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Smectic Layer Patterning based on Photo-induced N*-SmC* Transition in Azo-dye Doped Ferroelectric Liquid Crystal

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Smectic layer alignment in ferroelectric liquid crystal which has a chiral nematic (N*)-chiral smectic C (SmC*) phase sequence NC-FLC, the smectic layer normal in the SmC* phase does not coincide with the alignment (rubbing) axis in a sandwich cell with a conventional rubbing treatment, and there are two directions of layer arrangements whose layer normals make angles of $\pm\theta$ (tilt angle) with respect to the rubbing axis (Fig. 1.). The direction of the layer alignment can be controlled by selecting the polarity of the applied electric field during the phase transition from N* to SmC*.

On the other hand, the phase transition temperature is strongly affected by the molecular structure of the dopant in the liquid crystal. If a photochromic molecule is doped in the NC-FLC, the N*-SmC* phase transition point shifts upon the UV irradiation. Normally, the irradiation of UV light in the SmC* phase, the N* phase is induced, and an opposite isomerization process upon sequentially stopping the UV irradiation induces the SmC* again. Therefore, if we applied voltage under the irradiation of UV light, the layer alignment can be selected by the polarity of the applied voltage. In this study, we demonstrate the layer switching upon UV irradiation in the dye doped NC-FLC and propose a layer patterning based on this layer switching upon light irradiation. Using this technique, the fabrication of microstructure for the optical grating is expected.

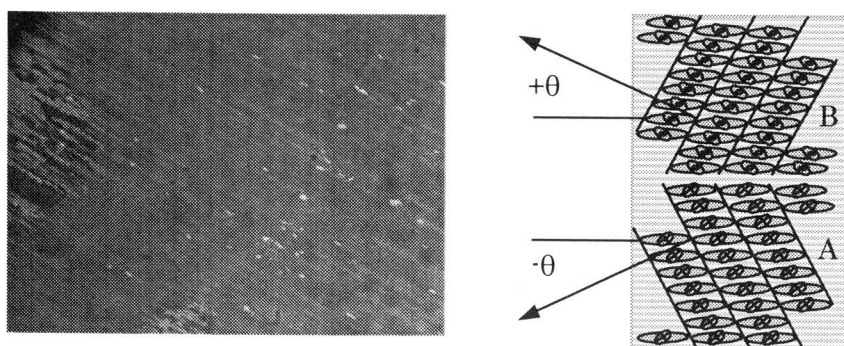
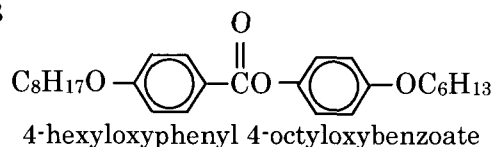


Fig. 1. Two domains with different layer alignments coexist after the phase transition from N* to SmC* without electric field.

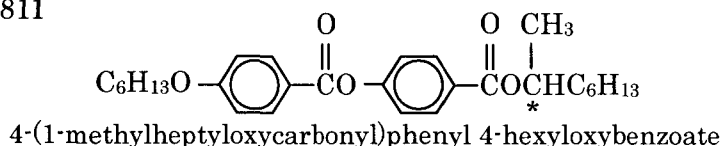
Figure 2 shows the molecular structures of the achiral liquid crystal, chiral dopant and dye and the phase sequence of the mixture in this study. An achiral smectic-C liquid crystal, 4-hexyloxyphenyl 4-octyloxybenzoate (HOPOOB), doped with a chiral molecule (S811, Merk) of 1

wt % concentration, was used for the NC-FLC. 4-diethylaminoazobenzene was doped as photochromic azo dye.

