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PRELIMINARY COMMUNICATION

Optical studies of high tilt SiO aligned thin layers of smectic C materials

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In thin layers of aligned smectic C materials, the balance between surface and bulk elastic forces within the confine of the chevron layer geometry led to the proposal for a triangular director profile (TDP), and an understanding of the director profile in parallel aligned low tilt cells. We have measured the wavelength dependent extinction angles of high tilt cells fabricated using 5° SiO alignment, and offer a qualitative explanation based on the TDP. We conclude that the differences in the extinction angles at wavelengths around $\lambda = \Delta n d$ are a useful probe of the S_C director profile.

Ferroelectric liquid crystal devices [1] provide fast, bistable, optical modulations suitable for display and other applications. The effect of surface alignment and the resulting director profiles in these devices are not properly understood, but can be probed by studying the wavelength dependent optical transmission properties. Such devices usually have the chevron layer structure with regions of oppositely tilted layers separated by zig-zag defects [2], and show domains corresponding to up or down spontaneous polarization. At the cell orientation giving minimum transmission between crossed polarizers, a domain usually has some colouration when illuminated by white light, which suggests that the layer is not simply a uniform birefringent slab. Furthermore, a single domain crossed by a zig-zag can appear to have a slighly different colour on either side of the defect. This has been observed in cells with the symmetric chevron structure typical of most practical devices [3] and in asymmetric chevron cells with half-splayed states [4]. Colour differences can also be observed (see figure 1) using a smectic C host material in which half-splayed states, which are caused by polar surface terms, should not occur. This indicates that the surface alignment and the chevron angle interact to effect subtly the director profile. We might, therefore, expect a significant effect on the director profile of the large difference in surface tilt angle between about 2° typical on rubbed polyimide and about 30° found on SiO evaporated at 5°. It has already been observed [5] that the optical and electrooptical properties of ferroelectric liquid crystal devices fabricated using parallel high tilt SiO surface alignment are markedly different to those fabricated using low tilt polyimide, suggesting the existence of quite different director profiles, although the chevron layer structure is still present [6].

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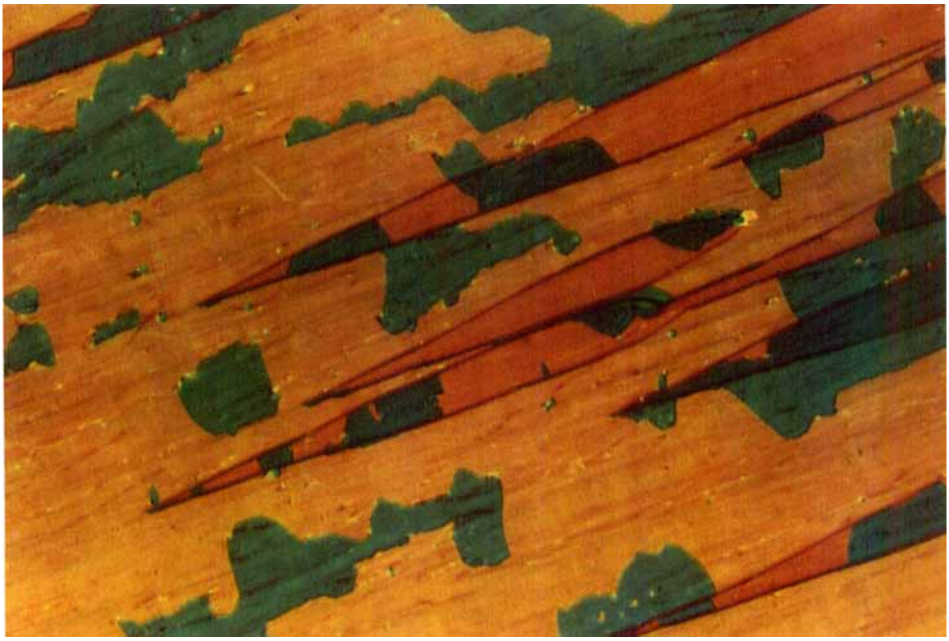
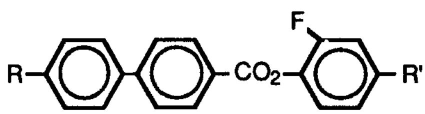


Figure 1. The colour difference occurring at either side of a zig-zag defect in a 2·9 μm polyimide aligned cell filled with the biphenyl ester host, between crossed polarizers.

