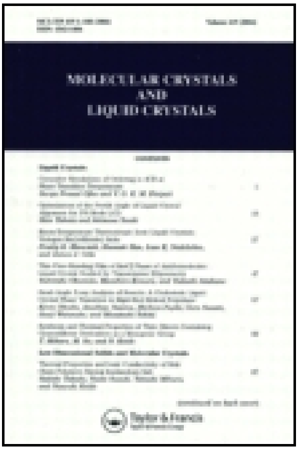

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Investigation of Liquid Crystal Alignment and Pretilt Angle Generation in the Cell with Linearly Polarized UV Light Irradiation on Polymer Surface

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Investigation of Liquid Crystal Alignment and Pretilt Angle Generation in the Cell with Linearly Polarized UV Light Irradiation on Polymer Surface

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We have investigated the generation of pretilt angle in nematic liquid crystal (NLC) and electro-optical (EO) characteristics of photo-aligned TN-LCD with polarized ultraviolet (UV) light irradiated on polyimide (PI) surface. It was found that the LC alignment capability increases with increasing the UV light irradiation time. In case of the fact that the polarized UV light of oblique angle of 60° irradiated on PI surface rotated by 90° at 10 min. after being normally irradiated on PI surface at 30 min., the generated pretilt angle of NLC is about 1.5°. Also, we obtained that the pretilt angle in NLC strongly depends on oblique angle and UV light irradiation time. We considered that the pretilt angle of NLC is attributed to the interaction between the LC molecules and the polymer surface due to photo-depolymerization of polymer. Finally, we measured that the EO characteristics of photo-aligned TN-LCD is almost same in comparison to rubbing-aligned TN-LCD.

Keywords: nematic liquid crystal; polyimide; pretilt angle; photo-alignment; photo-depolymerization; EO characteristics

INTRODUCTION

The successful operation of LCDs requires uniform alignment and controlled pretilt of LCs on substrate surfaces. Most LCDs with pretilted homogeneous LC alignment are prepared using rubbed PI surfaces. The leading technology for LCD is based on twisted nematic (TN)-LCDs; the pretilt angle prevents creation of reverse tilt disclinations in TN-LCD. The generation of pretilt angle in NLC on various alignment layers by unidirectional rubbing has been demonstrated and discussed by many investigators [1-5]. Rubbed polymer surfaces have been widely used for aligning LC molecules. Recently, rubbingless techniques for LC alignment are needed in thin-film-transistor (TFT)-LCD fabrication. In a previous paper, we reported that the TFTs are damaged by the induced static electricity produced during rubbing [6]. The photo-alignment method for LC alignment is expected to achieve the high resolution LCDs; Gibbons et al. have reported the new method for LC alignment by using polarized laser light [9].

Also, the pretilt angle on Langmuir-Blodgett (LB) film has been controlled by regulation of the fraction of trans-azobenzene units using light wavelength tuning [8]. More recently, the LC alignment on polarized UV light irradiated poly(vinyl)cinnamate films have been reported by some researchers [9-11]. The photo-polymerization reaction of a photo-polymer with polarized light has been shown to induce uniaxial orientation of NLCs on PVC surfaces. Also, recently the LC alignment with polarized UV light irradiation PI surface has been reported by some researchers [12-14]. That the photo-depolymerization of PI main chains parallel to the electric field of polarized UV light (257nm) caused anisotropic dispersion force is discussed [12]. The detailed mechanism of LC alignment by photo-alignment method is not yet understood.

In this study, we report the generation of pretilt angle in NLC and EO performance of photo-aligned TN-LCD with polarized UV light irradiation on PI surface with side chain.

EXPERIMENTAL

In this study, we used the polymer with side chain type. Figure 1 shows the chemical structure of used polymer. We used the PI films were coated on indium-tin-oxide (ITO) coated glass substrates by spin-coating, and were imidized at 250℃ for 1 hr. The thickness of PI layers was about 500Å. The substrates were irradiated for 5~60 min. by using polarized UV light at a wavelength of 365nm (power : 1kW). The system of used UV light irradiation on substrates is shown in Fig. 2.

