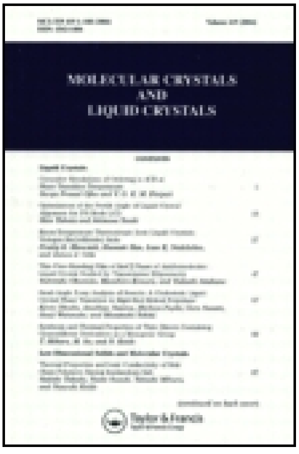

Molecular Crystals and Liquid Crystals Incorporating Nonlinear Optics
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl17

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

A. Scharkowski [a] , H. Schmiedel [a] , R. Stannarius [a] & E. Weisshuhn [a]
[a] Sektion Physik, Karl-Marx-Universität, DDR-7010, Leipzig
Version of record first published: 22 Sep 2006.

Mol. Cryst. Liq. Cryst. 1990, Vol. 191, pp. 419–423
Reprints available directly from the publisher
Photocopying permitted by license only

Printed in the United States of America

ELASTIC CONSTANTS AND DIAMAGNETIC SUSCEPTIBILITY OF NEMATIC LC DETERMINED BY A COMBINED ELECTRO-MAGNETO-OPTICAL METHOD

A. SCHARKOWSKI, H. SCHMIEDEL, R. STANNARIUS and E. WEISSHUHN
Sektion Physik der Karl-Marx-Universität, DDR-7010 Leipzig

ABSTRACT

For a determination of K_1, K_3 and the anisotropy of the diamagnetic susceptibility $\Delta\chi$ of two alkoxyphenyl-hexylpyrimidines and a mixture of both, and six cyano-phenyl-alkylcyclohexanoates, we have used a combined electro-magneto-optical method. The temperature dependence of K_1 and K_3 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

$$I = I_0 \sin^2(\delta/2) , \qquad \delta = 2\pi/\lambda \int_0^d (n_e(z) - n_o) \, dz ,$$

where z is the direction of light propagation, d is the cell thickness and n_e, n_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

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

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 ^{1}H 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 $\varepsilon_{\parallel}$ and $\varepsilon_{\perp}$ 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.

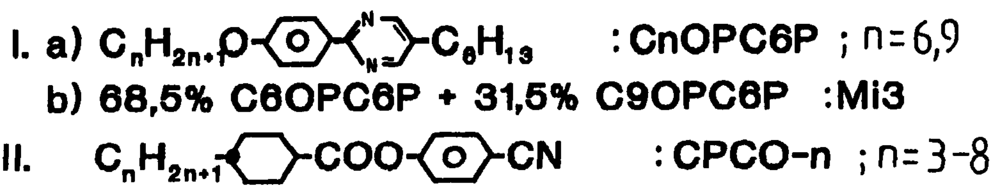

FIGURE 1: Chemical structures of the investigated LC
Ia) 5-n-hexyl-2-[4-n-alkyloxy-phenyl]-pyrimidines.
Ib) mixture of 68.5 mol% C6OPC6P and 31.5 mol% C9OPC6P.
II) 4-cyanophenyl-4-n-alkylcyclohexanoates.

RESULTS

All elastic constants decrease with increasing temperature. According to Saupe[3], 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 Gruler[4], who assumed changes in short-range order, and by Priest[5], 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[6] 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.

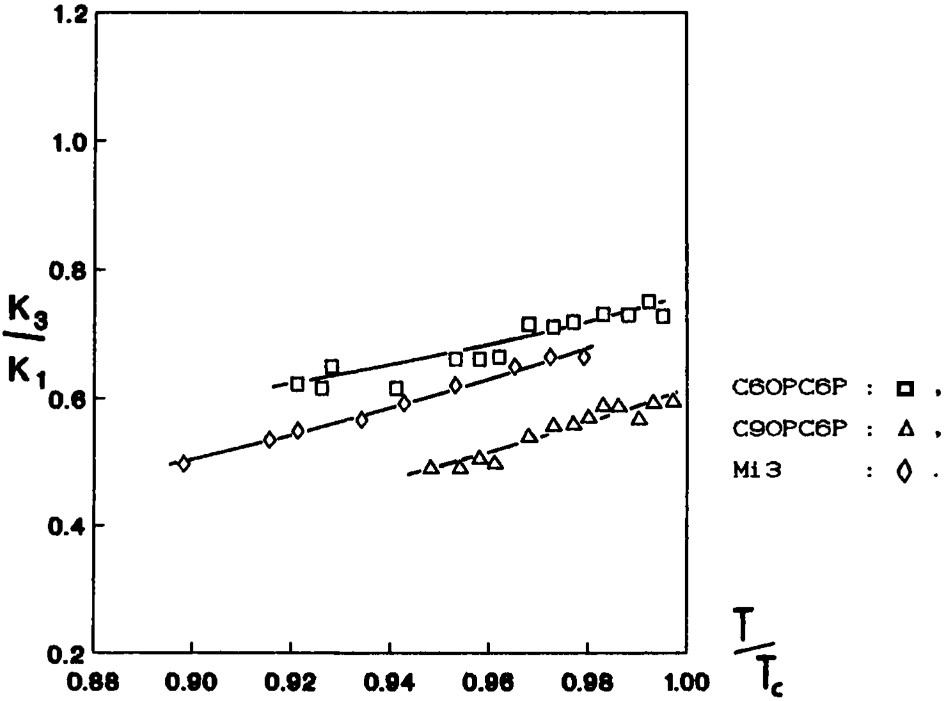

FIGURE 2: Temperature dependence of K_3/K_1 for CnOPC6P.

