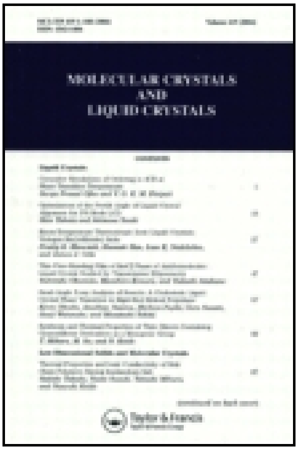

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Molecular Alignment Structure and Switching of a Ferroelectric Liquid Crystal Stabilized by a Polymer Network Created in the SmA Phase

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Molecular Alignment Structure and Switching of a Ferroelectric Liquid Crystal Stabilized by a Polymer Network Created in the SmA Phase

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In order to realize monostability in surface-stabilized ferroelectric liquid crystals, polymer stabilization techniques have been proposed, and the polymer-stabilized ferroelectric liquid crystals (PSFLCs), which is fabricated by UV photocure of doped photocurable mesogenic monomers at a temperature where the FLC medium is in the SmA phase, has been reported to show V-shaped electrooptical characteristics. However, the reason why the monostable V-shaped switching can be realized has not been clear yet. In this research, the electrooptical characteristics, the microscopic textures, the tilt angle and the chevron angle of the PSFLCs photocured in the SmA phase were measured, and then the molecular alignment structure was discussed from these results.

Keywords: chevron angle; ferroelectric liquid crystal; monostability; polymer; SmA; tilt angle; V-shaped electrooptical characteristics

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INTRODUCTION

Surface-stabilized ferroelectric liquid crystal displays (SSFLCDs) form the basis of a rapidly developing technology of significant potential impact in display applications, in particular, such as video image displays by taking advantage of their fast response speed [1–4]. However, the bistability of SSFLC is disadvantageous for LCDs which possess grayscale or full-color capability, because the size of bistable switching domains may become almost equal to the pixel size of LCDs.

In previous papers we reported a polymer-stabilized (PS) FLC fabricated by a UV photocure of doped photocurable monoacrylates, which have mesogenic side chains, at a temperature where the LC medium is in the SmC* phase under the application of a monopolar electric field [5–8]. This PSFLC exhibits monostable and asymmetric electrooptical characteristics with grayscale capability without a threshold. Furthermore, recently our research group has reported that a PSFLC, which is fabricated by the photocure under the application of an AC electric field, exhibits monostable and symmetric (V-shaped) electrooptical performance [9–12]. Moreover, a PSFLC which is fabricated by UV photocure of doped photocurable mesogenic monomers at a temperature where the FLC medium is in the SmA phase has been reported to show V-shaped electrooptical characteristics [13]. However, the reason why the monostable V-shaped switching can be realized in the PSFLC polymerized in the SmA phase has not been clear yet. In this paper, the molecular alignment structure of the PSFLC photocured in the SmA phase is discussed from the experimental results of electrooptical characteristics, microscopic textures, the tilt angle and the chevron angle.

EXPERIMENTALS

The materials used in this research were as follows: the FLC was FELIX-M4851/100 (Clariant Japan); the photocurable mesogenic monoacrylate and diacrylate were UCL-001 and 2A363, respectively (Dainippon Ink and Chemicals) which were doped with 1wt% photoinitiator; and the LC alignment film was polyimide RN-1199 (Nissan Chemical Industries) which induced a defect-free FLC alignment with the C2-chevron structure [14,15]. The relevant properties of FELIX-M4851/100 given by the catalogue are shown in Table 1.

A solution of polyimide was spun on glass substrates coated with indium-tin-oxide (ITO) and then baked. After the thermal treatment, the substrates were rubbed. Then the FLC, which was doped with the photocurable mesogenic monomer, was injected in the isotropic

TABLE 1 Properties of FELIX-M4851/100

Properties	
Phase sequence	Cryst.(< 20)SmC*(67)SmA(71)N*(76)Iso. [°C]
Spontaneous polarization	$22 nC/cm^2$ (20°C)
Tilt angle	30.5° (20°C)
Switching time	38 μs (E = 15 V/μm, 20°C)

phase via capillary action into an empty cell, in which the rubbing directions were parallel and the cell gap was 2 μm. Next, the cell was cooled gradually to the temperature where the LC medium is in the SmA phase. Then, the LC medium was photocured with a UV light source (365 nm, $2\,mW/cm^2$).

The microscopic textures of the PS-FLCD cells fabricated by this method were observed with a polarizing microscope and their electrooptical characteristics were measured with a conventional measuring system. The layer tilt angle of chevron structure (chevron angle) was measured by X-ray diffraction technique.

