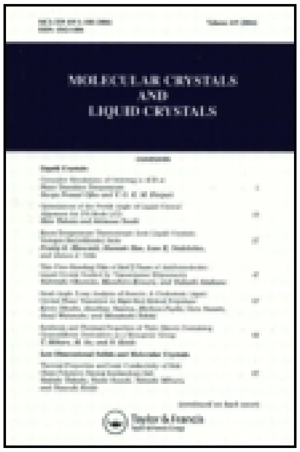

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Measurement of the Elastic Constants and Effective Surface Anchoring Energy for a Smectic C Liquid Crystal

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MEASUREMENT OF THE ELASTIC CONSTANTS AND EFFECTIVE SURFACE ANCHORING ENERGY FOR A SMECTIC C LIQUID CRYSTAL

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Abstract Optical extinction angle spectra of a pyrimidine smectic c material in the surface stabilised geometry have been measured as a function of applied ac electric field and temperature. The results were fitted using a model which assumes uniformly tilted layers either side of a infinitely anchored chevron interface. The model presented uses the free energy expression of Leslie *et. al.* [1] to calculate the liquid crystal c-director profile through the cell and Jones calculus to determine the associated optical properties. With no applied voltage this gives a structure very similar to a triangular director profile[2]. An applied ac voltage couples to the dielectric biaxiality causing director reorientation in the bulk of the cell. At increased voltages an excellent fit is obtained by allowing movement of the director at the surface. This surface movement is described by inclusion of finite surface anchoring in the model. The fits give the c-director bend (B_1) and splay (B_2) elastic constants and the effective surface anchoring as a function of temperature.

INTRODUCTION

Continuum theory has been an extremely successful tool for predicting and optimising electro-optic properties of nematic liquid crystal devices. It is envisaged that similar device improvements will result for ferroelectric technology through the development and application of a similar smectic continuum theorem. Previously, Brown *et. al.*[3] have developed a model based on incompressible continuum theorem which neglects the layer distortion and surface anchoring energies and describes the behaviour of a surface stabilised ferroelectric liquid crystal device in terms of those elastic constants affecting the director profile. The model self consistently calculated the electric displacement across the width of the liquid crystal cell and included the effects of the three biaxial electric permittivities. The splay and bend elastic constants were extracted by fitting of wavelength dependent extinction angle spectra at several voltages for the commercial material SCE8R. This work is extended here to include the extraction of the temperature dependence of the elastic constants and the effective surface anchoring for a mixture containing phenyl-pyrimidine materials[4].

SMECTIC C CONTINUUM THEORY WITH FINITE SURFACE ANCHORING

The surface energy (W_s) for an achiral smectic C can be described simply by a quadrapolar interaction which arises from the combined requirements for the director to be on the smectic cone and the director to lie in the preferred alignment direction. For an angle of preferred orientation (ϕ_0) the surface energy is given by:

$$W_s = W_\phi \sin^2(\phi - \phi_o) \quad (1)$$

The torque at the surface can then be balanced with the bulk elastic torque (W_B) via:

$$\left(\frac{\partial W_B}{\partial \phi'}\right) = \pm\left(\frac{\partial W_s}{\partial \phi}\right) \quad (2)$$

where the bulk elastic energy W_B, as derived from the Leslie bulk elastic free energy density, is given by[2]:

$$W_B = \left[\left(B_1 \sin^2\phi + B_2 \cos^2\phi\right)\cos^2\delta + B_3 \sin^2\delta - B_{13} \sin\phi \sin 2\delta\right]\phi'^2 \quad (3)$$

The combination of the surface anchoring with the bulk elasticity requires the self consistent solution of the director profile, electric displacement field and the balance of torques at the surface.

EXPERIMENTAL RESULTS AND DISCUSSION

The extinction angle of a phenyl-pyrimidine material in a 2.5μm cell was measured as a function of wavelength and voltage at five temperatures using the method described by Anderson *et. al.*[2] The optical extinction angle spectra were generated from the continuum model director using standard Jones 2x2 matrix formalism. The principal refractive indices of the material were found as a function of temperature and wavelength using an Abbé refractometer[5]. The dielectric permittivities and chemical composition of the material have been published previously[5].

