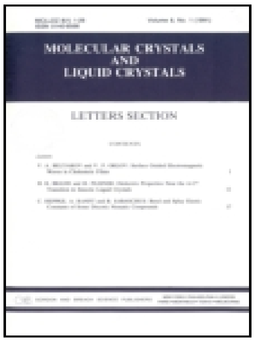

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PSV-FLC Fabricated Using Photo-Alignment Technique

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Polymer-stabilized V-mode Ferroelectric Liquid Crystals (PSV-FLCs) are attractive for a next generation of LC display. However, in the rubbing technique which is conventionally used for LC molecular alignment, the rubbing scratches form on the alignment film surface, and then, the rubbing scratch pattern is clearly observed in the texture of FLC. Therefore, the high contrast ratio cannot be obtained due to the optical leakage. In this research, we introduce the photo-alignment technique to PSV-FLC. As a result, the optical leakage can be largely suppressed by the photo-alignment technique, and thus, the photo-alignment technique is effective to PSV-FLCs.

Keywords ferroelectric liquid crystal; polymer stabilization; PSV-FLC; rubbing; photo-alignment

Introduction

Ferroelectric liquid crystals (FLCs) are attractive for a next generation of LC display (LCD) having high performances such as high-quality moving video image and very low power consumption, because of their unique characteristics such as high-speed response, wide viewing angle and bistability. [1–6] However, the bistability is disadvantageous for LCDs which possess grayscale or full-color capability. In previous papers, [7–19] we reported that polymer-stabilized FLCs (PS-FLCs), in which a photocurable mesogenic monomer is doped into an FLC and UV photocuring is carried out in the SmC* phase under the application of a bipolar AC electric field or in the SmA phase at the quiescent condition, may show monostable and V-shaped electrooptical characteristics with a grayscale capability without a threshold. The PS-FLCs with V-shaped electrooptical characteristics are usually called PSV-FLCs. Many papers concerned with PSV-FLCs photocured in the SmC* phase were published, whereas there have been only few for PSV-FLCs photocured in the SmA phase [16–19] and the characteristics are not known in detail. In this study, we focus on the

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Table 1. Properties of FLC-X

Property	
Phase sequence	SmC*(78.5)SmA(87.1)N* [°C]
Spontaneous polarization	49.5nC/cm^2 (at room temp.)
Tilt angle	30.1° (at room temp.)

PSV-FLCs photocured in the SmA phase. The PSV-FLCs photocured in the SmA phase are expected to obtain a uniform alignment of FLC molecules because the photocure is carried out in the SmA phase which has much more uniform molecular alignment than the SmC* phase. However, there is a fundamental problem for their display application. Although the rubbing technique is conventionally used for the LC molecular alignment, the rubbing scratches form on the alignment film surface. In the case of nematic LC, the rubbing scratch pattern of the LC molecular alignment texture fall into obscurity to some extent because of relatively easy self-assembly of the molecular orientation. On the other hand, the smectic LC forms a layer structure of the molecular alignment, and is relatively similar to crystal. Therefore, the rubbing scratch pattern of the texture is clearly observed, and then, gives rise to the optical leakage. In this research, to suppress the optical leakage and increase the contrast ratio, we introduce the photo-alignment technique to the PSV-FLC.

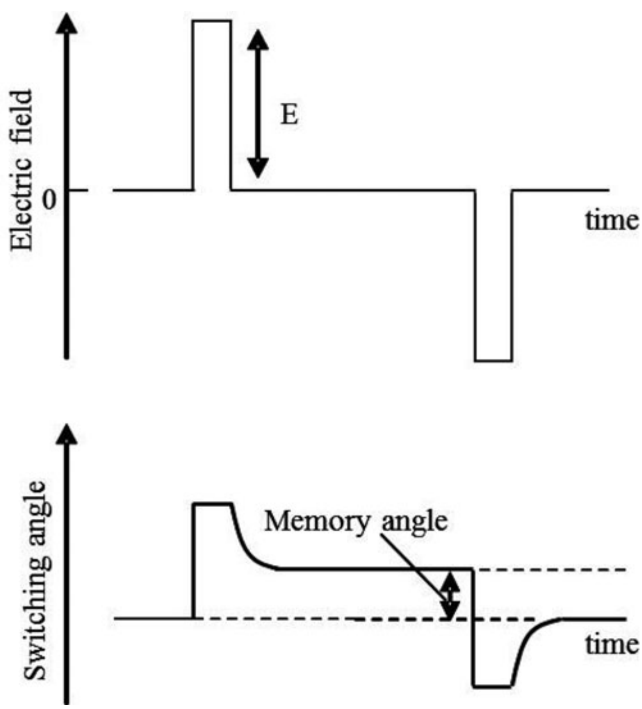

Figure 1. Definition of memory angle.

