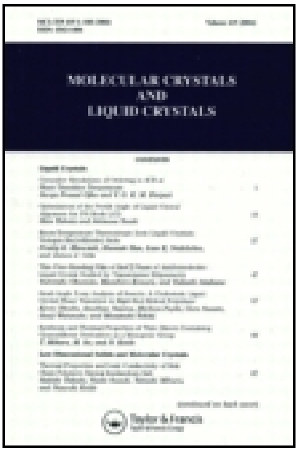

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Electrooptics of Antiferroelectric PDLC

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Version of record first published: 18 Oct 2010

To cite this article: Stanisław J. Kłosowicz & Krzysztof L. Czupryński (2002): Electrooptics of Antiferroelectric PDLC, Molecular Crystals and Liquid Crystals, 375:1, 195-204

To link to this article: http://dx.doi.org/10.1080/713738366

Mol. Cryst. Liq. Cryst., Vol. 375, pp. 195-204

1058-725X/02 $12.00 + .00

Electrooptics of Antiferroelectric PDLC

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Abstract. Polymer-dispersed liquid crystal composites containing antiferroelectric smectic phase have been obtained. An electro-optical behaviour of those systems has been studied. The effect different factors on PDAFLC properties has been discussed.

Keywords Antiferroelectric liquid crystals; smectic liquid crystals; PDLC; electrooptics

INTRODUCTION

Polymer-dispersed liquid crystals (PDLC) are very interesting due to the curvilinear geometry of the confined LC, the pronounced effect of LC interaction with the surface of polymer cavity and possible size effects[1,2]. The main electro-optical effect observed in such structures containing nematic and chiral nematic LC is electrically-induced light transmission[2]. In PDLC containing ferroelectric smectics S_C* bistable effects of helix unwinding, similar to the SSFLC and DHF effects, are observed[3-5]. On the other hand, PDLC containing antiferroelectric S_{CA}* (PDAFLC) have been studied only recently[6,7]. One could expect that such composites should present behaviour analogous to that one observed for S_{CA}*phase in thin layer geometry. In particular, field-induced transition from antiferrolectric to ferroelectric state, i.e. effect resembling tristable switching of thin S_{CA}* layer should be observed. This suggestion has been confirmed in very first works[6,7]. In this contribution electro-optical properties of PDAFLC are presented and discussed.

EXPERIMENTAL

Antiferroelectric LC mixtures W-101, W-101A and W-104 (Institute of Chemistry MUT), described in details elsewhere[8], have been used. PDLC have been prepared by photopolymerisation-induced phase separation between glass plates with conductive ITO layer. Polymerkaptoesters NOA-65 and NOA-68 (Norland Optical Adhesives) have been chosen as prepolymers. PDAFLC thickness has been fixed by glass spacers 6, 9 or 14 μm thick. LC droplets obtained in this way had spherical shape and statistical orientation of optical axes and spontaneous polarisation vector. Bias electric field and shearing of the upper glass plate have been adopted as additional aligning factors during curing the prepolymer to obtain elongated ellipsoidal LC droplets with uniformly oriented optical axes and spontaneous polarisation vector in the solid polymer matrix[4]. The term "droplet size" d used below means the diameter of spherical LC droplets, i.e. obtained without elongation stage, due to a simplicity of comparison, however all electrooptical studies have been done for PDAFLC containing ellipsoidal LC droplets.

Electro-optical properties of PDAFLC composites have been measured by automatized set-up[4] with dedicated HP VEE 3.2 software. This system enables also indirect measurements of LC viscosity and spontaneous polarisation from response times. Rising time of rectangular driving pulse has been always lower than 20 ns and could be neglected during measurements of electro-optical characteristics. Photodetector output signal, driving pulse and voltage drop at standard resistor RD have been monitored by HP 54501A oscilloscope (Hewlett Packard). Measuring cell has been placed in the thermostatic chamber THMSE 600 (Linkam) driven by the temperature controller TMS 90 (Linkam) with temperature stability of $0.1^{o}C$ and the accuracy of temperature changes of $0.01^{o}C/min$.

RESULTS AND DISCUSSION

Rectangular bias signal applied to the PDAFLC sample has caused tristable switching of $S_{CA}*$ phase. In case of W-104 mixture also bistable switching after transition to ferroelectric phase S_C* has been observed. Those effects, compared in Fig. 1, have been fully reversible. Modulation amplitude of light beam by rectangular bias linearly increased with an amplitude of applied voltage up to the saturation for a given sample (see Fig. 2).

