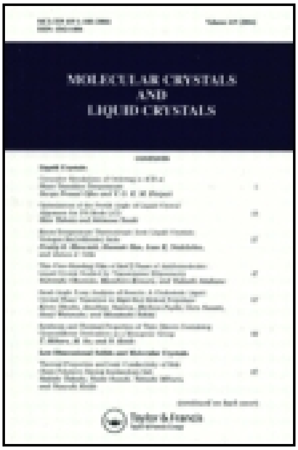

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The Influence of Alkyl Spacer on Helical Structure of Polymer-Stabilized Ferroelectric Liquid Crystals

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The Influence of Alkyl Spacer on Helical Structure of Polymer-Stabilized Ferroelectric Liquid Crystals

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Polymer stabilization is a technique for stabilizing a liquid crystal molecular orientation. The effect of polymer stabilization on the helical structure of FLCs can be analyzed by the observation of the conoscopic figures of polymer-stabilized ferroelectric liquid crystals (PSFLCs) obtained from the computer simulation and the experiment. In this study, we investigate the conoscopic figures of PSFLCs fabricated using a new acrylate polymer having an alkyl spacer part between main- and mesogenic side-chain. The strength of polymer stabilization originated in the side-chain becomes lower due to the alkyl spacer. Although the polymer stabilization usually increases the threshold electric field, the increase may be controlled by utilizing a suitable spacer.

Keywords: alkyl spacer; conoscope; ferroelectric liquid crystal; helical structure; polymer stabilization

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 beautiful 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 of

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a moving image. A leading candidate is ferroelectric liquid crystal (FLC) [1]. Surface-stabilized (SS) FLCs are attractive because of their unique characteristics such as high-speed response, wide viewing angle and bistability [2–4]. Although the bistability is suitable for passive matrix-addressed displays, it is disadvantageous for LCDs which possess grayscale or full-color capability [5].

Polymer stabilization has been studied extensively as an attractive technique that may realize a monostable SSFLC with a gray-scale capability [6]. However, a problem of polymer stabilization is the increase of the threshold electric field. In this study, we fabricate a new type PSFLC with a polymer having an alkyl spacer part between main- and mesogenic side-chain and investigate the effect of the alkyl spacer on the polymer anchoring strength by the comparison of the conoscopic figures between the experimental and the computer simulation results.

2. EXPERIMENTALS AND COMPUTER SIMULATION

2.1. Experimental Method

An FLC material used in this research was FELIX-M4851/100 (Clariant), an alignment film was SE1211 (Nissan Chem.) which can produce a homeotropic LC alignment, and a mesogenic monomers were UCL-001 (Dainippon Ink Chem.) [6] and LC-1 (Nissan Chem.). LC-1 is a mesogenic monoacrylate having an alkyl spacer part, as shown in Figure 1, while UCL-001 dose not have the spacer. The relevant properties of FELIX-M4851/100 given by the catalogue are shown in Table 1.

Homeotropically aligned FLC cells for conoscope measurements were fabricated using glass substrates coated with SE1211. Two pieces of aluminum plate were used as spacers and electrodes for the cell. The cell thickness was 200 μm. The FLC medium doped with the mesogenic monomer was injected into the empty cell, and then the medium

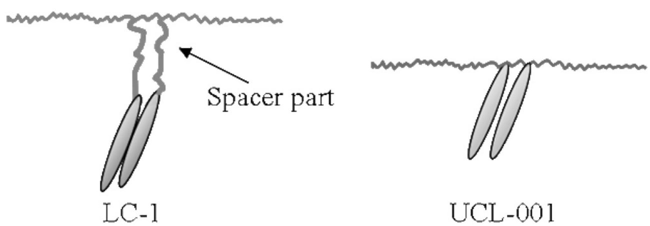

FIGURE 1 Schematic molecular structure of polymers used in this research.

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)

was photocured with UV light source (365 nm, 2mW/cm^2) under zero bias field. After UV irradiation, we observed conoscopic figures with a polarizing microscope. An electric field was applied in parallel to the smectic layer and along the 45° direction relative to the polarized planes of the crossed Nichols polarizers.

