Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

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Version of record first published: 05 Oct 2009

To cite this article: Hirokazu Furue, Hiroaki Tsuda & Kohei Yagihara (2009): Reorientational Motion of Polymer-Stabilized Ferroelectric Liquid Crystals, Molecular Crystals and Liquid Crystals, 508:1, 267/[629]-273/[635]

To link to this article: http://dx.doi.org/10.1080/15421400903065721

Mol. Cryst. Liq. Cryst., Vol. 508, pp. 267/[629]–273/[635], 2009

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400903065721

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Reorientational Motion of Polymer-Stabilized Ferroelectric Liquid Crystals

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A polymer-stabilized ferroelectric liquid crystals (PSFLCs), in which photocurable mesogenic monomers are doped into an FLC and then a UV photocure is carried out in the SmC phase under the application of a bipolar AC electric field, can exhibits monostable and V-shaped electrooptical characteristics. In this research, the time-resolved ellipsometry is applied to the PSFLCs, and we investigate the dependence of the molecular reorientational motion of the PSFLC on the photocuring condition such as the tilt angle which FLC molecules take in the photocure stage. The measurement results show that the dynamic behavior of PSFLC-molecular reorientation strongly depends on the photocuring condition of the tilt angle in addition to the concentration of polymer. Furthermore, the molecular reorientation of the PSFLC is 2-steps motion originated in the difference of the threshold voltage between near and far from polymer.*

Keywords: ferroelectric liquid crystal; photocure; polymer stabilization; reorientation; tilt angle

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.

The authors thank Mr. H. Fukuro and Mr. H. Endoh of Nissan Chem. Ind. for supplying polyimide materials. We also thank to Dr. H. Takatsu and Dr. H. Hasebe of Dainippon Ink and Chemicals for supplying photocurable mesogenic materials.

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Therefore, it is necessary to substitute the conventional nematic LC with a new LC material in order to realize a high-quality display of a moving 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 (PS) FLCs fabricated by 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 an electric field [6–11]. A PSFLC photocured under the application of a monopolar electric field exhibits monostable and asymmetric electrooptical characteristics with grayscale capability without a threshold [6–9]. On the other hand, A PSFLC photocured under the application of a bipolar AC electric field shows a symmetric V-shaped performance [10,11]. Although numerous studies mainly concerned with the application research of PSFLC have been reported, it has not been clarified in detail yet how polymer stabilization influences the dynamic behavior of molecular reorientation for an electric field. The reorientational motion of FLC molecules can be investigated in terms of two independent optical parameters concerned with elliptically polarized light: the phase difference angle Δ and the angle of the relative amplitude ratio Ψ measured with time-resolved ellipsometry [12]. It is known that Δ and Ψ depend mainly on the out-of-plane and in-plane molecular motion for the cell substrate surface, respectively. The in-plane angle of the molecular alignment direction (*i.e.,* the apparent tilt angle) can be obtained from the value of Ψ [13]. In this study, the time-resolved ellipsometry is applied to the PSFLCs, and we research the effect of polymer stabilization on the dynamic behavior of molecular reorientation.

EXPERIMENTALS

The materials used in this research were as follows: the FLC was FELIX-M4851/100 (Clariant Japan); the photocurable mesogenic diacrylate was 2A363 (Dainippon Ink and Chemicals), 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 C_2-chevron structure [14,15]. The relevant properties of FELIX-M4851/100 given in the catalogue are shown in Table 1.

TABLE 1 Properties of FELIX-M4851/100

Properties	
Phase sequence	Cryst.(<−20) SmC*(67) SmA(71) N*(76) Iso. [°C]
Spontaneous polarization	22.8 nC/cm^2 (20°C)
Tilt angle	30.5° (20°C)
Switching time	38 μs (E = 15 V/μm, 20°C)

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 and the cell gap were set parallel and 2 μm, respectively. The concentration of the diacrylate was set at 3, 5, or 8 wt%. Next, the cell was cooled gradually to the temperature where the LC medium was in the SmC* phase whose tilt angle was 5, 15, or 25°, as shown in Figure 1. Then, the LC medium was photocured with a UV light source (365 nm, 2mW/cm^2) under the application of a bipolar square-pulsed AC electric field (±5 V/μm, 100 Hz).