We report here the investigation of the wavelength dependent extinction angles of high tilt SiO aligned cells and compare them with low tilt polyimide aligned cells using the same S_C liquid crystal. We offer a qualitative explanation of the results using the TDP [7] introduced previously to describe the optical properties of low tilt parallel aligned polyimide cells.

Parallel aligned cells of approximately 2–4 μm thickness fabricated using either polyimide or 5° evaporated SiO alignment were filled with a mixture of biphenyl esters of the general structure



and transition temperatures

$$C \quad 25^\circ C \quad S_B \quad 32^\circ C \quad S_C \quad 73{\cdot}3^\circ C \quad S_A \quad 84^\circ C \quad N \quad 135^\circ C \quad I$$

and cooled slowly into the S_C phase. A small amount of chiral dopant was also added to induce a small $P_S(\leqslant 0{\cdot}5\,nC/cm^2)$ to allow the use of an electric field to form reasonable sized single domains in the SiO cell. The P_S was kept small to minimize complications due to polar surface terms and any influence of P_S on the director profile. Transmission spectra of defect free single domains between crossed polarizers were obtained using an optical multichannel analyser and a Nikon Optiphot-pol polarizing microscope. The data were collected over the wavelength range 450–700 nm as a function of cell orientation and the wavelength dependent extinction angle extracted. The extinction

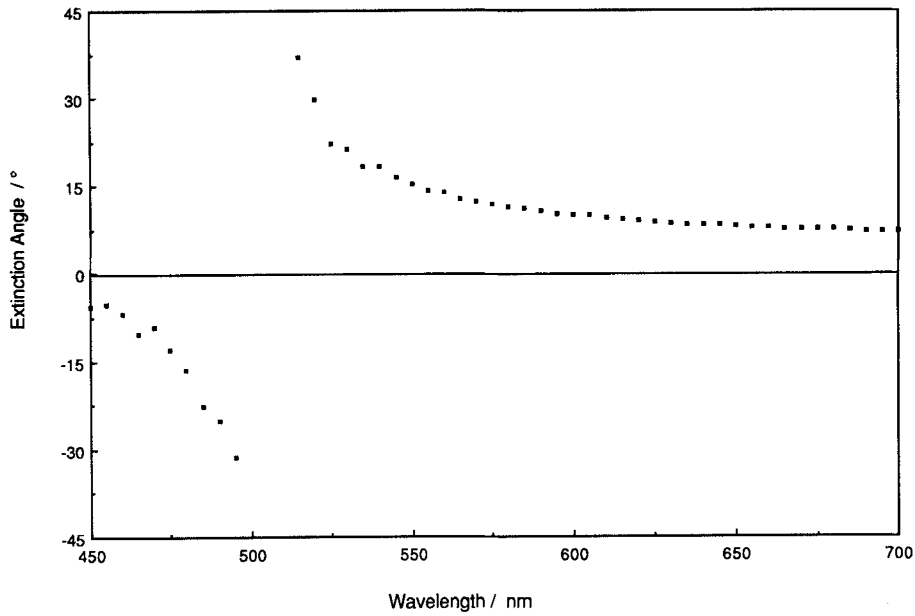


Figure 2. The experimental extinction angle spectrum for a 3·2 μm parallel aligned polyimide cell at 40°C.

