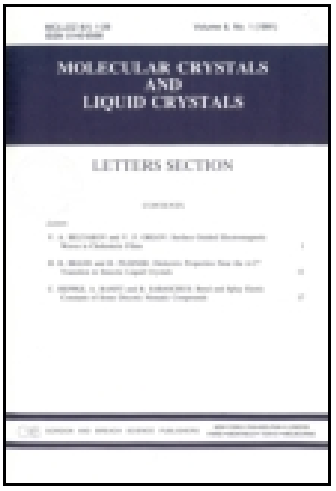

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Tsubasa Shime[a], Mana Amano[a], Ikuri Shimokawa[a], Shinichiro Oka[b], Shinichi Komura[b], Shunsuke Kobayashi[c] & Hirokazu Furue[a]

[a] Department of Materials Science and Technology, Tokyo University of Science, Katsushika, Tokyo, Japan

[b] R&D Division, Japan Display, Mobara, Chiba, Japan

[c] Liquid Crystal Institute, Tokyo University of Science, Yamaguchi, Sanyoonoda, Yamaguchi, Japan

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Study on Fabrication Conditions of Polymer-Stabilized V-Mode FLCD

TSUBASA SHIME,[1,*] MANA AMANO,[1] IKURI SHIMOKAWA,[1] SHINICHIRO OKA,[2] SHINICHI KOMURA,[2] SHUNSUKE KOBAYASHI,[3] AND HIROKAZU FURUE[1]

[1]Department of Materials Science and Technology, Tokyo University of Science, Katsushika, Tokyo, Japan
[2]R&D Division, Japan Display, Mobara, Chiba, Japan
[3]Liquid Crystal Institute, Tokyo University of Science, Yamaguchi, Sanyoonoda, Yamaguchi, Japan

In this research, we focus on the polymer-stabilized V-mode FLC (PSV-FLC) in which a doped monomer is photocured in the SmA phase. PSV-FLC may show monostable and V-shaped electrooptical characteristics with a grayscale capability. In this paper, we investigate the dependence of the monostable capability on the fabricating conditions such as monomer materials, polymer concentration, and UV energy. Furthermore, in order to increase the contrast ratio, we introduce a photo-alignment technique. As a result, it is found that the monostable capability of PSV-FLC strongly depends on their conditions. Furthermore, the more uniform molecular alignment without rubbing scratch pattern was obtained by using the photo-alignment film.

Keywords Ferroelectric liquid crystal; polymer stabilization; photocure; monostability; memory angle; 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 [7–18], 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 [16–18] and the characteristics are not known in detail. In this study, we focus on the

*Address corresponsence to Tsubasa Shime, Department of Materials Science and Technology, Tokyo University of Science, Katsushika, Tokyo 125-8585, Japan. Tel.: +81-3-5876-1717; Fax: +81-3-5876-1614. E-mail: hfurue@rs.noda.tus.ac.jp

Table 1. Properties of FLC-X

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

Table 2. Characteristics of monomers used in this research : the monomer has an alkyl spacer between the main chain and mesogenic side chain in polymer

	Characteristics
Monomer-A	long alkyl spacer, large molecular weight
Monomer-C	short alkyl spacer
Monomer-D	middle alkyl spacer

Table 3. Monomer materials dependence of memory angle

	Memory angle (deg.)
Monomer-A	0.6
Monomer-C	0.8
Monomer-D	0.8

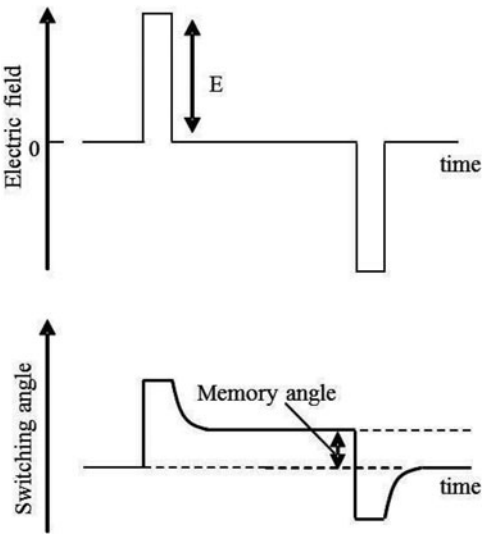

Figure 1. Definition of memory angle.

