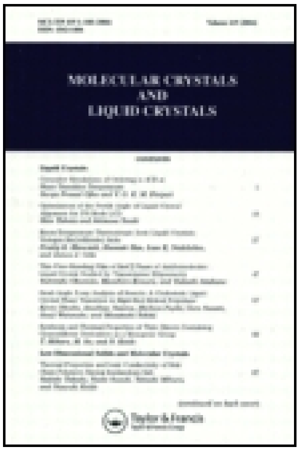

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BANDED TEXTURE INDUCED BY AN ELECTRIC FIELD IN LYOTROPIC LIQUID CRYSTALS.

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Abstract Using polarization microscopy, the formation of transient banded textures in a liquid crystalline solution of poly(γ -benzyl L-glutamate), PBLG, that had applied in-plane DC and AC electric fields was investigated. Striped bands perpendicular to the direction of the electric field were observed under an applied electric field. The images depended on time and were recorded by video camera and then analyzed. The dynamics of director-reorientation was followed by the measurement of the optical transmittance of a sample between crossed polarizers. A reproducible optical response to a low frequency square wave was observed. The dependencies of the band spacing and the reorientation rate of director on the field strength were quantitatively investigated.

INTRODUCTION

Rodlike polymers in concentrated solutions form liquid crystalline phases. The rheological behavior of the phase is much more complicated than that of an ordinary polymeric liquid, showing such unusual effects as negative normal stresses in a steady shear flow and nonlinear electrooptical behaviors.[1] Unlike low molar mass liquid crystalline molecules, liquid crystalline polymers(LCPs) are, in general, imperfectly aligned and the attainment of uniform orientation is difficult. Hence, various textures appear both in static and dynamic transient states. Generally, there is a distribution of molecular weight in synthetic polymers and heterogenity is an essential characteristic of polymers and also LCPs. However, in spite of a wide distribution of molar mass, uniform size domains are frequently observed.[2] A prominent phenomenon is band texture formation during and after shear of mesophase of liquid crystalline polymers.[3]

In this paper, we report band texture formation in an electric field instead of a shear field. We are aware, of course, that an changing the field characteristic may lead to new phenomena.

BANDED TEXTURE

Experiments

PBLG(Mw=48000) was used in our experiments. PBLG was dissolved in 1,1,2-trichloroethane(TriCE) at a concentration of 0.18(V/V) to prepare the cholesteric liquid crystalline solution. At first, the solution was sandwiched between two parallel glass plates partially coated with Au electrodes. The lateral dimensions of the cell were 0.5cm × 0.5cm, as shown in fig.1. The main experiments were performed with a cell thickness of 0.08mm. The cell was placed on a microscope stage between crossed polars. The lower polarizer is oriented along the direction of an electric field and the upper polarizer is perpendicular to it. A video camera was mounted on top of the microscope, permitting the video recording of images of the textures. The textures were recorded on video tape and then the individual frames were digitized at fixed intervals. The frame grabber has a resolution of 1024 × 512 pixels with 256 gray scales.