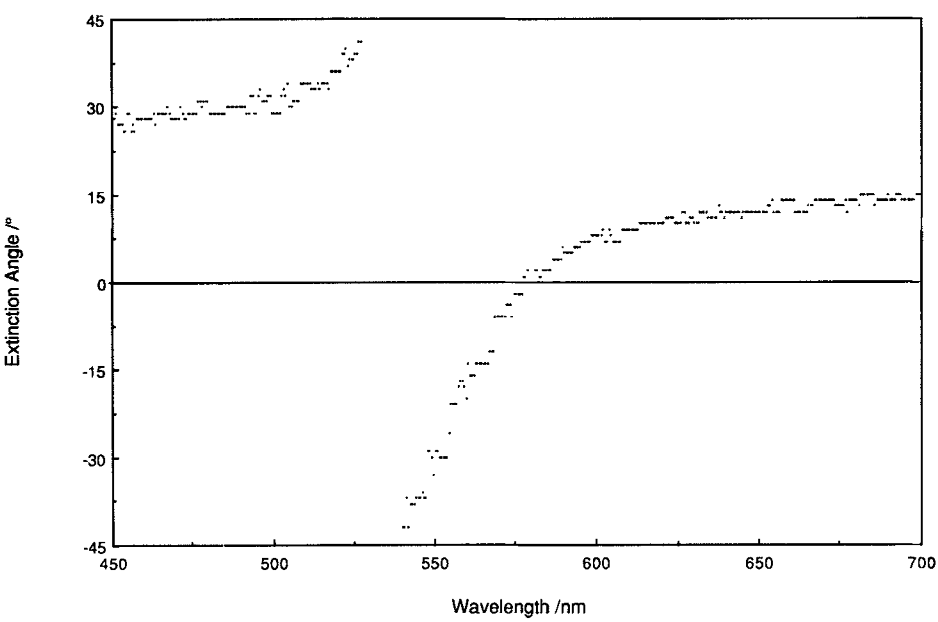
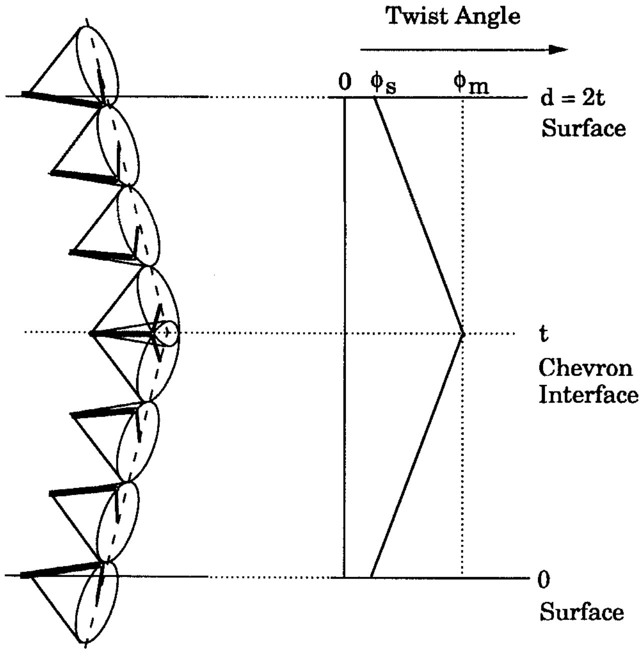
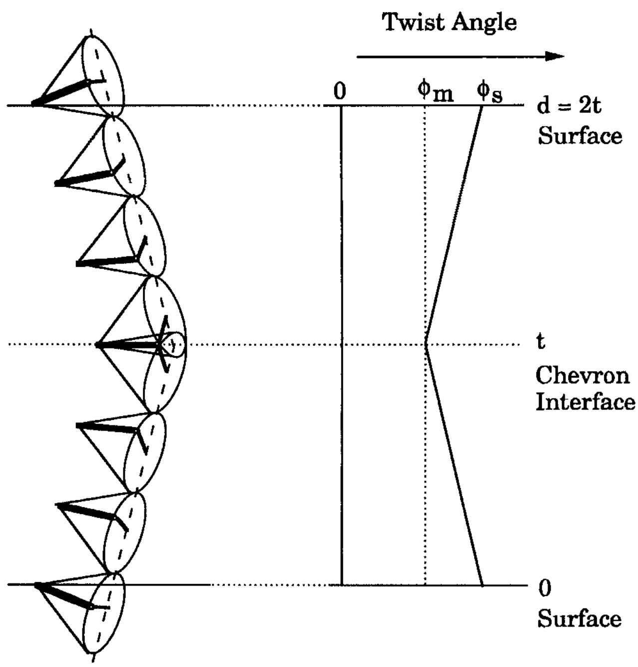


Figure 3. The experimental extinction angle spectrum for a 3·6 μm parallel aligned 5° SiO cell at 40°C.



(a)



(b)

Figure 4. The triangular director profiles based on the chevron layer geometry: (a) a positive TDP with $\phi_m > \phi_s$; (b) a negative TDP with $\phi_m < \phi_s$.

angle was measured as the angle between the first polarizer and the anchoring direction determined in the S_A phase. Further details of the method can be found in the paper by Anderson *et al.* [7].