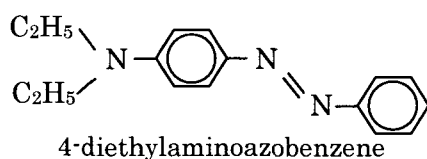
HOPOOB



S811



Azo-dye



HOPOOB(94%) + S811(1%) + Azo-dye(5%)

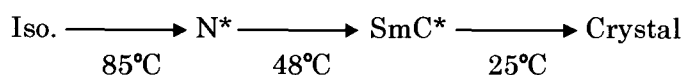
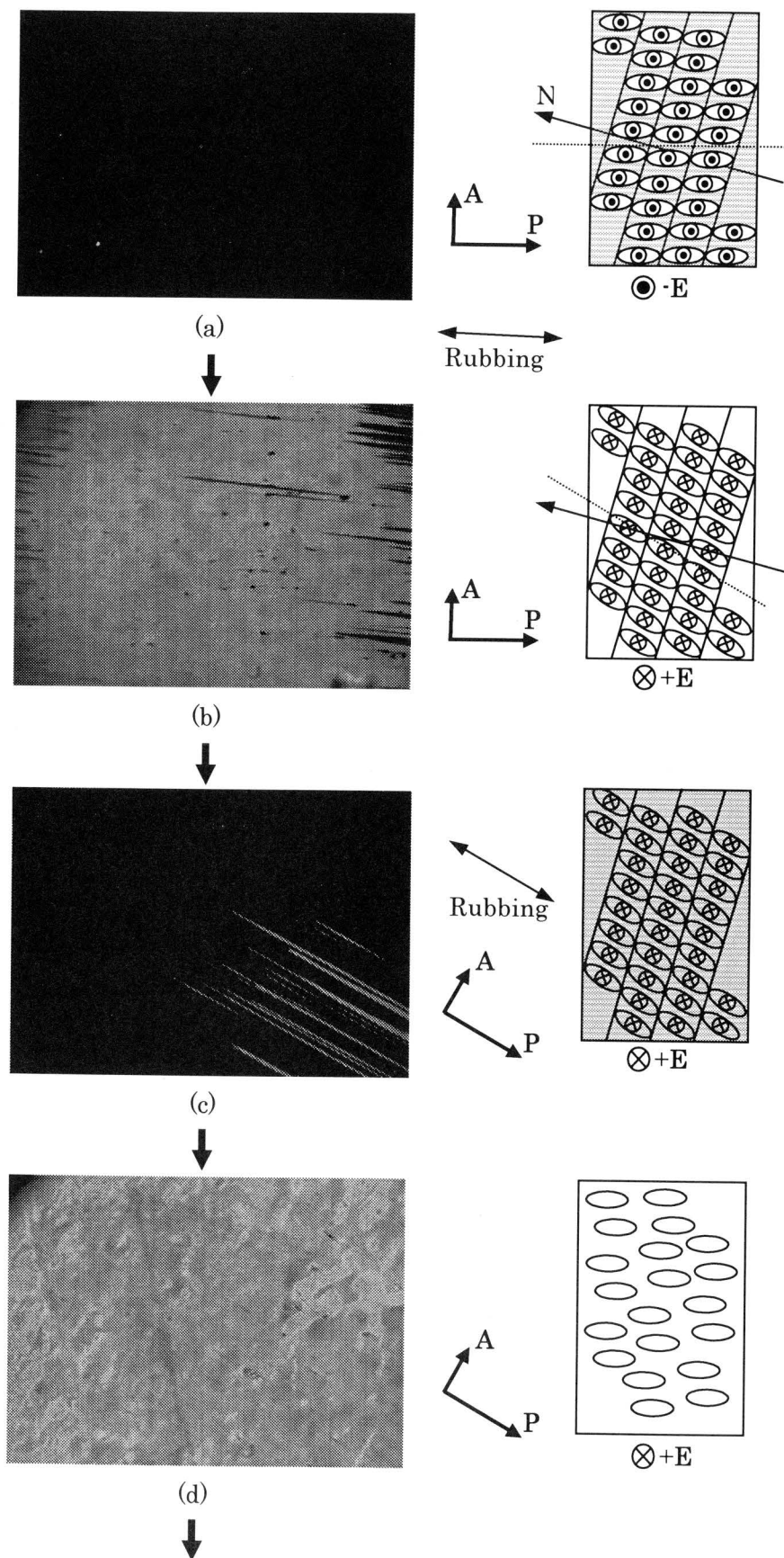


Fig. 2. The molecular structures of the achiral liquid crystal, chiral dopant and dye and the phase sequence of the mixture.