RESULTS AND DISCUSSION

Figure 1 demonstrates an example of the electrooptical characteristics of PSFLC fabricated using the monoacrylate UCL-001. When the

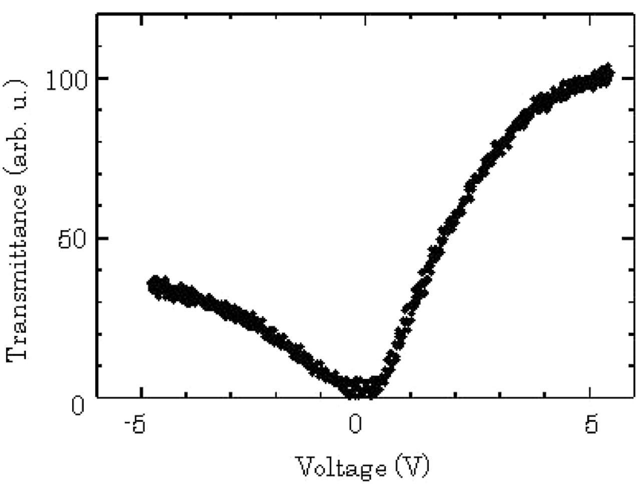

FIGURE 1 An example of electrooptical characteristics of PSFLC fabricated using UCL-001 (14wt%).

density of polymer is less than 14 wt%, a perfectly monostable medium cannot be obtained. Although the monostable PSFLC can be realized at the density of more than 14 wt%, the electrooptical effect is asymmetric and the asymmetry depends on the condition of the PSFLC cell. Figure 2 shows a microscopic photograph of the PSFLC cells fabricated using 14 wt% UCL-001. Domain structure with two types of monostable domains is confirmed. It is guessed that since a molecule of UCL-001 has only one acrylate group, the polymer of UCL-001 may be relatively soft and then mesogenic side chains may tilt from the smectic layer normal together with FLC molecules at the SmA to SmC* phase transition. As a result, the molecular alignment structure with two monostable directions can appear, as illustrated in Figure 2.

Figure 3 demonstrates the electrooptical effect of PSFLC fabricated using the diacrylate 2A363. When the density of polymer is less than 6 wt%, a perfectly monostable medium cannot be obtained. In the PSFLC with UCL-001, the V-shaped electrooptical characteristics cannot be obtained, but on the other hand, in the PSFLC with 2A363, the V-shaped electrooptical performance is obtained. Figure 4 shows

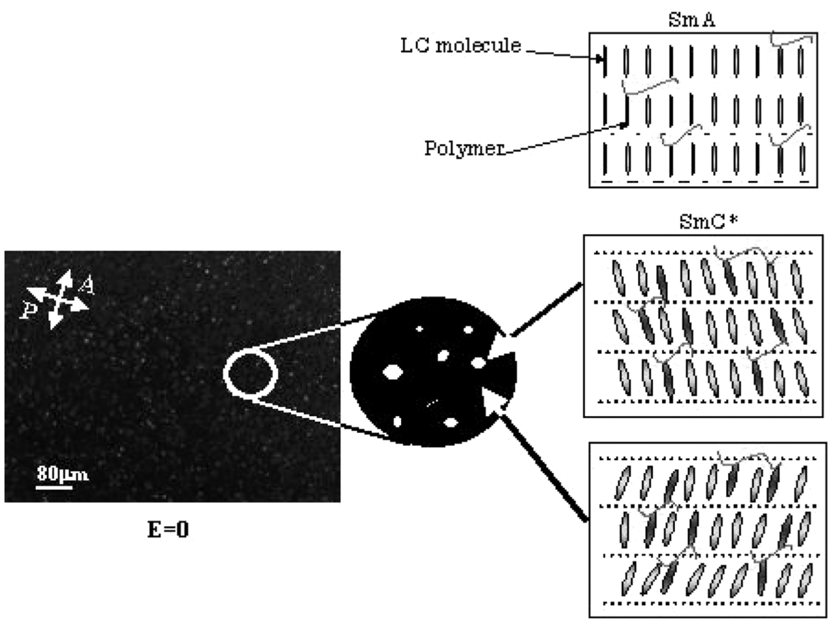

FIGURE 2 Microscopic texture of PSFLC in 14wt% UCL-001 with schematic alignment structure models.