2.2. Computer Simulation

The molecular alignment under an electric bias field was numerically calculated from the free energy density on the basis of a continuum theory [7–13]. The free energy density of FLCs (g) is expressed as [13]

$$g = \frac{1}{2}K\left\{\frac{\partial\phi}{\partial z} - q_0\right\}^2 - \frac{1}{2}Kq_0^2 - P_S E\cos\phi + \frac{1}{2}\varepsilon_0\varepsilon_a(E\sin\phi)^2, \qquad (1)$$

where K, ϕ, q_0, P_s, E, ε_0, and ε_a are an elastic constant for the twist deformation of the c-director, an azimuthal angle of the c-director, a parameter describing a spontaneously twisting structure, a spontaneous polarization, an electric field, the vacuum dielectric constant and a dielectric anisotropy, respectively. As assigning the Eq. (1) to Euler-Lagrange equation, the following expression is obtained,

$$K\frac{d^2\phi}{dz^2} - P_S E\sin\phi + \frac{1}{2}\varepsilon_0\varepsilon_a E^2\sin\phi\cos\phi = 0, \qquad (2)$$

where the z-axis is set parallel to the helical axis, that is the smectic layer normal. The conoscopic figure was simulated using the distribution of ϕ by 4×4 matrix method [14]. It is guessed that the value of K may increase in the PSFLC rather than the conventional pure FLC. For the polymer anchoring strength, we investigated the value of K from the comparison between the conoscopic figures obtained by the experiment and the computer simulation.

3. RESULTS AND DISCUSSION

Figure 2 shows photographs of the conoscopic figures in FLC media, in which the tilt angles of all media are same. It is confirmed that the helical structure does not change in the quiescent condition even if the polymer is introduced. Under the application of an electric field, the center of the conoscopic figure can shift to the normal direction to the electric field. However, the degree of the shift in PSFLC is less than that in the conventional FLC under a same electric field, and then the threshold electric field to unwind the helical structure (E_C) is higher in PSFLC. Therefore, this means that the helical structure can be stabilized by polymer networks. Furthermore, it is found that the threshold of PSFLC with LC-1 is lower than that with UCL-001.

Figure 3 shows an example of the simulation result of the conoscopic image. Under the application of an electric field, the center of the conoscopic figure can shift as well as the experimental results. It is found that the biaxiallity having an optic plane parallel to the direction of the electric field increases as the elastic constant K increases. In order to quantitatively investigate the biaxiallity, we define the biaxiallity B as the ratio of the distance between top and bottom of melatope to that between left and right sides of melatope, as shown in Figure 4. Figure 5 shows the electric field dependence of B obtained from the simulation results of conoscopic figures. It is confirmed that the biaxiallity increases as the elastic constant increases. Figure 6 demonstrates the electric field dependence of B obtained from the

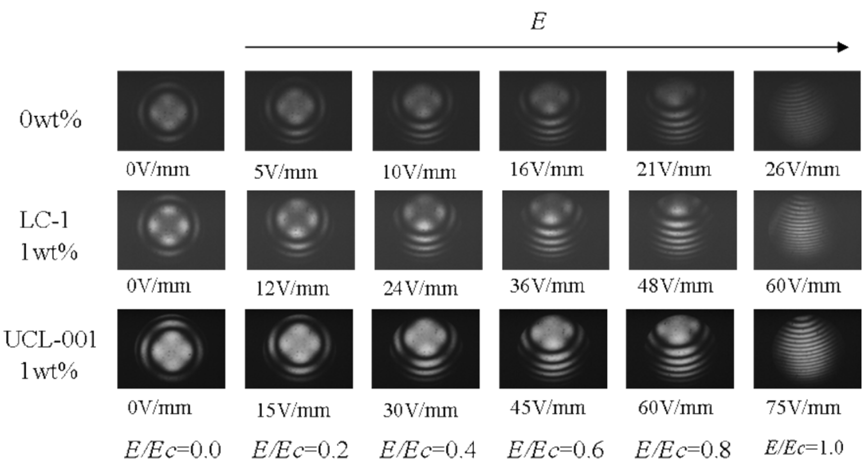

FIGURE 2 Conoscopic figures of FLC media: for the condition, all media have same tilt angle. E_C means the threshold electric field.

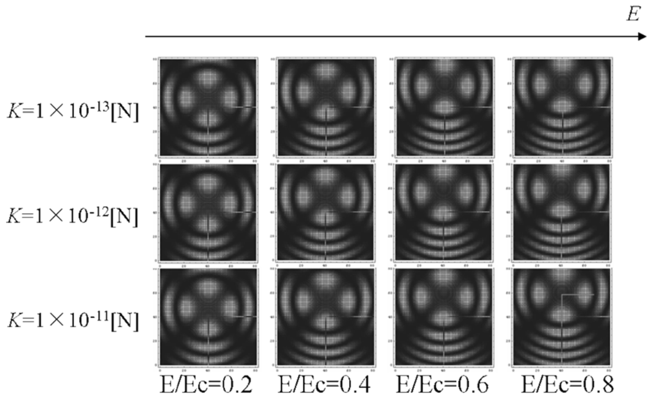

FIGURE 3 An example of simulation result of conoscopic image: *K* is the elastic constant.

