitted light in the spectral region 530–630 nm. So, there are the possibilities to create relatively easily a temperature sensor of an 'on-off' type by measurement of transmitted light in a proper spectral region.

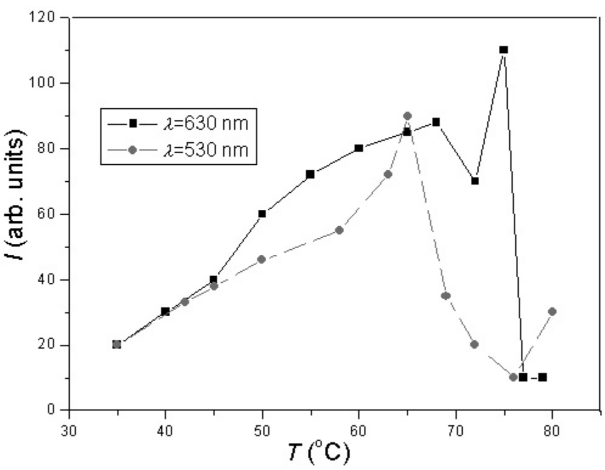

Figure 6. Spectral response of PSLC and PDLC in the active region.

The observed spectral responses of each of the three samples were measured. The measurements were taken for a few months. The samples of PSLC and PDLC showed very good reproducible and reversible properties while the sample with pure LC changed its chemical and physical properties.

The spectral response at 40°C and 50°C within the alternative regions with light intensity modulation followed by regions without modulations can be explained by the memory effect in capsulated TLC.

To estimate the cholesteric pitch (P) through equation [5]

$$P = \frac{\lambda}{n}, \tag{2}$$

where n is the effective index of refraction of PDLC equal 1.5013 [6] and $\lambda = 530$ nm is the incident green light. Thus evaluate $P = 0.353 \times 10^{-6}$ m. This value coincides with that shown in the [7].

4 Conclusion

In conclusions:

- ‘spectral distance–temperature’ relation shows the possibility to create a precise thermometer based on PDLC and PSLC in wider temperature range $40 \div 70$°C;
- the intensity of transmitted light measured in the ‘green-red’ spectral region means that precise measurement of temperature in TLC active range is possible;
- we suggest that the observed intensity modulation to be provided by the effect of memory in PDLC and PSLC.

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