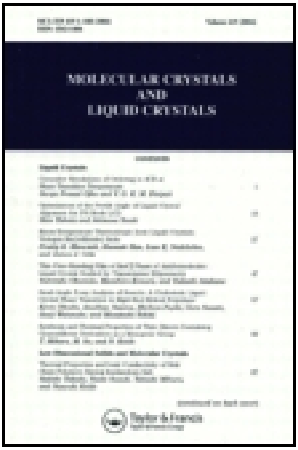


Molecular Crystals and Liquid Crystals

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

# Texture Transformation in Nematic Droplets Caused by Ionic Modification of Boundary Conditions

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

[a] L. V. Kirensky Institute of Physics, Krasnoyarsk Scientific Centre, SB RAS, Siberian Federal University, Krasnoyarsk, Russia

Version of record first published: 05 Apr 2011

*Mol. Cryst. Liq. Cryst.*, Vol. 489, pp. 273/[599]–279/[605], 2008

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400802219189



# Texture Transformation in Nematic Droplets Caused by Ionic Modification of Boundary Conditions

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

*The novel orientational effects caused by the electrically controlled modification of surface anchoring have been considered in liquid crystal droplets. The polymer dispersed liquid crystal films based on nematic 5CB doped with ion-forming cetyl-trimethyl-ammonium-bromide (CTAB) have been tested. Under the action of electric field the surface-active* $CTA^+$ *ions in nematic droplets shift towards the cathode. This displacement can alter dramatically the boundary conditions at the part of interface. Two types of ion-induced surface modification are possible: when the anchoring of LC molecules change from the tangential one to the homeotropic and vice-versa. Both variants have been considered as well as the resultant transformation of texture patterns and the proper director configurations within the nematic droplets.*

**Keywords:** electrically commanded surfaces; ions; nematic; polymer dispersed liquid crystals; surface anchoring; surfactants

## 1. INTRODUCTION

There are two ways to control the orientation of liquid crystal (LC). In the first one, well-known as classical Friedericksz effect [1], the external forces (electric, magnetic, etc.) reorient the whole volume of LC cavity without changing of surface anchoring. This effect is the basis of the operation of the modern electrooptical LC devices.

This work was supported in part by the grants of DSP, No 2.1.1.1814; RFBR, No 08-03-01007; Council of the President of the RF for Support of Young Scientists and Leading Scientific Schools (projects NSh-3818.2008.3, MK-3624.2007.2); RAS, No 8.1, 2.10.2; SB RAS, No 33.

Address correspondence to V. Ya. Zyryanov, L. V. Kirensky Institute of Physics, Krasnoyarsk Scientific Centre, SB RAS, Siberian Federal University, Krasnoyarsk 660036, Russia. E-mail: zyr@iph.krasn.ru

Recently an alternative approach utilizing the local Fredericksz transition [2–4] has been intensively developed. In this case, the external factors act at the interface LC-substrate changing appreciably the surface anchoring, which, in turn, initiates the director reorientation in the LC volume. This approach has been realized as the method of electrically commanded surfaces in [5,6] for the electrooptical cells with the substrates coated with the ferroelectric LC-polymer as a surfactant. The change of director configuration in the surfactant film results in the corresponding transformation of the orientational structure of the nematic layer.

Another method to create the LC devices with electrically controlled surfaces has been proposed in [7]. It is based on the modification of boundary conditions due to the creation of a monolayer of ion-forming surfactants at the interface under the influence of electric field. In this report we briefly describe two variants of ion-surfactant method to control the director orientation in application to PDLC films.



## 2. EXPERIMENTAL

The PDLC films under study have been made by emulsification method [8]. The nematic LC 4-n-pentyl-4′-cyanobiphenyl (5CB) is emulsified into an aqueous solution of film-forming polymer polyvinyl alcohol (PVA). Then the mixture is poured out onto glass substrates with ITO electrodes and dried. The ratio of 5CB:PVA is 1:19 by weight. PVA provides the tangential anchoring with molecules of the mesomorphic alcylcyanobiphenyl derivatives [9].