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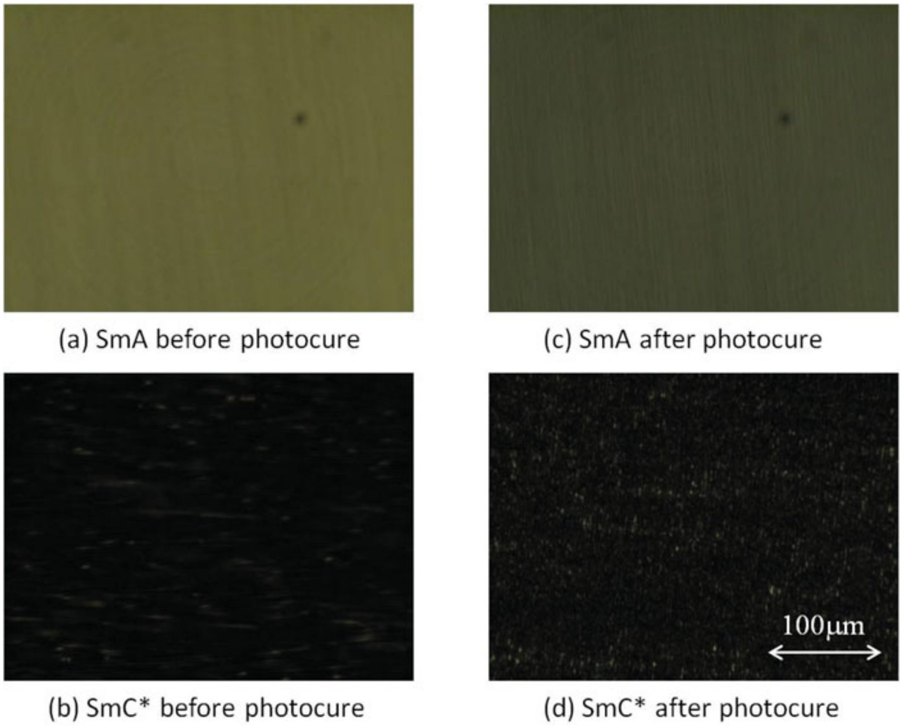

Figure 2. Microscopic textures in FLC cells fabricated using Monomer-A and rubbed RN-1199 alignment films before and after photocure: the photographs of a dark state were taken in the SmC* phase.

Experimentals

The materials used in this research were as follows: the FLC was FLC-X (DIC) with a relatively large tilt angle; the monomers were Monomer-A and 2A363 (DIC) which are photocurable mesogenic diacrylates [16–19]; and the LC alignment films were polyimide RN-1199 and SE-150 (Nissan Chemical Industries) for rubbing technique and PHAL-A (Nissan Chemical Industries) for photo-alignment technique. The relevant properties of FLC-X given by the catalogue are shown in Table 1. The main difference of the monomers used is the existence of alkyl spacer between the main-chain and the mesogenic side-chain of the polymer: Monomer-A has the spacer, but 2A363 does not have any spacer.

A solution of polyimide was spin-coated on glass substrates coated with indium-tin oxide (ITO) and then baked. After the thermal treatment, glass substrates coated with RN-1199 or SE-150 were rubbed and those coated with PHAL-A were irradiated with a non-polarized oblique UV light (254 nm). Then, the FLC, which was doped with the photocurable mesogenic monomer (6 wt%), was injected in the isotropic phase via capillary action into an empty cell, in which the molecular alignment direction and the cell gap were set parallel and 2.0 μm, respectively. Next, the cell was cooled gradually to the SmA phase temperature. After that, UV light irradiation (365 nm) was carried out in the quiescent condition for photocuring the monomers.