Data fitting was performed by minimisation of the least sum of squares difference using a quasi-Newtonian fitting routine. It can be shown that in the chevron geometry the bend (B_1) and splay (B_2) elastic constants dominate the observed optical behaviour whilst the twist (B_3) and twist-bend cross term (B_{13}) have minimal effect due to the low layer tilt and can be assumed constant. In addition to elastic constants the cone angle (θ), layer tilt angle (δ), surface twist orientation (ϕ_s) and cell spacing (d) must be defined. The dielectric biaxiality was also a free parameter during fitting due to large uncertainty associated

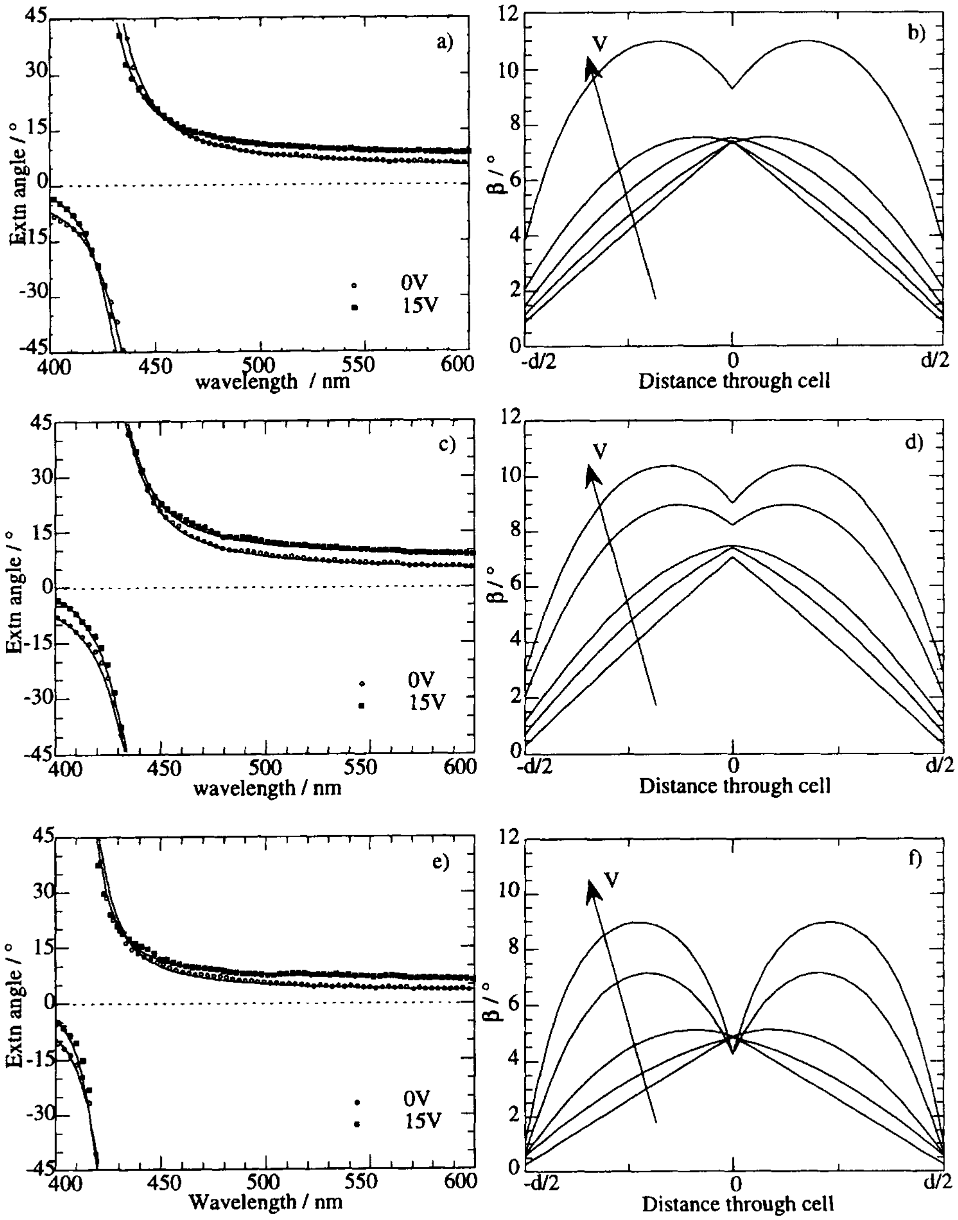

FIGURE 1: Experimental data (every fifth data point is plotted for clarity) and best fits for 0 and 15V are given in a), c) and e). The twist profiles of these fits for 0V, 5V, 10V, 15V and 18V are b), d) and f). a) and b) are at T_{ac}-T=30°C, c) and d) are at T_{ac}-T=20°C and e) and f) are at T_{ac}-T=10°C