The sample was filled by 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 homogeneously aligned cell, the surfaces were coated with polyimide (AL1254, Japan Synthetic Rubber) and rubbed in the antiparallel direction to each other. The sample was set between crossed polarizers and observed by a polarizing optical microscope. The texture was recorded using a charge-coupled device digital camera (HC-300, FUJIFILM).

The temperature of the sample was controlled using hot bath and a temperature controller (Mettler FP90). Light illumination was performed by a 160 W metal-halide lamp (IMH-160, SIGMA KOKI). In order to induce *trans-cis* photoisomerization of the azo-dye, a UV pass filter C-40C (TOSHIBA) was installed in front of the sample, which transmitted light having a wavelength region from 280 to 420 nm. For the observation of textures, a long-pass filter O-55 (>560 nm; orange light) was used to avoid *trans-cis* photoisomerization of the azo-dye.



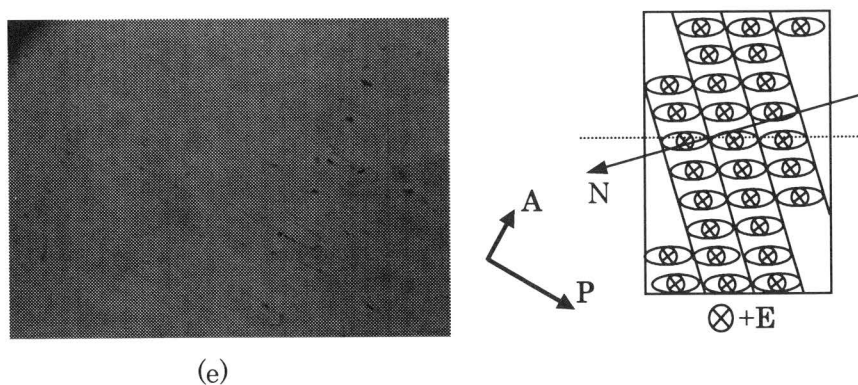


Fig. 3. Polarizing micrograph of the dye-doped NC FLC before and after UV irradiation under applied voltage of $\pm 7V$. (a) SmC* phase before irradiation with $-E$ electric field; (b) Same condition with $+E$ electric field; (c) Observed at 2θ tilt angle; (d) N* phase induced by UV irradiation; (e) SmC* phase after stopping UV irradiation.

Figure 3 shows polarizing micrograph of the sample under the applied voltage of $\pm 7V$. As mentioned above, two kinds of layer alignment, whose layer normal make angles of $\pm\theta$ with respect to the rubbing direction, can be formed in the SmC* phase. To Obtain uniform unidirectional layer alignment, first the sample was heated to the isotropic phase and then cooled down to the SmC* phase with a negative electric field ($-E$) was applied at the above of the phase transition temperature from N* to SmC*. Then the temperature of the sample was kept just below the N*-SmC* phase transition, as shown in Fig. 3a, however uniform unidirectional layer can be realized in the entire area of the cell (e.g., domain B), in this condition we found dark state. When the polarity of the applied field is reversed ($+E$), the molecules tilt away from the rubbing direction by 2θ (Fig 3b), which is making bright state. Figure 3c observed when the molecule reach 2θ tilt angle (one of the crossed polarizers was set parallel to the rubbing direction), dark state again. In this state, if UV light is irradiated by changing the long-pass filter into UV pass filter, the N*-SmC* phase is induced due to *trans-cis* photoisomerization of the azo-dye and liquid-crystal molecules tend to align direction along the rubbing direction as shown in Fig. 3d. Upon sequentially stopping UV irradiation, an opposite photoisomerization process (*cis-trans*) causes reentrance into the SmC* phase, keeping molecules parallel to the rubbing direction, as shown in Fig. 3e. Consequently another domain (domain A), in which the layer normal tilts to the opposite direction with respect to that in Fig. 3a, can be obtained.

References

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