Table 4. Polymer concentration dependence of memory angle in Monomer-A

Polymer concentration	Memory angle (deg.)
2 wt%	1.5
4 wt%	0.5
6 wt%	0.6

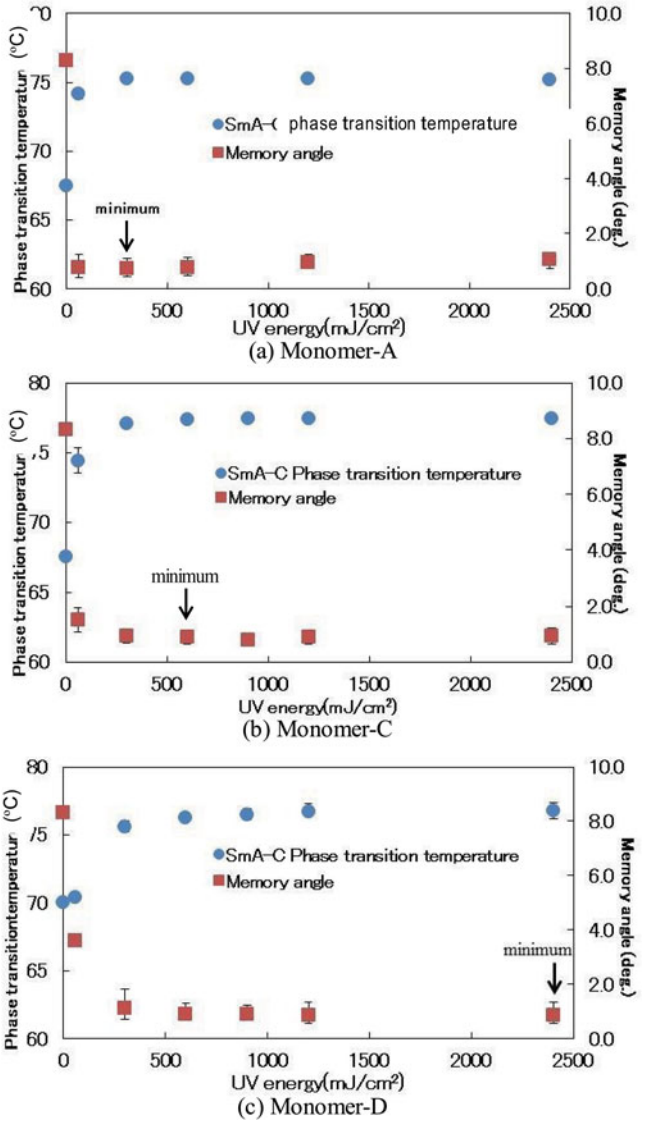

Figure 2. Photocuring time dependence of phase transition temperature and memory angle in PS-FLC cells fabricated using RN-1199 alignment films: UV intensity is 20 mW/cm2.

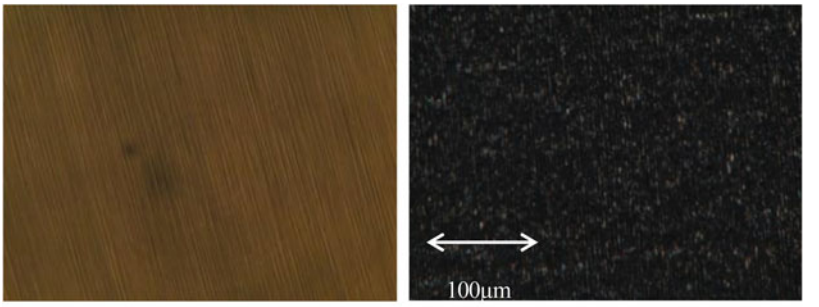

Figure 3. Microscopic textures in a PSV-FLC cell fabricated using RN-1199 rubbing films.

PSV-FLCs photocured in the SmA phase since the fabrication process and conditions are not relatively complicated, and research in detail how the fabrication conditions of PSV-FLCs such as photocuring time (UV energy), polymer materials and polymer concentration influence the monostable capability. Furthermore, in order to increase the contrast ratio, we introduce a photo-alignment technique.

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, -C and -D (DIC) which are photocurable mesogenic diacrylates [18]; and the LC alignment films were polyimide RN-1199 and SE-150 (Nissan Chemical Industries) for rubbing and photo-alignment technique, respectively. The relevant properties of FLC-X given by the catalogue, and the characteristic difference of the monomers used are shown in Table 1 and 2, respectively.

