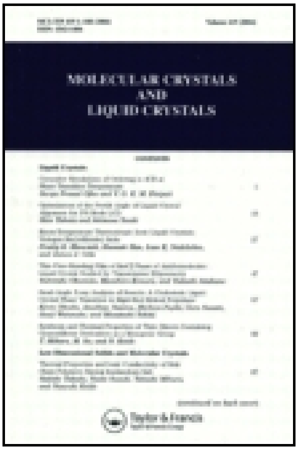

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Switching of orthoconic antiferroelectric mixtures in PDLC system

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SWITCHING OF ORTHOCONIC ANTIFERROELECTRIC MIXTURES IN PDLC SYSTEM

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Polymer-dispersed liquid crystals containing orthoconic antiferroelectric smectics were prepared by photopolymerization-induced phase separation. Mean droplet size allowed formation of antiferroelectric helix inside droplets. Bias electric field applied during phase separation aligned helical axes parallel to the cell plane. Obtained ellipsoidal droplets were optically uniaxial for perpendicular light beam. The cells were switched by square or triangle driving signal unwinding the helix. V-shape switching was found instead of threshold one observed in conventional cells of the same mixture. The switching time was crucially depended on temperature. Those effects were caused by anchoring conditions inside polymer cavities.

Keywords: antiferroelectric orthoconic smectics; electrooptical switching; PDLC

INTRODUCTION

Polymer-dispersed liquid crystals (PDLC) are heterogeneous composites in which liquid crystal (LC) nano- or microdroplets are embedded in a solid polymer matrix. They are very interesting due to curvilinear geometry of confined LC and enhanced effect of LC interaction with the polymer, moreover size effects in LC [1,2]. PDLC morphology (concentration, size and shape of LC droplets and the director field inside them) affecting electrooptical and thermooptical properties of those composites depends on properties of components and the process of preparation. PDLC exhibit different electrooptical and thermooptical effects depending on the dispersed LC phase [3–6], physical properties of the LC material, morphology and driving. In particular, electrooptical switching of PDAFLC, i.e., composites containing antiferroelectric smectics has been described in several works

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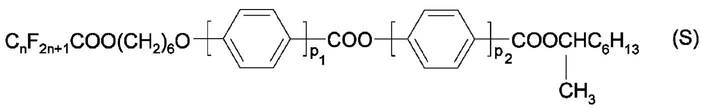
[7–10]. In this paper we present the results of studies on electrooptical properties of PDLC containing orthoconic SmC_A^* mixtures [11] which are of particular interest from application point of view due to the highest optical contrast ratio.

EXPERIMENTAL

Antiferroelectric orthoconic (conic angle 90°) mixtures W-182, W-190 and W-190A have been used as LC materials. They have been prepared using partly fluorinated compounds of a common formula



synthesized in the Institute of Chemistry MUT. W-182 with the following phase transitions: Cr < -20 SmCA* 99.8–100.5 SmC* 121–123 Iso has been used as a basic mixture. Other mixtures have been modifications of the basic one. Most of the experiments have been done for W-190 due to the best fitting to the used polymer binder. Its phase transitions are as follows: K -3 SmC_A^*90.0 SmC* 105.6 SmA 115 Iso. The helical pitch of studied mixtures is about 0.9 μm. Their detailed properties will be described separately [11]. The liquid-crystalline properties of studied mixtures have not changed under UV flux used during PDLC preparation.

The following procedure of samples preparation has been used. At first a homogeneous mixture of a prepolymer NOA-65 (Norland Optical Adhesives) and a respective LC mixture (from 20 to 35 per cent by weight) has been prepared. After adding glass spacers 8 or 18 μm thick, a drop of mixture has been deposited onto a glass plate coated with ITO layer and covered by the same glass plate. When the layer thickness has become equal to the spacers' diameter the cell has been illuminated by UV flux, usually of 20 W/cm^2. As a result of prepolymer curing the phase separation has taken place and LC droplets have emerged in a solidified polymer binder. The choice of curing ratio and LC fraction allowed to obtain droplets size of 2–3 μm in which antiferroelectric helix of used materials has not been unwound. Bias electric field (50–120 V_{pp} depending on PDLC thickness, 150 Hz) has been applied during phase separation process to align helical axes parallel to the main cell plane. LC droplets of ellipsoidal shape with average aspect ratio 2–3 due to the effect of aligning electric field have been obtained in PDAFLC system.

