

## CHARGE CARRIER MOBILITY MEASUREMENTS IN SOME NEMATIC MIXTURES\*

BY G. DERFEL, A. LIPIŃSKI AND W. MYCIELSKI

Institute of Physics, Technical University of Łódź\*\*

(Received February 7, 1978; final version received May 27, 1978)

The electrohydrodynamic mobility of ions in the nematic mixtures Merck 5 and 7a was found to be about  $10^{-5} \text{ cm}^2\text{V}^{-1} \text{ s}^{-1}$  with the activation energies 0.3 eV and 0.4 eV respectively. It is proposed that the conductivity in the investigated substances is controlled by ion transport, and not by the generation process.

Ion mobility measurements in liquid crystals have been carried out over the last ten years. Results published during that time differ not only quantitatively, but also qualitatively [1-11]. This may be due to the different experimental methods and conditions used by different authors. It seems necessary to carry out a systematic investigation and the analysis of applied methods.

One of the methods used for mobility measurements is the time-of-flight method described by Helfrich and Mark [12]. In that method the voltage step applied to the layer of the substance causes the injection of the carriers into the layer. The value of mobility can be obtained from the position of the cusp of the transient injection current: it appears after the time

$$t = 0.79 \frac{d^2}{\mu V}, \quad (1)$$

where  $d$ ,  $\mu$  and  $V$  are the thickness of the specimen, mobility and voltage respectively [13]. The above formula is valid for the unipolar injection of carriers. The presence of this kind of injection was shown by additional microscopic investigations of the electrohydrodynamic instabilities. On the basis of those observations one may determine the negative sign of the carriers.

---

\* Presented at the Second Liquid Crystal Conference of Socialist Countries, Sunny Beach, Bulgaria, September 27-30, 1977.

\*\* Address: Instytut Fizyki, Politechnika Łódzka, Żwirki 36, 90-924 Łódź, Poland.

The time-of-flight method was applied to liquid crystals already in 1967 by Heilmeyer and Heyman [1]. Later it was employed by other investigators (Refs. [2, 5, 9, 11]), but not always with the original Helfrich and Mark's bridge.

In our experimental set-up, a voltage step pulse was applied to two circuits simultaneously: one containing the specimen having capacitance  $C_p$  and resistance  $R_1$ , and another containing a resistance  $R_2 = R_1$  and capacitance  $C_s = C_p$  (Fig. 1). Voltage drops

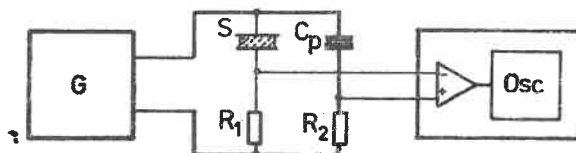


Fig. 1. Block scheme of the experimental arrangement for drift mobility measurements. G — step voltage generator, S — liquid crystal sample (capacitance  $C_s$ ),  $C_p$  — comparative capacitor,  $R_1, R_2$  — identical resistors, Osc — oscilloscope with differential input

arising across the resistance were subtracted by the use of a differential amplifier in the oscilloscope, which showed only the conduction current. An example of the transient current is shown in Fig. 2.

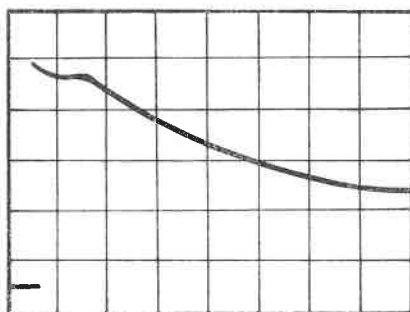


Fig. 2. Typical transient current in the mixture Merck 7a at room temperature. Thickness of sample  $50 \mu\text{m}$ , vertical scale  $5 \times 10^{-7} \text{ A/div}$ , horizontal scale  $20 \text{ ms/div}$ , applied voltage  $54 \text{ V}$

