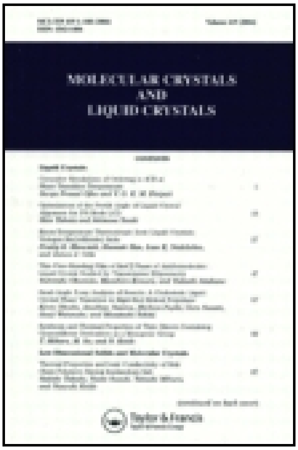

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Polymer-Dispersed Cholesteric Liquid Crystals Reflecting In the Infrared Region

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POLYMER-DISPERSED CHOLESTERIC LIQUID CRYSTALS REFLECTING IN THE INFRARED REGION

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Polymer-Dispersed Cholesteric Liquid Crystals (PDCLC) have been obtained using different cholesteric liquid crystals mixtures by the Photopolymerization-Induced Phase Separation method. PDCLC samples of different thickness and different LC concentrations have been studied. The selective reflection spectra for different voltages have shown maximum reflectivity in the infrared region.

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INTRODUCTION

Polymer/liquid crystal composites include Polymer-Stabilized Liquid crystal (PSLC) and Polymer-Dispersed Liquid Crystal (PDLC) systems.

PSLC are thin films of liquid crystal (LC) stabilized by volume polymer network. The polymer content in those composites is small (usually about few per cent).

PDLCs consist of micrometer size LC droplets embedded in a solid polymer matrix [1]. If the LC content is relatively high, the droplets can be connected to each other through channels. The PDLCs are systems with high surface–to–volume ratios. Traditional LC devices are formed as thin LC films between two parallel substrates. The substrates are usually treated to obtain uniform alignment of the LC at each surface. Anchoring effects are due to the two bounding substrates. In the PDLC systems there is a large increase in the relative surface area. As a result, the interfacial effects become more important, because of the anchoring properties of the LC at the surface and of the hydrodynamic flow characteristics of the LC in close proximity to a surface [1].

PDLC devices exhibit an electro-optical effect because of optical heterogeneity between the polymer and the LC domains. In a polymer-dispersed *nematic* liquid crystal one achieves switching between an opaque field-"off" and a transparent field-"on" states by matching the ordinary refractive index of the LC to the refractive index of the polymer matrix. In Figure 1 is presented the schematic working principle of nematic PDLC (1a) and Polymer Dispersed Cholesteric Liquid Crystals – PDCLC (1b).

PDLC films have various applications: displays, bistable devices, polarizers, modulators of different kind, memory devices, selective permeable membranes, thermal switches, etc., their properties varying strongly with the temperature.

PDLC CONTAINING CHOLESTERIC LIQUID CRYSTALS

The cholesteric liquid crystals, also called chiral nematics [3], are locally nematic, but the director rotates spatially, describing a helix of pitch p; the helical axis, around which the molecules twist, lies perpendicular to the local director. The periodicity of the structure is p/2. When the wavelength of light incident on the sample has the same value as the cholesteric pitch multiplied by average refractive index, (the incident light parallel to the helix axis) the circularly polarized component with the same handedness as the helix is totally reflected [2,4].

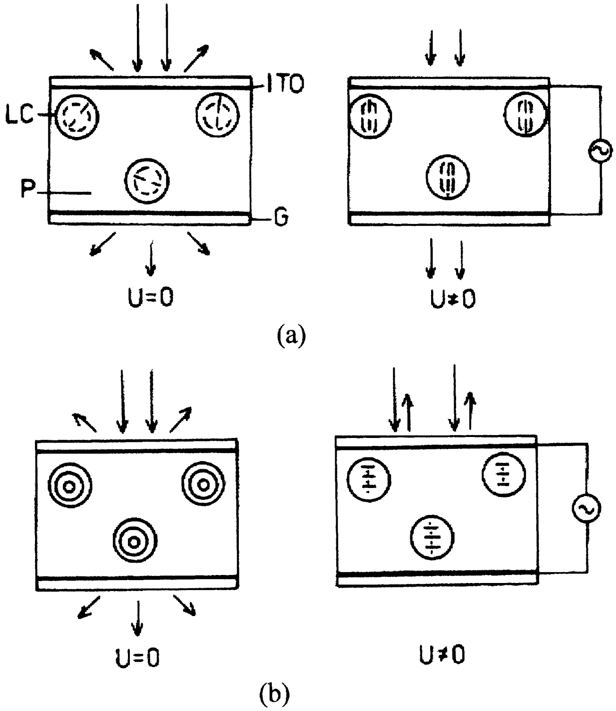


FIGURE 1 Schematic presentation of the work principle of nematic PDLC (a) and PDCLC (b): LC-liquid crystal droplet; P-polymer matrix; ITO-G-glass substrate; ITO- indium tin oxide transparent conductive layer [2].

