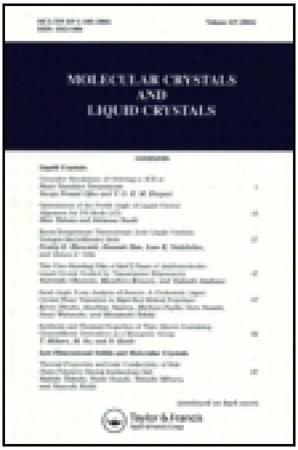

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Inverse Mode of Ion-Surfactant Method of Director Reorientation Inside Nematic Droplets

M. N. Krakhalev [a], O. O. Prishchepa [a b] & V. Ya. Zyryanov [a b]

[a] Kirensky Institute of Physics, Krasnoyarsk Scientific Centre, SB RAS

[b] Siberian Federal University, Krasnoyarsk, Russia

Version of record first published: 05 Oct 2009

Mol. Cryst. Liq. Cryst., Vol. 512, pp. 152/[1998]–157/[2003], 2009

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400903050814

Inverse Mode of Ion-Surfactant Method of Director Reorientation Inside Nematic Droplets

M. N. Krakhalev[1], O. O. Prishchepa[1,2], and V. Ya. Zyryanov[1,2]
[1]Kirensky Institute of Physics, Krasnoyarsk Scientific Centre, SB RAS
[2]Siberian Federal University, Krasnoyarsk, Russia

Inverse mode of a novel electrooptical effect caused by the ionic modification of boundary conditions has been studied for liquid crystal droplets. We have considered the droplets of nematic 5CB doped with cationic surfactant cetyltrimethyl-ammonium-bromide and dispersed in polyvinyl alcohol. In the initial state the surface anchoring was normal on the whole interface due to the high concentration of homeotropic surfactant. Applied voltage results in the purification of a section of the interface from the surface-active cations thereby restoring here a tangential anchoring and stimulating the significant transformation of droplet structure. At that three different types of director field distribution can be realized within the same droplet. The proper textures of the droplet both in the crossed polarizers and without analyzer are considered.

Keywords: electrically commanded surfaces; ion surfactant; nematic; polymer dispersed liquid crystals; surface anchoring

PACS Numbers: Codes 61.30.Pq; 61.30.Hn; 61.30.-v

This work was partially supported by the grants Nos. NSh-3818.2008.3; 02.740.11.0220, and No. 08-03-01007 of RFBR, and Nos. 27.1; 110; 144 of SB RAS. M. Krakhalev acknowledges the financial support from K.I. Zamaraev MBN Foundation. O. Prishchepa acknowledges the financial support from Russian Science Support Foundation.

Address correspondence to M. N. Krakhalev, L. V. Kirensky Institute of Physics of SB RAS, Akademgorodok, 50/38, Krasnoyarsk, Russian Federation. E-mail: kmn@iph.krasn.ru

I. INTRODUCTION

Liquid crystals (LC) are the convenient material for low-voltage optoelectronic devices especially for displays. It necessitates searching for the novel electrooptical effects in LC materials, which can extend the field of their application. In this regard the development of the methods of electrically commanded surfaces [1–4] is much-needed because it enables to control submicro- and nano-sized LC cells in the modern photonic systems.

One of the methods is based on the use of ferroelectric liquid crystal polymer to produce the surfactant films at the cell substrates [1,2]. Applied voltage influences, first of all, on the liquid crystal polymer and reorients its director. Then the orientation structure of low-molecular LC in the gap between the substrates is transformed according to a new alignment condition at the surfactant film.

Another approach proposed in [3,4] is the electrically induced ionic modification of surface anchoring. In this case the liquid crystals within droplets dispersed in polymer matrix are doped with ion-forming surfactant. For the *normal mode* of the effect, the boundary conditions at the whole droplet interface in the initial state are determined by the tangential forces of polymer matrix. Under the action of dc electric field the surface-active ions are concentrated at a certain region of droplet interface and change here the surface anchoring to the homeotropic one. The modification of boundary conditions is accompanied by a considerable transformation of director configuration inside LC droplets and, as a consequence, by the change of the optical properties of polymer dispersed liquid crystal (PDLC) films.

In this paper we consider the *inverse mode* of the ion-surfactant effect when the boundary conditions are changed locally from homeotropic to tangential ones what also leads to the transmutation of director configurations inside nematic droplets.

