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# SURFACE POLARIZATION AND DOMAIN STRUCTURES IN THIN NEMATIC LAYERS

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Abstract A new electrooptical effect occuring in nematic, which proves existence of surface polarization in liquid crystal, is discovered experimentally.

The electrooptical effects in nematics, caused by the dielectric, flexoelectric and hydrodynamical mechanisms, have been clarified to satisfactory extent. Similar effects also can be induced by the surface polarization of the nematic, caused by assymmetric molecule orientations on the boundary.[1-3] However, one did not manage to distinguish them unambiguously from the background. The present paper gives account of the observation and interpretation of a new electrooptical effect which proves the existence of surface polarization.

We studied the homeotropically oriented layers (Fig.1 a,b) of penthylcyanobiphenyl (5CB) with positive dielectric anisotropy $\Delta\varepsilon$ . The external DC electric field was directed vertically, which enables us to exclude the destabilizing influence of dielectric and the majority of electrohydrodynamical effects. In order to separate surface polarization from flexoelectric mechanism, we employed two types of cells of thickness d=10-100 $\mu$m differing in the orienting covers and the-

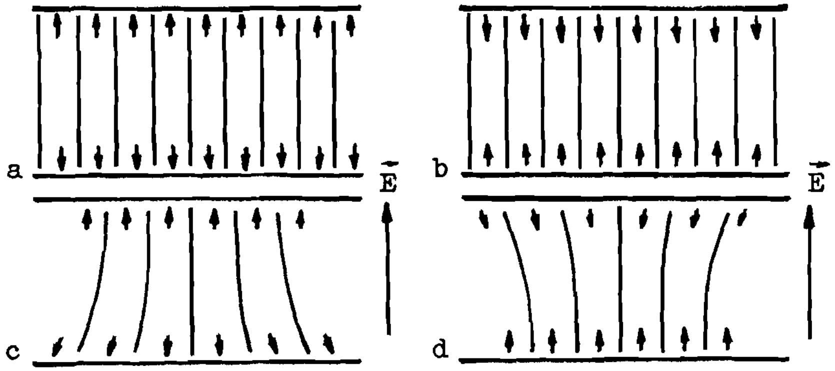

FIGURE 1. Surface instability geometries in A- (left side) and C- (right side) cells: a,b) below threshold, c,d) above threshold. Surface polarization is marked by arrows.

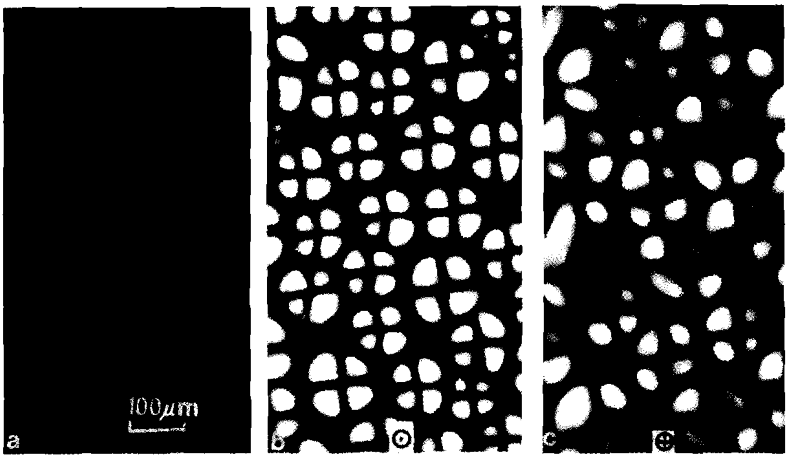

FIGURE 2. Textures of the anode surface instabilities in A-cell: a) homeotropic texture, below threshold; b) domains on the lower electrode; c) domains on the upper electrode. Direction of the field are shown by traditional symbols.

refore, in the type of surface polarization. In the A-cells, the $SnO_2$ electrodes were covered by a layers of silicon elastomer, which is hydrophilic and so favours the orientation of polar CN groups of 5CB molecules towards the substrate. In the C-cells, additional layers of lecithin were coated on the elastomer, and opposite direction of molecules would be expected.[2]

As soon as field is applied, the cell is enlightened and domains are formed (Fig.2). The effect occured similarly in the cells of both types and appeared at voltage U greater than some critical $U_c \sim 1V$ (Fig.3).

