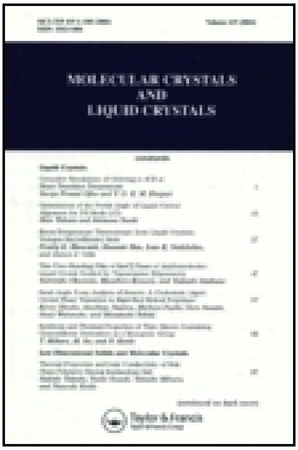

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Polymer-Stabilized Ferroelectric Liquid Crystals Photocured at Nematic Phase

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Polymer-stabilized ferroelectric liquid crystals (PSFLCs), in which a photocurable mesogenic monomer is doped into a ferroelectric liquid crystal and a UV photocure is carried out in the SmA or the SmC phase under the application of a bipolar AC electric field, show the monostable and V-shaped electrooptical characteristics, and thus are expected to be a newly developed materials for LC devices. In this study, in order to increase the thermal reliability of PSFLCs, we fabricate a new PSFLC photocured at the nematic (N) phase, and then investigate its characteristics in terms of the electrooptical effect and the X-ray diffraction. Results show that the PSFLC photocured at the N phase does not become monostable because the chevron angle does not coincide with the tilt angle.*

Keywords: ferroelectric liquid crystal; monostablity; nematic phase; photocure; polymer stabilization

1. 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 that possess grayscale or full-color capability, because the size of bistable switching domains may become almost equal to the pixel size of LCDs.

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In previous papers we reported a polymer-stabilized (PS) FLC fabricated by a UV photocure of doped photocurable acrylates, which have mesogenic side chain, 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 a bipolar AC electric field, exhibits a monostable and symmetric (V-shaped) electrooptical performance [9–13]. Moreover, a PSFLC photocured at the SmA phase under no electric field also may show the V-shaped electrooptical characteristics [14,15]. In this study, in order to improve the thermal stability in the characteristics of the PSFLC, we research a new PSFLC photocured at the N phase which is higher temperature phase than the SmA and SmC* phases.

2. EXPERIMENTALS

The materials used in this research were as follows: the FLC was FELIX-M4851/100 (Clariant Japan); the photocurable mesogenic acrylate 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 [16,17]. The relevant properties of 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 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 N phase. Then, the LC medium was photocured with a UV light source (365 nm, 2mW/cm^2).

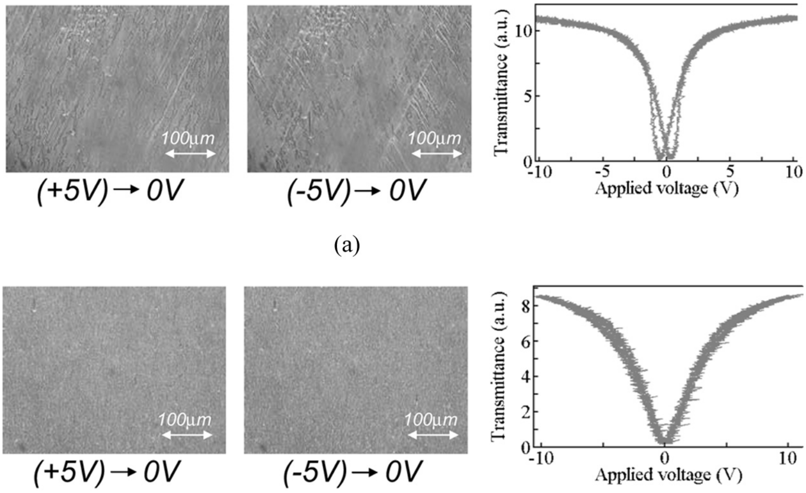
TABLE 1 Properties of FELIX-M4851/100

Properties	
Phase sequence	Cryst. (<−20) SmC* (67) SmA (71) N* (76) Iso. [°C]
Spontaneous polarization	−22nC/cm^2 (20°C)
Tilt angle	30.5° (20°C)

The microscopic textures of the PSFLC cells fabricated by this method were observed with a polarizing microscope, and their electrooptical characteristics and tilt angles were measured with a conventional measuring system under the condition that temperature was 30°C. The layer tilt angle of chevron structure (chevron angle) was measured by X-ray diffraction technique under the condition that temperature was room temperature.