PS-FLCs fabricated by above method were observed with a crossed-Nichol polarizing microscope and their electrooptical characteristics were measured with a conventional

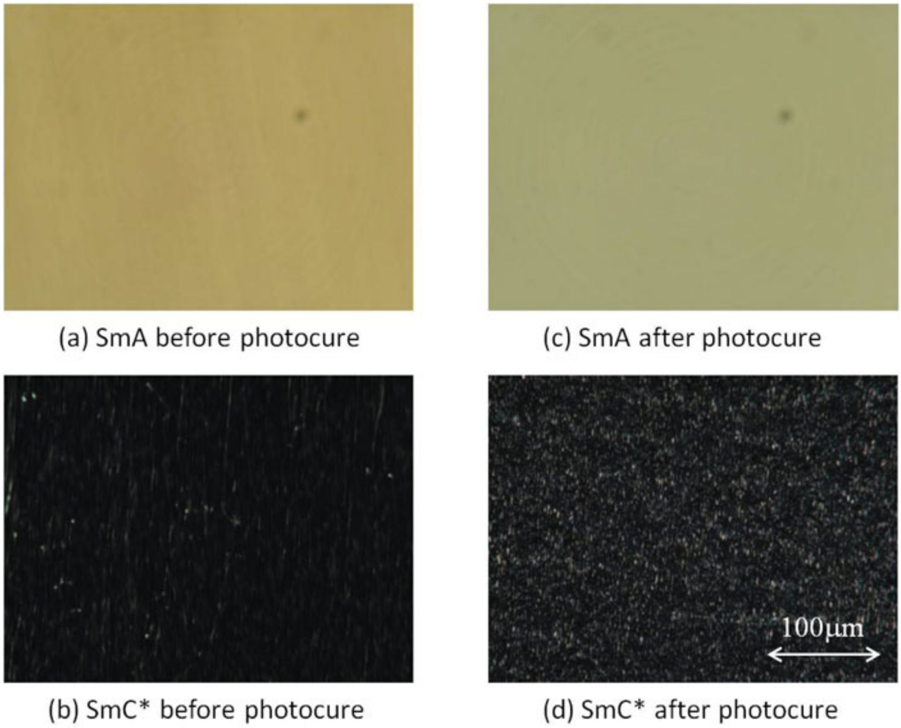

Figure 3. Microscopic textures in FLC cells fabricated using Monomer-A and rubbed SE-150 alignment films before and after photocure: the photographs of a dark state were taken in the SmC* phase.

measuring system based on the polarizing microscope. The photographs of microscopic textures were taken under light situations as the director of LC molecules does not coincide with the polarized optical plane and under dark situations as the director coincides with the polarized plane in the SmA and SmC* phases, respectively. We define the memory angle of FLC molecules as the twice of the apparent tilt angle in the quiescent condition, and the memory angle becomes 0 in the perfect monostable situation. The switching angle (apparent tilt angle) of FLC molecules was calculated from the measurement results of the electrooptical characteristics. The memory angle is defined as the switching angle shown in Fig. 1.

Results and Discussion

Figures 2 and 3 show the microscopic textures in FLC cells fabricated using Monomer-A, and rubbed RN-1199 and SE-150 alignment films, respectively. The rubbing scratch pattern is clearly observed and gives rise to the optical leakage in a dark state. Since the surface topography of RN-1199 alignment film is much more even than that of SE-150 [20], a relatively better alignment can be obtained by using RN-1199. Therefore, the surface topography of alignment film is a very important factor for obtaining the uniform alignment of smectic LC. Figures 4 and 5 show the microscopic textures in FLC cells fabricated using 2A363 monomer, and rubbed RN-1199 and SE-150 alignment films, respectively. It is found that the optical leakage decreases in a dark state after the photocure. It is supposed