with its measurement. Experimental data was taken with 0, 5, 10, 15 and 18 volts (r.m.s.) at 30°C, 25°C, 20°C, 15°C and 10°C below the smectic A to smectic C phase transition and fitted. In figure 1 the best fits for applied voltages of 0V and 15V are shown at three temperatures and the twist profiles obtained are also shown. Satisfactory fits are obtained for all temperatures and voltages although at high voltages and closer to the S_A to S_C transition the fit quality is reduced.

The layer tilt and cone angle as a function of temperature is given in figure 2 and as expected the variation follows a critical dependence. The cone angle values agree well with published results[5].

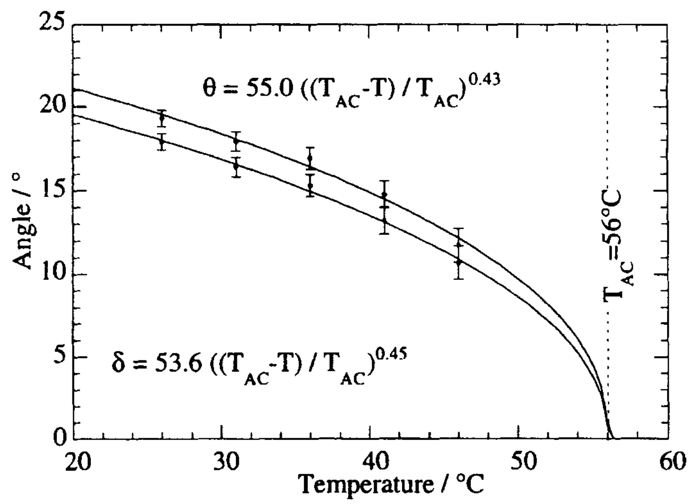

FIGURE 2 Temperature dependence of the Cone and layer tilt angles

B_1 and B_2 are plotted as a function of temperature in figure 3, together with the best fit to $B\sin^2\theta$. This shows that the uniaxial approximation, in which the smectic C elastic constants are related to those of the nematic is satisfactory:

$$B_1 = \left(K_{22}\cos^2\theta + K_{33}\sin^2\theta\right)\sin^2\theta \qquad \text{4a)}$$

$$B_2 = K_{11}\sin^2\theta \qquad \text{4b)}$$

The experimental uncertainties are relatively large and prevent more detailed fitting to equation 4a).