3. RESULTS AND DISCUSSION

Figure 1 shows microscopic textures and electrooptical characteristics of a pure FLC and PSFLC photocured at the SmA phase (5 wt% polymer), in which the rubbing directions were set parallel to the polarized direction of incident light in the cross-Nichol situation. It is confirmed that the pure FLC is bistable with switching domains in the surface stabilized situation, whereas the PSFLC photocured at the SmA phase is monostable without switching domain. Figure 2 shows microscopic textures and electrooptical characteristics of PSFLC photocured at the N phase. It is found that the textures are not uniform but disarray. The PSFLC having 5 wt% polymer remains bistable. As the polymer concentration increases to 8 wt%, the PSFLC tends to be monostable.



(a)

(b)

FIGURE 1 Textures and electrooptical characteristics of (a) FLC and (b) PSFLC photocured at SmA phase doped with 5 wt% polymer.

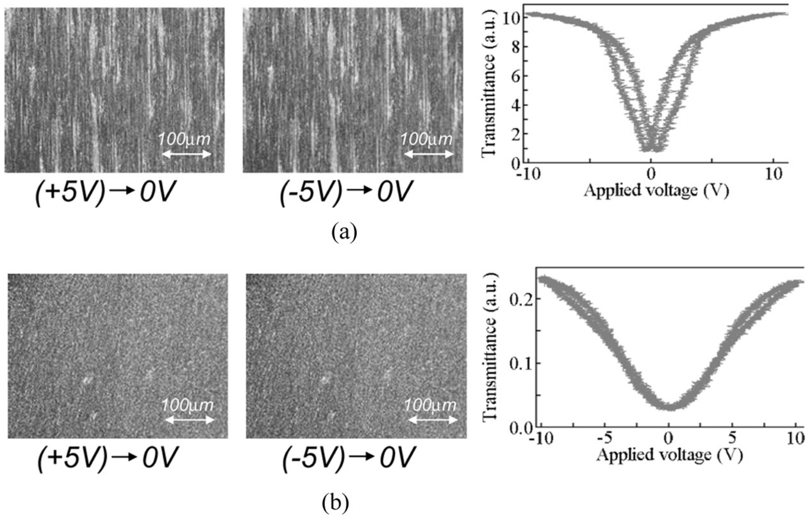


FIGURE 2 Textures and electrooptical characteristics of PSFLC photocured at N phase doped with (a) 5 wt% and (b) 8 wt% polymer.

Figure 3 shows results of X-ray diffraction measurement. It is found that all media have chevron layer structure, and the chevron angles are 24.8°, 25.6°, 24.5°, and 24.6° in the pure FLC, PSFLC photocured at SmA phase (5 wt%), photocured at N phase (5 wt%) and (8 wt%), respectivery. Therefore, the chevron angle of FLC is not changed by photocuring at the N phase, on the other hand, the photocure at the SmA phase increases the chevron angle. Thus, it is found that the molecular alignment structure and the physical properties are largely different in between the PSFLCs photocured at the N and SmA phases.

Table 2 summarizes the properties of PSFLCs. It is found that δ is less than θ and nearly equal to 0.8θ in PSFLC photocured at the N phase as well as a pure FLC. So, the PSFLC photocured at the N phase results in essentially being bistable. The characteristics of PSFLC photocured at the N phase (8 wt% polymer) were monostable-like. It is guessed that the areas, in which FLC molecules are strongly anchored near the polymer, increase as the polymer concentration increases, and finally these areas occupy the whole of the cell. As a result, the PSFLC having a large quantity of polymer can be monostable. Therefore, the mechanism of the PSFLC being monostable even in $\delta = 0.8\theta$ is different from that of PSFLC photocured at the SmA phase.

