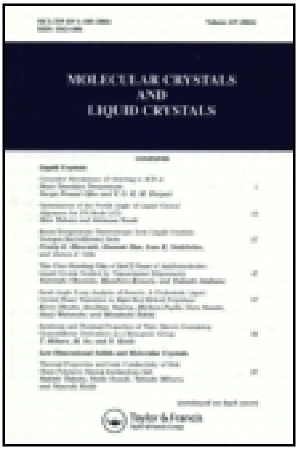

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Effects of Electric Fields as a Function of depth in a Smectic Film

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EFFECTS OF ELECTRIC FIELDS AS A FUNCTION OF DEPTH IN A SMECTIC FILM

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The response of liquid crystals (LC) to applied electric fields is the basis for most display applications. Optically it is known that the bulk portion of a LC cell responds to an applied field. The remainder of the film is assumed to consist of LC molecules and layers that do not reorient due to surface interactions. The inactive interfacial layer has not been accessed directly nor characterized. We have used a 8CB smectic-A cell consisting of two ITO coated glass plates to look into the layers with grazing incidence X-ray diffraction. The plates are connected to a voltage source with a maximum output of 40.7 V DC. The changes in lattice spacing vary as a function of depth within the sample, which suggests the presence of different regions of layer reorientation within the film.

Keywords: depth analysis; effects of electric field; grazing incidence X-ray diffraction; interface structure; interface interaction

INTRODUCTION

The way liquid crystals (LC) respond to applied voltages is the basis for most display applications. Optically it is known that the bulk portion of a LC cell responds to an applied electric field [1]. The remainder of the film is assumed to consist of LC molecules and layers that do not reorient due to surface interactions. However, the interface between the reoriented and stationary regions is not well known. Furthermore, the inactive interfacial layer has not been accessed directly nor characterized. This raises the question of how the structure of smectic liquid crystal evolves within this inactive region into the bulk. A better understanding of this interface can

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potentially improve the reliability of applications as well as the potential to optimize cell sizes and uniformity.

EXPERIMENTAL

We have used a smectic A cell consisting of two ITO coated glass plates separated by 200 μm [2]. A sketch of the cell is shown in Figure 1. One of the glass plates has a channel grating photolithographed on it. The plates are connected to a voltage source with a maximum output of 40.7 V DC. The spacing between the plates was chosen to allow a beam of X-rays to cross through the gap between the plates without being absorbed by the glass, and to allow the incidence angle to vary. This is shown in Figure 1a. Four thicknesses were examined, between 50 and 200 μm thick. The LC used, 8CB, is a room temperature smectic A phase. This sample reorients very slowly in the presence of an electric field of 0.11 V/μm (for 150 μm), over an 18 hour period, as verified by optical microscopy, shown in Figure 2, which facilitated the measurements. The temperature at the Synchrotron was measured between 22.5°C and 24°C which is within the smectic A phase. In this region, there are no variations in the bulk properties.

Grazing incidence X-ray scattering (GIXS) was used to characterize the in-plane structure of the films and to perform a depth profile of the films [3–5]. The geometry of this technique is shown in Figure 1b. In this technique, the scattering wave vector is parallel to the plane of the film. In-plane measurements were performed at the National Synchrotron Light source at Brookhaven National Laboratory beamline X-18A, using 1.305 Å

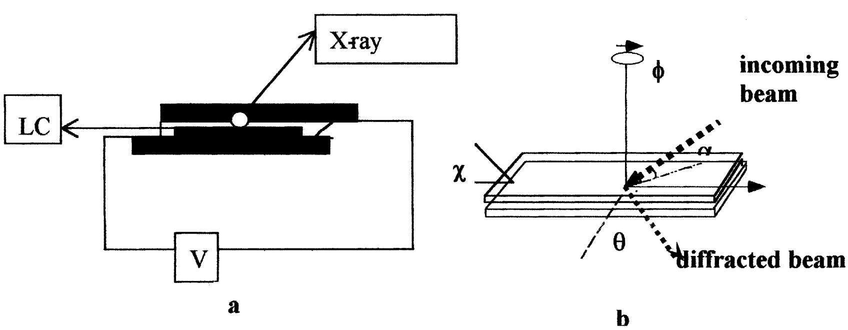

FIGURE 1 a) Cell used in the study of the electric field effects. Notice that the X-ray beam, shown as an open circle, crosses the sample through a gap between the plates. b) How the grazing incidence X-ray scattering GIXS experiment is performed in the cell.

