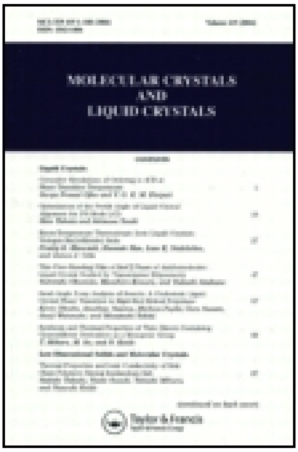

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Dependence of Polymer-Stabilized Ferroelectric Liquid Crystals on Photocuring Condition

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Dependence of Polymer-Stabilized Ferroelectric Liquid Crystals on Photocuring Condition

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Polymer-stabilized ferroelectric liquid crystals may show monostable and V-shaped electrooptical characteristics. We have investigated the dependence of their characteristics on the photocuring condition, especially ultraviolet light intensity. Furthermore, we offer a new scheme of the photocure being done under an electroclinic effect. The bistability of ferroelectric liquid crystals remains partially in the case of a weak ultraviolet light intensity and the saturation voltage increases as the ultraviolet light intensity increases. The tilt angle decreases as the ultraviolet light intensity increases. The decrease of tilt angle cannot be suppressed even in polymer-stabilized ferroelectric liquid crystals fabricated using the electroclinic effect.

Keywords Electroclinic effect; ferroelectric liquid crystal; photocure; polymer stabilization; tilt angle

1. Introduction

Liquid crystal displays (LCDs) are currently used extensively in information display devices, particularly in the displays of computers and even televisions. As the LCDs will be expected to play more important role in the multimedia network era, LCDs that are capable of displaying a moving video image are required to be developed. Therefore, it is necessary to substitute the conventional nematic LC with a new LC material in order to realize a high-quality display for a moving video image. A leading candidate is ferroelectric liquid crystal (FLC). Surface-stabilized (SS) FLCs are attractive because of their unique characteristics such as high-speed response, wide viewing angle and bistability [1–4]. Although the bistability is suitable for passive matrix-addressed displays, it is disadvantageous for LCDs which possess grayscale or full-color capability [5].

In previous papers, we reported polymer-stabilized ferroelectric liquid crystals (PSFLCs), in which a photocurable mesogenic monomer is doped into a ferroelectric liquid crystal and a ultraviolet light (UV) photocure is carried out in the SmC* phase under the application of a bipolar AC electric field or in the SmA phase at the

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quiescent condition, may show monostable and V-shaped electrooptical characteristics with a grayscale capability without a threshold [5–10]. Although numerous studies mainly concerned with the application research of the PSFLC have been reported, it has not been clarified in detail yet how the polymer stabilization influences the molecular alignment structure and the molecular reorientation for applying an electric field. In this study, we focus on the photocuring condition and investigate the dependence of the characteristics of the PSFLCs on the photocuring condition, especially the UV intensity. Furthermore, we offer a new scheme of photocure in which PSFLCs are fabricated by photocuring under an electroclinic effect in the SmA phase, i.e., a combination of the SmC* and the SmA photocuring methods mentioned above.

2. Experimental

The materials used in this research were as follows: the FLC was FH-8002 N (DIC); the photocurable mesogenic diacrylate was 2A363 (DIC), which was doped with 1 wt% 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 [11,12]. The relevant properties of FH-8002 N given in the catalogue are shown in Table 1.

A solution of the polyimide was spun on glass substrates coated with indium-tin oxide and then baked. After the thermal treatment, the substrates were rubbed. Then, the FLC, which was doped with the photocurable mesogenic monomer at 5 wt%, was injected in the isotropic phase via capillary action into an empty cell,

Table 1. Properties of FH-8002N

Properties	
Phase sequence	Cr.(−19)SmC*(62)SmA(76)N*(82)I [°C]
Spontaneous polarization	$25 nC/cm^2$
Tilt angle	22° (at room temp.)