II. EXPERIMENT

The samples of PDLC films were prepared by the emulsification method [5]. The 4-n-pentyl-4′-cyanobiphenyl (5CB) doped with the cationic surfactant cetyl-trimethyl-ammonium-bromide (CTAB) was emulsified into a 10% aqueous solution of film-forming polymer polyvinyl alcohol (PVA). The ratio of 5CB : CTAB : PVA was 1 : 0.1 : 19 by weight. PVA was plasticized with glycerin at a ratio of 3 : 1 by weight, respectively. In the liquid crystal the CTAB molecules are dissociated into Br^- anions and cetyl-trimethyl-ammonium (CTA^+)

cations. Polymer matrix provides the tangential anchoring with the molecules of mesomorphic alcylcyanobiphenyl derivatives [6]. On the contrary, the surface adsorbed layer of CTA^+ ions can align the LC molecules homeotropically [6] provided that the content of CTAB admixture in LC is sufficiently large.

ITO electrodes at the glass substrates were moulded on the parallel stripes with a distance of 250 μm between them providing the orientation of the dc electric field along the PDLC film plane. We have considered LC droplets arranged in the middle between the electrodes using the polarizing microscope in the crossed polarizers and with analyzer switched off. The size of droplets was approximately 7–11 μm. The thickness of PDLC film was about 30 μm. For all samples we applied the electric pulse of the same duration (5 sec) and made the photos at the end of the pulse. Characteristic time for the stabilization of novel orientational structures was approximately 1 sec. After that the director configurations remained stable.

III. RESULTS AND DISCUSSION

In Figure 1 the scheme of the cell under study is presented. In the unpowered state (Fig. 1a) a part of CTA^+ ions adsorbed at the polymer wall can form a surface-active layer possessing by homeotropic anchoring and screening the tangential orienting influence of PVA matrix at the whole interface. As a result, the radial director configuration should be formed inside nematic droplets. Under the action of applied voltage the CTA^+ ions shift to the left towards the negative electrode

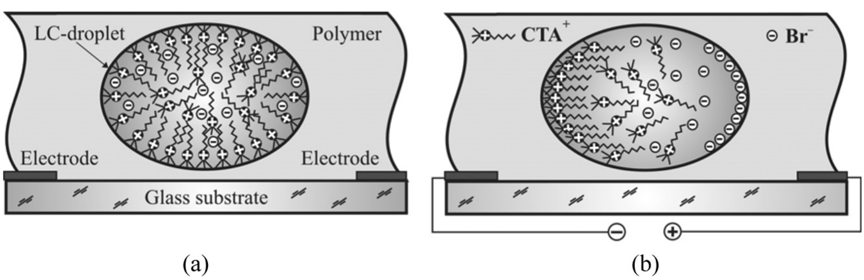

FIGURE 1 Scheme of PDLC cell with a 9% concentration of CTAB in nematic. (***a***) CTA^+ cations form the homeotropic surface-active layer on the whole interface in unpowered state; (***b***) tangential anchoring is restored in the right part of LC droplet because the cations shift from here towards the left boundary.

(Fig. 1b). It can result in the restoration of the tangential anchoring in the right part of the droplet.

This hypothesis is confirmed by the analysis of droplet texture transformations. The Maltese cross texture (Fig. 2a, top row), typical for the radial director configuration (Fig. 2a, bottom row) with the bulk point defect (hedgehog [7]) in the centre is the reliable evidence of the presence of the uniform homeotropic anchoring at all droplet surface.

The application of the electric field results in the dramatic change of texture inside droplets, which can occur in three different ways (Figs. 2b–d). It should be emphasized that all three types of the structures can be observed in the same nematic droplet.