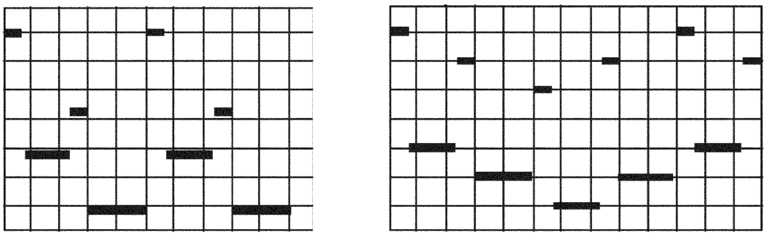

FIGURE 1. Schematic oscilloscope view of electro-optical switching of PDAFLC containing W-104 mixture by 100 Hz rectangular signal: a) bistable switching of S_C* phase at 85.5°C, b) tristable switching of S_{CA}* phase at 75°C, mean droplet size 2 μm.

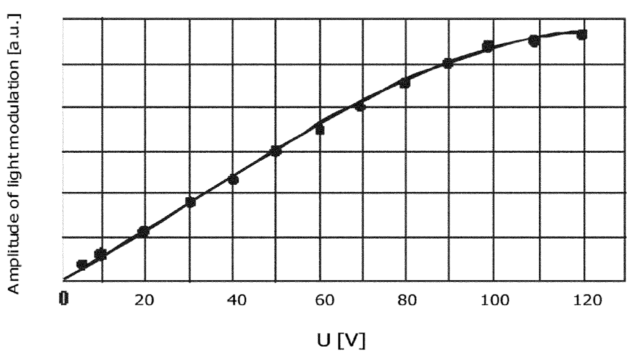

FIGURE 2. Amplitude of light modulation vs. applied bias voltage for PDAFLC containing S_{CA}* phase of W-104 at 30°C, mean droplet diameter 2 μm.

An optical contrast between off-state and on-state (see Fig. 3) has been 50-70% lower in comparison to the same mixture measured in thin layer. It is caused by the fact that only part of the volume of liquid crystal droplets can be switched by electric field. Moreover there is a significant effect of the surface of polymeric cavity on the alignment of mesogen molecules, especially in points of ellipsoidal droplets where the curvilinear geometry introduced by anchoring is the most pronounced. This is the situation analogous to that one observed in case of PDLC containing S_C* phase. As a result, significant part of the liquid crystal volume is not reoriented by driving electric field even for large fields applied.

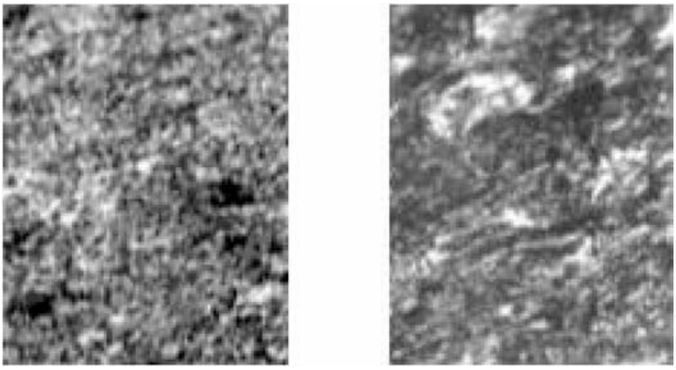

FIGURE 3. Microscopic view of the PDAFLC in off-state (left) and on-state (right), W-101 at room temperature, mean droplet diameter 2 μm.

Another reason of the relative low optical contrast has been the presence of very small droplets of liquid crystal which arise due to fast curing and too large amount of liquid crystal in those particular samples (relatively low solubility of liquid crystal mixtures in the prepolymer). This effect can be avoided by the careful choice of the properties of system components and preparation parameters for a given system, leading to the highest possible concentration of larger liquid crystal droplets without smaller ones.

An electro-optical response for triangle signal in room temperature is presented in Figure 4. This particular example is given especially to show very complicated situation in PDAFLC. The response is not similar to that obtained in thin cell of W-101. This behaviour is connected with imperfect alignment of LC inside droplets. First, a part of the droplet volume, especially close to ellipsoid points, is not aligned. Second, microscopic observations revealed that part of droplets is aligned in the opposite direction than the majority of them. For this reason switching in those two groups of droplets is opposite, what introduces noise. For higher temperatures characteristics are more resembling those obtained for thin cells. The careful preparation of the samples significantly reduces this effect.

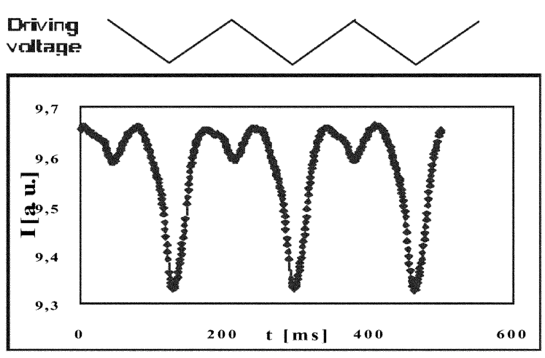

FIGURE 4. Electro-optical response of PDAFLC film containing 20 per cent by weight of W-101 measured at room temperature, mean droplet diameter 2 μm.