In PDCLC[2–9], when the applied field is zero, the configuration of the LC in the droplet is determined by the polymer-LC boundary conditions, and because of the helix axis non-uniform orientation, the incident light will be scattered. When a voltage is applied on the cell, the electric field forces will reorient the LC from the scattering texture to a planar helical alignment ($\Delta\varepsilon < 0$), with the helix axis parallel to the field and the film will be selectively reflective in the corresponding wavelength region.

PDLC are usually obtained by phase separation methods [1]:

- PIPS – Photopolymerisation-Induced Phase Separation: LC is mixed with low molecular weight monomers or oligomers, which act as a solvent for the LC. Polymerization is induced by heat or UV radiation. The growing polymer chains phase separate from the LC to form a matrix surrounding discrete LC domains. The phase separation process is sensitive to temperature, light intensity (in photo-cured systems), presence of impurities, solubility characteristics and molecular weight of the starting materials.

- TIPS – Thermally-Induced Phase Separation: thermoplastic polymer is heated into a melt and mixed with a LC to form a single-phase solution. The LC phase separates into droplets as the system is cooled back to room temperature.
- SIPS – Solvent-Induced Phase Separation: the polymer is mixed with the LC and an organic solvent to form a single-phase mixture. Evaporation of the solvent causes phase separation of the polymer and liquid crystalline phases.

In each case the droplet size can be controlled by the rate of polymer curing, a smaller curing rate leads to bigger droplets.

EXPERIMENTAL

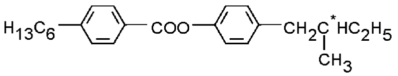
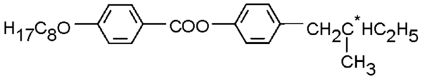
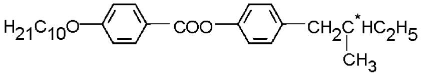
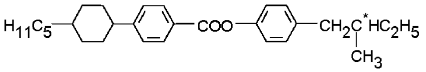
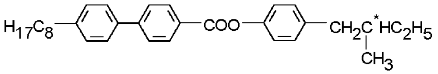
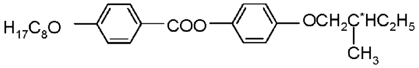
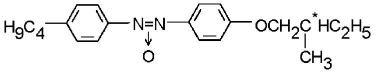
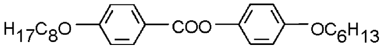
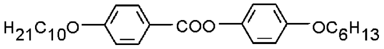
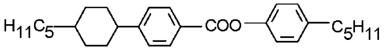
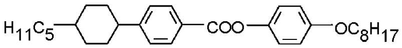
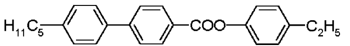
Polymer-Dispersed Cholesteric Liquid Crystals (PDCLC) have been obtained by the PIPS [10]. Different cholesteric LC mixtures have been used (especially those with codenames: CH2000 and LEX3 prepared in the Institute of Chemistry, MUT) on the basis of the LC individual compounds given in Table 1.

The photocurable resin NOA 65 (Norland Optical Adhesives) has been used as a polymer matrix. A homogeneous mixture of the prepolymer, LC and glass balls 8 μm thick have been prepared. The LC concentration was of 20%, 35% and 50% b.w. Such mixtures have been placed between glass plates with conducting ITO layer and illuminated by UV flux 10–20 mW/cm^2 to perform phase separation and stabilize the system. The UV intensity was chosen to obtain LC droplets large enough to prevent helix unwinding, but much lower than film thickness, i.e. diameter of 2–3 μm.

The choice of presented liquid crystal mixture components have the following reasons.

1. The used compounds exhibit good miscibility with each other.
2. The melting points and clearing points of used compounds are quite different allowing to obtain mixtures with different temperature range of LC phases (see e.g. compounds no. 1 and 7 vs. compounds 10, 11 and 12). This depends of course on the molecular structure of used compounds.
3. Thermo-optical effect, i.e. fast change of the maximum of selectively reflected light, can be observed in mixtures having also SmA phase. For this reason compounds 2, 3, 4, 5, 6, 9, 10, 11 and 12 have been used.