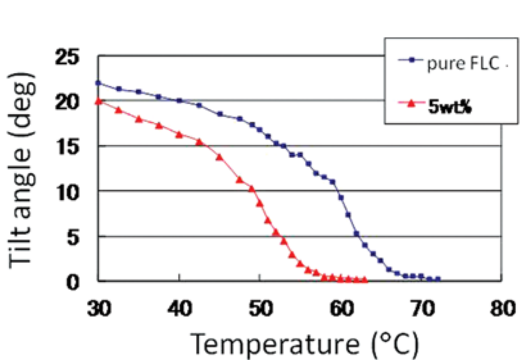

Figure 1. Temperature dependence of tilt angle in FLC media used in this research before UV photocure. (Figure appears in color online.)

in which the rubbing directions and the cell gap were set parallel and 2 µm, respectively. Next, the cell was cooled gradually to the temperature where the LC medium was in the SmA phase (70°C) or in the SmC* phase (43°C) whose tilt angle was 15°, as shown in Figure 1. Then, the LC medium was photocured with a UV light source (365 nm) under the application of a bipolar square-pulsed AC electric field (±5 V/µm, 100 Hz) and the quiescent condition for the SmC* and the SmA photocuring, respectively. The UV intensity and irradiation time were set so that the energy was equal in each and every cell (1.2 kJ/cm^2).

The microscopic texture observation, the electrooptical effect investigation, and the tilt angle measurement for PSFLC cells fabricated by the above method were done using a conventional measuring system with a polarizing microscope.

3. Results and Discussion

Figure 2 shows the microscopic textures at the off-state after the application of electric field with + or − polarity and the electrooptical characteristics in the PSFLC cells fabricated by photocuring in the SmA phase. It is found that the performance of the PSFLC strongly depends on the UV intensity. In the case of a weak UV intensity, the bistability may remain partially and the perfect monostability cannot be obtained. Furthermore, as the UV intensity increases, the angle of the V-shape of electrooptical effect broadens and the saturation voltage increases. The similar results were obtained also in the case of the PSFLC cells fabricated by photocuring

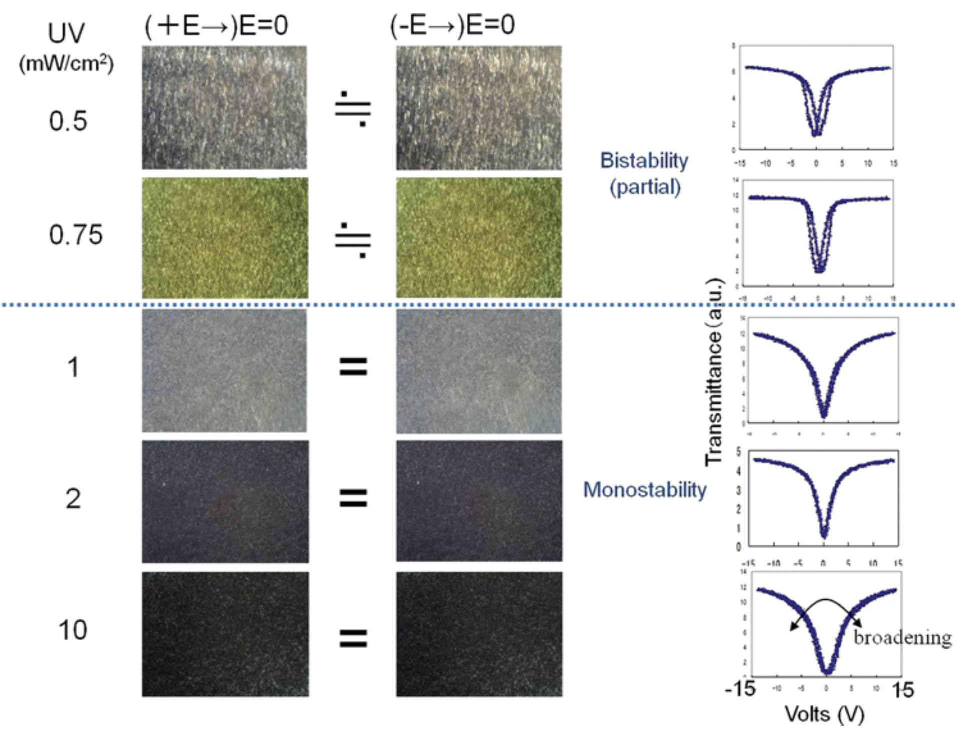

Figure 2. Microscopic textures and electrooptical characteristics of PSFLCs fabricated by photocuring in SmA phase. (Figure appears in color online.)

