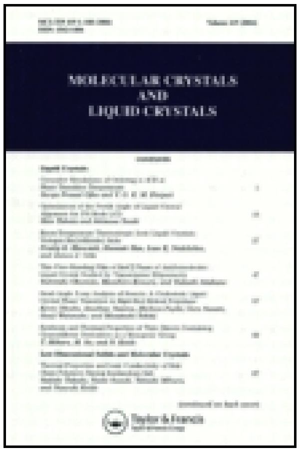

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Electrooptic Characteristics of Free-Standing Chiral Smectic Ultra-Thin Film

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ELECTROOPTIC CHARACTERISTICS OF FREE-STANDING CHIRAL SMECTIC ULTRA-THIN FILM

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Abstract Electrooptic effects in a free-standing ultra-thin (60~500 Å) film of ferroelectric liquid crystal have been studied. The response time of the electrooptic effect in the free-standing film becomes shorter with increasing electric field and especially at a certain threshold electric field it changes abruptly. Transient molecular dynamics at a moment of field reversal have also been discussed.

INTRODUCTION

Free-standing (FS) film of ferroelectric liquid crystal (FLC) has a layer structure and thickness of the film can be varied from only two layers to several hundreds layers, so that free-standing ferroelectric liquid crystal (FSFLC) has recently been investigated as a thin two-dimensional liquid crystal system.[1-6] FS film is also suitable object to investigate the interaction of FLC molecules with surface. In a previous paper[7], we have reported that the threshold field of the electrooptic effect in the FS film is negligible compared with that in a sandwich cell. It indicates that the existence of threshold field for the electrooptic effects in the sandwich cell originates from the interaction of FLC molecules with the surface of the substrates. In this paper, a study of electrooptic response of a FSFLC film is carried out.

EXPERIMENTAL

FS film was prepared across two metal blades in an oven which allows light transmission.[7] These blades were also used as electrodes to apply a uniform electric field to the FS film. The FLC, (R)-4'-(1-butoxycarbonyl-1-ethoxy) phenyl 4-[4-(*n*-octyloxy)phenyl] benzoate (1BC1EPOPB)[8], was used in this study, and all experiments were carried out in the chiral smectic C (SmC*) phase. For the electrooptic measurements, the ellipsometric setup was used.[7] The film thickness was measured by ellipsometry as described in ref.9. As the single layer thickness of 1BC1EPOPB, we used 3.4 nm measured by X-ray diffraction. As the principal refractive indices of

1BC1EPOPB, we adopted 1.49 and 1.65 for ordinary and extraordinary lights, respectively. These values can be estimated from a variation of the ellipsometry parameters[10] δ and φ for various thickness of the FS films. Texture in the FS film was investigated using a polarizing optical microscope. In order to achieve the clear contrast of the images, we used compensator between the FS film and analyzer.

RESULTS AND DISCUSSION

Figure 1 shows a field dependence of a response time for the FS film with 42 smectic layers at 60 ℃, when an applied field is switched stepwise from negative to positive polarity. In the FS films, smectic layers are parallel to the film surface, so that the molecules can be oriented in suitable directions along a tilt cone depending on the applied field. The response time is defined as the time required for the transmission change of 90 % after the field reversal. The field dependence of the electrooptic response time show abrupt change at about 100 V/cm.

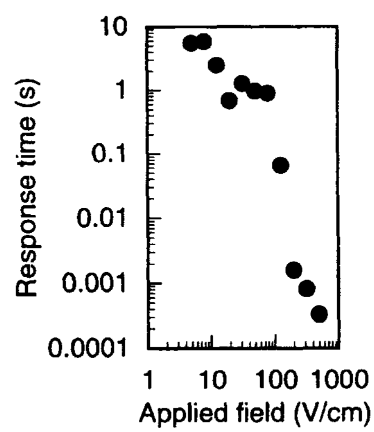


FIGURE 1 Applied field dependence of the response time for the FS film with 41 smectic layers at 60 °C.

In order to clarify the switching mechanism, the texture of the FS film has been observed using the polarizing microscope. Figure 2 (a), (b) and (c) show sequential photographs of the molecular reorientation at 5 V/cm. The compensator is used for this observation as mentioned above, so that bright and dark areas in the photograph correspond to the area in which c-directors are parallel to B and D axes in Fig.2 (d), respectively. The schematic models of textures in Fig.2 (a), (b) and (c) are shown in Fig.2 (e), (f) and (g), respectively.

