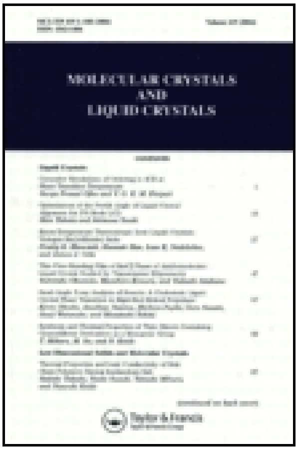


Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

# Polymer-Dispersed Ferroelectric and Antiferroelectric Liquid Crystals

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Version of record first published: 24 Sep 2006

*Mol. Cryst. and Liq. Cryst.*, 2000, Vol. 351, pp. 343-349
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# Polymer-Dispersed Ferroelectric and Antiferroelectric Liquid Crystals

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PDLC structures containing ferroelectric and antiferroelectric liquid crystal phase of the same material have been obtained. The initial studies of electrooptical properties of those materials have been done.

*Keywords:* PDLC; antiferroelectric liquid crystals; optical switching

## 1. INTRODUCTION

Polymer-dispersed liquid crystals (PDLC) are considered as very promising materials due to their simple technology, low cost and good electrooptical performance. Moreover, they exhibit several new properties in comparison with a classic thin-layer geometry of liquid crystal films [1,2]. Apart from the well-known nematic-containing PDLC, ferroelectric smectics embedded in a polymer matrix have been also studied [3-6]. PDLC composites can be adopted for information displays [7] and optical devices [8,9]. Due to very interesting properties of antiferroelectric liquid crystals [10], especially low sensitivity to mechanical stress and a possibility to obtain thresholdless transitions, it has been interesting to study properties of those materials embedded in polymer matrix.

## 2. EXPERIMENTAL

PDLC composites containing smectic liquid crystals have been prepared by photopolymerization-induced phase separation. As a liquid-crystalline material the mixture encoded W-104 (Institute of Chemistry MUT), having both ferroelectric ($S_C^*$) and antiferroelectric ($S_{CA}^*$) phases has been used. This material has the following phase transitions temperatures: (-3) $S^*_{CA}$ 84,5 $S^*_C$86,5 $S_A$92 N* 104 I which makes it very convenient for an experiment. Other properties of W-104 will be described elsewhere [11].

The 20 per cent bw of liquid-crystalline mixture has been mixed with NOA-65 photocurable resin (Norland Optical Adhesives) and glass spacers 14 μm thick. Then phase separation has been performed by a photopolymerization with UV intensity from 5 to 20 mW/cm$^2$. Due to properties of $S_{CA}^*$ phase, the morphology of obtained PDLC is more complicated than in case of nematic-containing PDLC and resembling

PDLC containing ferroelectric smectics [4]. It requires a proper alignment of director and spontaneous polarization vector.

For this reason the preparation method has been modified to obtain elongated and uniformly oriented droplets of smectic liquid crystals by the application of longitudinal shear to the system during last stage of curing [4]. As the effect, measuring cells containing elongated liquid crystal droplets with aligned director and spontaneous polarization vector, have been obtained. The mean diameter of liquid crystal droplets has depended on curing rate (1-4 μm).

Phase separation process has been performed at different temperatures, i.e. for different liquid-crystalline phases. Due to limited solubility of $S^*_{CA}$ phase in NOA-65, the mixing of components has been done in N* phase while temperature of the system has been decreased during curing process.

Electrooptical properties of obtained PDLC films have been studied by standard method [2,4] at different temperatures enabling to obtain results for both interesting smectic LC phases.

## 3. RESULTS

Fig. 1 shows the dependence of amplitude of light modulation on applied voltage for PDLC film containing $S^*_{CA}$ phase. In Fig. 2 the schematic comparison between bistable switching in PDLC containing $S^*_C$ phase and tristable switching in PDLC containing $S^*_{CA}$ phase is given. In Fig 3 the dependencies of response time on the temperature and applied voltage are presented.

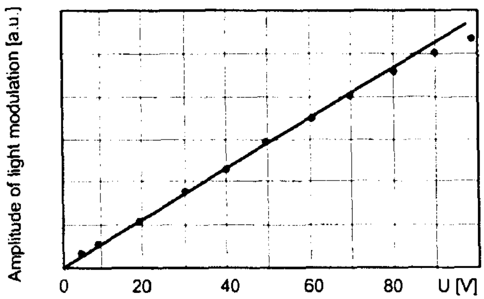


FIGURE 1 The amplitude of light modulation vs. applied voltage for PDLC containing $S^*_{CA}$ phase at 30°C, mean droplet diameter 2 μm.

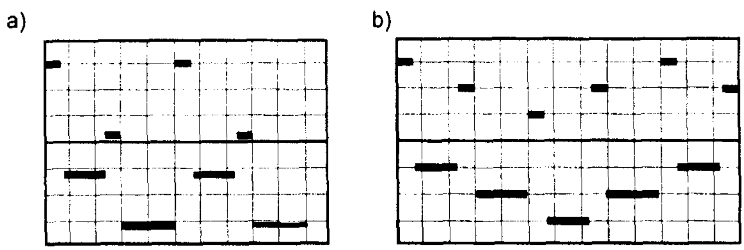


FIGURE 2 The schematic view of the electrooptical switching by 100 Hz square wave signal duration of 100 ms: a) PDLC containing $S^*_C$ phase, at 85,5°C, b) PDLC containing $S^*_{CA}$ phase at 75°C, mean droplet diameter 2 μm.