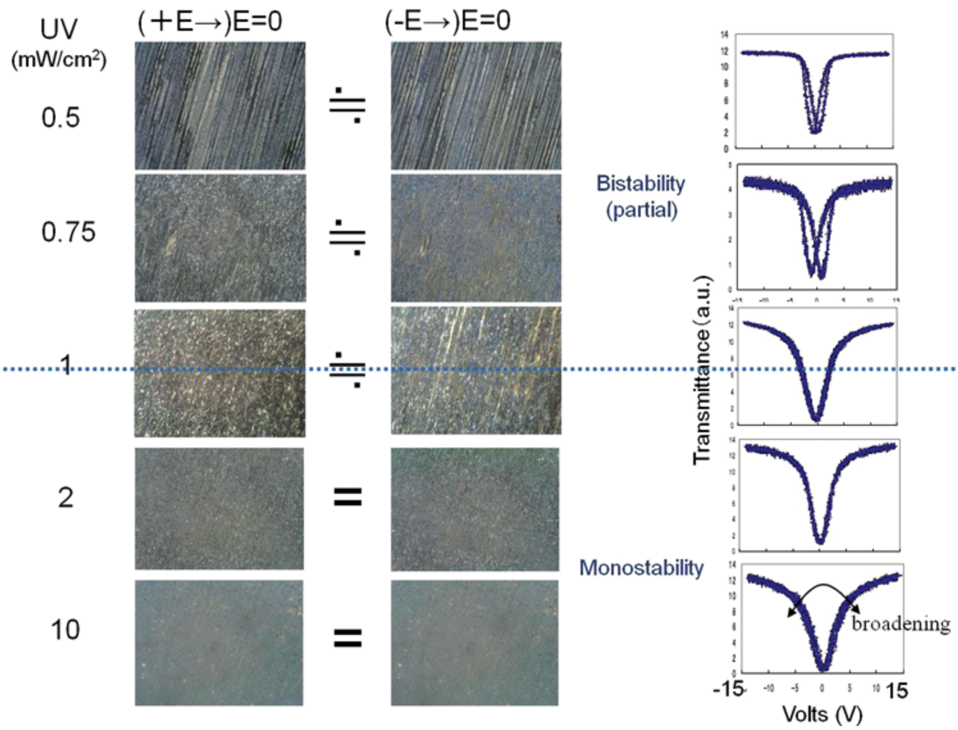

Figure 3. Microscopic textures and electrooptical characteristics of PSFLCs fabricated by photocuring in SmC* phase. (Figure appears in color online.)

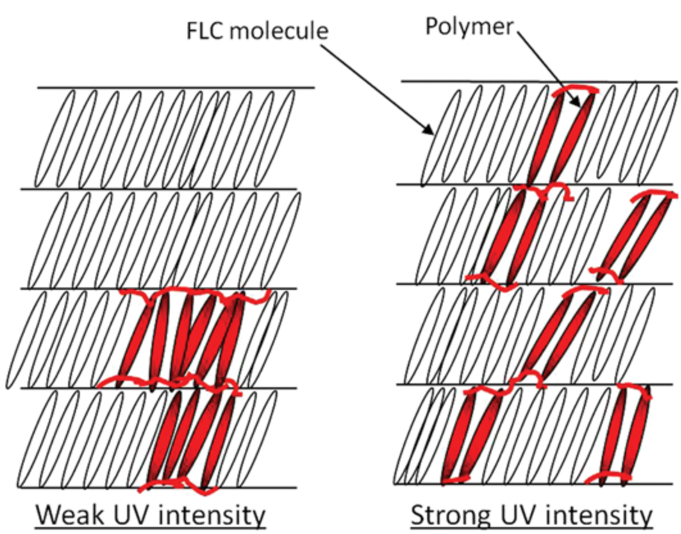

Figure 4. Models of molecular alignment structure in PSFLCs fabricated by photocuring with a weak or strong UV intensity. (Figure appears in color online.)