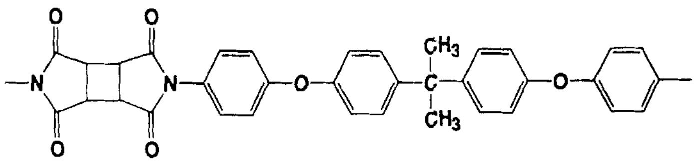


FIGURE 1 The molecular structure of used polymer.

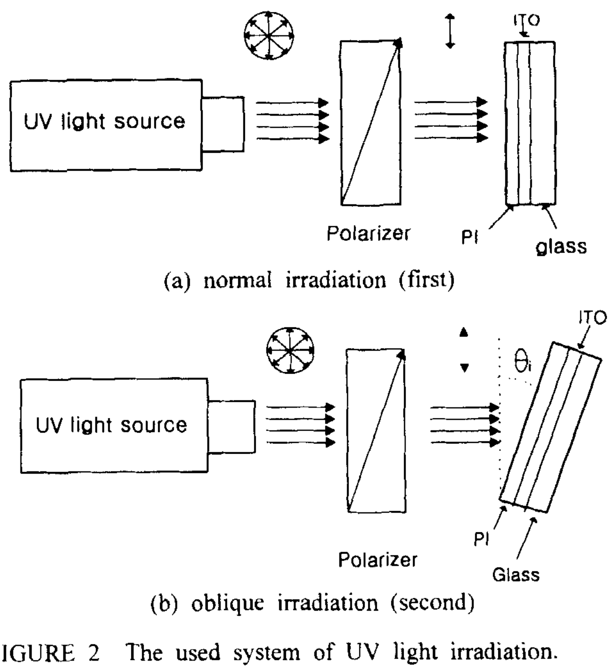


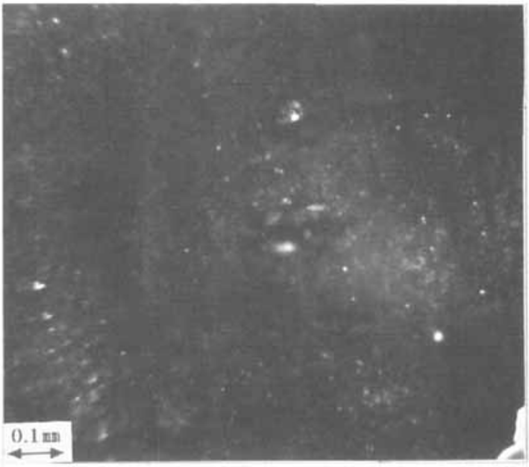
FIGURE 2 The used system of UV light irradiation.

For pretilt angle measurement, the LC was assembled into sandwich-type cells with antiparallel-UV irradiation direction. All the sandwich-type cells had LC layer thickness of 60μm. After assembly, the cells were filled with NLC (fluorinated type mixture; T_c=87° for TFT-LCD) in the nematic phase; the cells were annealed for 10 min. at isotropic phase. To measure pretilt angles, we used the crystal rotation method and measurements were done at room temperature. For the EO characteristics, we assembled the photo-aligned TN-LCD with polarized UV light irradiation on PI surface. In order to estimate the EO characteristics, we measured the characteristics of the voltage-transmittance (V-T) and response time on photo-aligned TN-LCD.