Obtained samples have been dark during observation between crossed polarizers (birefractive set-up) regardless of sample orientation, due to the fact that droplets have been optically uniaxial. This uniaxiality of droplets is caused by averaging of the biaxial indicatrix of a single smectic layer along helix (with cone angle $\theta = \pi/2$). The system has been slightly scattering due to imperfect matching of polymer and wound AFLC refractive indices.

PDLC cells have been switched by driving signal (triangle for static and square for dynamic characteristics; 5–40 V_{pp}, 5–10000 Hz) which unwound the antiferroelectric helix. An unwound structure is optically biaxial (to be absolutely true three-axial, but because of very small hindrance of molecule rotation around long molecular axis one can neglect that there are exist two slow axes). This biaxial system became transparent in birefractive set-up] The switching process has been registered by oscilloscope and observed under microscope in crossed polarizers.

RESULTS AND DISCUSSION

Phase transitions of studied composites have not changed significantly in comparison to pure smectic mixtures, therefore mutual solubility of components could be neglected.

Obtained PDAFLC samples have been dark in crossed polarizers due to optical uniaxiality of droplets with respect to normal light beam. An application of electric driving signal caused electrooptical switching similar to ordinary thin-layer samples, i.e., samples became bright in crossed polarizers. However V-shape switching has been found in PDAFLC instead of threshold one observed for a thin layer of a pure LC materials in the same temperature. This effect is caused by strong anchoring conditions inside polymer cavities.

It is worth mentioning that without polarizers driving signal slightly increased transparency of the sample, i.e., weak effect of electrically-induced light transmission in reversed mode has been observed.

Observed optical contrast ratio has been significantly larger than for antiferroelectric materials with tilt angle different than 45°, e.g., optical contrast ratio of the PDLC cell 8 μm thick containing 30 per cent by weight of LC in form of droplets of similar size and shape has been about 30 percent larger for orthoconic material [9]. However it has been about 40 per cent lower than in case of thin-layer cells containing the same LC. The example of comparison of static electrooptical characteristics of both systems is presented in Figure 1, while the respective microscopic images and schematic view of LC alignment inside droplets are shown in Figure 2. Those examples are representative for all samples because properties of mixtures are very similar.

In Figure 3 the example of dynamic response of PDAFLC is shown. Switching time has critically depended on the temperature and varied from

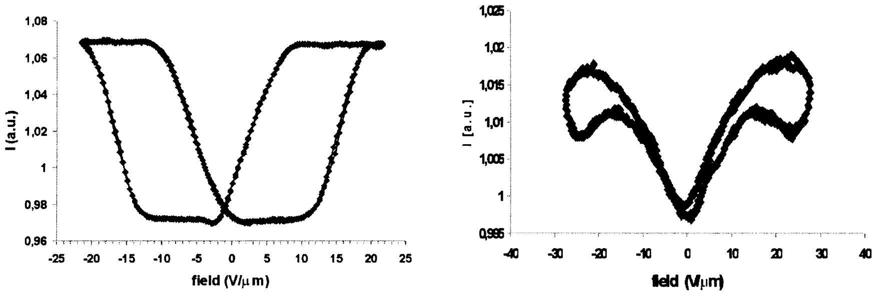


FIGURE 1 An example of comparison of static electrooptical characteristics of orthoconic SmC_A* in thin layer (left) and PDAFLC (right); W-190 mixture, 25 per cent by weight, 35°Celsius, 5 Hz, 40 V_{pp}.

100 milliseconds in room temperature up to tens microseconds in 55 Celsius. Driving voltage has depended on cell thickness and modulation depth and varied from 6 to 40 Volts.