Before the emulsification the nematic is doped with the cation surfactant cetyl-trimethyl-ammonium-bromide (CTAB). Two compositions with different CTAB concentrations (1 and 10 percents by weight regarding LC) have been tested. In the liquid crystals the CTAB molecules (see Fig. 1) are dissociated into the negative $Br^-$ ions

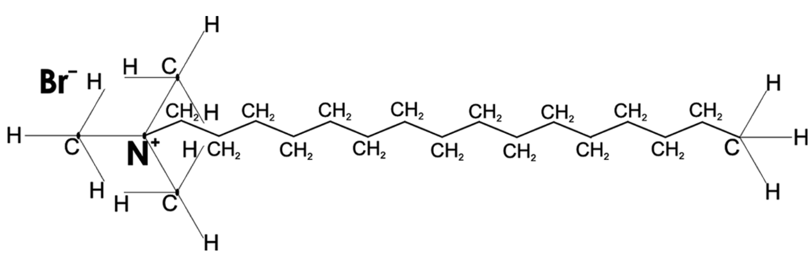

**FIGURE 1** The structure of cetyl-trimethyl-ammonium-bromide (CTAB) molecule.

and the positive ions of cetyl-trimethyl-ammonium ($CTA^+$). The cations are adsorbed partially at the interface so that the trimethyl-ammonium segments are attracted to the surface, while the alkyl chains are aligned transversely to it. The monolayer of such ions can provide a homeotropic anchoring of LC molecules with interface [9–11], if the content of CTAB admixture in liquid crystal is sufficiently high.

An ITO coating at glass substrates is etched so as to form strip-like electrodes separated from each other at the distance of $150 \div 300\,\mu m$. It has been tested the LC droplets of $4 \div 28\,\mu m$ size arranged in the middle between the electrodes. The film thickness does not exceed $30\,\mu m$. It means that the electric field produced by two electrodes is oriented approximately parallel to the film plane. An applied electric signal is a square waveform with pulse duration of 1 sec and variable amplitude.

The texture patterns of samples have been studied using polarizing microscope equipped with digital camera both in the geometry of crossed polarizers and without analyzer.

## 3. RESULTS AND DISCUSSION

### 3.1. Tangential → Homeotropic Modification

The experimental cell is schematically shown in Figure 2 for low concentration of CTAB admixture. In the initial state (Fig. 2a), the part of $CTA^+$ ions are adsorbed uniformly at the interface, however their amount is not enough to screen the tangential surface forces of polymer matrix.

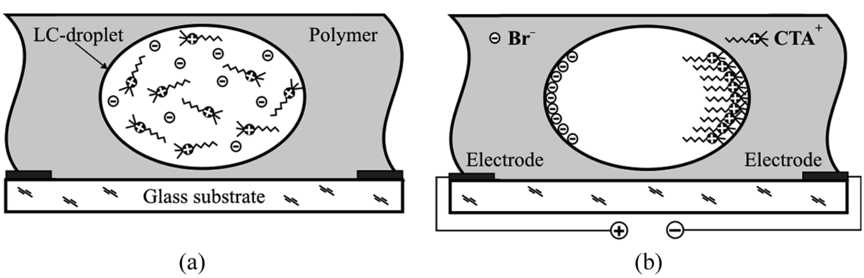


**FIGURE 2** Scheme of the experimental cell with low concentration (1%) of ion surfactant in the liquid crystal droplets. (a) Electric field is switched off, boundary conditions are tangential at the whole interface; (b) ion's ensemble is separated under the action of dc electric field, $CTA^+$ ions produce the homeotropic anchoring in the right section of droplet interface.

Under the action of dc electric field (Fig. 2b) the ions of different signs are spatially separated and localized at the corresponding sides of LC droplet. The ions of bromine have not revealed the surface activity in our experiments; therefore they will not be considered further. The cations $CTA^+$ are concentrated at the right boundary of droplet and can form here the monolayer sufficient to screen locally the tangential orienting forces proper to PVA and produce the homeotropic anchoring.

The change of optical texture observed inside the nematic droplet (see Fig. 3) agrees well with the above-stated model of surface modification. In the unpowered state (Fig. 3a), the orientational structure is bipolar with two surface defects (boojums [12]) arranged at the ends of long axis of droplet. They are seen distinctly as two dark points in the photo made without analyzer (Fig. 3a, central column).