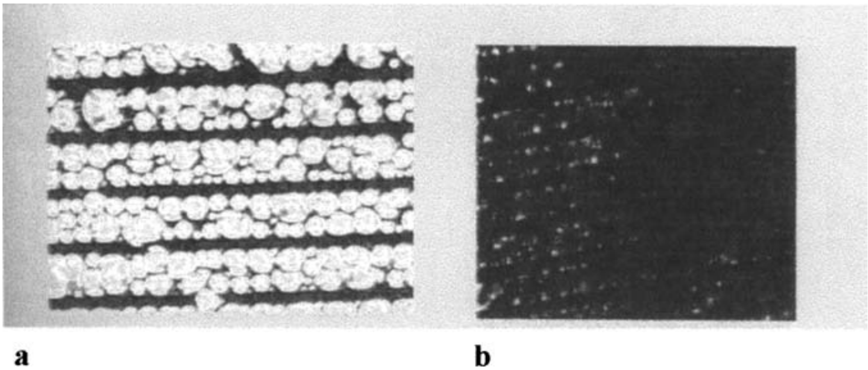

FIGURE 2 Optical microscopy study of a 150 μm thick sample under 40.7 volts. a) At time t = 0. b) At time t = 17 hours. The sample holder was the same used for the X-ray study.

(98.5 keV) X-rays, a resolution of 3×10^{-3} Å^{-1} and a beam spot size of 1 mm^2. In all instances, the samples were mounted on a four-circle Huber goniometer such that the gratings were perpendicular to the direction of the beam when the in-plane azimuthal angle $\phi = 0°$. Depth profiling was achieved by varying the angle χ of the four circle diffractometer. The incidence angle was determined from the relationship,

$$\sin\alpha = \sin\theta \sin\chi. \tag{1}$$

We note that as α increases, the depth accessed by X-rays into the sample increases.

RESULTS AND DISCUSSION

Results for a 150 μm thick sample taken over an 1028 minute period appear in Figure 3. The sample was exposed to a field of 0.11 V/μm. The measurements were taken from the center of the film, as illustrated in Figure 1. The higher incidence angle corresponds to a depth of approximately 30–40 μm into the film. The smallest angle corresponds to a depth of 20–25 μm into the film. A larger angle was not obtainable because of the geometry of the sample. From Figure 3 we see that at these depths, the in-plane d-spacing remains basically the same (Fig. 3a) while the intensity of the three depths decreases 40% as a function of time, and appears to be constant from t/1028 = 0.55 until the end of the run. The in-plane spacing had a 7.91° tilt, as obtained from the formula,

$$\cos\varphi = a/31.5, \tag{2}$$

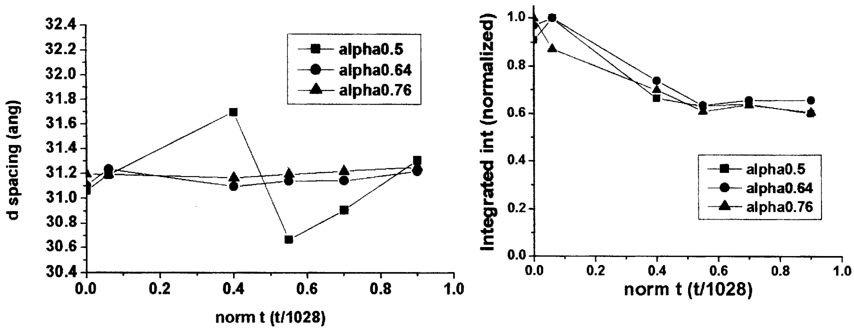

FIGURE 3 a) The value for the d-spacing as a function of depth and time for the 150 μm sample. b) The variation in the intensity of the same in-plate peaks, which shows that there are some regions left aligned parallel to the surface.

where a = 31.2 Å [4]. The angle is shown in Figure 4. The reduction of intensity is further illustrated in Figure 2b, which shows an almost homoe tropic alignment of the sample.