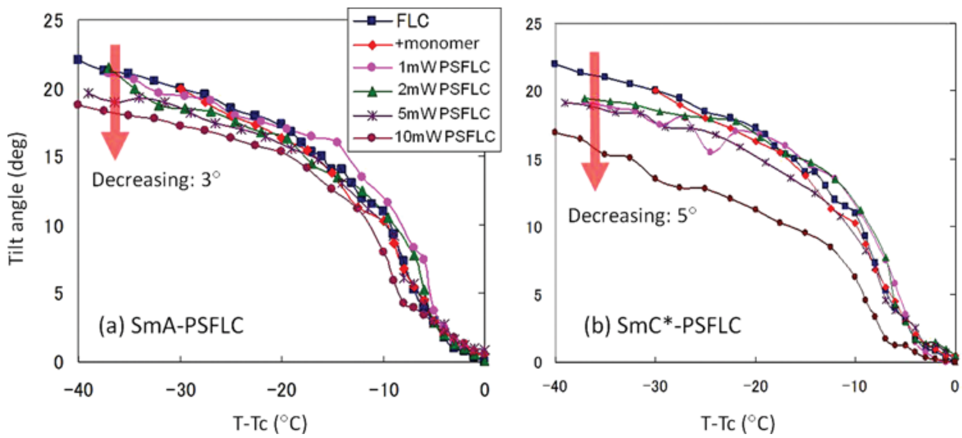

Figure 5. Temperature dependence of tilt angle in PSFLCs fabricated using several UV intensities in (a) the SmA and (b) SmC* phases: *T*c is SmA-SmC* phase transition temperature.

in the SmC* phase, as shown in Figure 3. Therefore, it is important to select the suitable UV intensity for the device application. These results would originate in the difference of the formation process and size of polymer networks for the UV intensity, as illustrated in Figure 4. In the case of weak UV intensity, the occurrence of polymerization core may be a few, and thus the molecular weight of polymer may largely increase in the process of photocure. Therefore, the large size polymers may locally exist in the FLC medium. Then, because there are regions far from the polymers, the bistability may partially remain. On the other hand, in the case of strong UV intensity, lots of polymerization cores may occur, and the small size polymers may be distributed uniformly in the FLC medium. Therefore, the perfect monostability can be obtained. Moreover, it is thought that the uniformity of the distribution may increase as the UV intensity increases. As the uniformity increases, the polymer anchoring strength to the FLC molecules may increase, and thus the saturation voltage of electrooptical effect may increase.

Figure 5 shows the temperature dependence of the tilt angle. It is found that the tilt angle decreases as the UV intensity increases, and the extent of its decrease in the

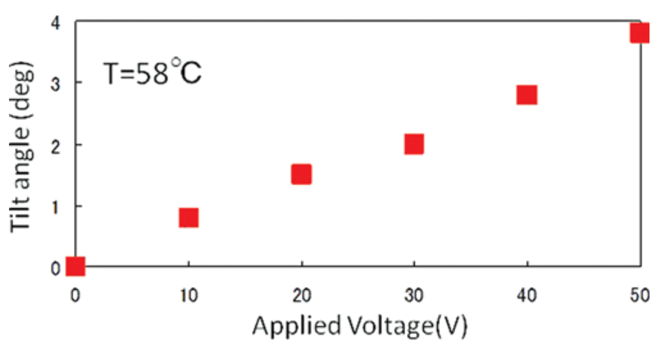

Figure 6. Applied voltage dependence of induced tilt angle measured in SmA phase (electroclinic effect): FLC medium used is not photocured. (Figure appears in color online.)

