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HOLOGRAPHICAL FABRICATION OF PERIODICALLY ALIGNED DOMAIN STRUCTURE USING AZO-DYE DOPED FERROELECTRIC LIQUID CRYSTAL HAVING N*-C* PHASE SEQUENCE

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HOLOGRAPHICAL FABRICATION OF PERIODICALLY ALIGNED DOMAIN STRUCTURE USING AZO-DYE DOPED FERROELECTRIC LIQUID CRYSTAL HAVING N*-C* PHASE SEQUENCE

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We have demonstrated a holographical fabrication of periodically aligned domain structure in an azo-dye-doped ferroelectric liquid crystal with chiral nematic (N) – chiral smectic C (SmC*) phase sequence (NC-FLC). This optical fabrication of periodically aligned domain structure is based on the N*-SmC* phase transition induced by the photoisomerization of doped azo-dye. This periodically aligned domain structure can be applied for the optical devices such as grating, memory and photonic crystal with electrical tunabilities.*

Keywords: azobenzene; ferroelectric liquid crystal; layer structure; N*-C* phase sequence; optically designed multidomain; photoisomerization

1. INTRODUCTION

Recently, fabrication of a designed multidomain structure has attracted considerable attention from technological point of view such as improvement of a viewing angle in a liquid crystal (LC) display, fabrication of a grating and photonic crystal and so on. We have proposed before the photo-assisted fabrication technique of the designed multidomain structure using a ferroelectric liquid crystal having chiral nematic (N*) – chiral smectic C (SmC*) phase sequence (NC-FLC) based on laser light heating [1] and photoisomerization of doped azo-dye [2,3].

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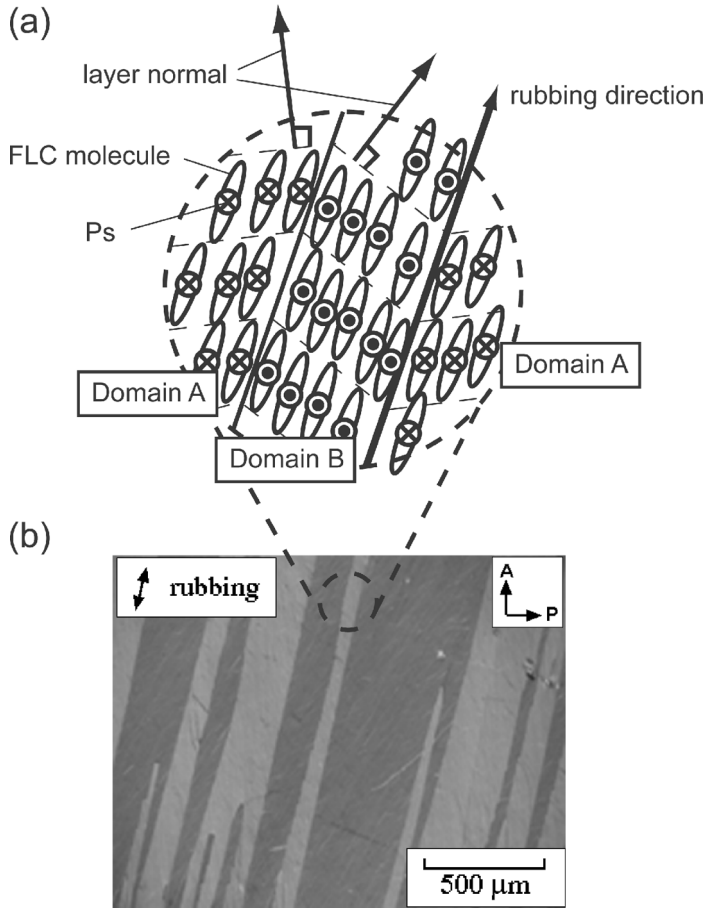


FIGURE 1 (a) Schematic representation of two possibilities of layer arrangements in the SmC* phase of NC-FLC. (b) Polarizing microphotograph of HOPOOB in the SmC* phase.

In an NC-FLC planer cell, there are two types of layer arrangements whose layer normals make angles of $\pm\theta$ (tilt angle) with respect to the rubbing axis in the SmC* phase as shown schematically in Figure 1(a). These two layer domains can be selected arbitrary by the polarity of the applied electric field. In our previous studies, photoassisted control of the layer structure was proposed and demonstrated. In this study, holographic fabrication of periodically aligned domain structure based on this technique is investigated.