The example of temperature dependence of PDAFLC response is presented in Figure 5. As one can see, the response time decreases with temperature in S^*_{CA} phase, and slightly increases after transition to S_A phase, due to change of the nature of electro-optical effect. This behaviour is similar to that observed in thin cell of modified mixture W-101A [8]. The values of response time have been slightly lower in a composite due to more pronounced anchoring effects and could be as low as 2 μs over 60°C.

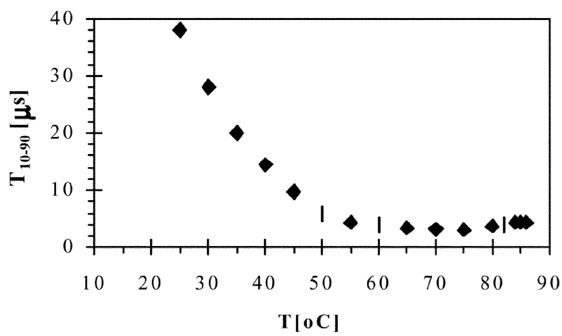

FIGURE 5. Response time vs. temperature for PDAFLC film containing 20 per cent b.w. of W-101, mean droplet diameter 2 μm.

The optical contrast ratio decreases with temperature (see Figure 6). Its value is rather moderate what confirms suggestion that an orientation of liquid crystal in droplets has not been perfect. The example of the dependence of response time of PDAFLC samples on applied bias and temperature is presented in Fig. 7.

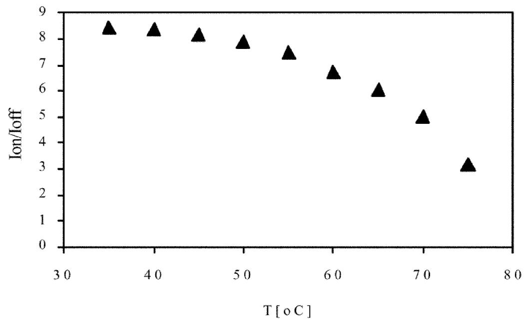

FIGURE 6. Optical contrast ratio vs. temperature for the sample containing 20 per cent by weight of W-101, mean droplet diameter 2 µm.

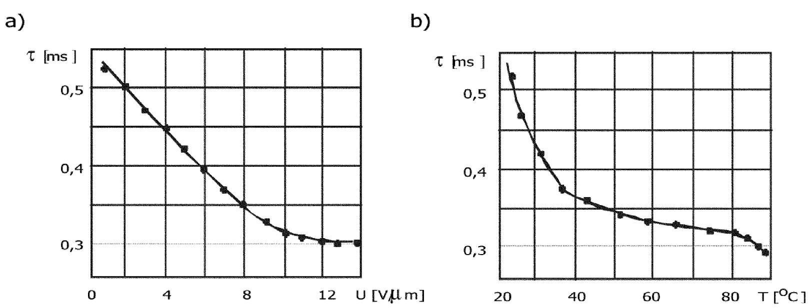

FIGURE 7. The dependence of total switching time of W-104 PDAFLC on: a) applied voltage, T = 30°C, b) temperature, U = 4 V; mean droplet size 2 µm

Electro-optical parameters of the PDLC samples slightly depended on the size and shape of liquid crystal droplets, i.e. on parameters of sample preparation. Larger droplet diameter reduces driving voltage but decreases optical contrast. Increasing elongation of LC droplets one can obtain better uniformity of the PDAFLC but at the cost of decreasing the oriented part of droplet volume. Composites containing W-101 and W-101A show less homogeneous alignment of LC than those with W-104 mixture. There are no changes of electro-optical parameters of obtained samples during 12 months.

PDAFLC can be used as fast light modulators, but to increase their contrast ratio the optical parameters of composite parameters should be better matched. It is not easy task due to relatively small number of antiferroelectric mixtures with useful parameters known till now.

There is also a necessity to improve preparation method to increase PDAFLC homogeneity and to reduce volume of unaligned LC inside droplets.

CONCLUSIONS

1. Studied PDAFLC exhibit similar electro optical behaviour as the respective LC materials in form of thin layer, e.g. tristable switching.
2. Driving voltages are higher, while switching times are slightly shorter than for thin-layer geometry due to more pronounced anchoring effects inside polymer cavity.
3. Optical contrast is much lower than in the case of thin-layer geometry because only part of the LC droplet volume can be reoriented by electric field.

4. Observed effects depend on conditions of PDLC preparation, especially phase and temperature of phase separation, as well as the temperature of measurement.
5. PDAFLC can be applied as fast electro-optical modulators but this application needs further studies on the matching of properties of PDAFLC components.

Acknowledgements

This work has been supported by the State Committee for Scientific Research (under MUT Statutory Task PBS-637) and INCO-COPERNICUS grant IC15-CT98-0806.

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