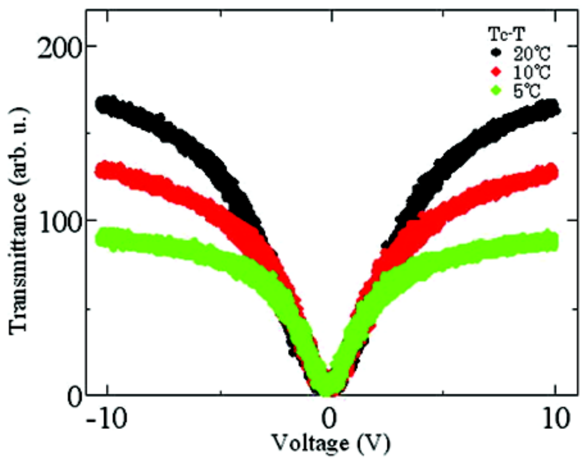

FIGURE 3 Electrooptical characteristics of PSFLC fabricated using 2A363 (6wt%): Tc = (phase transition temperature from SmA to SmC*).

microscopic textures of the PSFLC fabricated using 6 wt% 2A363. It is found that a uniform alignment structure appears, in which the optical axis is parallel to the rubbing direction. As a result, the V-shaped electrooptical effect can be realized. For the molecular alignment structure, if the FLC director is parallel to the rubbing direction or to the direction of director in the SmA phase, the tilt angle of smectic layer in the chevron structure of FLC (chevron angle) δ has to be equal to the "tilt angle" of FLC molecules θ, as shown in Figure 5. It is well

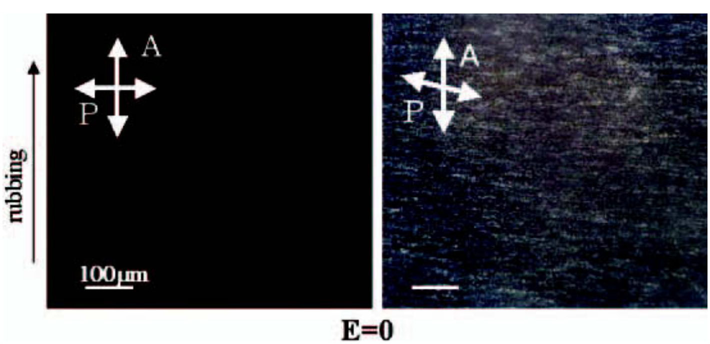

FIGURE 4 Microscopic texture of PSFLC in 6wt% 2A363 at quiescent condition.

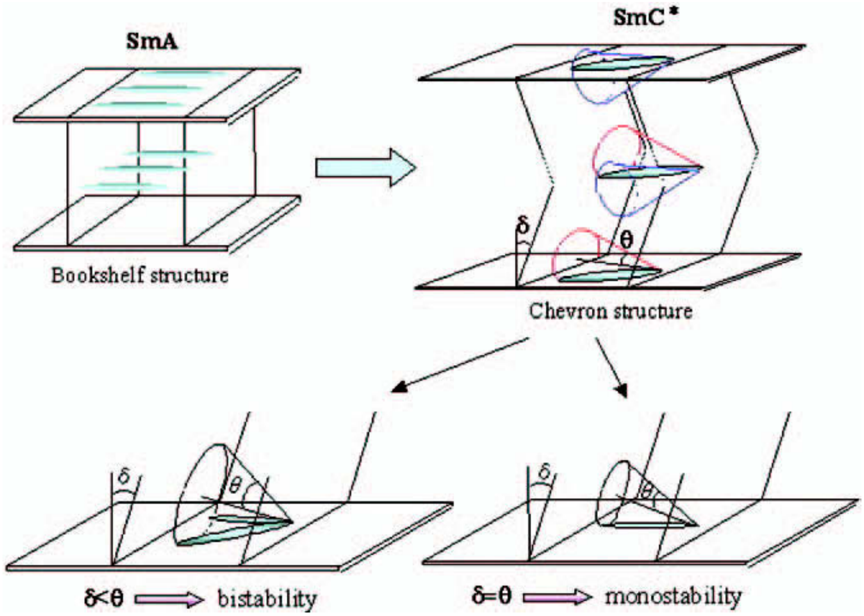

FIGURE 5 Schematic chevron structure model.

known empirically that in a conventional SSFLC, $\delta = 0.8\theta$. In this situation, there exist two energically stable states at the quiescent condition, and therefore conventional SSFLCs may exhibit bistability.