2. MATERIALS

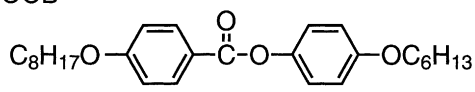
Figure 2 shows the molecular structures of liquid crystal and azo-dye used in this study. An achiral smectic-C liquid crystal, 4-hexyloxyphenyl 4-octyloxybenzoate (HOPOOB), doped with a chiral molecule (S811) of 1 wt% concentration, was used for the NC-FLC. 4-diethylaminoazobenzene was doped as a photochromic azo-dye. The concentration of the azo-dye in the FLC was 5 wt% as same as previously reported [2,3]. These mixtures show an isotropic-N*-SmC* phase sequence with cooling temperature.

As mentioned above, in an NC-FLC planer cell, there are two types of layer arrangements whose layer normals make angles of $\pm\theta$ with respect to the rubbing axis in the SmC* phase. As presented previous reports, HOPOOB shows stripe domains with a long axis parallel to the rubbing direction in SmC* phase (Fig. 1(b)). Using this characteristic stripe domain, fine grating structure can be expected.

3. EXPERIMENTAL

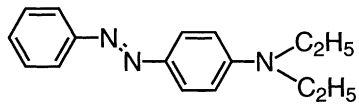
The sample was filled by a capillary action into a sandwich cell, which consists of two indium-tin-oxide (ITO)-coated glass plates. The cell gap was 2 μm. In such a thin cell, no texture due to the helix was observed. To obtain a homogeneously aligned cell, the surfaces were coated with a polyimide (AL1254, Japan Synthetic Rubber) and rubbed in the anti-parallel direction to each other. The sample was set between crossed polarizers and observed by a polarizing optical microscope. The texture was recorded using a CCD digital camera (HC-300, FUJIFILM).

HOPOOB



4-hexyloxyphenyl 4-octyloxybenzoate

AZO-DYE



4-diethylaminoazobenzene

FIGURE 2 Molecular structures of achiral liquid crystal and azo-dye used in this study.

The temperature of the sample was controlled using a hot bath and a temperature controller (FP21, SHIMADEN). For light irradiaton in order to induce *trans-cis* photoisomerization of doped azo-dye, blue diode laser light with 400 nm in wavelength (LDT-4005: Nichia) was used. For the holographic light irradiation, Ar^+ laser (Beamlok2060-4S, Spectra Physics) whose wavelength was 488 nm was used.

4. RESULTS AND DISCUSSION

4.1. Fabrication of Stripe-shaped Domain Structure

First, optical patterning of stripe-shaped domain structure was performed with a photomask (Fig. 3). The fabrication method is as same as reported before [2,3]. The sample was heated to the isotropic phase and then cooled down to the SmC* phase. To obtain uniform unidirectional layer alignment, a negative electric field (−E) was applied at the phase transition from the N* to SmC* phases. The temperature of the sample was kept just below N*-SmC* phase transition point. Polarizer was set parallel to the rubbing direction as shown in Figure 3(a). The polarity of the applied field was reversed to +E before UV irradiation, as shown in Figure 3(b), and the sample was rotated to obtain a dark state as shown in Figure 3(c). By UV irradiation through a photomask, the layer switching was induced partially, and stripe-shaped domain structure was recorded as shown in Figure 3(d). By a reversal of a polarity of an applied electric field, each domain can be switched reversibly as shown in Figure 3(e) and (f).

4.2. Holographic Fabrication of Periodically Aligned Domain Structure

Next, holographic fabrication of periodically aligned domain structure was demonstrated. The holographic light irradiation was performed using single interferometric geometry. As shown in Figure 4, periodically aligned domain structure was recorded by holographic light irradiation. The periodicity of this periodically aligned domain structure was about 100 μm, which can be controlled by changing the angle of two interfering recording laser lights. The switching of each domain can be performed reversibly by switching the polarity of the applied electric field as same as stripe-shaped domain structure.

5. CONCLUSIONS

We proposed a photo-induced layer alignment control in an azo-dye-doped ferroelectric liquid crystal with N*-SmC* phase sequence. This layer

