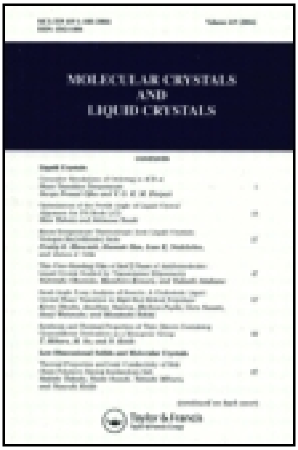

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Polymer-Dispersed Antiferroelectric Liquid Crystals

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Polymer-Dispersed Antiferroelectric Liquid Crystals

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An electro-optical behaviour of W-101 antiferroelectric mixture in PDLC system has been studied. It has been found that it is extremely difficult to obtain proper liquid crystal alignment inside droplets for the mixture which has not got N* phase.

Keywords: Antiferroelectric liquid crystals; smectic liquid crystals; polymer-dispersed liquid crystals; electrooptics

INTRODUCTION

Polymer-dispersed liquid crystals (PDLC) are very interesting from scientific point of view because they enable to study liquid crystal behaviour in confined geometries [1]. Moreover, they exhibit several new properties in comparison with a classic thin-layer geometry of liquid crystal films. They are also promising for applications due to their simple technology, low cost and good electro-optical performance.

Electro-optical properties of PDLC depend on a phase embedded in polymer cavities. In case of PDLC containing nematics, electrically-induced light transmission is the main electro-optical effect [2]. PDLCs containing ferroelectric smectics exhibit effects similar to SSFLC and DHF effects observed in thin films of those materials [3], depending on a relation between helical pitch and droplet size.

Antiferroelectric liquid crystals, synthesised a few years ago, have very interesting properties [4], especially low sensitivity to mechanical stress and a possibility to obtain thresholdless electro-optical response [5]. There are only few works concerning PDLC structures containing those phase [6,7], so it is still interesting to study a behaviour of new antiferroelectric smectic materials embedded in polymer matrix.

EXPERIMENTAL

PDLC composites containing antiferroelectric smectic liquid crystals have been prepared by photopolymerization-induced phase separation. Liquid crystalline mixture encoded W-101 (Institute of Chemistry MUT) have been used as a liquid-crystalline material. This mixture has the following phase transition temperatures $Cr6.6S_{CA}70.5S_{A}93\text{-}97.6I$, making it very convenient for an experiment. The composition and other properties of W-101 are described elsewhere [8].

From 15 to 30 per cent by weight of liquid-crystalline mixture has been mixed with NOA-65 photocurable resin (Norland Optical Adhesives) and glass spacers 9 μm thick. Then phase separation has been performed by resin photopolymerization with UV intensity 5 to 20 mW/cm^2 to obtain composites with different droplet size. The morphology of S^*_{CA} phase in PDLC droplets is much more complicated than in case of nematic-containing PDLC and resembling PDLC containing ferroelectric smectics [3]. In order to obtain measurable electro-optical response one should secure a proper alignment of the director and spontaneous polarization vector inside liquid crystal droplets.

For this reason, the longitudinal shear has been applied to the system during the last stage of curing to obtain elongated and uniformly oriented droplets of smectic liquid crystals. As the effect, cells containing elongated liquid crystal droplets with more or less homogeneous alignment of the director and spontaneous polarization vector have been obtained. The mean size of liquid crystal droplets has depended on curing rate (spherical droplets had diameter of 1-4 μm, typical elongation of ellipsoidal droplets from 5 to 10).

Phase separation process has been performed at different temperatures, also in S_A phase.

Electro-optical properties of obtained PDLC films have been studied by standard method at different temperatures.

RESULTS AND DISCUSSION

In Figure 1 microscopic images of obtained PDLC structures in off- and on-states are compared. As one can see, the size of liquid crystalline droplets is not completely uniform, moreover there is a part of liquid crystal volume which do not form macroscopic droplets at all.

Nevertheless, also this part of liquid crystal is switched by external voltage.

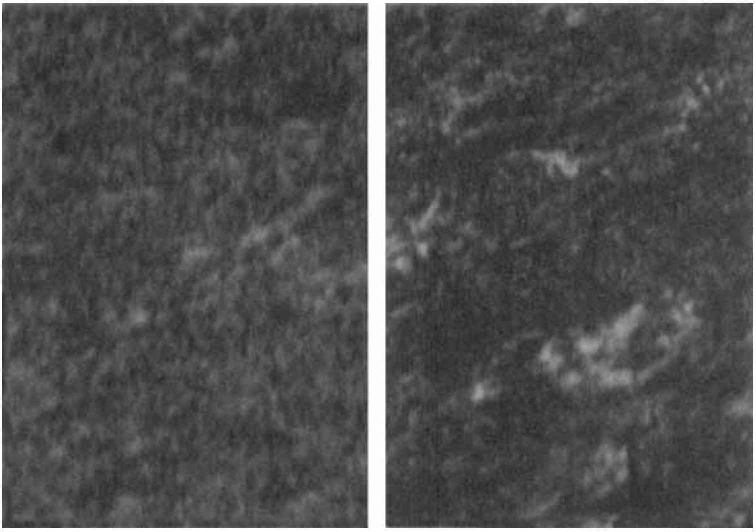

FIGURE 1. Microscopic images of PDLC structure in off-state (left), and on-state (right).