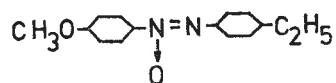
We investigated two mixtures Merck 5 and Merck 7a, nematic in temperature ranges  $-5^\circ \div 75^\circ\text{C}$  and  $-10^\circ \div 80^\circ\text{C}$  respectively. Chemical structure of Merck 5 is presented in Fig. 3. Merck 7a has the same composition but it contains 10% of some nematic ester. The results obtained for both substances are similar. We found that the presence of SCLC is what makes the use of Eq. (1) valid. The existence of intrinsic carriers in the substance caused deviations from the square-of-the-voltage-current dependence. The intrinsic current dominated over the injected one, therefore the slope of the current-voltage characteristic on the logarithmic scale were  $1.4 \div 2$ . This current decreased with time and caused the differences between the shape of experimental and theoretical transient current curves.

The values of the mobility measured at room temperature are  $1.2 \times 10^{-5} \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$  for Merck 5 and  $1.3 \times 10^{-5} \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$  for Merck 7a. They are independent of electric

field strength, contrary to Lacroix and Tobazeon's result [9]. The exponential temperature dependence of mobility was found, with an activation energy in nematic phase of 0.3 eV for Merck 5 and 0.4 eV for Merck 7a. These values are within the limits of error for the conductivity and viscosity activation energies [14].

Merck 5

mixture of



and

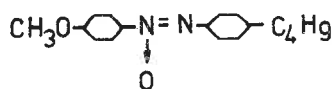


Fig. 3. Chemical structure of Merck 5

The mobility was measured in the region of electrohydrodynamic instabilities. The hydrodynamical properties of a substance ion transport. The approximate equality of all three activation energies suggests that the temperature dependence of conductivity is controlled by the transport mechanism, and not by the carrier generation process. The mentioned values are therefore the effective ion mobility in the presence of EHD flows. The effect of these flows on ion motion will be the subject of our subsequent investigation, carried out in order to obtain the value of ion mobility due to their motion in a quiet liquid.

#### REFERENCES

- [1] G. H. Heilmeyer, P. M. Heyman, *Phys. Rev. Lett.* **18**, 583 (1967).
- [2] G. H. Heilmeyer, L. A. Zanoni, L. A. Barton, *Proc. IEEE* **56**, 1162 (1968).
- [3] D. G. Shaw, J. W. Kaufman, *Phys. Status Solidi (a)* **4**, 467 (1971).
- [4] G. Briere, R. Herino, F. Mondon, *Mol. Cryst. Liq. Cryst.* **19**, 157 (1972).
- [5] K. Yoshino, S. Hisamitsu, Y. Inuishi, *J. Phys. Soc. Jap.* **32**, 867 (1972).
- [6] S. Hisamitsu, K. Yoshino, Y. Inuishi, *Techn. Rep. Osaka Univ.* **22**, 201 (1972).
- [7] K. Yoshino, K. Yamashiro, Y. Inuishi, *Jap. J. Appl. Phys.* **13**, 1471 (1974).
- [8] R. Chang, J. M. Richardson, *Mol. Cryst. Liq. Cryst.* **28**, 189 (1974).
- [9] J.-C. Lacroix, R. Tobazeon, *C. R. Acad. Sci. Paris* **278B**, 623 (1974).
- [10] K. Yoshino, K. Yamashiro, Y. Inuishi, *Jap. J. Appl. Phys.* **14**, 216 (1975).
- [11] T. Yanagisawa, H. Matsumoto, K. Yahagi, *Jap. J. Appl. Phys.* **16**, 45 (1977).
- [12] W. Helfrich, P. Mark, *Z. Phys.* **166**, 370 (1962).
- [13] A. Many, G. Rakavy, *Phys. Rev.* **126**, 1980 (1962).
- [14] S. Nagai, P. Martinoty, S. Candau, *J. Phys.* **37**, 769 (1976).