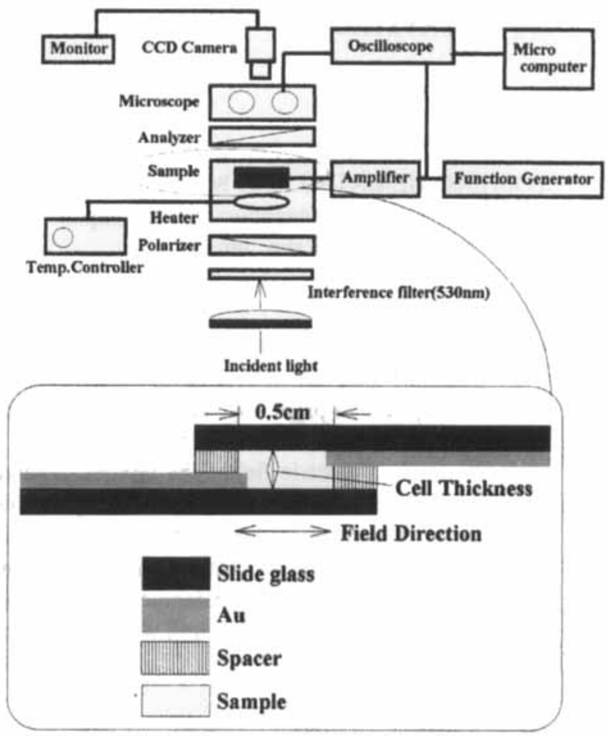


FIGURE 1 The experimental setup for measuring the electrooptical response with a DC electric field and Cell Structure.

RESULTS AND DISCUSSION

The Cholesteric LC solution of PBLG, at first, was sandwiched between two parallel plates partially coated with Au as electrodes. At the beginning, a DC electric field was applied across the cholesteric solution as shown in fig.1. It was observed through the microscope that the cholesteric texture gradually transformed to a nematic one. The cholesteric to nematic transition took place when the applied voltage exceeded a certain threshold values. The transition was followed by a drastic decrease of transmitted intensity. Extinction of light occurs when the director is parallel to one of the two crossed polars. Thus, the directors roughly align parallel to the DC field. In a typical experiment, the sample was aligned by an applied field higher than the critical field and then subjected to some transient change, stepping up in voltage or field reversal.

Through a polarization microscopy, the transient banded texture in the LC solution of PBLG, was easily observed when the field direction was suddenly reversed. This texture appeared as alternating bright and dark bands perpendicular to the field direction. Between every adjacent band a dark thin line was seen. Corroborating evidence for the structural features in the banded texture was furnished by the observation made with a wave plate(1/4 λ) inserted diagonally between crossed polarizers. A three colored pattern, blue and yellow bands partitioned by red fringes, was observed. We believe that the director is flipped out of the field direction and it is rotated in the clockwise and anticlockwise direction in the adjacent bands respectively. That is, in this banded texture, the director arranges itself in a zig-zag fashion along the field direction.

Further investigation of the texture and its evolution under an electric field was undertaken by utilizing samples initially aligned with a DC field as mentioned above, and then varying the field strength. Textural evolution as a function of field strength was directly characterized under crossed polars. The modulation of the optic axis of the nematic in the external electric field was followed by the transmitted light intensity. To obtain the space averaged temporal characteristics of the dissipative structure, the intensity of transmitted light through the whole area of the cell was measured with a photometric adapter and to analyze the local variation of the director, the intensity with gray scale on the individual horizontal video lines obtained from the images was analyzed.

Textural Evolution

Typical banded textures are shown in fig.2. Photomicrographs of the sample with an applied DC field of 240V/cm under crossed polars with the lower polarizer parallel to the field direction are shown. In these experiments the initial conditions of samples are well defined by the previously applied DC field as mentioned above. As shown in fig.2 (2), fine bands perpendicular to the field direction appear at 2.3 sec after inversion of field direction. After a while(t=10s), these bands disappear and are replaced by a uniform dark field. After that, bands regenerate again with the same width and at the same position as those of the former bands respectively, expect for the band colors