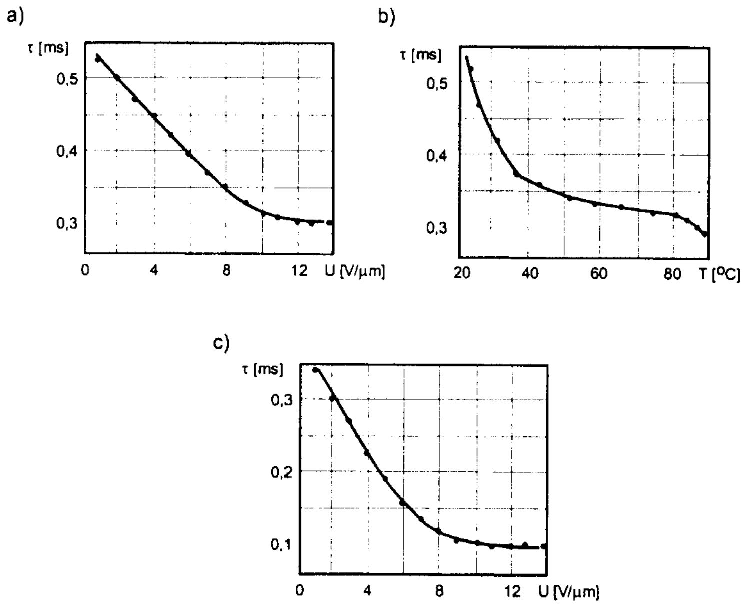


FIGURE 3 The dependence of response time of PDLC containing $S_{CA}^{*}$ phase on: a) applied voltage, T = 30°C and b) temperature, U = 4 V; c) PDLC containing $S_{C}^{*}$ phase, T = 85,5 °C; mean droplet diameter in all cases was 2 μm.

As the result of an application of square wave signal to the samples studied, a bistable switching for PDLC containing $S_{C}^{*}$ phase and tristable switching for PDLC containing $S_{CA}^{*}$ phase have been observed. The optical contrast ratio has been about 50-70% lower than in case of thin liquid crystal layer of the same material because the part of droplets' volume has not been switched due to the effect of anchoring conditions. Amplitude of light modulation has linearly depended on applied voltage up to saturation.

Response time has depended on temperature and applied voltage and varied from 0.3 to 0.5 ms.

Electrooptical properties of obtained PDLC containing $S^*_{CA}$ slightly depended on the LC droplets' size (about 20% in the range studied). They have not changed during 6 months after cell preparation.

## 4. CONCLUSIONS

PDLC structures containing material having both $S^*_{CA}$ and $S^*_C$ have been prepared. The obtained results suggest that electrooptical performance of both dispersed phases is similar with the exception of tristable switching observed for $S^*_{CA}$ phase. It seems that PDLC containing $S^*_{CA}$ phase are promising for applications as fast light modulators, however better matching of component properties is required.

Acknowledgement

This work has been partially supported by the State Committee for Scientific Research (grant no. 3 T0 9A 07315 and MUT Statutory Activity Fund PBS171) and INCO-COPERNICUS grant IC15-CT98-0806.

## *References*

[1] G. P. Crawford and S. Žumer, in *Liquid Crystals in Complex Geometries*, ed. G. P. Crawford and S. Zumer, Taylor & Francis, London, 1996, Chap. 1.

[2] S. J. Kłosowicz and J. Żmija, *Optical Engineering*, **34**(12), 3440–3450 (1995).

[3] H. Molsen and H. -S. Kitzerow *J. Appl. Phys.*, **75**, 710, (1994).

[4] S. J. Kłosowicz, Z. Raszewski, W. Piecek and W. Drzewiński, *Ferroelectrics,* **180,** 165 (1996).
[5] H.-Ş. Kitzerow, in in *Liquid Crystals in Complex Geometries,* ed. G. P. Crawford and S. Zumer, Taylor & Francis, London, 1996, Chap. 8. and references therein.
[6] V. Vorflusev and S. Kumar, *Ferroelectrics,* **213,** 117 (1998).
[7] S. J. Kłosowicz, E. Nowinowski-Kruszelnicki and J. Żmija, *Proc. SPIE,* **2372,** 360–362 (1995).
[8] T. Fujii, H. Kikuchi, M. Kawakita, H. Fujikake and K. Takizawa, *SID Proc., Eurodisplay '96,* Birmingham, 80 (1996).
[9] S. J. Kłosowicz and E. Nowinowski-Kruszelnicki, *Proc. SPIE,* **2372,** 367–371 (1995).
[10] A. Fukuda, Y. Takanishi, T. Isozaki, K. Ishikawa and H. Takezoe, *J. Mater. Chem.,* **4**(7), 997 (1994).
[11] Z. Raszewski, W Piecek, P. Perkowski, J. Rutkowska, J. Kędzierski and R. Dąbrowski – to be published.