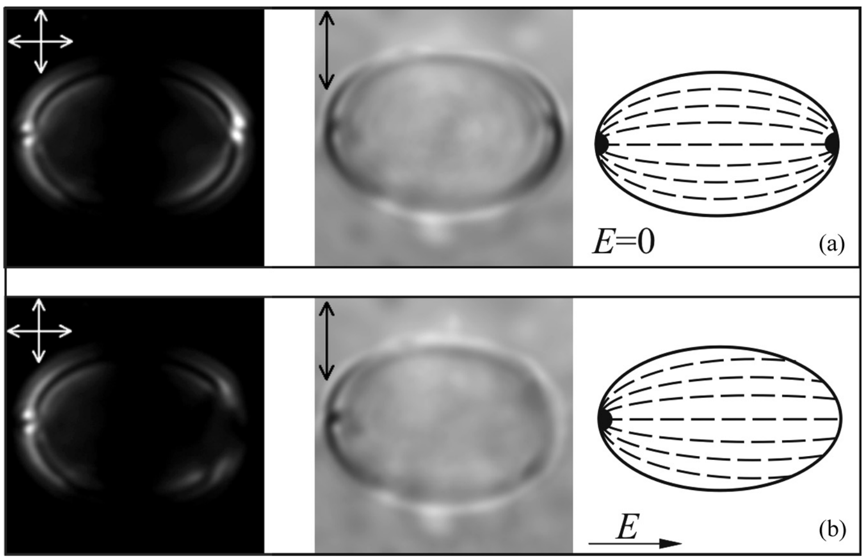


**FIGURE 3** Typical texture patterns within nematic droplets in PDLC films with the ratio 5CB:PVA:CTAB equal 1:19:0.01 by weight. Microphotos are shown in the left column (for crossed polarizers) and central one (without analyzer). The corresponding schemes of director configurations are presented in the right column. (a) LC droplet in unpowered state; (b) LC droplet just after the switching off electric pulse with amplitude U = 50 V. The double arrows show the polarizer's orientation. The lengths of droplet axes are equal 18.0 μm and 13.5 μm in the film plane. The distance between electrodes is 166 μm.

Under the action of the electric field directed along the bipolar axis (Fig. 3b), one of the boojums close to the cathode is collapsed. As a result, the initial bipolar director configuration is transformed into the monopolar structure. Such a transformation cannot be explained by the influence of electric field on the bulk of LC droplets, because the external field is compensated almost completely by the electric field generated by the separated ion charges [13]. This effect is possible only if the tangential anchoring at the droplet's interface close to the negative electrode is modified to the homeotropic one due to forming here of the monolayer of the surface-active cetyl-trimethylammonium ions.

## 3.2. Homeotropic → Tangential Modification

Another situation can be realized for the PDLC film with high content of CTAB admixture. In this case, $CTA^+$ ions adsorbed at the interface can form the surface-active monolayer screening the tangential orienting influence of polymer walls (Fig. 4a). It means that in the initial state the radial structure should be formed inside nematic droplets with homeotropic surface anchoring at the whole boundary. The application of electric field results in the shift of cations towards the negative electrode (Fig. 4b). Then the left part of droplet boundary is purified of surface-active $CTA^+$ ions, and the tangential anchoring can be restored here.

The transformation of droplet texture for nematic with 10 percents of CTAB (see Fig. 5) confirms this scenario of surface modification. For this composition, the LC droplets possess the radial director configuration with the bulk point defect (hedgehog [12]) in the centre (Fig. 5a).

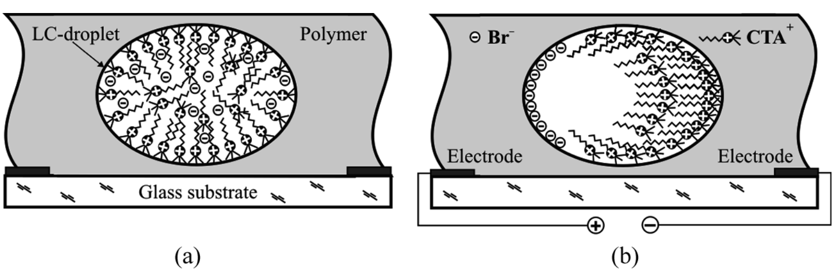


**FIGURE 4** Scheme of the cell with high concentration (10%) of ions. (a) $CTA^+$ ions form homeotropic surface-active layer at the whole interface in unpowered state; (b) tangential anchoring is created on the left because the cations shift towards the right boundary of droplet.