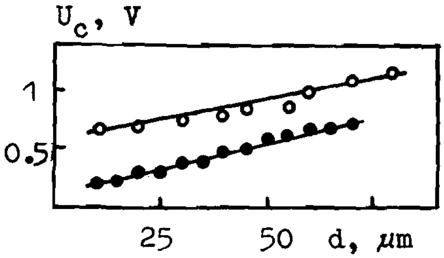

FIGURE 3. Threshold voltage vs cell thickness for A-cells ( • ) and C-cells ( ∘ ).

For $U \gtrsim U_c$ the domains look as "cloudy" patterns similar to those described by Monkade et al,[3] and for $U=(2\div3)U_c$, they look as distinct rounded domain whose geometry is shown in Fig.1c,d. Changing the microscope focusing it is possible to find that the distortions are localized near the anode in A-cells and near the cathode in C-cells. This peculiarity is crucial for revealing the nature of the effects.

Firstly let us discuss the possible flexoelectric mechanism. It is known[3], that a surface tilt of the director n can generate a flexopolarization $\vec{P}_f = e_1 \vec{n}\,\mathrm{div}\,\vec{n} + e_3\,\mathrm{rot}\,\vec{n} \times \vec{n}$ and thus lowers the coupling energy $(-\vec{P}_f\vec{E})$ with applied field. However, the signs of flexocoefficients $e_1$ and $e_3$ are the same in the cells of both types, thus the polarity of flexoinstabilities must be the same in A- and C-cells. This conclusion contradicts the data.

The data can be explained taking into account the surface polarization of 5CB, which brings the similar contribution ($-\vec{P}_s\vec{E}$) in the surface density of the free energy.[3] Inasmuch as the direction of $\vec{P}_s$ are different in A- and C-cells, for sufficiently large $|P_s|$ one should expect that the anode instability must occur in the A-cells, and the cathode instability must be developed in the C-cells (Fig.1). At least in one of these cells the destabilizing moment cannot be caused by any effect other than surface polarization; both flexoelectric and dielectric moments make stabilizing effect, as well as the surface anchoring responsible for the initial homeotropic orientation and bulk elastic curvature. In order to estimate $|P_s|$ values we use an expression that follows from the theory of one-dimensional surface polar instability:[4]

$$(e \pm P_s)^2 = \beta^2 + \beta W d\,(Wd/U_c\beta + 2\coth(U_c\beta/K_{33}))/U_c, \qquad (1)$$

where $e=e_1+e_3$, $\beta^2=\Delta\varepsilon K_{33}/4\pi$, $K_{33}$ is bend elastic constant, W is anchoring energy, "+" and "-" correspond to A- and C-cells, respectively. Substituting $K_{33}=10^{-6}$dyn, $\Delta\varepsilon=14$, $e=1.5\cdot10^{-4}$dyn$^{1/2}$ (Ref.5), and specially measured values $W_A=2\cdot10^{-3}$dyn/cm, $W_C=5\cdot10^{-3}$dyn/cm one obtains $|P_{sA}|=6\cdot10^{-3}$dyn$^{1/2}$ and $|P_{sC}|=4\cdot10^{-3}$dyn$^{1/2}$.

Let us compare the values obtained to the maximum possible $P_{s,max}$. Assuming the 5CB molecule dipoles to be oriented in the boundary layer of thickness $\xi$ uniformly, we obtain $P_{s,max}=\xi\mu N$, where $\mu$ is molecular dipole moment, N is the molecular density of 5CB. Since $\xi\sim100$ Å (Ref.2), $N=2.5\cdot10^{21}$cm$^{-3}$ and $\mu\sim4$ D, we have $P_{s,max} \simeq 10^{-2} dyn^{1/2}$ in agreement with our estimations of $P_{sA}$ and $P_{sC}$.

In conclusion we emphasize that the electrooptical effect observed is not associated 1) with the electrohydrodynamical instabilities: any motions of the substance in the cells did not occur up to the voltage U= 10V, which is much higher than $U_c$; 2) with the current carrier injection from electrodes, which was blocked by the elastomer layers; 3) with probable inhomogeneities of the cells: the domains were formed simultaneously on the whole cell surface, and their centers were not connected with any distinguished points and changed their locations as the field was switched on and taken away. More detail study will be published elsewhere.

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