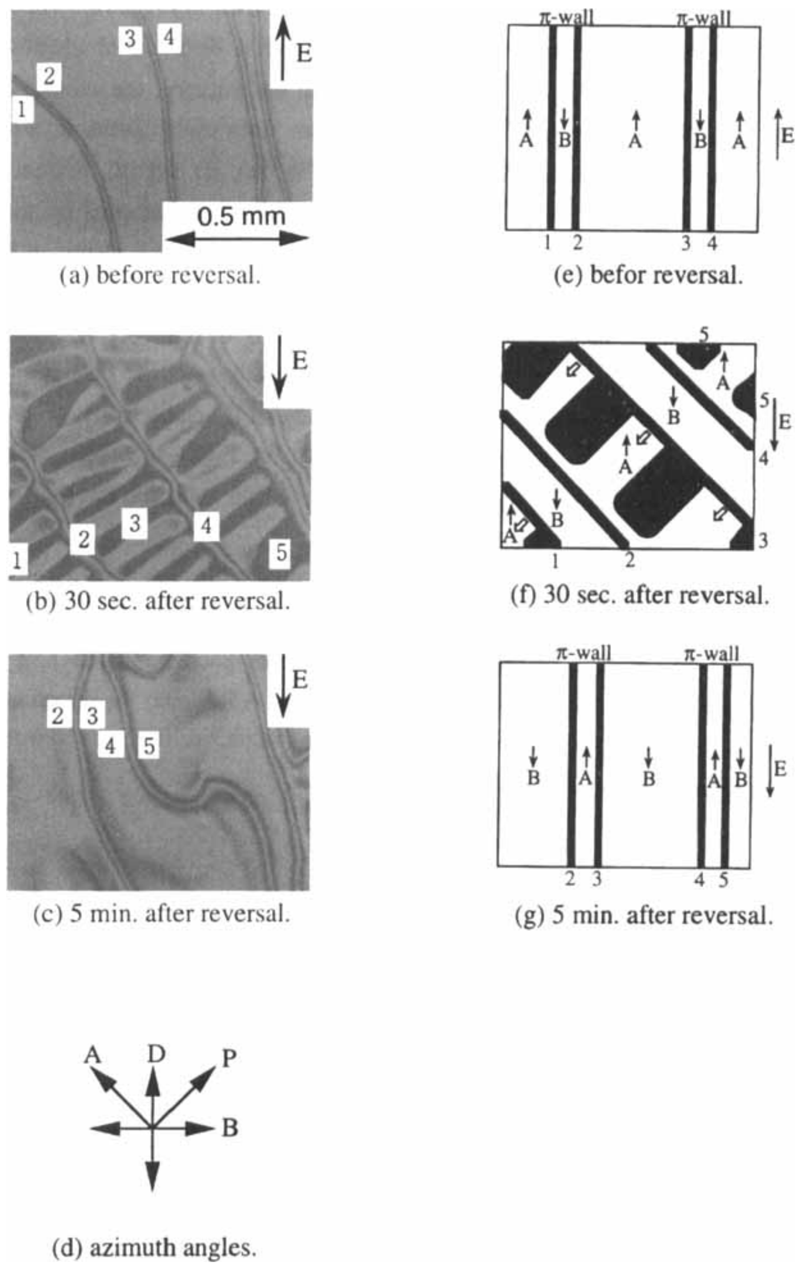
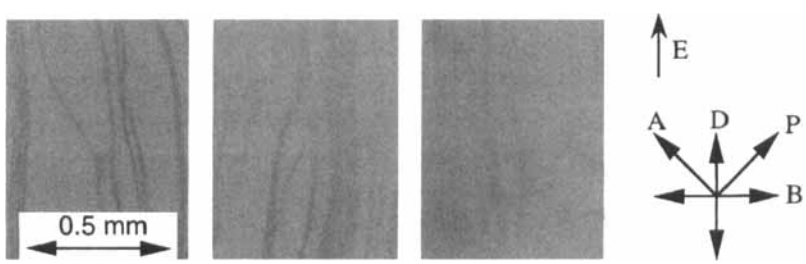


FIGURE 2 Sequential phtographs of the FS film with 42 smectic layers at field reversal and schematic models. E= 5kV/cm and T= 60°C.

There are several π-walls before field reversal, as shown in Fig.2 (a). The bright areas between the π-walls are favorable areas in which a direction of spontaneous polarization Ps coincides with the applied field E. On the contrary, the another bright areas between the two dark lines of the π-walls are unfavorable areas in which a direction of Ps point the counter direction of E. In Fig. (e), (f) and (g), normal short arrows and long arrows in the figures indicate the direction of spontaneous polarization and the applied field, respectively. The dark lines in these figures are identified by the number shown in the figures.

In Fig.2 (e), the areas A are favorable and the areas B are unfavorable, so that the unfavorable areas B are squeezed into the π-walls. When the opposite field is applied, the areas A and B change to be unfavorable and favorable, respectively. Therefore, areas A are squeezed into the π-walls, as shown in Fig.2 (g). The molecular reorientation is the transition between the state shown in Fig.2 (e) and the state shown in Fig.2 (g).

However, the process of this transition is relatively complicated. That is, immediately after the field reversal, initial favorable areas A are divided into a lot of domains along the direction perpendicular to E. And dark lines numbered 1, 3 and 5 drift to approach to the neighboring dark line over area A inclining the direction with respect to E, as shown in Fig.2 (b). The directions of the drift of the π-walls are indicated as opened arrows in Fig.2 (f).



(a) E = 80 V/cm. (b) E = 107 V/cm. (c) E = 133 V/cm. (d) Azimuth angles.

FIGURE 3 The textures of the FS film of 42 layers under the various dc-field at 60 ℃.

On the other hand, in the field region higher than the abrupt change of the response time shown in Fig. 1, no π-walls are observed at the moment of the field reversal. That is, c-directors are switched from a uniformly aligned state to an opposite uniformly aligned state. Figure 3 shows the π-walls for various dc-field. There are clear π-walls at 80 V/cm, as shown in Fig. 3 (a). However, the π-walls are disturbed as the dc-field is increased, as shown in Fig. 3 (b) and (c). The origin of this disturbance has not been clarified yet, but the field at which π-walls begin to be disturbed coincides with the field at which the response time change abruptly.

CONCLUSIONS

The electrooptic response of FS film was investigated. There is the abrupt change of the response time at certain threshold field. The molecular reorientation at 5 V/cm corresponds to the drift of the π-walls to expand the favorable areas. Many domains appear at the moment of the field reversal in the favorable areas. The disturbance of the π-walls by dc-field occurs at the field higher than the field at which response time changes abruptly.

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