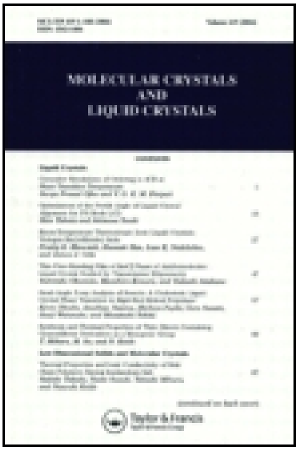

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BASIC CHARACTERISTICS OF A NEW FERROELECTRIC LIQUID CRYSTAL WITH HIGH SPONTANEOUS POLARIZATION

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Abstract The temperature dependence of the spontaneous polarization, P_s, and the tilt angle were measured for a new ferroelectric liquid crystal. P_s reaches the saturated value of about 80 nCcm^{-2}. Its temperature dependence reveals the second order ferroelectric phase transition. At high frequencies, the permittivity data exhibit great contributions from the Goldstone mode and from the soft mode. An additional contribution to permittivity was detected arround the phase transition S_A-N^*.

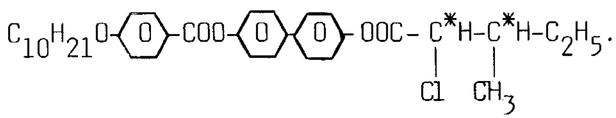
INTRODUCTION

During the last few years, the number of known liquid crystals exhibiting the ferroelectric S_C* phase has extremely increased. Among newly synthetized materials, there are some compounds which have the spontaneous polarization, P_s, at least by one order of magnitude higher[1] than DOBAMBC, the first studied ferroelectric liquid crystal (FLC). Due to high values of P_s, the soft mode contribution to permittivity, which is hardly measurable with most FLC, will be high; the Goldstone mode contribution, however, will also increase.

In this paper we present basic characteristics (spontaneous polarization, tilt angle, dielectric properties) of such a new FLC.

EXPERIMENTAL RESULTS

A new material has been synthetized



It exhibits the following phase diagram determined from the observation of the sample textures

$$Cr \xrightarrow{70^oC} S_{C^*} \xrightarrow{140^oC} S_A \xrightarrow{143^oC} N^* \xrightarrow{159^oC} \text{Blue phase} \xrightarrow{161^oC} Is.$$

The spontaneous polarization P_s was measured with planar samples 25 μm thick by the Diamant method,[2] with which conductivity and capacitance of the sample can be compensated. To achieve the planar sample orientation it was necessary to use glasses with rubbed polyimid coating, otherwise, the homeotropic alignment occured.

The temperature dependence of P_s measured at 50Hz is shown in Fig. 1. Far below the phase transition temperature T_c, P_s reaches

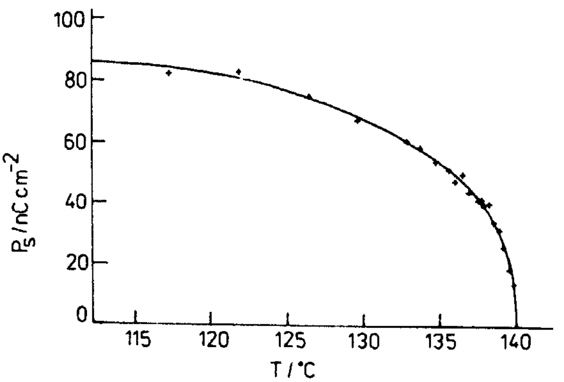


FIGURE 1
The temperature dependence of the spontaneous polarization measured at 50Hz.

the value of about 80 $nCcm^{-2}$. The shape of $P_s(T)$ near T_c indicates that the phase transition $S_{C^*} - S_A$ is of the second order.

The spontaneous tilt angle, θ, has been determined from the temperature dependence of the smectic layer spacing (see Fig. 2) which was measured by X-ray diffraction. Knowing the smectic layer thicknesses d_A and d_{C^*}, in the S_A and S_{C^*} phases, resp., the tilt angle θ is calculated[3] as $\theta = \arccos(d_{C^*}/d_A)$. Its temperature dependence is shown in Fig. 3.

The complex permittivity ε has been measured using a Hewlett--Packard 4192A impedance analyser in the frequency range 10Hz÷30kHz in S_{C^*}, S_A, and N^* phases. The planar sample geometry ensured by

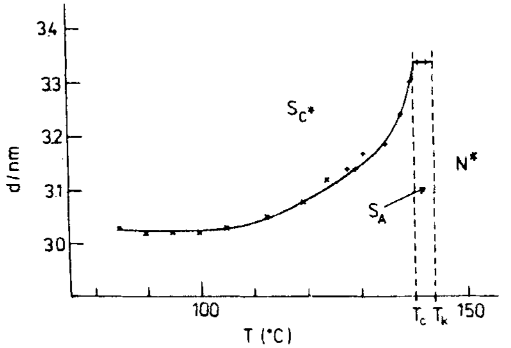


FIGURE 2 The temperature dependence of the layer spacing.