The 50 μm sample shows a variation of the d spacing that depends on the depth, as shown in Figure 5a. The 20–25 μm (0.5°) depth shows a change of 4.7% in the in-plane d spacing, the 25–30 μm (0.64°) shows a 1.3% change in the layer spacing, and the 30–40 μm (0.76°) shows a −1.5% change in the layer spacing. The change in the layer spacing for the 20–25 μm (0.5°) layer goes from the sample being elongated in the plane, having an angle of 0° when the run starts, to a maximum angle of 14.4° from the bulk spacing, according to Eq. (2) [4], when t/512 = 0.7. The angle for the intermediate layer (25–30 μm, 0.64°) has a maximum [4] of 13.73° and a minimum of 7.91°, according to Eq. (2). The angle sustained by the 30–40 μm (0.76°) layer is close to 6.46° for most of the duration of the experiment, and is 0° at t/512 = 0.6. Since the 0.76° layer is closest to the interface, this indicates that near the interface, the surface forces tend to keep the liquid crystal aligned nearly parallel to the surface.

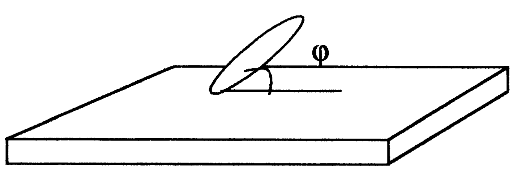

FIGURE 4 Angle made by the liquid crystal with respect to the surface, as shown in Figure 2b, which shows an almost homeotropic alignment of the layers.

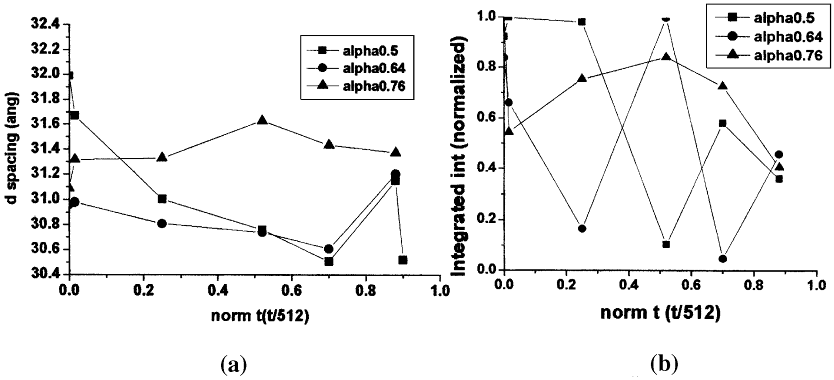

FIGURE 5 a) The value for the d-spacing as a function of depth and time for the 50 μm sample. b) The variation in the intensity of the same in-plane peaks. Note the increase from the 0.76° depth when its d-spacing value is 31.6 Å.

The intensity of the peak, shown in Figure 5b, varies widely for the 20–25 and 25–30 μm depth. However, note that for the 30–40 μm depth, it increases to 80% when the angle is 0°, indicating that although the field has been on 60% of the time, this layer is under the influence of the interface. Eventually, all layers reduce their intensities to 40%. Note that this happens at the end of the experimental run. It is difficult to say whether the sample will stay aligned with the electric field or will undergo another cycle in which the intensities rise again, as has been previously observed in the electric field free behavior of some sm-C* samples [5].

CONCLUSION

We have observed several samples of a smectic A liquid crystal as a function of depth under an electric field in order to look at how the layers align as a function of time. We were able to observe the transitional layers more clearly in the 50 μm sample, and determined that the effects of the interface can be observed clearly at a depth of 30–40 μm, which corresponds to 20–10 μm from the interface.

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