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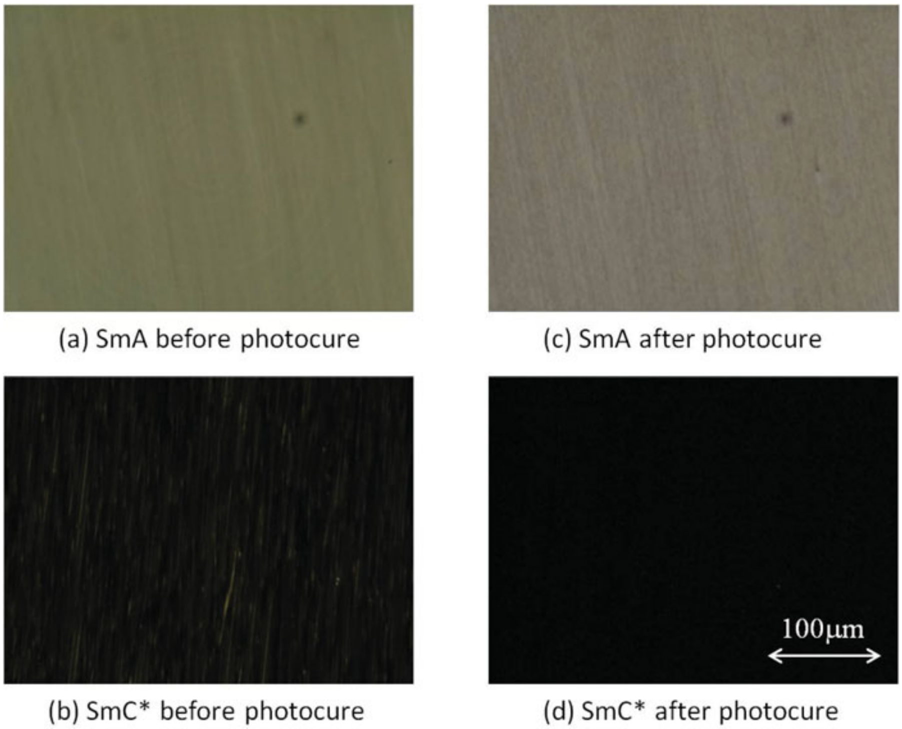

Figure 4. Microscopic textures in FLC cells fabricated using 2A363 monomer and rubbed RN-1199 alignment films before and after photocure: the photographs of a dark state were taken in the SmC* phase.

that since 2A363 does not have alkyl spacers, the polymer is more rigid and the polymer anchoring strength is much higher than Monomer-A. As a result, the uniform alignment in the SmA phase can be strongly stabilized even in the SmC* phase.

In order to suppress the optical leakage and increase the contrast ratio, we introduce the photo-alignment technique to PSV-FLC. Figure 6 shows the microscopic textures in FLC cells, which were fabricated using rubbing and photo-alignment films, during the phase transition from the isotropic liquid to the nematic phase. It is obviously seen that the nematic LC droplets appear randomly in the photo-alignment FLC cell, whereas the droplets align due to rubbing scratches in the rubbing cell. Figures 7 and 8 show the microscopic textures in FLC cells fabricated using PHAL-A photo-alignment films, and Monomer-A and 2A363 monomer, respectively. It is found that the more uniform alignment without the rubbing scratch pattern can be obtained and the optical leakage can be considerably suppressed by utilizing the photo-alignment technique. Table 2 shows the optical transmittance in the dark state and the memory angle of PSV-FLC after the photocure. The transmittance shown in Table 2 is normalized as the ratio to the transmittance in the isotropic liquid phase. It is confirmed that the transmittance decreases and the considerably uniform alignment can be obtained by using the photo-alignment films. Furthermore, it is found that in the case of using 2A363, the transmittance decreases after the photocure. On the other hand, in the case of using Monomer-A, the transmittance tends to increase after the photocure because the polymer usually disarranges the LC molecular alignment structure. It is thought that since

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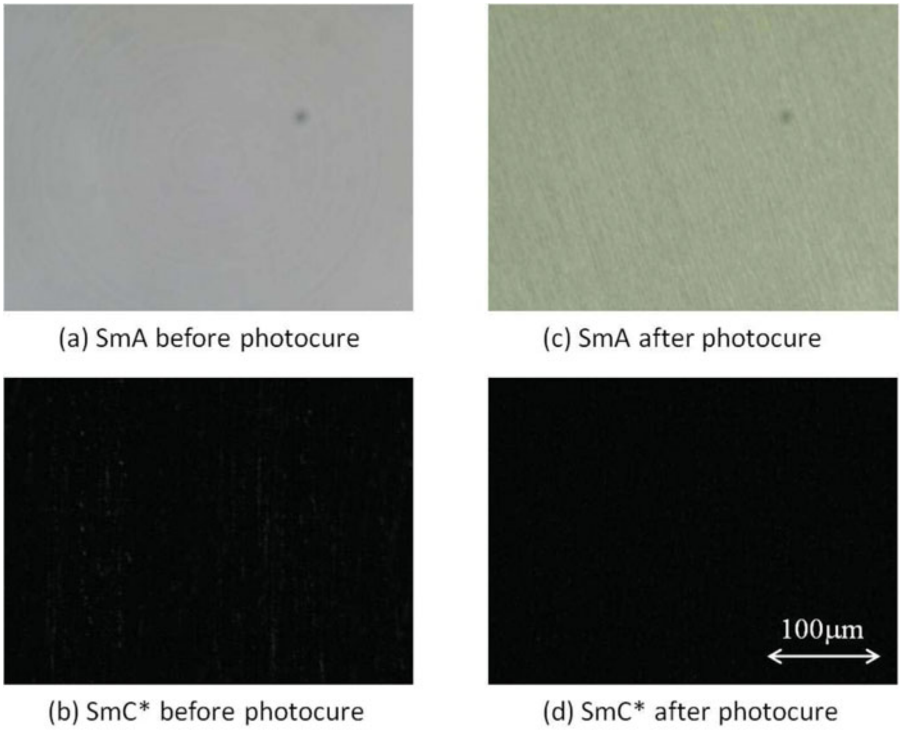