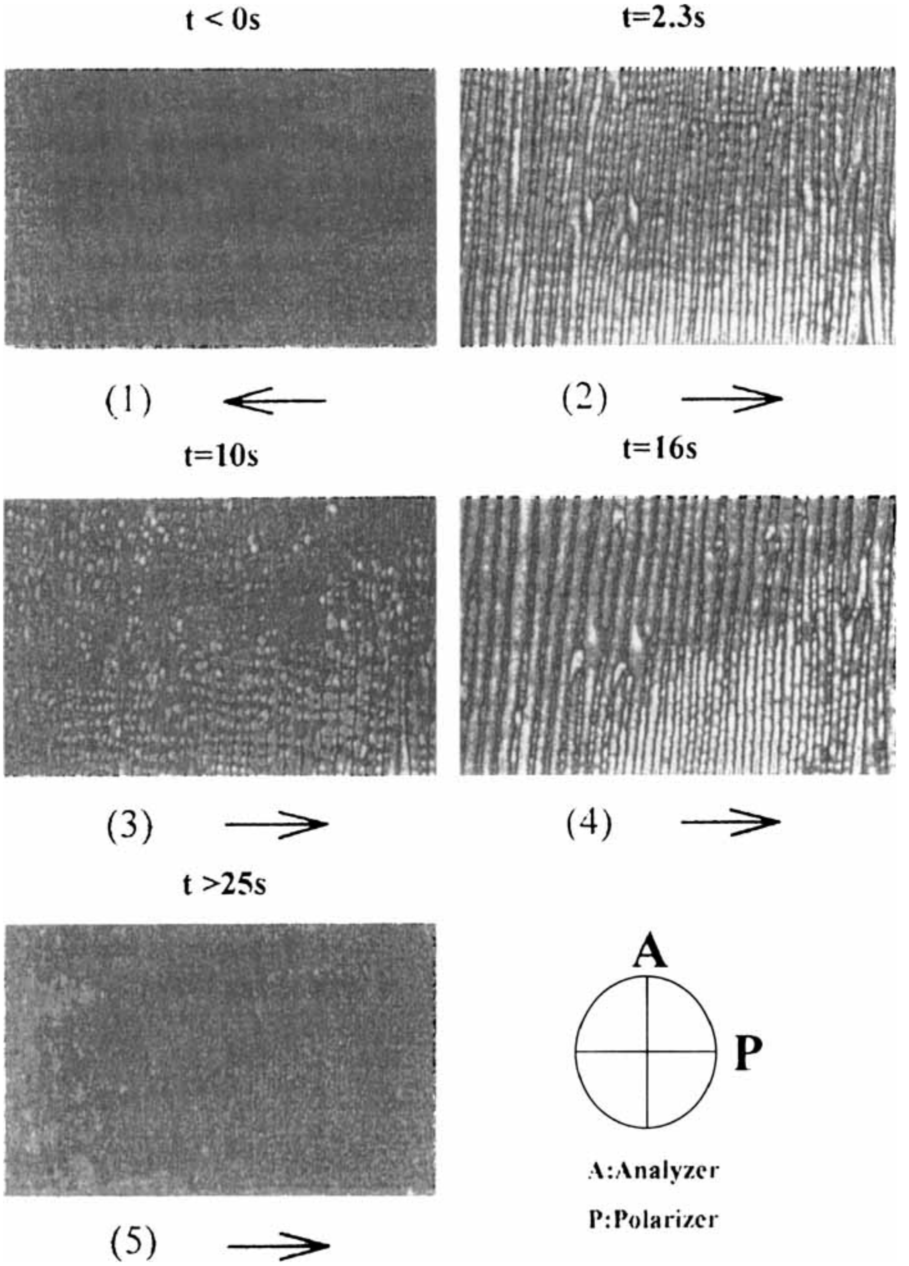


FIGURE 2 Photomicrographs taken under crossed polars of the reorientation process of director following an inversion of the applied DC field direction (applied field:240 V/cm) (arrows represent the field direction).

observed with a wave plate inserted between crossed polars; they changed, respectively, yellow to blue and blue to yellow through a dark field. That is, the banded texture appears two times in the reorientation process of director following the field inversion. The dependence of band width, L(μ m) on the field strength, E(V/cm) is shown in fig.3. We obtained the relationship as follows equation (1).

$$L^2 \sim k/E \quad \cdots(1)$$

Here, k is a constant.

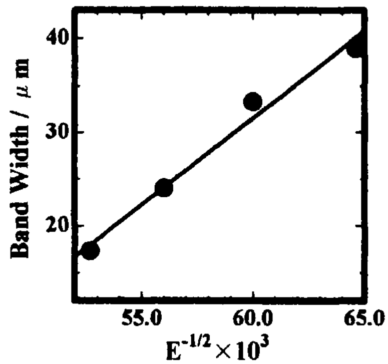


FIGURE 3 The Relationship between Band Width(L) and Applied Field Strength(E: V/cm).