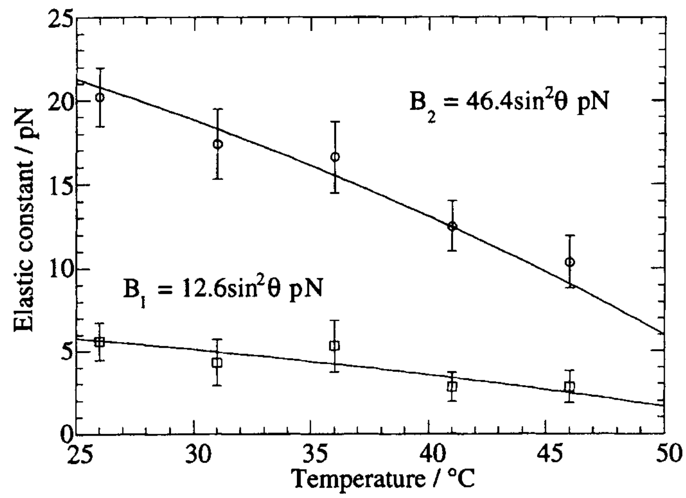

FIGURE 3 Temperature dependence of the splay and bend elastic constants.

At each temperature a significant movement of the director at the surface was encountered, see figure 4. This variation has been fitted using the simple surface model giving a surface anchoring energy of 11.9 ($\pm$ 3.0) $\times$ 10^{-5} N/m. At higher temperatures the error associated with the meaurement is relatively larger but a similar anchoring energy is observed. Again using a uniaxial approximation for the smectic C surface energy, then W_ϕ is a combination of the nematic azimuthal and zenithal surface anchoring energies. Typically, the nematic zenithal anchoring energy is of the order of 10^{-4}-10^{-3} N/m whilst the azimuthal is in the range 10^{-7}-10^{-4} N/m. Therefore, the value of W_ϕ found here is fully consistent with expectations.

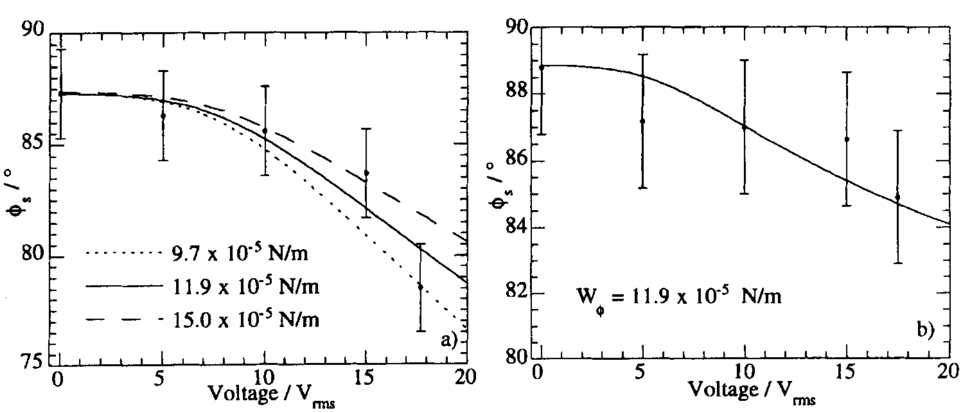

FIGURE 4 Fits to the surface anchoring model at a)T_{ac}-T = 30°C and b) T_{ac}-T=10°C.

CONCLUSIONS

The director profile of surface stabilised smectic C liquid crystals under applied ac fields can be described using a model based on incompressible continuum theory. It has been demonstrated that the use of a simple surface anchoring model adequately describes the variation of surface director orientation as a function of voltage. To within experimental error the surface anchoring energy is constant over the small temperature range investigated. Future work will include the investigation of chiral materials and the incorporation of a more realistic chevron interface into the model.

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REFERENCES

1. F. M. Leslie, I. W. Stewart and M. Nakagawa, Mol. Cryst. Liq. Cryst. **198**, 443 (1991)
2. C. V. Brown, P. E. Dunn and J. C. Jones. submitted for publication in Euro. J. Appl. Maths.
3. M. H. Anderson, J. C. Jones, E. P. Raynes and M. J. Towler, Liquid Crystals **10** **(3)**, 439 (1991).
4. J. C. Jones, E. P. Raynes, M. J. Towler and J. R. Sambles, Mol. Cryst. Liq. Cryst. **199**, 227-285 (1991)
5. J. C. Jones, PhD thesis (University of Hull, 1991)