A solution of polyimide was spun on glass substrates coated with indium-tin oxide (ITO) and then baked. After the thermal treatment, glass substrates coated RN-1199 were rubbed and those coated SE-150 were irradiated with a non-polarized oblique UV light (254 nm, 5 mW/cm^2). 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

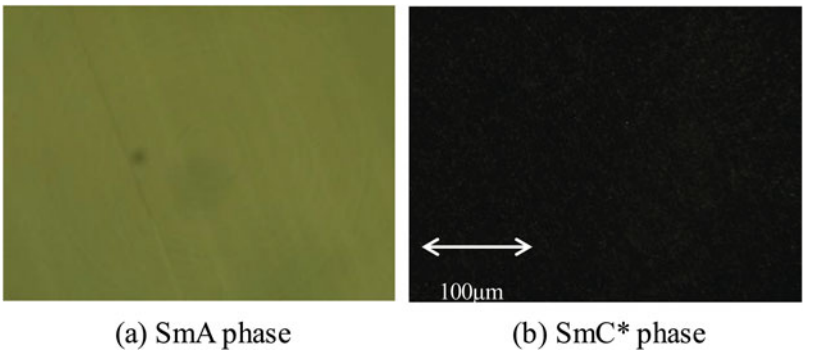

Figure 4. Microscopic textures in a PSV-FLC cell fabricated using SE-150 photo-alignment films.

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, 20 mW/cm^2) was carried out in the quiescent condition for photocuring the monomers.

PS-FLCs fabricated by above method were observed with a polarizing microscope and their electrooptical characteristics were measured with a conventional measuring system. 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 in Fig. 1.

Results and Discussion

Figure 2 shows the photocuring time (UV energy) dependence of the phase transition temperature and the memory angle in PS-FLC cells fabricated using rubbed RN-1199 alignment films and 6 wt% monomer. It is found that the phase transition temperature saturates at the early stage of photocuring. Therefore, the phase separation of LC / polymer almost finishes at the early stage of photocuring. On the other hand, the memory angle takes minimum at a certain UV energy, although it almost saturates similarly to the phase transition temperature. It is guessed that in the case of the long time photocure, the molecular weight of the polymer may become large during the photocure and the polymer network may exist bulky. As a result, although the region near the polymer can be monostable, that far from the polymer remains bistable. Furthermore, it is found that the optimum UV energy is different between the monomer materials. Therefore, the UV energy is an important factor for the fabrication of monostable PSV-FLC. Table 3 shows the minimum memory angle measured from Fig. 2. It is found that the polymer anchoring strength of the Monomer-A is stronger than those of Monomer-C and -D. It is guessed that since the molecular weight of Monomer-A is relatively large, its polymer network is more rigid.

Table 4 shows the polymer concentration dependence of the memory angle in PS-FLC cells fabricated using rubbed RN-1199 alignment films and Monomer-A. It is found that the memory angle becomes nearly 0 in the case of the polymer concentration is 4 wt% or more. On the other hand, the higher the concentration of polymer is, the higher the driving voltage is. Therefore, it is concluded that the 4 wt% concentration of Monomer-A is the optimum condition for the fabrication of monostable PSV-FLC.

Figure 3 shows the microscopic textures in a PSV-FLC cell fabricated using rubbed RN-1199 alignment films and 4 wt% Monomer-A. The rubbing scratch pattern is clearly observed and gives rise to the optical leakage. In order to suppress the optical leakage and increase the contrast ratio, we introduce the photo-alignment technique to PSV-FLC. Figure 4 shows the microscopic textures in a PSV-FLC cell fabricated using SE-150 photo-alignment films and 4 wt% Monomer-A. It is found that the more uniform alignment without the rubbing scratch pattern can be obtained by utilizing the photo-alignment technique.

Conclusions

In this research, in order to realize PSV-FLCs having monostability, we investigated the memory characteristics of PSV-FLCs photocured in the SmA phase. It is found that the UV energy is an important factor for the fabrication of monostable PSV-FLC. Furthermore, it is found that the monomer having larger molecular weight is suitable for the monostabilization

of PS-FLC, because the large monomer can form the rigid polymer and increase the polymer anchoring strength after the polymerization. Moreover, in this study, in order to increase the contrast ratio, we try to 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.

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