

## PERSISTENT INTERNAL POLARIZATION EFFECT IN SOME LIQUID CRYSTAL COMPOUNDS\*

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P-hexyloxyphenyl-p-pentoksybenzoate and p-octyloxyphenyl-p-pentylobenzoate show electret properties. These compounds are nematic substances. After polarization and cooling the samples, the polarizing field was removed and the samples were shortened. The samples are reheated and the ensuing discharge current is measured. The total released charge, as determined by graphical integration of the corresponding current-time curve, gives the charge of the samples. The shapes of the curves are different from the discharge curves of traditional electrets.

"Frozen-in" charge in cholesteric liquid crystals was first discovered by Takamatsu in 1971 [1]. That year Kapustin noticed the persistent internal polarization in p-azoxyanisole — PAA [2]. In 1975 Grossman and Lipiński found an electret effect in 4-n-heptyloxyphenyl 4-n-hexybenzoate.

Two compounds were used in our experiment:

- I. p-hexyloxyphenyl-p-pentoksybenzoate,
- II. p-octyloxyphenyl-p-pentylobenzoate,

Their phase transition temperatures are presented below:

- I. solid state<sup>56°C</sup>nematic phase<sup>89°C</sup>isotropic liquid,
- II. solid state<sup>52°C</sup>nematic phase<sup>85°C</sup>isotropic liquid.

The samples were placed between two glass windows which were covered with a conducting transparent layer (SnO<sub>2</sub>). The thickness of the samples was 50 μm. The electrode areas were of the order of 3 cm<sup>2</sup>. The influence of the separating teflon foil was taken into account by a special pickling of the electrode layer (teflon shows electret properties). The polarization of the samples was carried out at 75°C (nematic phase).

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After that temperature had been reached a polarization voltage was applied to the samples. We used an electric field strength ranging from 600 V/cm to 1400 V/cm. Polarization times were 15 minutes. The temperature was kept constant during this time. The accuracy of the temperature stabilization, in the range from 20°C to 100°C, was of the order of 0.2°C. After the samples were cooled to room temperature the polarizing voltage was removed and the samples were shortened. They were kept in this conditions for periods of 2 to 48 hours.

Samples were measured individually. The electrodes of the sample were connected to an electrometer. The temperature increased within 20 min. to 95°C and subsequently was kept constant for an additional 30 min. The total heating interval time allowed practically a complete discharge<sup>1</sup>. The liberated depolarization currents were measured with an electrometer.

### Result and discussion

Some curves of the thermally stimulated current (TSC) are shown in Fig. 1: the solid line is due to compound I and the dashed line is due to compound II. One observes two positive maxima. The first peak of TSC current appears at the transition point: solid state —

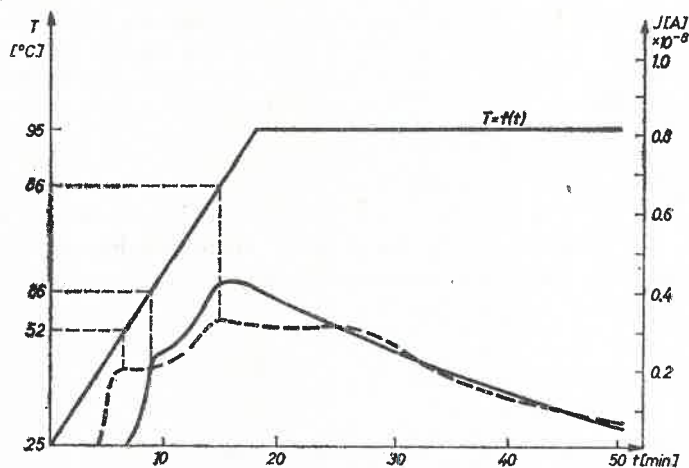


Fig. 1. Discharge current and temperature curves as a function of time: the solid line is due to compound I and the dashed one is due to compound II

nematic phase, and the second one at the transition point: nematic phase — isotropic liquid. The shapes of the curves changed more or less in repeated experiments, but the temperatures for the peaks were quite reproducible. The position of the peaks corresponds approximately to the phase transition temperatures derived from visual observation. In our opinion it gives a new tool for defining the temperature of the phase transitions