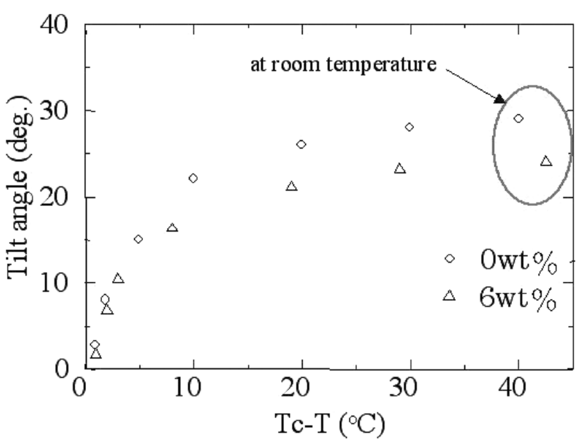

FIGURE 6 Temperature dependence of tilt angle in conventional SSFLC (0wt%) and PSFLC with 6wt% 2A363.

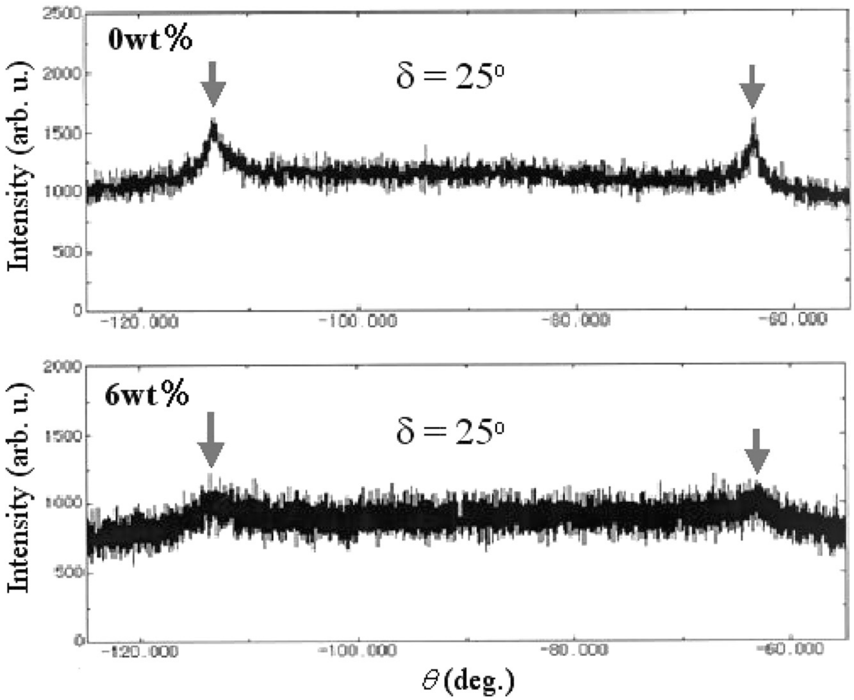

FIGURE 7 The results of chevron angle measurement with X-ray diffraction.

However, if $\delta = \theta$, there is only one stable state and then the SSFLC may exhibit monostability. Figure 6 shows the temperature dependence of tilt angle in a conventional SSFLC and PSFLCs fabricated using 2A363. The tilt angle of the conventional SSFLC and the PSFLC with 6wt% 2A363 are 29.7° and 24.5°, respectively, at room temperature. Figure 7 shows the results of X-ray diffraction measurement in which the detector was fixed to the Bragg angle concerned with layer spacing and FLC cell was rotated, *i.e.* θ-scan method. The chevron angle is the half angle between two peaks due to the chevron structure. The chevron angle of conventional SSFLC and the PSFLC with 6 wt% 2A363 is 25° at room temperature, and thus it is confirmed that in the PSFLC cell, the chevron angle is nearly equal to the tilt angle although the chevron angle is less than the tilt angle in the conventional FLC cell. Therefore, it is thought that the molecular alignment direction in the SmA phase is strongly stabilized with polymer network of 2A363 even after the phase transition to the SmC* phase and then the monostable V-shaped characteristics is realized.

SUMMARY

In this research, the electrooptical characteristics, the microscopic textures, the tilt angle and the chevron angle of the PSFLCs photocured in the SmA phase were measured, and then the molecular alignment structure was discussed from these results. In the PSFLCs fabricated using UCL001, the V-shaped electrooptical characteristics cannot be obtained even in a relatively high concentration of polymer. On the other hand, as using 2A363, the V-shaped electrooptical performance is obtained. From the measurement results of the tilt angle and the chevron angle, it is found that the chevron angle is nearly equal to the tilt angle. Therefore, it is thought that the molecular alignment direction in the SmA phase is strongly stabilized even after the phase transition to the SmC* phase, and then the monostable V-shaped characteristics is realized.

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