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New electro-optical effect in the smectic-*C* phase of a liquid crystal

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A new electro-optical effect observed in a homotropically oriented smectic-*C* phase is described. A comparison is made with the known effect produced in samples with planar molecular orientation.

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One of the decisive factors in the mechanism and character of electro-optical effects observed in liquid crystals, in addition to the parameters of the medium, is the form of the initial orientation of the molecules of the liquid-crystal sample. A characteristic feature of recent experiments is therefore that they are made with monolayer liquid crystals, with distinctly prescribed initial orientation of the molecules. This feature pertains mainly to nematic liquid crystals, whereas in the case of smectic crystals the known experiments were performed either with non-oriented samples or with samples having one fixed orientation of the molecules. This fact, which is frequently due to the difficulty of obtaining oriented smectic monolayers, does not make it possible to reveal all the possible effects that can be observed in smectic liquid crystals.

We report here the rests of an investigation that demonstrates the existence of two different effects in oriented layers of the smectic-*C* phase.

The object of the investigation was p-n-nonyl-oxybenzoic acid, which has a smectic-*C* and a nematic phase. The planar and homotropic textures (the liquid-crystal molecules and the smectic fields are respectively parallel to the surface of the cell) of the smectic-*C* phase were obtained by using a high-frequency field and by displacing the cell, whose surfaces were prepared beforehand. The liquid-crystal thickness was 20 μm.

In the case of planar orientation of the molecules, dc and low-frequency voltages produced in the sample a domain texture with a threshold voltage that increased with increasing frequency. At a definite frequency f_1, domains with a smaller period came into being, and their direction was perpendicular to the original domains.

A domain structure was first observed in smectic-*C* by Vistin' and Kapustin[1] and was subsequently the subject of various studies.[2-6] The main features of the low-frequency domains are satisfactorily described by Pikin's theory developed for nematics with oblique orientation of the molecules.[7] Thus, whether so stipulated or not, the smectics investigated in Refs. 1–6 had a planar orientation of the molecules.

In the case of homotropic molecule orientation, no noticeable change in texture was observed up to a definite value of the applied voltage. In the case of the threshold voltage, local turbulent motion set in in individual sections, as a rule at the cell defects. These sections spread and eventually covered the entire cell area.

Figure 1 shows the dependence of the threshold voltage of the turbulent motion on the frequency of the applied field (curve 1). From a comparison with the anal-

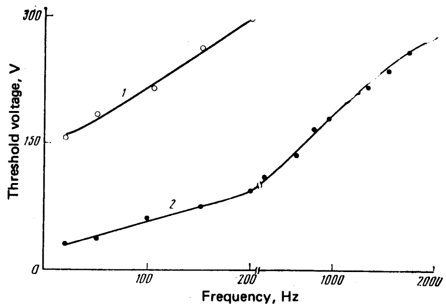

FIG. 1. Frequency dependences of the threshold voltages of the onset of electro-optical effects in the smectic *C* phase for an initial homotropic orientation of the molecules (1) and for an initial planar orientation of the molecules (2).

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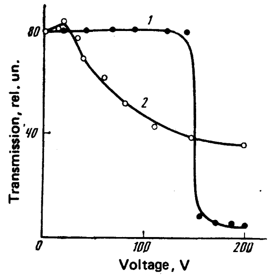

FIG. 2. Dependences of intensity of the light passing through the liquid crystal on the applied voltage in the case of homotropic (1) and planar (2) orientation of the molecules.

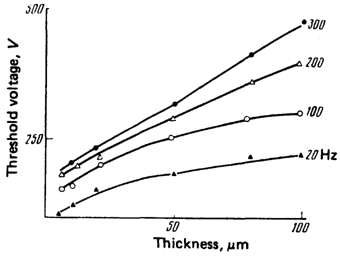

FIG. 3. Dependence of the threshold voltage on the thickness of the liquid-crystal layer at various frequencies of the applied voltage.

ogous relation for the formation of the domain texture (curve 2) it is seen that to observe the effect it is necessary to apply relatively high voltages to the cell. The resultant instability destroys the ordered texture of the smectic and decreases drastically the intensity of the light passing through the sample (Fig. 2, curve 1). The formation and evolution of the domain texture are also accompanied by a decrease of the transmissivity of the sample, but both the relative change of the transmissivity and its rate of change are much smaller in this case (curve 1). With increasing temperature of the sample, a decrease is observed in the threshold instability voltage and an increase in the rate of its propagation. This change is apparently due to the decrease of the viscosity of the liquid crystal.

It is known that one of the important characteristics of the effects observed in liquid crystals is the dependence of the threshold voltages of these effect on the thickness of the liquid-crystal layer. As seen from Fig. 3, which shows the dependence of the threshold on the thickness for various applied-voltage frequencies, the instability threshold increases with increasing thickness. When the voltage that produces the instability is turned off, a confocal texture that scatters light strongly is produced. The relaxation time of this texture is several order of magnitude longer than the relaxation time of the domain texture.

It was established that the described effect is observed also in the smectic-C phase of other liquid crys-crystals. Addition of optically active impurities to the smectic-C phase, or else consideration of a smectic-C phase consisting of asymmetric molecules, has led to the conclusion that the appearance of twisting of the structure does not manifest itself qualitatively in the appearance and in the observation of the effect.

A study of the main characteristics of the observed effect suggests that it is brought about by the following two mechanisms.

First, owing to the negative anisotropy of the permittivity of the investigated liquid crystals, the action of a dielectric moment $\sim\Delta\varepsilon E^2$ on the molecule can produce in the molecule only a purely dielectric transition.

Second, owing to the negative anisotropy of the electric conductivity and to the deformation of the smectic layers by the defective sections of the cell, electrohydrodynamic instability can be observed, similar to the instability observed in the smectic-A phase.[8]

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