Dynamics(Kinetics) for rotational motion (orientation process)

The time dependence of the light intensity transmitted through the whole area of the cell is shown in fig.4. The time between the two peaks of the intensity, Δ t, at different fields, E, was determined. The director rotation is not symmetrical. The rotation is slower and the distribution of the director is wider near the field direction. The change of Δ t, a measure of the orientational relaxation time, with DC field indicates that Δ t is inversely proportional to E^2, as shown in fig.5. By extrapolating the data to Δ t equal infinity, we find the electric field defined through a threshold voltage. Additionally, it is confirmed that L^4 is directly proportional to Δ t.

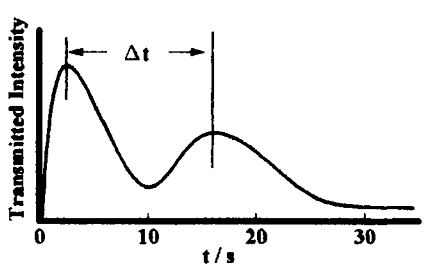


FIGURE 4 The transmitted intensity under crossed polars as scaled time following the reverse of the DC field direction keeping the same voltage.

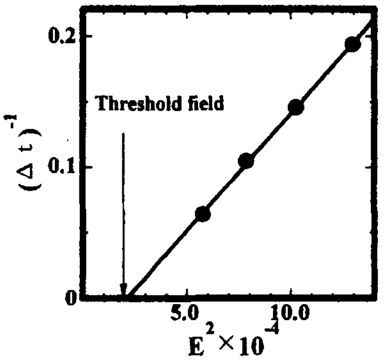
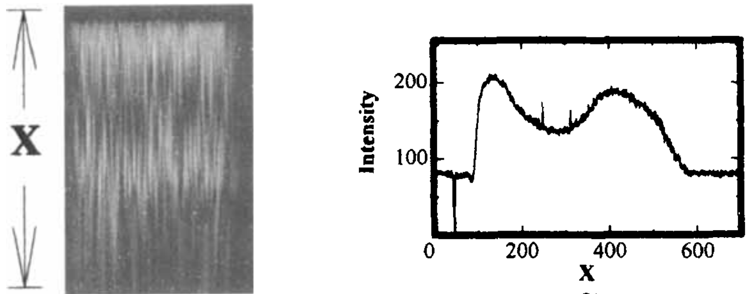


FIGURE 5 The Relationship between the Applied Field Strength(E) and the Reorientation Velocity(Δ t) $^{-1}$.



(1) (2)

FIGURE 6 The individual frames of video tape recorded for the field inversion process of PBLG solution were digitized at fixed intervals. (1) The texture scaled time. (2) The transmitted intensity at various X position.

In order to examine the local movement of the director, using the images recorded on video tape, a fixed horizontal video line(200th pixel) of each frame was picked and analyzed at a fixed interval(every 0.05 sec/1 pixel) and "texture on the scale of time" were reconstructed. An example is shown in fig.6. The X position represents time scaled in 20 pixels/sec. The variation of transmitted intensity in gray scale at a fixed vertical line in fig.6(1) is represented graphically in fig.6(2). The ordinates give the transmitted intensity at various X positions indicated by abscissae. The time interval, from peak to peak, Δ t, obtained in fig.6(2) is consistent with the value obtained from the time dependence of space averaged intensity transmitted through the whole area of the cell.

SUMMARY

The transient banded texture in the LC solution of PBLG, was easily observed when the field direction was suddenly reversed. The reproducible optical response to a square wave in the low frequency regime was well characterized. Two peaks of the transmitted intensity could be observed with an inversion of field direction. From the result, the values of Δ t may easily be obtained for various fields. The band width(L) is inversely proportional to $E^{1/2}$ and reorientation velocity(Δ t$)^{-1}$ is directly proportional to E^2. The detailed results will be published, elsewhere.

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