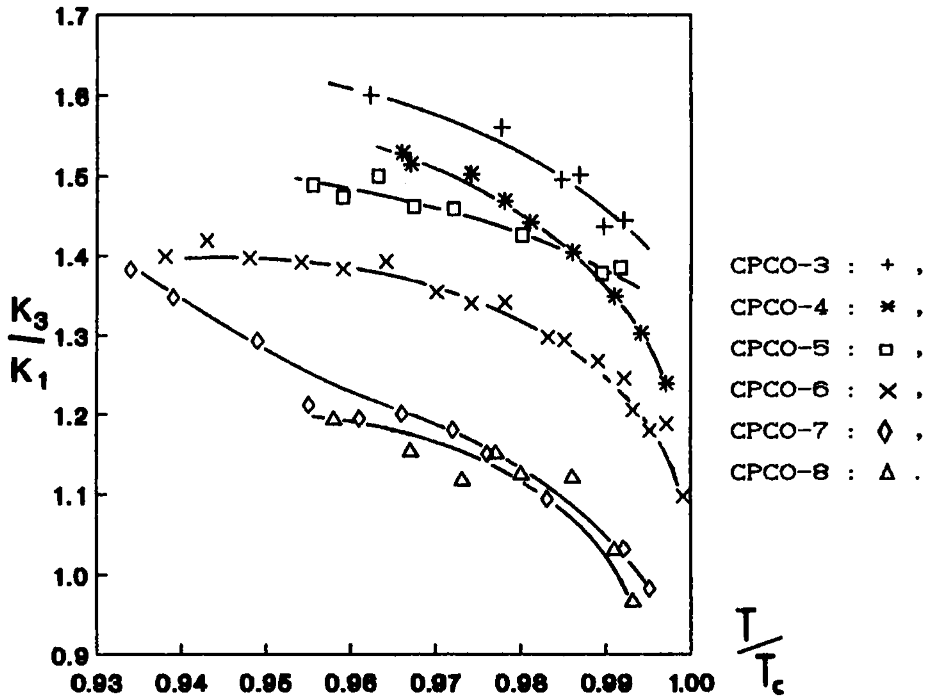

FIGURE 3: Temperature dependence of K_3/K_1 for CPCO-n.

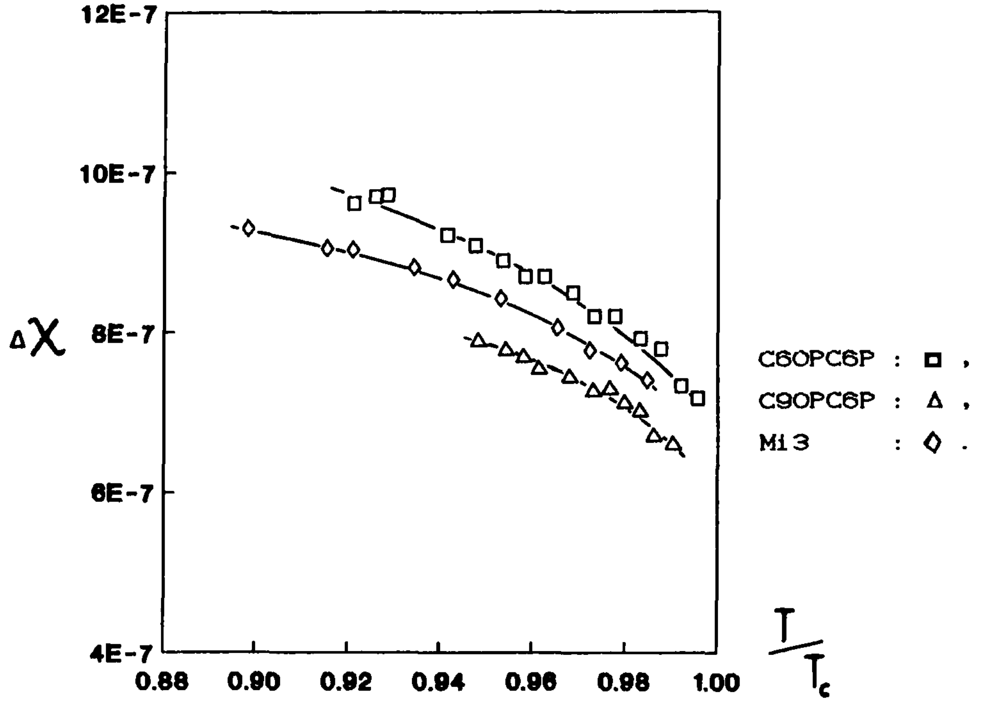

FIGURE 4: Temperature dependence of $\Delta\chi$ for CnOPC6P.

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].

The authors wish to thank the Halle LC Group, especially Prof. Dr. H. Zaschke and Dr. E. Pönicke for supplying the substances and Dr. H. Kresse and Dr. H. Stettin for measuring the dielectric constants.

REFERENCES

1. H. Kresse and H. Stettin, private communications.
2. A. Scharkowski et al., to be published in Z. Naturforsch.
3. A. Saupe, Z. Naturforsch. 15a, 810 (1960).
4. H. Gruler, Z. Naturforsch. 28a, 474 (1973).
5. R. G. Priest, Phys. Rev. A 7, 720 (1973).
6. M. Schadt and P.R.Gerber, Z. Naturforsch. 37a, 165 (1982).
7. Hp. Schad, G. Baur and G. Meier, J. Chem. Phys. 70, 2770 (1979).