TABLE 1 Chiral Nematic Compounds Used to Prepare CLC Mixtures

No. 1	Formula 2	Phase transitions temperatures [°C] 3
1.		K 17,6 (N*) I; ΔH = 5,90
2.		K 47,2 (32,5 SmA 44,4 N*) I
3.		K 41,9 SmA 42,2 N* 45,3 I
4.		K 79,4 Sm$_A$ 110 N* 148 I
5.		K 50,5 SmG 63 SmI 65 SmF 67 SmI 71 SmC* 81 SmA 136 N* 140 I
6.		K 42,5 SmC 43,5 SmA 59 N* 62 I;
7.		K 13,7 N* 26 I
8.		K 53,7 SmC 66,5 N89,9 I
9.		K 60,7 SmC 77 SmA 83 N89,5 I
10.		K 73,5 SmB 98 SmA 134,3 N172,8 I
11.		K 78,8 SmB 105,5 SmA 158,5 N 180,3 I
12.		K 106 SmA 125 N168 I;

4. Mixtures of compounds 8, 9, 10, 11 and 12 allowed to unwind the helix due to the absence of chiral terminal group; in this way the helical pitch of the mixture could be adjusted.
5. Using several compounds (4, 10 and 11) with the same core and a common terminal group we can study the effect of the second terminal group.

In the following we show the results concerning the feasibility of PDCLC samples containing particular mixtures of such compounds in the infrared region.

In Figure 2 is represented the reflectivity versus a.c. voltage at 1 kHz for the sample containing as LC the mixture LEX3, 20% b.w, at room temperature. Similar results have been obtained for the PDCLC samples containing the CH2000 liquid crystal mixture, for which the best reflectivity was found at 35% b.w. LC concentration. The maximum reflectivity was situated in the infrared region for all samples.

The selective reflectivity for zero applied voltage on the sample is relatively high in our sample compared to the work presented in ref. [2]. An application of electric field gives more uniform orientation of the helix inside the droplets, and thus the reflectivity increases as clearly observed in Figure 2.

Concerning the wavelength value of this selective reflection, preceding papers [2,4] with comparable $\Delta\varepsilon < 0$ conditions does not show an evident wavelength shift of the peak at the variation of the field. Similarly to their case [2,4] and as expected from the reorientation mechanism of the helix,

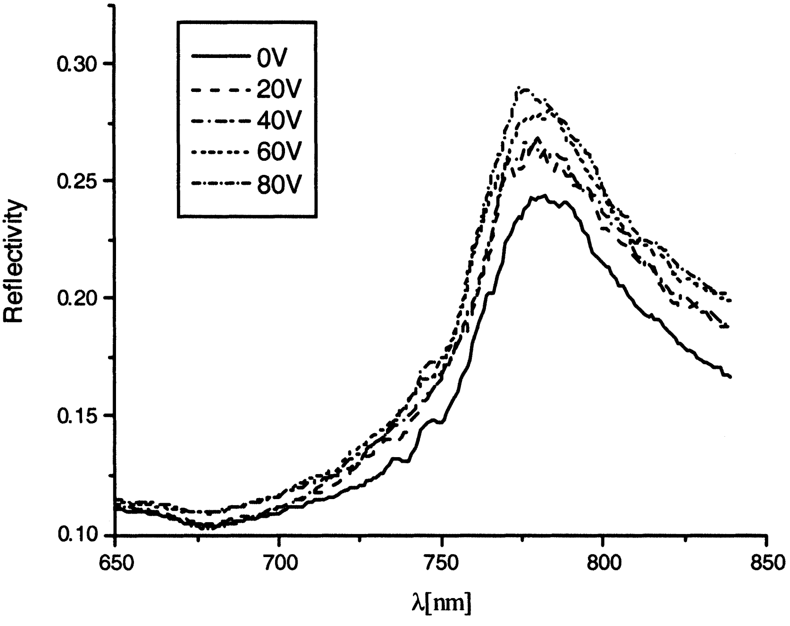


FIGURE 2 Reflectivity as a function of wavelength for several applied voltages, at 1 kHz for the LEX3/NOA65, 20% b.w. sample, at room temperature.

and due to the large width of our peak at low voltages, no significant shift can be extracted in our experiment.

CONCLUSIONS

Using the Photopolymerization-Induced Phase Separation method we have obtained Polymer-Dispersed Cholesteric Liquid Crystals with different cholesteric LC mixtures such as: CH2000 and LEX3 (Institute of Chemistry, MUT). As polymer matrix we used the photocurable resin NOA 65 (Norland Optical Adhesives).

The selective reflection spectra of the obtained mixtures have shown maximum reflectivity in the infrared region of the spectrum, which can be used in applications involving infrared lasers.

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