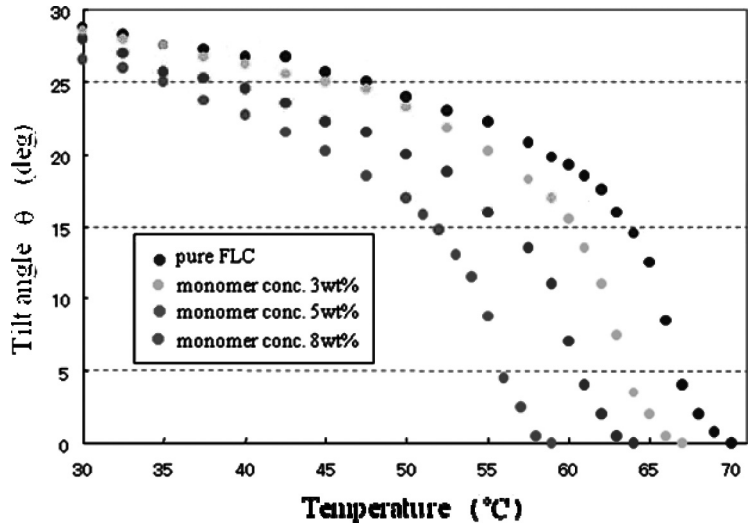

FIGURE 1 Temperature dependence of tilt angle in FLC media used in this research before UV photocure.

The transmission time-resolved spectroellipsometry measurement was performed with a polarization modulation ellipsometer ELC-300 (JASCO) with a 20μs time resolution. The applied electric field into the cell fabricated by the above method was a triangular-wave electric field (1 Hz). The measurement was carried out at the temperature T where $T_C - T = 10^\circ$C (Tc is the SmA to SmC* phase transition temperature).

RESULTS AND DISCUSSION

Figure 2 shows the time-dependent variations of the apparent tilt angle in a pure FLC. It is found that the apparent tilt angle arrangement due to the application of a triangular-wave electric field does not almost change at higher amplitude than 3 V. Figure 3 shows the time-dependent variations of the apparent tilt angle in the PSFLCs doped with 3 wt% 2A363. It is found that the apparent tilt angle arrangement of PSFLC is different from that of the pure FLC, and moreover can be varied by the photocuring condition of the tilt angle. The effect of the polymer stabilization on the reorintational motion of FLC molecules increases as the tilt angle which FLC has taken during

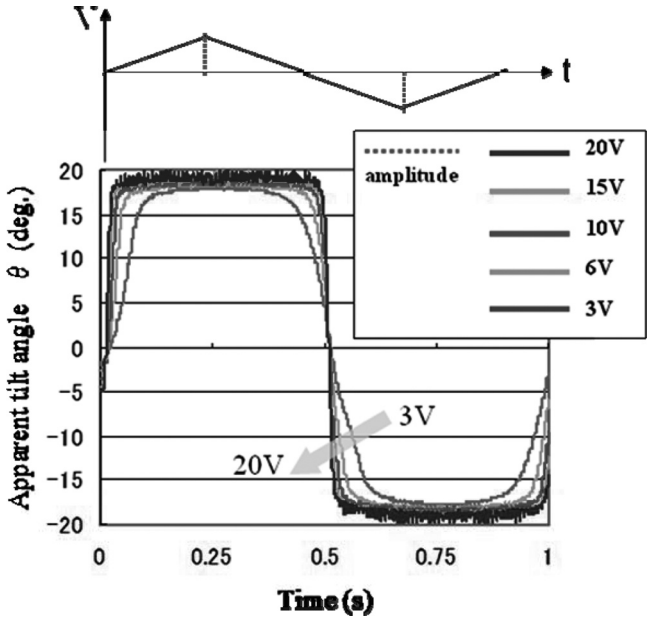

FIGURE 2 Time-dependent variations of apparent tilt angle in pure FLC.

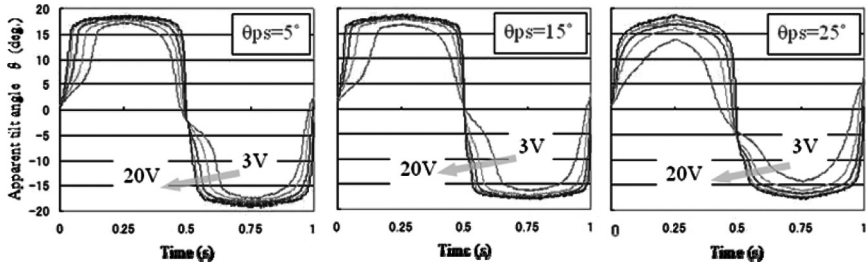

FIGURE 3 Time-dependent variations of the apparent tilt angle in PSFLCs doped with 3 wt% 2A363: θps is the tilt angle which FLC molecules have when the photocure is carried out.

