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Elastic Constants and Diamagnetic Susceptibility of Nematic LC Determined by A Combined Electro-Magneto-Optical Method

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LC DETERMINED BY A COMBINED ELECTRO-MAGNETO-OPTICAL METHOD

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ABSTRACT

For a determination of Ki, Ks and the anisotropy of the diamagnetic susceptibility $\Delta\chi$ of two alkoxyphenyl-hexylpyrimidines and a mixture of both, and six cyanophenyl-alkylcyclohexanoates, we have used a combined electro-magneto-optical method. The temperature dependence of Ki and Ks can be explained by common theories. The $\Delta\chi$ are relatively small, decreasing with longer alkyl chains.

THEORY

For the determination of the elastic constants K_1 and K_3 and the magnetic anisotropy $\Delta\chi=\chi_{\parallel}-\chi_{\perp}$, we used the optical observation of the director field deformation induced in a preoriented liquid crystal cell by electric (E) or magnetic (H) fields. The external fields and the monochromatic light beam are oriented perpendicularly to the cell surfaces. The transmitted intensity I of a monochromatic light beam is a function of the optical phase difference δ between ordinary and extraordinary waves

$$I = I_0 \sin^2(\delta/2) , \qquad \delta = 2\pi/\lambda \int_0^{\infty} (n_e(z) - n_0) dz$$

where z is the direction of light propagation, d is the cell thickness and $n_{\rm e}$, $n_{\rm o}$ are the refractive indices.

Fitting the optical response to the solution of the continuum equation, we obtain the parameter $\eta=K_3/K_1-1$ and the threshold field f_c (f_c denotes E_c and H_c , respectively).

From the threshold field we find K_1 by

$$K_1 = U_c^2 / \pi^2 \Delta \varepsilon \varepsilon_0$$
, with $U_c = d E_c$, or $K_1 = d^2 B_c^2 / (\pi^2 \mu_0) \Delta \chi$, with $B_c = \mu_0 H_c$.

The elastic constant K_3 is derived from η and K_1 .

If the dielectric anisotropy $\Delta \varepsilon$ is known, we can calculate the diamagnetic susceptibility anisotropy $\Delta \chi$ by comparison of the threshold fields,

 $\Delta \chi = d^{-2}(U_c/B_c)^2 \Delta \varepsilon/c^2$ (c being the velocity of light).

EXPERIMENTAL

The planar liquid crystal cell is placed between crossed polarizers with the initial director orientation at 45° to the polarization axis. The glass plates are coated with low-ohmic ITO electrodes. The homogeneous planar orientation of the director at the two glass surfaces is obtained by oblique evaporation of a SiO film (about 30 nm) at an angle of about 60° normal to the glasses. The electric field was produced by a programmable sine wave generator at a frequency of about 1 kHz. The magnetic field was provided by an electromagnet, calibrated by means of ¹H NMR. A computer was used to control the fields and to record and store the transmission curves. The minimum field steps were about 1 mV and 0.1 mT, resp. The variable sweep rate usually was chosen to be 0.3 mV/s and 0.025 mT/s, resp. The cell temperature was controlled to ±0.1 K.

The refractive indices n_o and n_e have been determined using an oriented wedge cell and a goniometer spectrometer. The dielectric constants ε_{\parallel} and ε_{\perp} were provided by the Halle LC Group ¹. Further details will be published elsewhere ².

The chemical structure of the compounds is shown in Fig.1.

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FIGURE 1: Chemical structures of the investigated LC

- Ia) 5-n-hexyl-2-[4-n-alkyloxy-phenyl]-pyrimidines.
- Ib) mixture of 68.5 mol% C60PC6P and 31.5 mol% C90PC6P.
- II) 4-cyanophenyl-4-n-alkylcyclohexanoates.

RESULTS

All elastic constants decrease with increasing temperature. According to Saupe³, the elastic constants K_1 and K_3 depend on temperature via the order parameter S and the molar volume V in the same way. Consequently, the ratio K_3/K_1 should have no temperature dependence. However, as can be seen in Figs. 2 and 3, there exists a weak dependence upon temperature. This weak dependence has been explained by Gruler⁴, who assumed changes in short-range order, and by Priest⁵, who made the assumption that the elastic constants depend upon higher terms of the Legendre polynomials.

Comparing the magnitude of the K_3/K_1 -values of the measured phenyl-pyrimidines with similar compounds from literature, we can say that small K_3/K_1 -ratios are typical for compounds with hetero-atoms in the rings (as pyrimidines or dioxanes), and with terminal non-polar alkyl chains. The cyanophenyl-cyclohexanoates exhibit relatively high K_3/K_1 -values which can be connected with their higher polarity.

The decrease in K_3/K_1 with increasing alkyl chain length, as shown in Figs. 2,3, has been proved for a lot of homologeous series. It is caused by the increase of smectic-like correlation for longer alkyl chains. The behaviour of Mi3 in Fig. 2 supports—the assumption that the elastic constants of mixtures of similar compounds are linearly related to their molar concentrations.

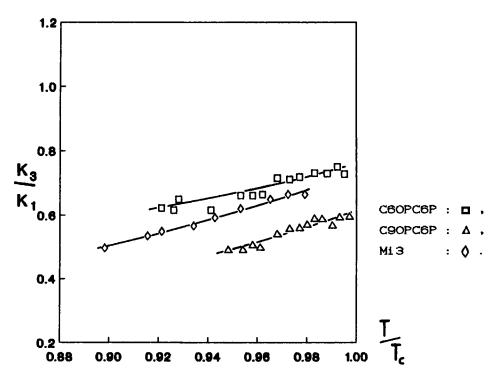


FIGURE 2: Temperature dependence of K_3/K_1 for CnOPC6P.

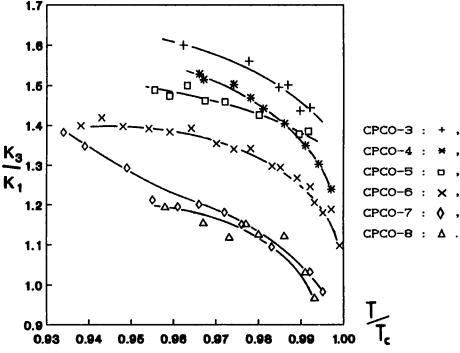


FIGURE 3: Temperature dependence of K_3/K_1 for CPCO-n.

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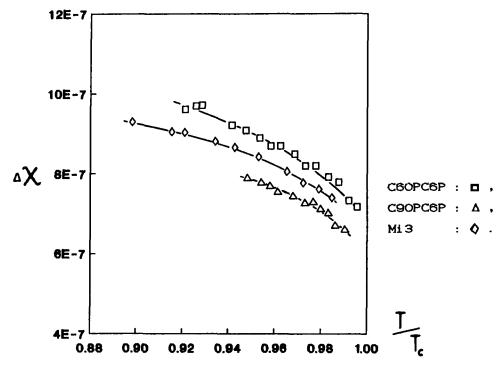


FIGURE 4: Temperature dependence of $\Delta\chi$ for CnOPC6P.

Fig. 4 gives the temperature dependence of $\Delta\chi$ (volume) of the phenyl-pyrimidines. Absolute values of $\Delta \chi$ are relatively small. $\Delta \chi$ decreases with longer alkyl chains, in agreement with measurements of PCH 7 .

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