SIGN REVERSAL OF NEMATIC LIQUID CRYSTAL CONDUCTIVITY ANISOTROPY AS FUNCTION OF TEMPERATURE

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A new property of nematic liquid crystals has been observed, namely the reversal of the sign of the electric-conductivity anisotropy as a function of the temperature. It is attributed to the change in the angle of the aligned slope of the molecules in the molecular-complex layers.

We have previously observed an unknown property of nematic liquid crystals, that the sign of the anisotropy of the electric conductivity changes with temperature. We investigated the nematic phase of p-n-octyloxybenzoic acid (OOBA); a layer 200 μ thick was placed between two flat silver electrodes. The electric conductivity was measured with an ac bridge (f = 1000 Hz) while the sample was cooled from the isotropic phase. The sample was oriented in a uniform magnetic field ∿2.4 kOe.

Figure 1 shows the temperature dependence of the specific anisotropy $\Delta\sigma = \sigma_{\parallel} - \sigma_{\perp}$ of the electric conductivity of the nematic mesophase of OOBA ($\sigma_{\parallel}$ and $\sigma_{\perp}$ are the specific conductivities parallel and perpendicular to the nematic-ordering axis, respectively). As seen from the figure, the OOBA nematic structure has a negative anisotropy after the transition from the isotropic phase. With decreasing temperature, the value of $\Delta\sigma$ decreases and at T = 146.2°C the negative anisotropy becomes positive and remains so at lower temperatures.

These results are obviously due to the structural features of the OOBA nematic mesophase. It follows from the observations of the texture that the nematic phase of the investigated substance goes over when cooled into the smectic phase. Recent x-ray diffraction studies have shown that the structure of the nematic mesophase produced when the smectic C phase is cooled differs from that of classical nematic liquid crystals [1, 2]. It consists of complexes, and within each complex ($\ell \sim 400$ Å) the molecules form layers and have an aligned slope α relative to the layer plane. The schematic orientation of the molecules in the complexes and of the complexes themselves in a sufficiently strong magnetic field is shown in Fig. 2. According to [3], the electric conductivity of the molecular complex is anisotropic, with the conductivity maximal along the layers.

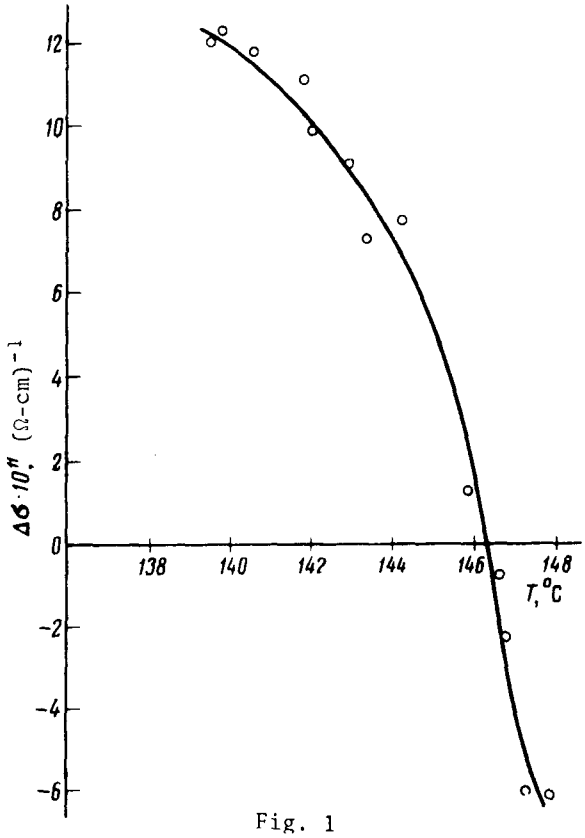

Fig. 1

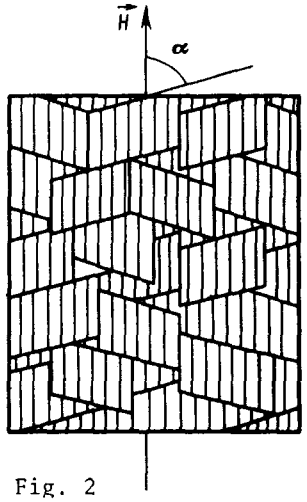

Fig. 2

Assume that the carrier diffusion coefficient D is much smaller than ℓ^2/τ (ℓ is the linear average dimension of the complex and τ is its average lifetime). Then, according to [4], the anisotropy of the electric conductivity of the nematic phase is determined to a considerable degree by the anisotropy of the electric conductivity of the complex. Recognizing that the nematic-ordering axis is a symmetry axis of infinite order, we obtain for the anisotropy of the electric conductivity of the nematic phase of OOBA

$$\Delta\sigma \sim -\Delta\sigma' \cos 2\alpha. \qquad (1)$$

Here $\Delta\sigma'$ is the anisotropy of a complex having molecular ordering of the smectic type A, for we know that $\Delta\sigma' < 0$. Hence, according to (1), the experimental behavior of $\Delta\sigma(T)$ can be attributed to a decrease of the angle α with decreasing temperature. The sign of the anisotropy reverses at $\alpha \sim \pi/4$.

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NEGATIVE CHARGE OF ELECTRON-HOLE DROPS IN GERMANIUM

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Drift of electron-hole drops was observed in germanium in a weak electric field. It is attributed to the negative charge possessed by the drops.

It was assumed in the analysis of the properties of the condensed phase of nonequilibrium carriers in semiconductors [1] that the drops are made up of electron-hole plasma, and that the number of electrons and holes in the drop as the same so that the drops are electrically neutral as units. This assumption, however, is not obvious, since the binding energies of the electrons and holes in the condensed phase may not be equal. An approximate calculation (private communication from T. M. Rice) shows that in the case of germanium the electron binding energy is approximately 0.5 meV higher than that of the holes. Therefore emission of holes from the drops will predominate until the negative charge of the drops becomes sufficient to equalize the rates of emission of the electrons and holes. If the crystal is continuously excited, there exist in the excitation region free electrons and holes that are not bound into excitons, and these screen the charge of the drop. According to the private communication from T. M. Rice, when the free-carrier density is approximately 4×10^{12} cm^{-3} (corresponding to an excitation rate 10^{20} - 10^{21} $cm^{-3}sec^{-1}$) the stationary charge of a drop of radius $R = 5\times10^{-4}$ cm should reach $\sim 500e$, where e is the electron charge.

We succeeded in determining the electric charge of electron-hole drops from the drift of the drops in weak electric fields. A sample of pure germanium measuring 11 × 5 × 0.5 mm was excited in quasistationary fashion with a helium-neon laser (wavelength 1.15 μ and power up to 10 mW) focused on the surface of the sample to produce a strip 0.1 mm wide. The magnified image of the surface of the sample, which was placed in superfluid liquid helium, was focused with a movable lens on the entrance slit of an MDR-2 spectrometer tuned to the recombination radiation of the condensed phase. By moving the lens in a direction perpendicular to the spectrometer slit we were able to determine the spatial distribution of the intensity of this radiation [2]. A dc voltage could ba applied to the ends of the sample through fused-in indium contacts. The intensity of the electron-hole drop radiation was registered at each position of the movable lens and at both polarities of the applied voltage, as well as in the absence of an electric field in the sample.

The figure shows the spatial distribution of the radiation of the electron-hole drops in the sample, in the absence of a field and at a field intensity E = 2.5 V/cm at both polarities. It is seen from the figure that in an electric field the radiation-intensity distribution is always shifted towards the anode relative to the center of the excitation region, regardless of