Figure 5. Microscopic textures in FLC cells fabricated using 2A363 monomer and rubbed SE-150 alignment films before and after photocure: the photographs of a dark state were taken in the SmC* phase.

the polymer anchoring of 2A363 is strong due to alkyl spacer less, the uniform alignment in the SmA phase can be strongly stabilized after the UV photocure, as mentioned above. Furthermore, since the unidirectional alignment in the SmA phase can be strongly stabilized by using 2A363, the memory angle in the case of 2A363 is lower than that of Monomer-A.

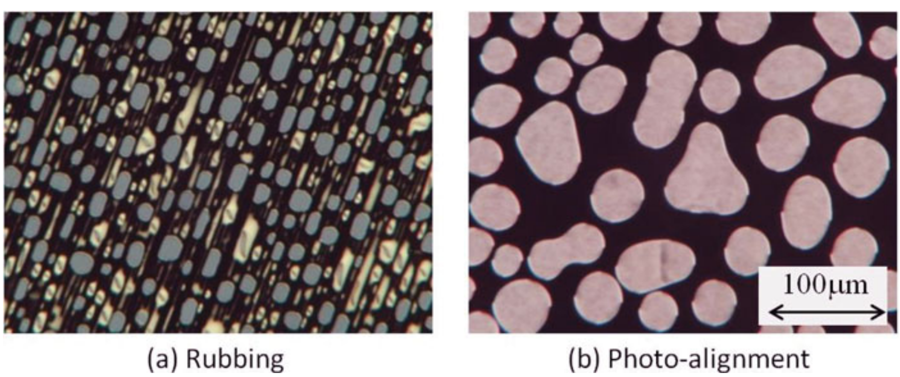

Figure 6. Microscopic textures in FLC cells fabricated using rubbing and photo-alignment films during phase transition from isotropic liquid to nematic phase (95°C).

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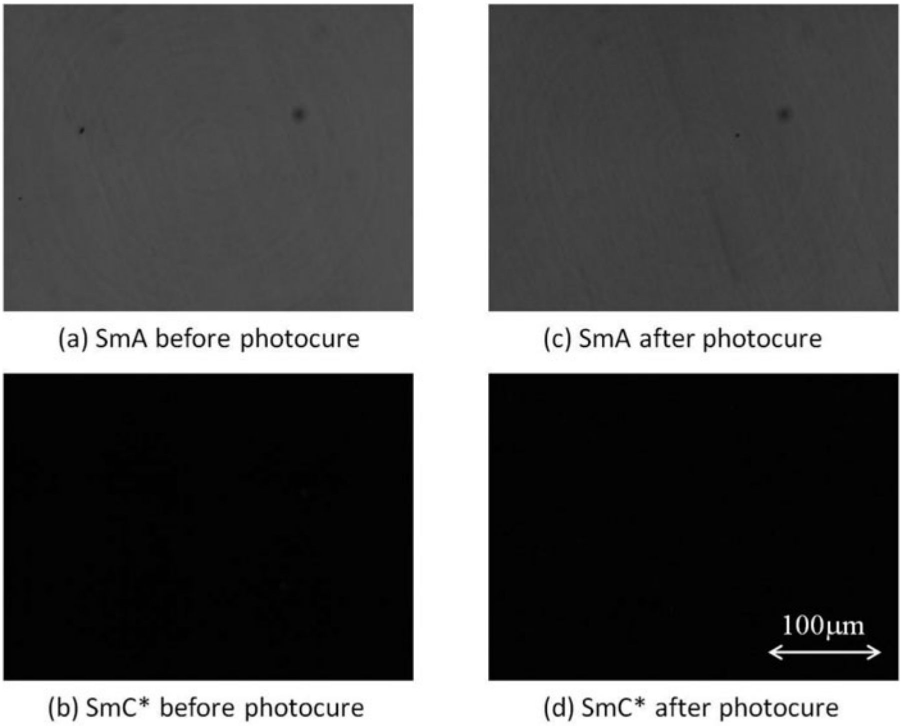