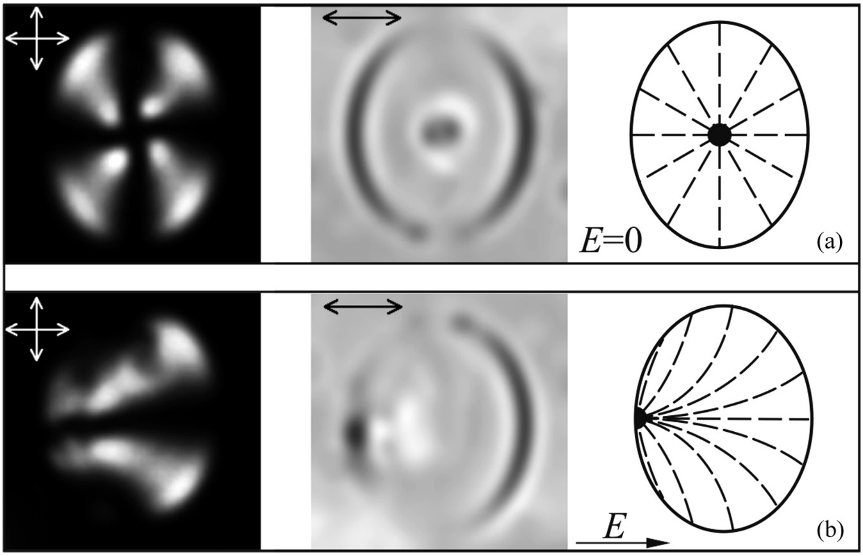


**FIGURE 5** LC droplets textures in PDLC films with the ratio 5CB:PVA: CTAB equal 1:19:0.1 by weight. The notation, arrangement of microphotos and electric pulse parameters are the same as in Fig. 3. The lengths of droplet axes are equal 8.6 μm and 10.5 μm in the film plane. The distance between electrodes is 280 μm.

That proves the formation of homeotropic anchoring at the whole interface.

The external electric field produces the strong texture transformation inside the nematic droplets (Fig. 5b). As a result, a surface defect-boojum arises in the left section of droplet with tangential director alignment at the adjacent part of interface. In the right section the texture pattern generally remains unaltered. These texture features are characteristic of the pre-radial orientational structure (Fig. 5b, right column) observed earlier [14] for the droplets with lecithin admixture without electric field.

## 4. CONCLUSION

The observed transformations are reverse, and the initial structures are restored after the electric field is switched off. Moreover, the change of electric signal polarity results in symmetric transformation of opposite surface of LC droplets.

The considerable variation of light scattering efficiency at the droplet interfaces allows supposing that the ion-surfactant method to control surface anchoring is a base to develop novel electrooptical effects in liquid crystal materials. Apparently, it will be especially effective to control the submicro- and nano-sized LC cells because the application of the classical Fredericksz effect is limited for such structures due to high value of operating voltage.

## REFERENCES

[1] Freedericksz, V. K. & Zolina, V. (1933). *Trans. Far. Soc.*, *29*, 919.
[2] Dubois-Violette, E. & De Gennes, P. G. (1975). *J. de Phys. Lett.*, *36*, L-255.
[3] Ryschenkow, G. & Kleman, M. (1976). *J. Chem. Phys.*, *64*, 404.
[4] Blinov, L. M., Davydova, N. N., & Sonin, A. A., *et al*. (1984). *Kristallografiya (Rus.)*, *29*, 537.
[5] Komitov, L., Helgee, B., & Felix, J., *et al*. (2005). *Appl. Phys. Lett.*, *86*, 023502.
[6] Drevensek-Olenik, I., Kunstelj, K., & Koncilija, J., *et al*. (2006). *J. Appl. Phys.*, *100*, 073514.
[7] Zyryanov, V. Ya., Krahalev, M. N., & Prishchepa, O. O., *et al*. (2007). *JETP Letters*, *86*, 383.
[8] Drzaic, P. S. (1995). *Liquid Crystal Dispersions*, World Scientific: Singapore.
[9] Cognard, J. (1982). *Alignment of Nematic Liquid Crystals and Their Mixtures*, Gordon and Breach Science Publishers: London, New York, Paris.
[10] Murazawa, N., Juodkazis, S., & Misawa, H. (2005). *J. Phys D: Appl. Phys.*, *38*, 2923.
[11] Murazawa, N., Juodkazis, S., Matsuo, S., & Misawa, H. (2005). *Small*, *1*, 656.
[12] Volovik, G. E. & Lavrentovich, O. D. (1983). *Zh. Eks. Teor. Fiz.*, *85*, 1997; *Sov. Phys. JETP*, *58*, 1159.
[13] Barannik, A. V., Lapanik, V. I., & Bezborodov, V. S., *et al.* (2005). *J. Info. Display*, *13*, 273.
[14] Prishchepa, O. O., Shabanov, A. V., & Zyryanov, V. Ya. (2005). *Phys. Rev. E*, *72*, 031712.