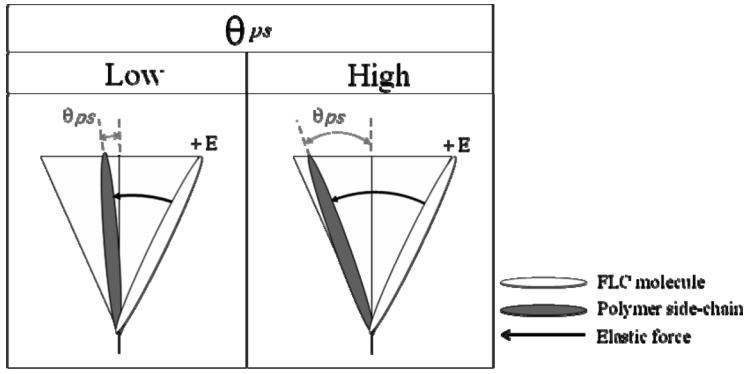

FIGURE 4 Alignment structure models of PSFLCs under the application of an electric field: PSFLCs are photocured at the conditions of a low and high tilt angles θps.

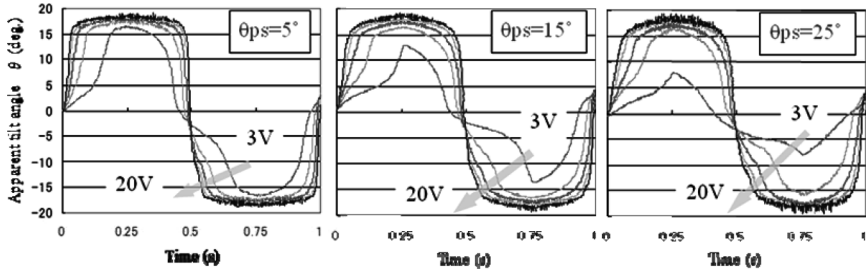

FIGURE 5 Time-dependent variations of the apparent tilt angle in PSFLCs doped with 5 wt% 2A363.

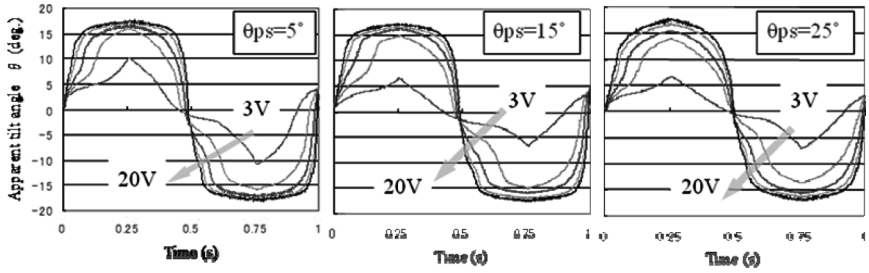

FIGURE 6 Time-dependent variations of the apparent tilt angle in PSFLCs doped with 8 wt% 2A363.

the photocure increases. Therefore, the photocuring condition of the tilt angle is an important factor to control the performance of PSFLC. Figure 4 illustrates the alignment structure models of PSFLCs which are photocured at the conditions of a low and high tilt angles θps. It is thought that since the elastic force originated with the mesogenic side-chains of polymer increases as θps increases, the above results would be obtained. Furthermore, in Figure 3, it is found that the molecular reorientation of PSFLC is 2-steps motion. It is guessed that this is due to the difference of the threshold voltage between near and far from polymer. Figures 5 and 6 show the time-dependent variations of the apparent tilt angle in the PSFLCs doped with 5 and 8 wt% 2A363, respectively. It is found that the higher the polymer concentration is, the stronger the effect of polymer stabilization is. As a result, the two-steps reorientational motion can be obviously observed in higher polymer concentration and lower amplitude of electric field.

CONCLUSIONS

The dynamic reorientational motion of PSFLC molecules has been investigated in terms of the apparent tilt angle obtained from the data of Ψ measured with the time-resolved transmission ellipsometry. The apparent tilt angle arrangement due to the application of a triangular-wave electric field can be varied by the photocuring condition of the tilt angle, and the effect of the polymer stabilization on the reorintational motion of FLC molecules increases as the tilt angle θps increases. This is because that the elastic force originated with the mesogenic side-chains of polymer increases as θps increases. Furthermore, for the first time, it is confirmed that the molecular reorientation of PSFLC is 2-steps motion. It is guessed that this is due to the difference of the threshold voltage between near and far from polymer.

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