Figure 7. Microscopic textures in FLC cells fabricated using Monomer-A and PHAL-A photo-alignment films before and after photocure: the photographs of a dark state were taken in the SmC* phase.

Table 2. Transmittance and memory angle of PSV-FLCs fabricated by using several alignment films and monomer materials: the transmittance is normalized as the ratio to the transmittance in the isotropic liquid phase

Alignment film	Monomer materials	Transmittance: Before photocure	Transmittance: After photocure	Memory angle After photocure
RN-1199 (rubbing)	Monomer-A	10.5	13.9	0.70°
RN-1199 (rubbing)	2A363	12.7	9.0	0.54°
SE-150 (rubbing)	Monomer-A	10.6	15.5	0.77°
SE-150 (rubbing)	2A363	9.4	8.7	0.71°
PHAL-A (photo)	Monomer-A	7.3	7.1	0.66°
PHAL-A (photo)	2A363	11.2	6.7	0.55°

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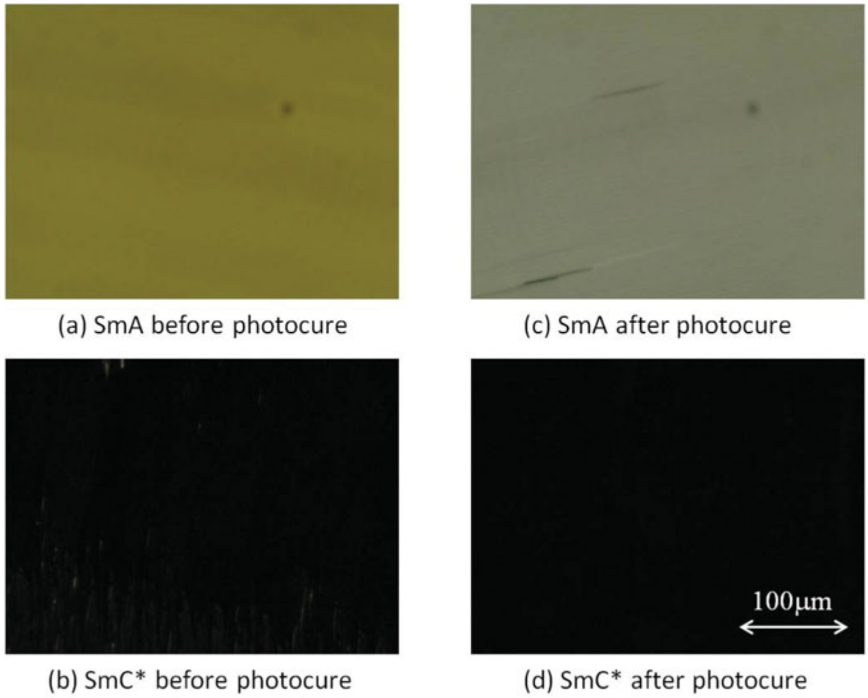

Figure 8. Microscopic textures in FLC cells fabricated using 2A363 monomer and PHAL-A photo-alignment films before and after photocure: the photographs of a dark state were taken in the SmC* phase.

Conclusions

In the rubbing technique which is conventionally used for LC molecular alignment, the rubbing scratches form on the alignment film surface, and then, the rubbing scratch pattern and optical leakage are clearly observed in the texture of PSV-FLC. In this study, to suppress the optical leakage and increase the contrast ratio, we introduce the photo-alignment technique to PSV-FLC. As a result, it is found that the more uniform molecular alignment without the rubbing scratch pattern can be obtained. Furthermore, in the case of using 2A363 monomer which does not have alkyl spacers, the considerably uniform texture with low optical leakage and the low memory angle can be obtained because the strong polymer anchoring can be stabilized the unidirectional alignment structure in the SmA phase.

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