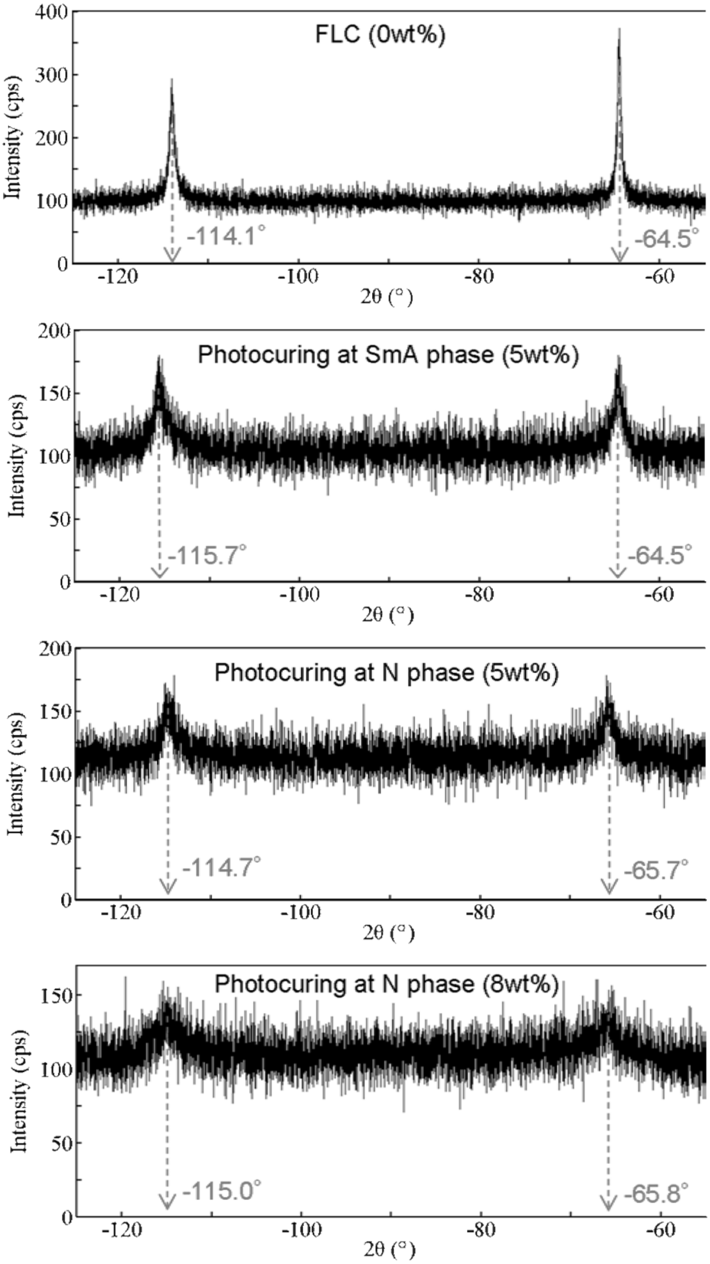
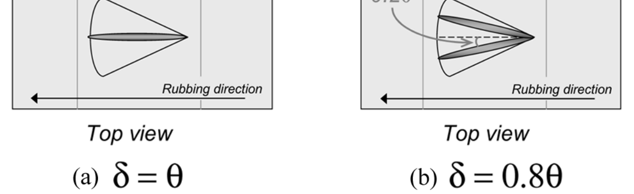


FIGURE 3 X-ray diffraction patterns of FLC and PSFLCs.

TABLE 2 Characteristics of PSFLCs

Phase at photocure (Polymer concentration)	Pure FLC	SmA (5 wt%)	N (5 wt%)	N (8 wt%)
Tilt angle θ	28.5°	26.5°	28.5°	29.5°
Chevron angle δ	24.8°	25.6°	24.5°	24.6°
Relation between θ and δ	$\delta = 0.87\theta$	$\delta = 0.97\theta$	$\delta = 0.86\theta$	$\delta = 0.83\theta$
Texture	uniform	uniform	disarray	disarray
Stability	bistable	monostable	bistable	monostable-like

Figure 4 schematically shows the FLC alignments after the polymerization. In PSFLC photocured at the SmA phase, $\delta = \theta$ and thus FLC molecules align along the rubbing direction as shown in Figure 4(a). This alignment is the only one stable state in the quiescent condition, and therefore this PSFLC shows a monostability and a V-shaped electrooptical performance. However, in the case of $\delta = 0.8\theta$, there are two stable states and then the FLC media are bistable. LC molecules have higher thermal motion without forming layer structure in the N phase. Therefore, it is thought that the orientation of the mesogenic side-chains of polymer photocured at the N phase is in disarray and then the side shains can not stabilize the orientation of FLC molecules to the rubbing direction. As a result, the microscopic texture is in disarray and δ remains less than θ after photocuring at the N phase.



(a) $\delta = \theta$ (b) $\delta = 0.8\theta$

FIGURE 4 Schematic models of molecular alignments in PSFLCs.

4. CONCLUSIONS

In this study, in order to increase the thermal reliability of PSFLCs, we fabricated a new PSFLC photocured at the N phase which is higher temperature phase than the SmA and SmC* phases, and then investigated its characteristics in terms of the electrooptical effect and the X-ray diffraction. As a result, in the PSFLC photocured at the SmA phase, $\delta = \theta$ and therefore this PSFLC shows a monostability. However, in the PSFLC photocured at the N phase, $\delta = 0.8\theta$ where this situation is same as in a pure FLC, and then the PSFLC remains bistable. It is guessed that since LC molecules have higher thermal motion without forming layer structure in the N phase, the orientation of the mesogenic side-chains of polymer is in disarray and then the side-chains cannot stabilize the orientation of FLC molecules to the rubbing direction.

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