<sup>1</sup> Heating depolarizes the electret completely if over a prolonged interval of time the temperature is kept higher than it was during polarization [3].

in liquid crystals. The charge stored in a poled sample was calculated by integrating the TSC curves. The charge density as a function of polarizing field strength  $E$  is shown in Fig. 2. The plots of charge density versus keeping time are shown in Fig. 3.

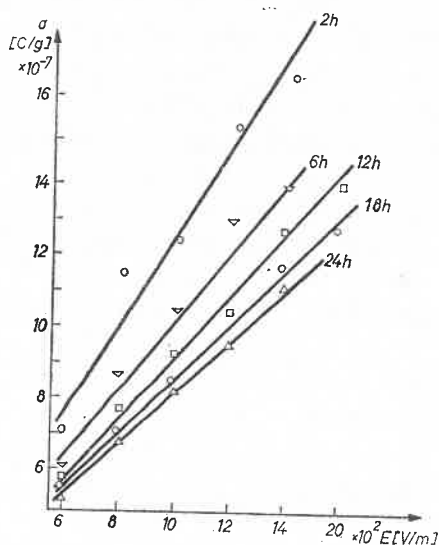


Fig. 2. Charge density as a function of polarizing electric field strength  $E$

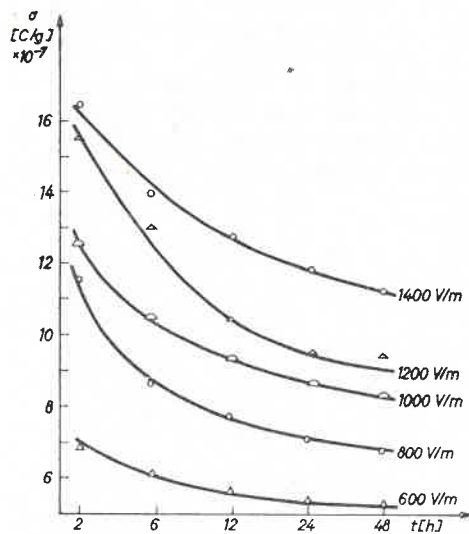


Fig. 3. Charge density as a function of time

Linear variation of total charge density with polarizing fields that the electret field is due to uniform bulk polarization [4, 5] which may arise either due to a true dipolar mechanism or due to migration of charge carriers over microscopic distances with subsequent trapping. The positive sign of the TSC current in our experiments is due to heterocharge

in the sample. The heterocharge is an internal volume effect; the nature of it is still doubtful. The dipole orientation as a cause of heterocharge is ruled out. If orientational polarization of dipolar molecules alone causes TSC, the depolarized charge will be calculated by Debye's dipole theory. Rough estimation shows it to be about  $10^{-10}$  C/cm<sup>2</sup>, but this value is too small in comparison to our results (see figures). Further, Perlman [6] has calculated that if heterocharge is due to dipole orientation in a carnauba wax sample, there should at least be 100 dipoles per molecule, which is a ridiculous value.

A model can be imagined in which stored charge is dominantly due to macroscopic space charge polarization and the microscopic displacement of ions with trapping which were formed between the sample and electrode, as well as in the bulk of the sample. Charges are due to ion impurities present in liquid crystal samples. Therefore, it is reasonable to consider that the TSC current is due to thermal release of ions trapped in the imperfections in solid and liquid crystal structure. Although liquid crystals have no crystal lattice, there might be some irregularities in it which trap ions.

One should assume that to obtain the electret from liquid crystals, relatively small electric field strengths are required.

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