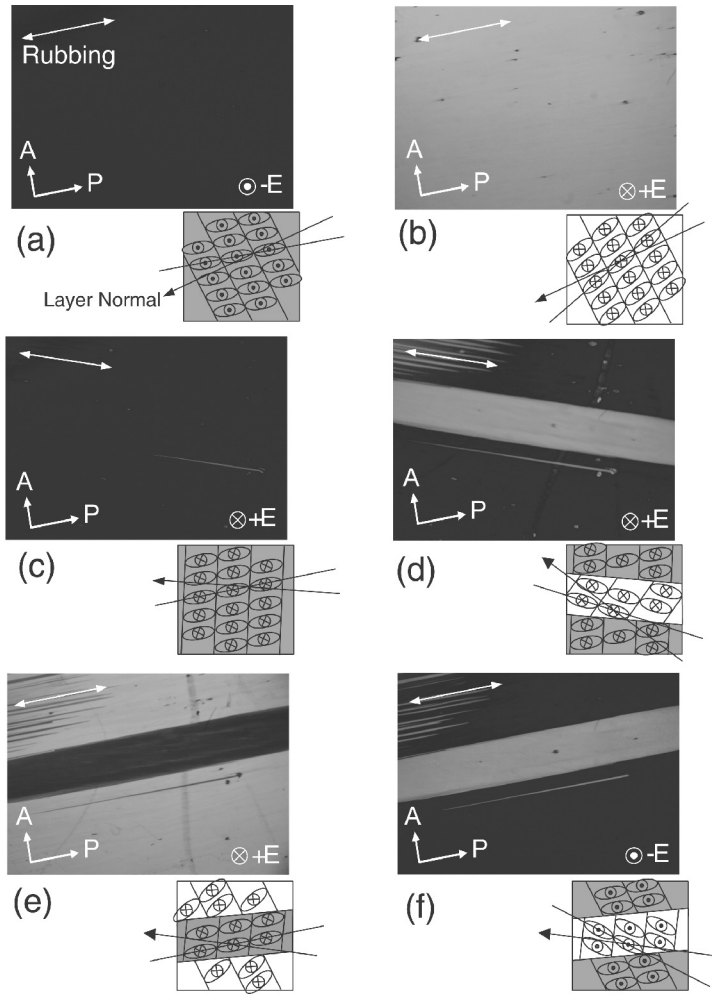


FIGURE 3 Polarizing microphotographs of the azo-dye-doped NC-FLC before and after smectic layer patterning by UV irradiation. (a) the homogeneous SmC* phase before UV irradiation with −E electric field. (b) the homogeneous SmC* phase before UV irradiation with +E electric field (applied electric field is reversed). (c) the SmC* phase before UV irradiation with +E electric field. The dark state was obtained by rotating the sample. (d)–(f) The UV irradiation was performed partially and stripe-shaped domain was recorded. By switching the polarity of the applied electric field, each domain can be switched reversibly as shown in (e) and (f).

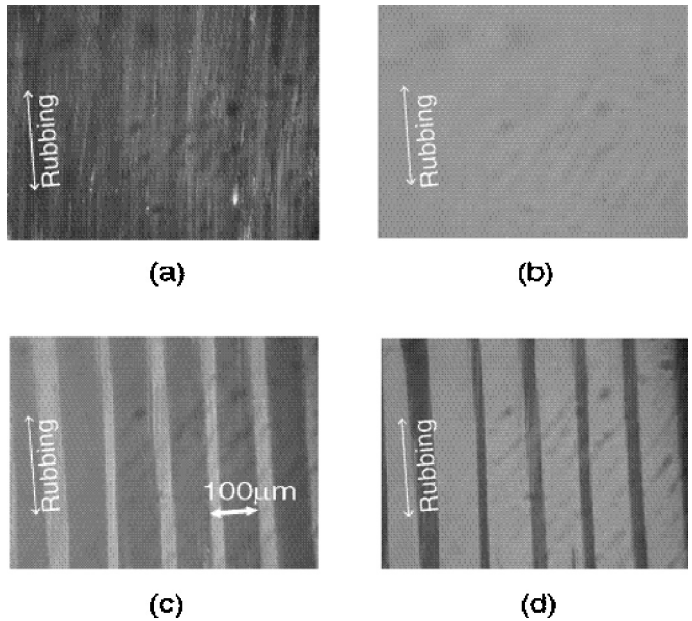


FIGURE 4 Polarizing microphotographs of the azo-dye-doped NC-FLC before and after holographic UV light irradiation. (a) the SmC* phase before holographic irradiation with −E electric field. (b) the SmC* phase before holographic irradiation with +E electric field. (c) the SmC* phase after holographic irradiation with +E electric field. (d) the SmC* phase after holographic irradiation with −E electric field.

alignment control was based on the N*-SmC* phase transition induced by the photoisomerization of doped azo-dye. By using masking and interfering method, a stripe-shaped domain and periodically aligned domain structure was recorded, respectively. This photo-assisted fabrication of periodically aligned domain structure can be applied to the fabrication of grating and photonic crystal with an electrical enability.

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