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THE STUDY OF THE CHARGE CARRIER TRANSPORT IN NEMATIC MIXTURES

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Abstract The electrical conductivity and the mobility measurements in nematic mixtures Merck 5 and Merck 7a are reported. The drift mobility of carriers about 10^{-5} cm^2/Vs at room temperature was determined. Identical activation energies of conductivity and mobility were obtained (0.4 eV for Merck 7a and 0.3 eV for Merck 5). In our opinion, the conductivity of examined mixtures is controlled by ionic transport.

EXPERIMENTAL

In this paper we report the results of d.c. conductivity and drift mobility measurements for nematic liquid crystals. We used two commercial mixtures: Merck 5 and Merck 7a. The samples (thickness 50 and 100 μm) were sandwiched between two metal electrodes (Al-Au or Cr-Au) evaporated on glass. The charge carrier drift mobility was determined by the time-of-flight method using generation of charge near electrodes by application of a voltage step. The scheme of the experimental arrangement is shown in Fig. 1. The step voltage pulse (rise time 0.1 μs, amplitude 10-100 V) was given into 2 branches of a symmetrical bridge. The transient current in the liquid crystal sample was obtained as a differential signal from equal resistors, R_1 and R_2. The capacitance C_0 was identical to that of the sample C_s. In this way, the current pulses in liquid crystal samples have been observed without their capacitance components. From the position of a cusp on the current-time curve (Fig. 1) the transit time and mobility were determined.

Stationary I-U characteristics were obtained in conventional circuit. All measurements (d.c. and transient currents) were executed for voltage over the electrohydrodynamic instability threshold (EHD) and at temperatures from 290 up to 350°K. In this range of temperature both mixtures were nematic.

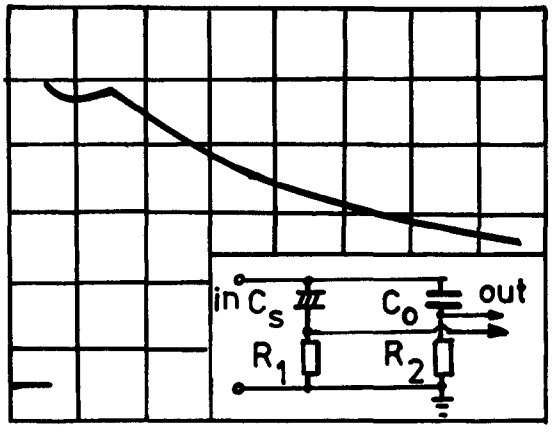

FIGURE 1. Typical transient current in Merck 7a. D=50 μm, U=54 V, vertical scale: 0.5 μA/div, horizontal scale: 20 ms/div, room temperature. The inset: scheme of measuring circuit.

RESULTS AND DISCUSSION

Steady state current-voltage characteristics were nonlinear for both mixtures: $i \sim U^n$ where n=2 for Merck 7a and 1.5-2 for Merck 5. We suggest that this nonlinearity can be due to space-charge limited currents, but other contributions, e.g. ionization of ion pairs by the secondary Wein effect can also be considered. The EHD instabilities were permanently present during measurements. Additional observations of EHD motion showed, that the instability begins at the cathode. It points that instability is of the Felici type and that there must exist a source of charge near that electrode. The charge must be large enough to cause EHD, therefore to create conditions for SCLC too. The mechanism of charge generation is probably due to unipolar injection of electrons from the electrode followed by oxidation of a molecule of the nematic kind. Another possibility is the field desorption of adsorbed double layer carriers is not likely to take place, because it would not give permanent EHD instabilities. However, independent of the "true" physical phenomena in the sample the mobility measurement results are not changed.

The carrier drift mobility μ is related to the transit time t and the applied voltage U by the expression

$$\mu = \frac{0.8\ D^2}{U\ t} \qquad (1)$$

where D is the sample thickness. The factor 0.8 is taken from SCLC theory for the unipolar injection case.[1] Reciprocal transit time is proportional to the applied voltage, i.e. the mobility is field independent in fields ranged 1-10 kV/cm (Fig. 2). At room temperature carrier mobilities

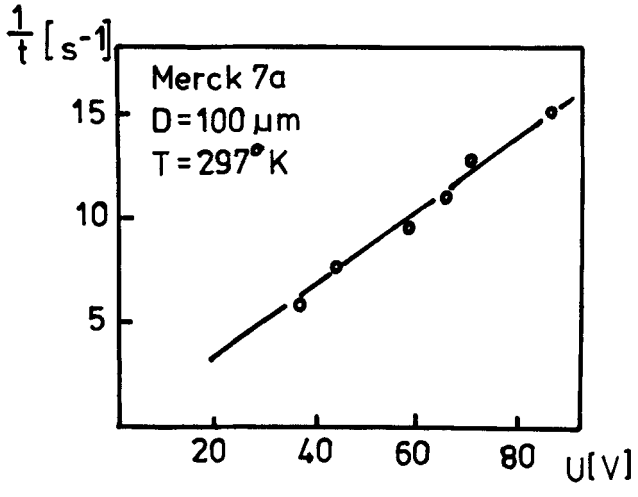

FIGURE 2. Reciprocal transit time versus applied voltage.

are $1.3 \cdot 10^{-5}$ cm^2/Vs and $1.2 \cdot 10$ cm^2/Vs for Merck 7a and Merck 5 mixtures, respectively. Similar data for ionic mobilities in nematic liquid crystals were also obtained by other authors.[2,3] The thermal activation energies of mobility and conductivity E_μ = (0.40 + 0.03) eV and E_σ = (0.38 + 0.02) eV for Merck 7a. Because these values are identical in the limit of experimental error, we suggest that temperature dependence of conductivity is controlled by ionic transport and not by generation processes. Energies $E_\mu = E_\sigma$ = 0.3 eV were obtained also for Merck 5. They are equal to viscosity activation energy calculated from results of other authors.[4] We also suggest that ion motion in nematic mixtures may be described by the rule of

Walden-Stokes.

$$\mu \eta = \text{const.}$$

or by Adamczewski's formula[5]

$$\mu \eta^{a} = \text{const.}$$

In our case exponent a is about 1 for Merck 5 and 1.3 for Merck 7a (if activation energies of viscosity are the same). These values are in good agreement with result a=1-1.5 obtained by Hisamitsu et al.[2] for p-azoxyanisole. This problem will be discussed in more detail in the next publication.

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