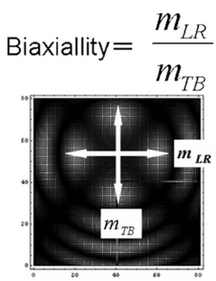

FIGURE 4 Definition of biaxiallity.

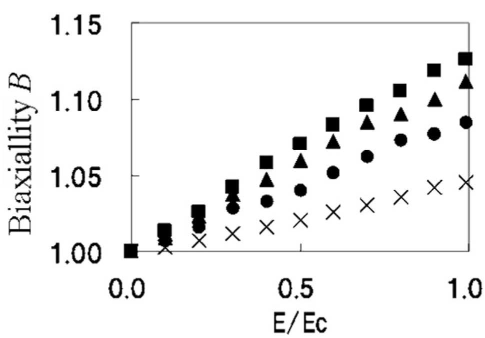

FIGURE 5 Electric field dependence of biaxiallity measured from simulation results.

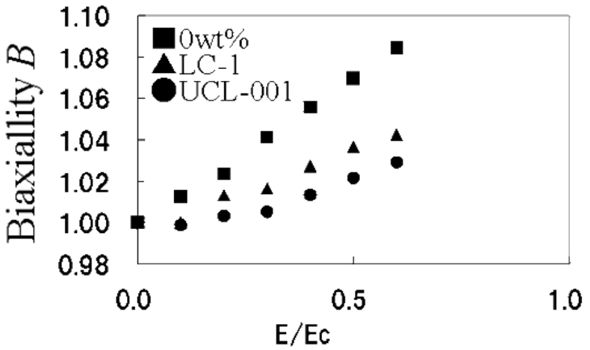

FIGURE 6 Electric field dependence of biaxillity measured from experimental results.

experimental results. It is found that the biaxiallity tends to increase due to polymer stabilization. Figure 7 shows the fitting results between the experimental and the simulation results. From the fitting, we can obtain the elastic constant. It is found that the elastic constant of PSFLC with UCL-001 increases in different classes due to the addition of the polymer anchoring strength even in a few polymer concentration. On the other hand, in the case of LC-1, the enormous increase of the elastic constant in PSFLC can be suppressed by the alkyl spacer.

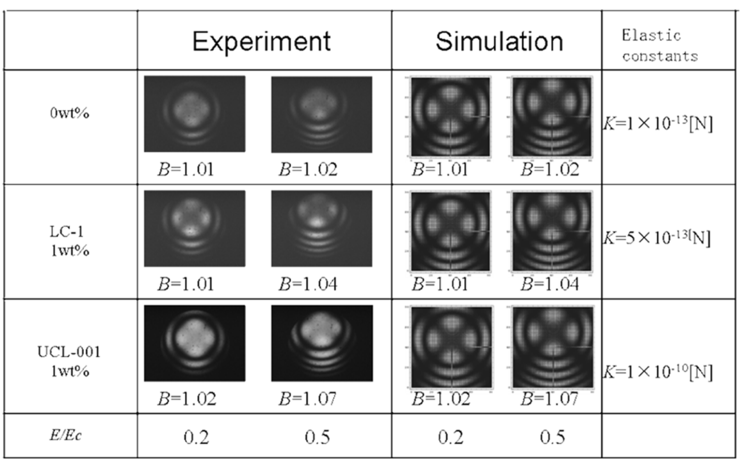

FIGURE 7 Fitting results between the simulation and the experimental conoscopic figures.

The alkyl spacers between the main- and mesogenic side-chain of polymer networks can reduce the polymer anchoring strength. As a result, PSFLC having alkyl spacers possesses a comparatively low elastic constant and threshold electric field. We confirmed that the surface-stabilized PSFLC can be monostable even in the use of 1 wt% LC-1 and the threshold decreases. Therefore, the characteristics of PSFLC can be controlled for device applications by utilizing a suitable spacer.

4. CONCLUSIONS

We researched the effect of the alkyl spacer on the helical structure of PSFLC by the comparison between the experimental and the computer simulation results of conoscopic figures. As a result, it was found that the elastic constant and threshold electric field of PSFLC having alkyl spacers are lower than those of a conventional PSFLC having no alkyl spacer. This fact originates in the decrease of the polymer anchoring strength due to the alkyl spacer. Therefore, it is concluded that the characteristics of PSFLC can be controlled by utilizing a suitable spacer.

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