An electro-optical response for triangle signal in room temperature is presented in Figure 2. This particular example is given to show very complicated situation in PDLC containing antiferroelectric liquid crystal droplets. 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, 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.

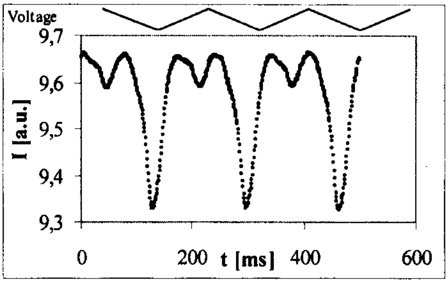

FIGURE 2. Electro-optical response of PDLC film containing 20 per cent by weight of W-101 measured at room temperature.

The dynamic electro-optical characteristic of the system is presented in Figure 3. As one can see, response time decreases with temperature in S^*_{CA} phase, and slightly increases after transition to S_A phase, due to change 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 PDLC system due to more pronounced anchoring effects and as low as 2 μs over 60 Celsius degree.

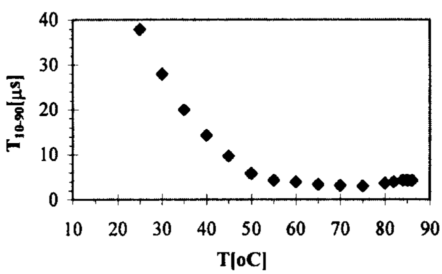

FIGURE 3. Response time vs. temperature for PDLC film containing 20 per cent by weight of W-101.

The optical contrast ratio decreases with temperature (see Figure 4). Its value is rather moderate what confirms suggestion that an orientation of liquid crystal in droplets was not perfect, moreover not uniform in all droplets.

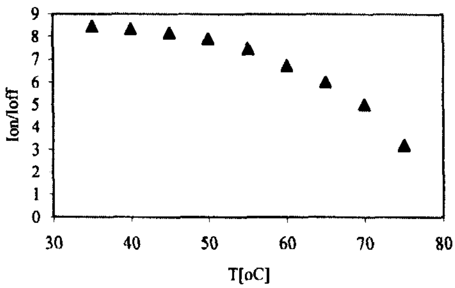

FIGURE 4. Optical contrast ratio vs. temperature for PDLC film containing 20 per cent by weight of W-101.

Obtained results are quite different from those obtained by us for antiferroelectric mixture W-104 [7]. The essential difference is much worse alignment of W-101 in droplets. This effect is caused by an absence of N* phase which allowed to obtain very good alignment of liquid crystal in W-104 droplets during PDLC preparation. This uniform alignment has been preserved after cooling to antiferroelectric phase. There is no such possibility in case of W-101 mixture. Nevertheless, W-101 and its derivative mixtures seem to be very promising from an application point of view. For this reason, aligning techniques should be improved in future to obtain more defined electro-optical response and better contrast ratio.

CONCLUSIONS

1. An electro-optical properties of new antiferroelectric liquid crystalline mixture embedded in polymer matrix has been studied. Observed behaviour is quite different than that for bulk liquid crystal measured in thin cell due to curvilinear geometry of antiferroelectric phase inside droplets.
2. Obtained results confirmed crucial role of an alignment in liquid crystal droplets. Despite the fact that only part of liquid crystal volume is aligned in wanted direction, the electro-optical response is also a result of optical axis reorientation in cavities with more or less statistically oriented optical axes. The total optical response depends on uniformity of a direction of droplet shape anisotropy, and can be affected by this part of liquid crystal which do not form macroscopic droplets.
3. It is necessary to improve aligning methods for PDLC containing S^*_{CA} phase, especially for substances which has not got N* phase.

Acknowledgements

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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] J.W. Doane in *Liquid Crystals Aplications and Uses*, ed. B. Bahadur, Singapore, New Jersey, London, World Scientific, 1990, Chap. 14.
[3] S.J. Kłosowicz, Z. Raszewski, W. Piecek, W. Drzewiński, *Ferroelectrics*, **180**, 165 (1996).
[4] A. Fukuda, Y. Takanishi, T. Isozaki, K. Ishikawa and H. Takezoe, *J. Mater. Chem.*, **4**(7), 997 (1994).
[5] W. Kuczyński, R. Dąbrowski, S. Gauza, F. Goc, J. Hoffman, K. Czupryński, J. Drzewiński, K. Kenig, *Proc. SPIE*, **4147**, 79 (2000).
[6] V. Vorflusev and S. Kumar, *Ferroelectrics*, **213**, 117 (1998).

[7] S.J. Kłosowicz, K.L. Czupryński and W. Piecek, *Mol. Cryst. Liq. Cryst*, in print (presented at ECLC'99, Hersonissos, Greece).
[8] G. Andersson, R. Dąbrowski, W. Drzewiński, J.P.F. Lagerwall, M. Matuszczyk, T. Matuszczyk, P. Perkowski and Z. Raszewski, *Ferroelectric*, in print.