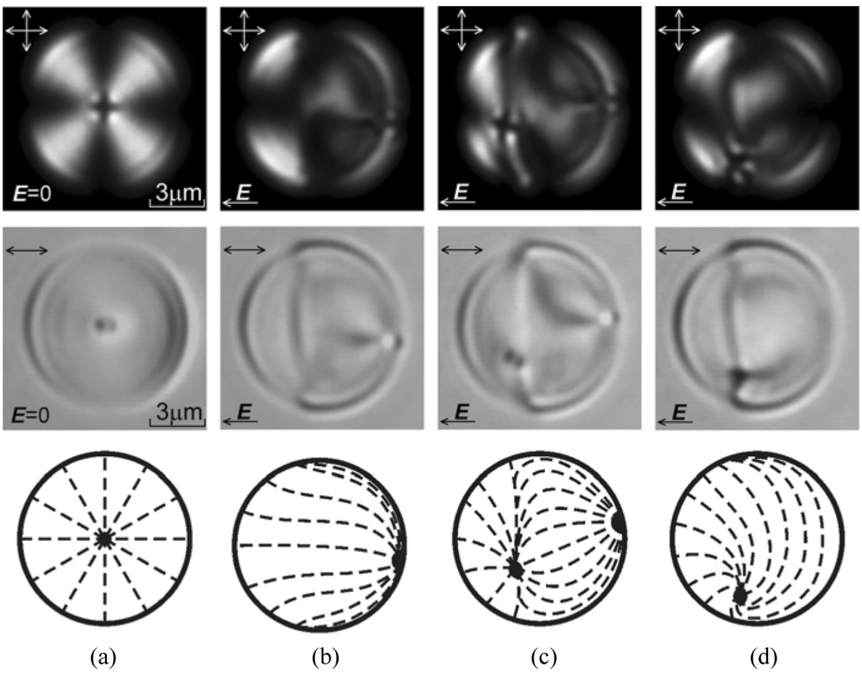

FIGURE 2 LC droplet textures in PDLC films with the ratio of 5CB : CTAB : PVA equal to 1 : 0.1 : 19 by weight. Microphotos are shown in the top row (for crossed polarizers) and central one (without analyzer). Double arrows show the orientation of polarizers. The corresponding schemes of director configurations are presented in the bottom row. In the columns: (a) LC droplet in unpowered state; (b–d) LC droplet 5 sec after dc electric voltage (U = 50 V) was switched on. (b) "Boojum + surface ring" structure. (c) "Hedgehog + boojum + surface ring" structure. (d) "Hedgehog + surface ring" structure.

a) Transition of Radial Configuration into "Boojum + Surface Ring" Structure

One of the ways is a transformation of the radial configuration into the monopolar one (Fig. 2b). In this case, at first the surface point defect (boojum [7]) arises in the right section of droplet. Then the hedgehog escapes to the boojum combining with it. In the end of the process a single boojum remains at the surface (see Fig. 2b). Such an effect cannot be explained by the influence of the electric field on the bulk of LC droplets because the external field is nearly completely compensated by the separated ion charges [8]. This transformation is possible only when the homeotropic anchoring at the droplet's interface close to the positive electrode is modified to the tangential one. At that the tangential anchoring occupies more than a half of droplet. The edges of this area at the top and bottom of the visible droplet boundary are seen clearly in Figure 2b (central row) as two points where light scattering regions (dark lines) come abruptly to an end. The surface ring defect arises at the turn of tangential and homeotropic anchoring. It is revealed as a vertical dark line at the left of droplet centre. The corresponding director field distribution is presented schematically in Figure 2b (bottom row).

b) Transition of Radial Configuration into "Hedgehog + Boojum + Surface Ring" Structure

More complicated structure can appear in the same droplet (see Fig. 2c). In addition to the formation of the boojum in the right part of droplet and surface ring defect, the hedgehog remains but it moves down to the plane of the ring defect.

c) Transition of Radial Configuration into "Hedgehog + Surface Ring" Structure

For the droplet under study the third scenarios is realized more often. Only the bulk point defect-hedgehog and surface ring line defect are characteristic for it (Fig. 2d). As in the previous case, the bulk defect moves to the bottom boundary. Director lines in such a structure bend clockwise (Fig. 2d, bottom row).

It should be noted that in all above described cases the ratio of tangential and homeotropic regions of interface remains permanent.

IV. CONCLUSION

Generally, a wide variety of different transmutations of droplet structure is characteristic of the ion-surfactant method to control PDLC films. Resultant structures formed within LC droplets in the electric field depend on the compounds in use, concentration of ionic surfactant, value of applied voltage and duration of electric pulse, droplet form and size, etc. Some different director configurations can be realized even in the same droplet, as it has been illustrated in this paper. The features described above allow designing various electrooptical devices based on micro- and nanosized composite LC materials.

REFERENCES

[1] Komitov, L., Helgee, B., Felix, J. *et al*. (2005). *Appl. Phys. Lett.*, *86*, 023502.
[2] Drevensek-Olenik, I., Kunstelj, K., Koncilija, J. *et al*. (2006). *J. Appl. Phys.*, *100*, 073514.
[3] Zyryanov, V. Ya., Krahalev, M. N., Prishchepa, O. O. (2007). *MCLC*, *489*, 273/[599].
[4] Zyryanov, V. Ya., Krakhalev, M. N., & Prishchepa, O. O. (2008). *MCLC*, *488/489*, (in press).
[5] Drzaic, P. S. (1995). *Liquid Crystal Dispersions*, World Scientific: Singapore.
[6] Cognard, J. (1982). *Alignment of Nematic Liquid Crystals and Their Mixtures*, Gordon and Breach Science Publishers: London, New York, Paris.
[7] Volovik, G. E., Lavrentovich, O. D. (1983). *Zh. Eks. Teor. Fiz.*, *85*, 1997 [*Sov. Phys. JETP*, 58, 1159 (1983)].
[8] Barannik, A. V., Lapanik, V. I., Bezborodov, V. S. *et al*. (2005). *J. Info. Display*, *13*, 273.