Figures 2 and 3 show the extinction angle for the polyimide and SiO cells, respectively. For the domains examined, the extinction angle is chosen to be positive at long wavelengths; as the wavelength is shortened, the extinction angle initially increases for the polyimide cell, and decreases for the SiO cell. This contrasting behaviour can be explained by considering a symmetric chevron; director continuity at the chevron interface dictates that the **n** director is untilted from the plane of the cell and at an angle ϕ_m from the rubbing direction given by

$$\cos \phi_m = \cos \theta_0 / \cos \delta, \tag{1}$$

where δ is the layer tilt and θ_0 the cone angle. Typically, $\theta_0 \approx 20°$ and $\delta \approx 18°$ [6], giving $\phi_m \approx 9°$.

There is a compromise between the surface energies and the bulk elastic terms which, together with the assumption that the director lies on a tilted cone, defines the surface twist angle ϕ_s. If we ignore out-of-plane tilt, and assume that the in-plane twist angle varies linearly from ϕ_s at one surface to ϕ_m in the middle and then back to ϕ_s at the other surface in a TDP (see figure 4), then the extinction angle θ_{ext}, measured with respect to the rubbing direction, is given by [7]

$$\tan 2(\theta_{ext} - \phi_s) = \tan \{(\phi_m - \phi_s)\sqrt{(1+\alpha^2)}\}/\sqrt{(1+\alpha^2)}, \tag{2}$$

where

$$\alpha = \Delta n t \pi / (\phi_m - \phi_s)\lambda,$$

and t is half of the cell thickness d. Figure 5 shows equation (2) plotted for a cell of thickness 2·5 μm using the measured $\Delta n(\lambda)$ [7] of the mixture for a positive TDP

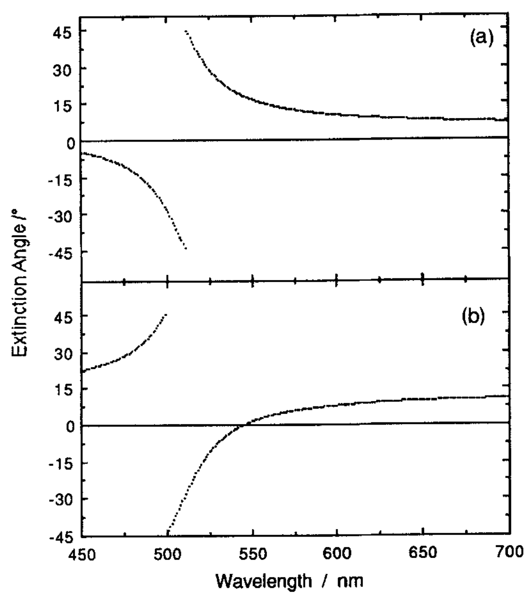


Figure 5. The calculated extinction angle spectra for a 2·5 μm cell with (*a*) a positive TDP with $\phi_m = 9°$ and $\phi_s = 1°$; (*b*) a negative TDP with $\phi_m = 9°$ and $\phi_s = 17°$.

($\phi_m > \phi_s$) and a negative TDP ($\phi_m < \phi_s$). These curves show qualitatively the same behaviour as the experimental results (see figures 2 and 3), suggesting that the experimental data indicate whether ϕ_s is less than or greater than ϕ_m. It appears therefore, that for the polyimide cell there is a positive TDP with $\phi_s < \phi_m$, whereas for the SiO cell there is a negative TDP with $\phi_s > \phi_m$. These conclusions are consistent with the known low surface tilt angle of nematic liquid crystals on rubbed polyimide surfaces and high tilt angles on 5° SiO surfaces, producing low and high ϕ_s, respectively.

We have shown that a positive TDP models the extinction angle spectra of the zero field states of a S_C liquid crystal in thin, parallel aligned low tilt polyimide cells, whereas a negative TDP, with a surface twist angle ϕ_s greater than the twist angle ϕ_m at the chevron interface, qualitatively models the spectra of parallel aligned high tilt SiO cells. It is clear that differences in the measured extinction angles at wavelengths around $\lambda = \Delta n d$ are useful probes of the S_C director profile.

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