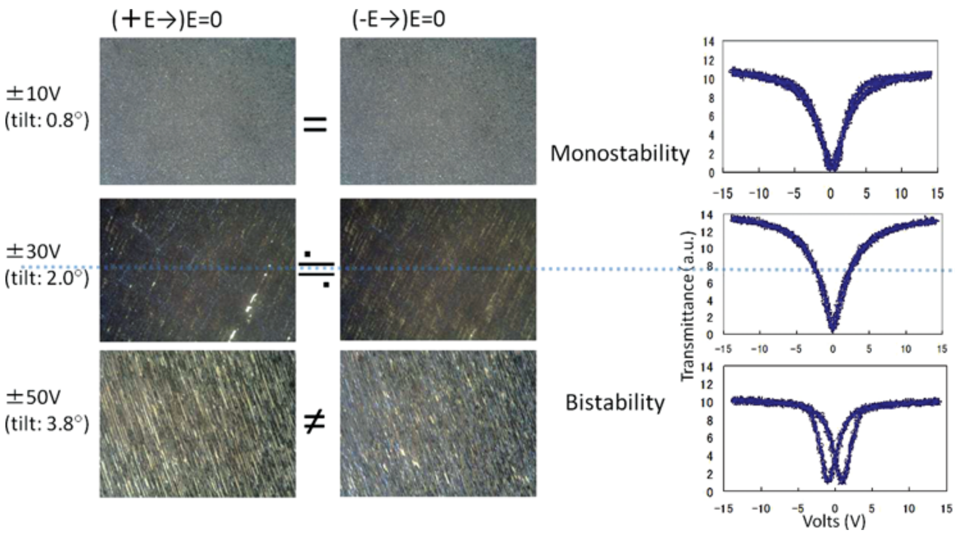

Figure 7. Microscopic textures and electrooptical characteristics of PSFLCs fabricated by photocuring under situation of electroclinic effect. (Figure appears in color online.)

SmA-photocured PSFLC is smaller than that in the SmC*-photocured PSFLC. The decrease of the tilt angle may become an obstacle to the application of PSFLC to LCD. So we attempted a new photocuring scheme in which the photocure was carried out in the SmA phase under the application of a bipolar square-pulsed AC electric field; i.e., electroclinic effect. Figure 6 shows the applied voltage dependence of the induced tilt angle in the SmA phase (58°C: near the phase transition temperature). It is confirmed that the induced tilt angle changes linearly for the applied

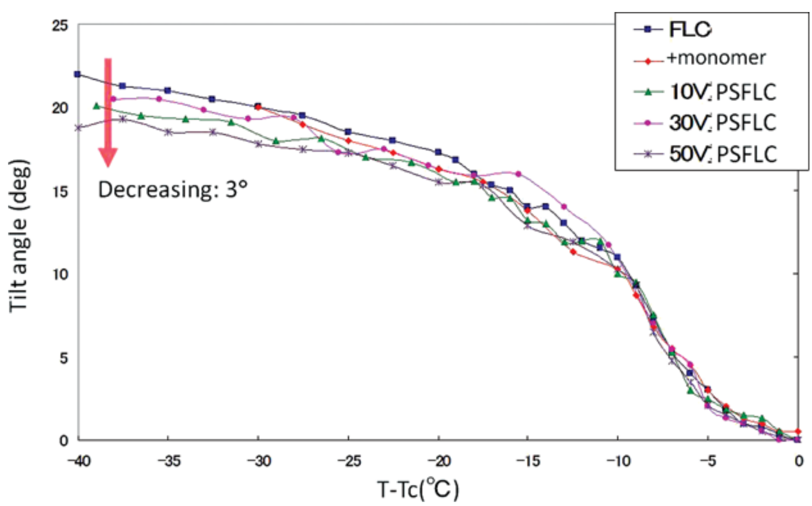

Figure 8. Temperature dependence of tilt angle in PSFLCs fabricated by applying different voltages under situation of electroclinic effect: *T*c is SmA-SmC* phase transition temperature.

voltage. Figure 7 shows the microscopic textures and the electrooptical characteristics of the PSFLC cells fabricated by photocuring in the SmA phase (58°C) with a UV light source ($2\,mW/cm^2$, 10 min) under the application of the electric field (±5, 15 or 25 V/μm, 100 Hz). It is found that the monostability cannot be obtained in the case of the photocure in the high field; i.e., the largely induced tilt angle. This fact means that the mechanism of polymer stabilization and the reason for realization of monostability are different between the SmA- and the SmC*-photocured PSFLCs [8–10]. Figure 8 shows the temperature dependence of the tilt angle. It is found that the tilt angle decreasing due to the polymer stabilization cannot be strongly suppressed even by utilizing the electroclinic effect.

4. Conclusions

The performance of PSFLC strongly depends on the UV intensity at the photocure. In the case of a weak UV intensity, the bistable regions may remain partially and the perfect monostability cannot be obtained. Furthermore, the saturation voltage of electrooptical effect increases as the UV intensity increases. Therefore, it is important to select the suitable UV intensity for the device application. Furthermore, it was found that the tilt angle decreases as the UV intensity increases, and the extent of its decrease in the SmA-photocured PSFLC is smaller than that in the SmC*-photocured PSFLC. In order to suppress the tilt angle decreasing, we attempted a new photocuring scheme in which the photocure was carried out under the electroclinic effect. However, the tilt angle decreasing due to the polymer stabilization was not able to be strongly suppressed even in the electroclinic effect-photocured PSFLC.

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