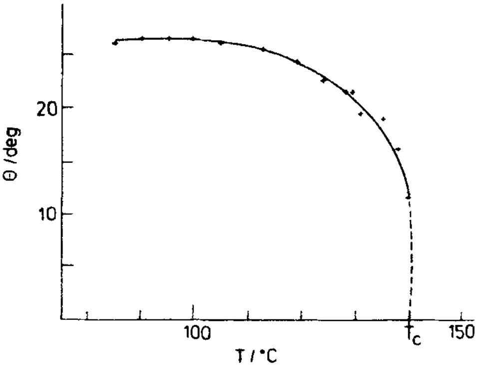


FIGURE 3 The temperature dependence of the spontaneous tilt angle.

polyaimid orienting layers has been used thus enabling one to determine the Goldstone and soft mode contributions to ε .

At low frequencies the real part of relative permittivity, ε', reaches the value of 500 even in the N^* phase. In the N^* phase the Goldstone and the soft mode contributions do not exist, so that ε' should be by two orders of magnitude smaller than observed. It is obvious that a parasitic effect contributes there to ε' and that the same effect predominates over the soft mode and the Goldstone mode contributions to ε' in the S_A and S_C* phases. The parasitic contribution falls down in the N^* phase above its relaxation frequency $\approx$ 700Hz.

In the frequency range of 800Hz÷5kHz, a peak in $\varepsilon'(T)$ at T_C appears which can be ascribed to the soft mode (see Fig. 4). At the frequency about 17kHz, where the contribution of the soft mode disappears, a new peak at the $S_A - N^*$ transition temperature T_k occurs (Fig. 4). The relaxation frequency of the Goldstone mode, which contributes to ε' in the S_C* phase, can be estimated from the frequency dependence of the complex permittivity within the range of 1÷2kHz.

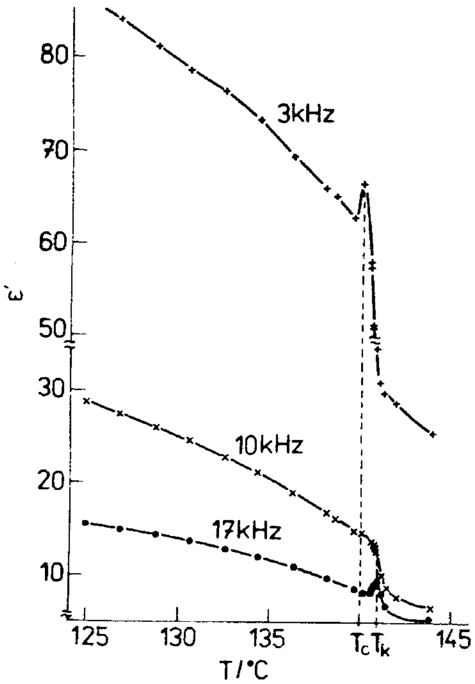


FIGURE 4

The temperature dependences of the real permittivity at indicated frequencies.

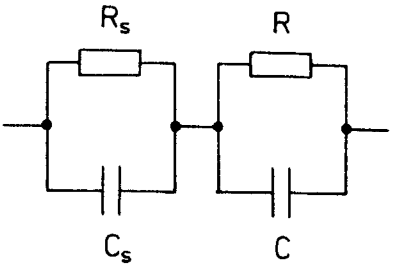


FIGURE 5

The equivalent circuit of the measured sample impedance.

DISCUSSION OF DIELECTRIC RESULTS

The analysis of the frequency dependences of measured data in all the three phases indicates that the sample impedance can be treated as a network combined of two capacitors and two resistors (see Fig. 5). C and R are the capacitance and the resistance of the liquid crystal, C_S and R_S are the series capacitance and the resistance of surface layers. Most probably it is the thin polyimid layer on the glass surfaces. The capacitance of polyimid layers C_S is estimated as about 3.5 nF.

Usually, C_S can be neglected being much higher than the liquid crystal capacitance C. From the analysis of the equivalent circuit (Fig. 5) it follows that C_S becomes significant especially at low frequencies, providing that R is much smaller than R_S. In our experiment where $R \approx 70k\Omega$, the sample capacitance is more or less affected by C_S up to several kHz. It is about one order of magnitude above the characteristic frequency of the parasitic effect (700 Hz) which is defined by the series resonance frequency $(2\pi RC_s)^{-1}$. The surface layer resistance R_s estimated as $8M\Omega$ influences the measured impedance only below 30 Hz. All parameters of the equivalent circuit were estimated from the frequency dependence of impedance in the N^* phase.

CONCLUSIONS

The FLC studied exhibits high temperature ferroelectric S_C* phase with quite a high saturated spontaneous polarization. The temperature dependence of P_s reveals the second order ferroelectric phase transition. Unfortunately, the measurement of spontaneous tilt around T_c is not precise enough to support this fact. The conductivity of the material is at least two orders of magnitude higher than of usual FLC. This is caused probably by chemical instability and high temperatures involved. The high conductivity of the liquid crystal combined with the high capacity of inevitable polyimid layers prevents reliable dielectric measurements at low frequencies. At high frequencies, the pronounced soft mode contribution to ε' has been detected around T_c. Besides a new contribution to ε' has been detected in the vicinity of T_K the origin of which remains unexplained.

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