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WHIRL ELECTROHYDRODYNAMIC INSTABILITY IN SMECTIC A PHASE LIQUID CRYSTALS

D.F.Aliev, N.M.Mamedov

(Received for Publication July 16, 1983)

Abstract. In planar oriented layers of smectic A phase a new type of instability, appearing as axial whirl, is observed and investigated. The system of lines with homeotropic orientation of molecules is necessary for creation of such kind of instability.

Due to the laminated structure and the translation ordering, at least in one direction, the smectic has some properties of viscosity-elastic, which differ it considerably from other liquid crystals /1/.

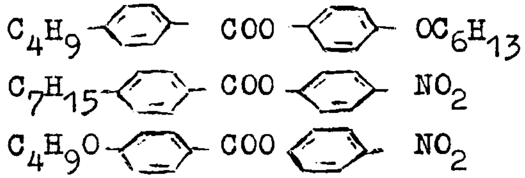
This fact leads to the "prohibition" of some electrooptical effects occuring in nematic and cholesteric liquid crystals /2/.

On this view the existance of whirl domain instability in smectics, which is similar to that occuring in nematics is of great interest. Such instability was not found in experiments on smectics A /3-5/.

Thus, the problem : if the moment conditioned by the electroconductivity can cause the whirl rotation in smectic A - remained unsettled.

In this paper the authors report on the experimental results, discovering the instability appearing in the form of axial whirls in a smectic A phase of liquid crystals.

A ternary mixture with the following structural form was the object for investigation.



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having the transition temperatures;

$$C \overset{\sim 10}{\rightleftarrows} S_A \overset{52}{\rightleftarrows} N \overset{57^\circ}{\rightleftarrows} J$$

The parameters of liquid crystals at the room temperature were the following

$$\varepsilon_{\parallel} = 24{,}2 \; ; \qquad \varepsilon_{\perp} = 7{,}2$$
$$\sigma_{\perp} = 3{,}4 \cdot 10^{-9} \; ; \qquad \sigma_{\parallel} = 2 \cdot 10^{-9} \, ohm^{-1} cm^{-1}$$

The original orientation is planar, which is obtained by a slow cooling of texture from the isotropic phase, accompanied by magnetic field of 8 KOe

A.C. field of a certain magnitude, applied to the cell, causes the formation of defects through the whole area, then the deffects are stretched out into strips. With negligible increasing of voltage these lines stretched in the direction perpendicular to the director, that is along the smectic layers. The formation of these lines in planar texture of smectic A phase was noted in /6/ but it was not investigated in detail.

The measurements performed by us showed that the threshold of this transition didn't depend on frequency and equals 120V with d = 30 μm , t = 24°C.

Fig.1 shows the temperature dependence of the threshold of line. As seen from this Fig. U^{ε}_{th} decreases considerably with the increasing temperature. This fact is due to lowering parameter of smectic order τ .

It follows from the energetic considerations that $U^{\varepsilon}_{th} \sim W_d^{1/2}$, where W_d stands for the probability of defect's formation, which in it's turn is propotional to $W_d \sim |\tau|^2$.

The distribution of permittivity, electrical conductivity and refractive index through the sample shows that in the regions of lines the homeotropic orientation of molecules is formed. Thus, threshold U^{ε}_{th} causes the local planarhomeotrop transition. The further increase of voltage leads to the gradual broadening of these regions, which then merge, and molecules are orien-

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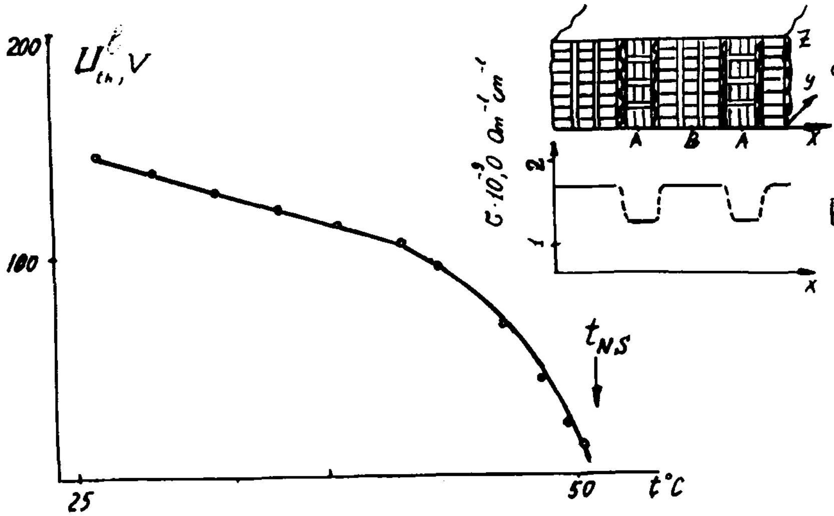

FIGURE 1. Temperature dependence of the threshold for the lines formation. In the inset it is represented in the schematic form:

a) the distribution of the director in a cell after lines formation;
b) the distribution of conductivity along X.

ted homeotropically through the whole area of the cell.