In the absence of the electric field the PDAFLC is optically uniaxial for normal light incidence because the slow optical axis is parallel to the optical beam while the fast axis is distributed randomly. The optical indicatrix is represented by an ellipsoid of revolution along its short axis. The

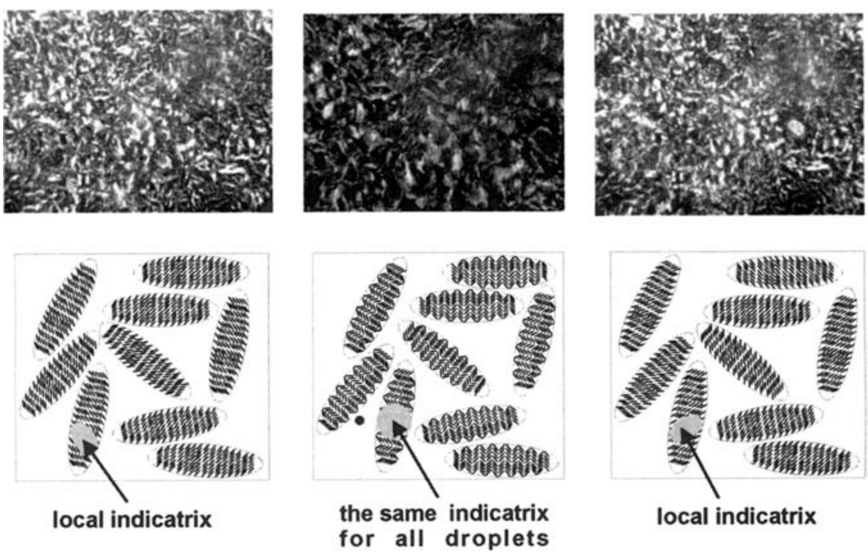


FIGURE 2 An example of microscopic images during electrooptical switching of orthoconic PDAFLC and the respective alignment of droplets' optical axes; +40 V (left), 0 V (center) and −407 V (right).

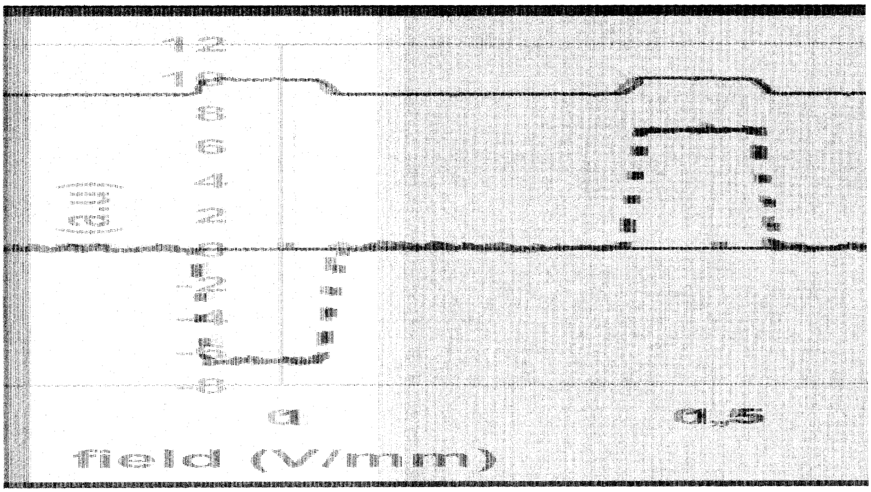


FIGURE 3 An example of dynamic response of orthoconic PDAFLC; W-190, 25 per cent by weight, 40 V, 55°C, 100 Hz.

field-induced helix unwinding changes anticlinic phase to the sinclinic one what results in a change of optical indicatrix to the ellipsoid of revolution along its long axis. For this reason part of droplets becomes transparent for light passing through birefractive system.

The observed optical contrast weakly increased with the amount of LC in the composite and the cell thickness.

Initial studies have been shown that the better contrast ratio could be obtained when LC droplets are aligned additionally by shearing during phase separation. This treatment enforced geometrical alignment of droplets what in turns significantly increased number of "bright" droplets in on-state. In our opinion the optical contrast ratio of orthoconic PDAFLC systems can be also improved by using specially designed LC material with large Δn and refractive indices perfectly matched to the polymer one.

CONCLUSIONS

- PDLC composites containing orthoconic antiferroelectric smectics SmC_A* have been obtained by photopolymerization-induced phase separation.
- The optical properties of such systems are different than those obtained for the same LC in thin layer. The effect of polymer binder manifests itself in induction of V-shape switching and strong dependence of switching time on temperature.

– PDAFLC containing orthoconic LC exhibit larger optical contrast than such composites with antiferroelectric materials with another tilt angle but further studies and optimization of system composition and preparation are necessary before possible application.

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