Thus, the voltage applied to the cell causes the formation of the system of lines, which retains for a long time, after the U_{th}^{ℓ} is turned off.

If continuous or low frequency fields are applied to such texture, the definite whirl rotation will occur.

The motion of liquid occurs strictly in the XZ plane, at the point B, where σ has the max. value, it flows up , and at the point A, where σ has min. value the liquid flows down.

The rate of motion rises with applying vol-

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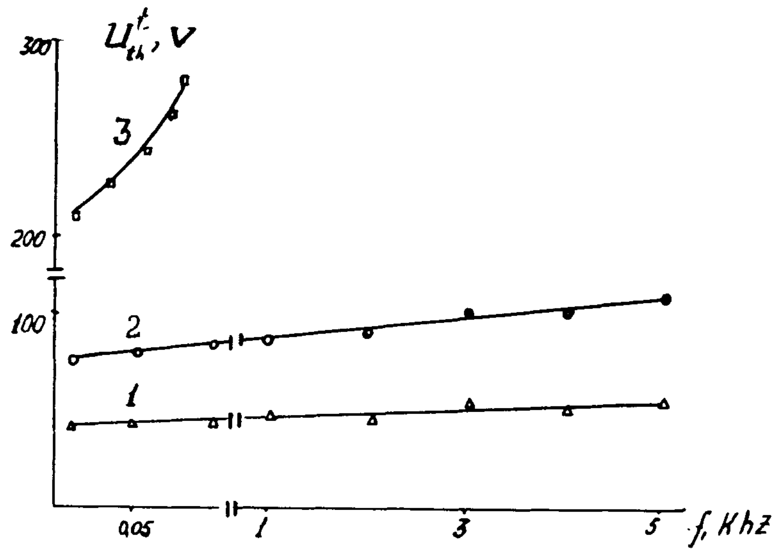

FIGURE 2. The frequency dependences of the threshold voltages, which occured in planar (1,2) and homeotropic (3) texture smectic A phase 1,3 - $\sigma_{\perp} = 2 \cdot 10^{-9}$, 2 - $\sigma_{\perp} = 10^{-9}$ ohm^{-1}. cm^{-1}; t = 25°C.

tage, but at higher voltage $U \approx 2U_{th}^{t}$ the regular rotation is disturbed gradually and the turbulent motion of liquid through the whole area of the cell is established.

Here for comparison U_{th} of instability is given appearing from the homeotropic texture /4/. This instability occurs only at low frequencies and it's threshold increases considerably in comparison with U_{th}^{t}(f). The threshold of whirl motion is a linear function of d and is weakly dependent on the thickness of liquid crystal in the $20 \leq d \leq 100$ μm range.(Fig.3)

The threshold voltage instability depends strongly on the electroconductivity anisotropy. For example: if $\sigma_{\perp}/\sigma_{\parallel} = 1,6$ corresponds to U = 60 V, then $\sigma_{\perp}/\sigma_{\parallel}$ = 2,8 corresponds to U = 46 V. U_{th}^{t} is also dependent on the anisotropy of permittivity $\Delta\varepsilon$ and decreases with it's increase.

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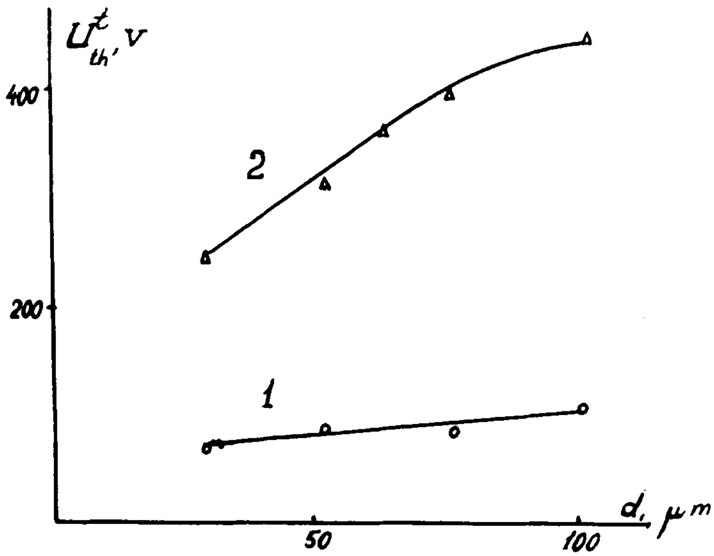

FIGURE 3. The dependence of threshold voltage instability, occurring from planar (1) and homeotropic (2) texture on the electrooptical cell thickness.

Perhaps, the divided space charge is responsible for the regular whirl motion.

The division of charge is caused by the distribution of conductivity through the whole cell.

In nematics such inhomogeneity is easily obtained and can be realized by means of director fluctuation.

As for the smectics, this condition, as shown in a paper can be created artificially.

Thus, in the smectic A phase with a definite geometry the moment caused by electroconductivity and it's anisotropy can lead to destruction of laminated structure order and creation of regular whirl motion.

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