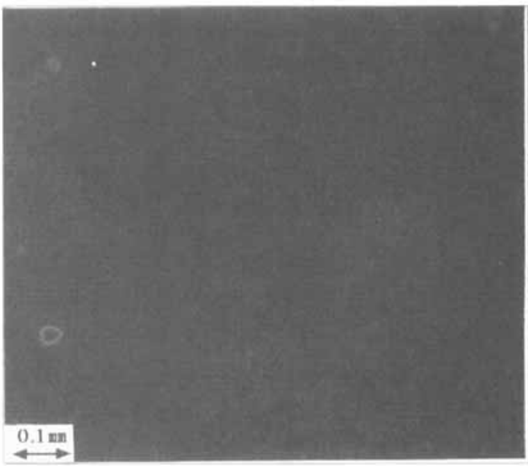
RESULTS and DISCUSSION

Figure 3 shows the microphotographs of aligned NLC in the cell with polarized UV light irradiation on PI surface (under crossed Nicols). Monodomain alignment of NLC is observed with polarized UV light irradiation PI surface with side chain. We also observed that the aligned NLC was parallel to the UV light polarization. The LC alignment capability increases with increasing the UV irradiation time. It is considered that the monodomain alignment of NLC is attributed to anisotropic dispersion force due to photo-polymerization of polymer with polarized UV light irradiation on PI surface.

The rubbing strength (RS) dependence of the pretilt angle in NLC on PI surface with side chain is shown in Fig. 4. It is shown that the generated pretilt angle is about 1.5° in RS=0.7mm region. Figure 5 shows the generation of pretilt angle of the NLC in the cell with polarized UV light is normally irradiated on PI surface with side chain as a function of UV irradiation time. It is shown that the generated pretilt angle of NLC is about 0.8° with polarized UV irradiation time of 5~60 min.



(a) irradiation time of 10min.



(b) irradiation time of 30min.

FIGURE 3 The microphotographs of aligned NLC in the cell with polarized UV light irradiation on PI surface (under crossnicols).
(See color plate X at the back of this issue)

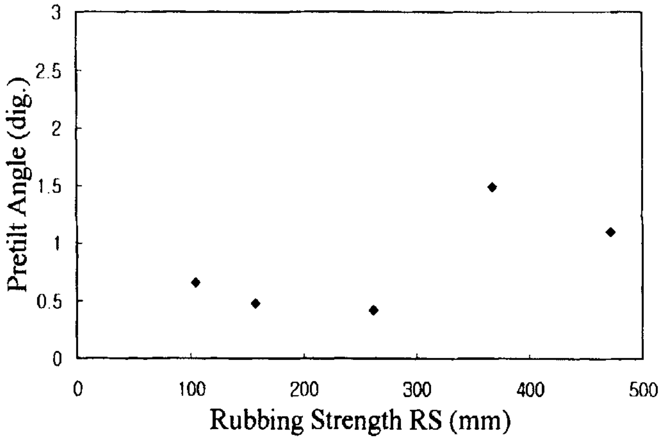


FIGURE 4 The generation of pretilt angle in NLC on PI surface with side chain as a function of rubbing strength.

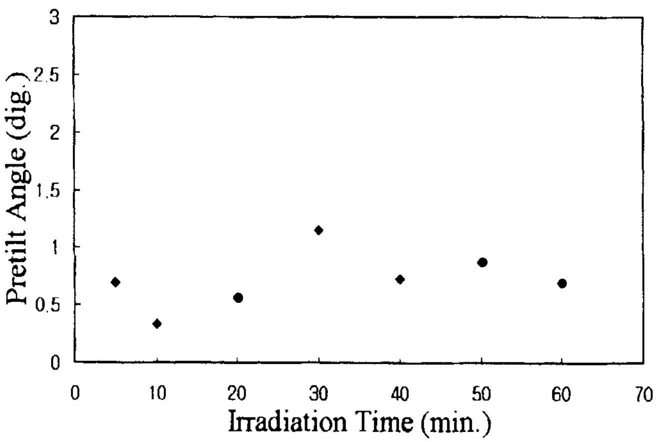


FIGURE 5 The generation of pretilt angle in NLC on PI surface as a function of polarized UV light irradiation time.

Figure 6 shows the oblique angle dependence of pretilt angle of NLC in the cell which polarized UV light obliquely irradiated on PI surface rotated by 90° after it is normally irradiated on PI surface at 30 min. The obtained pretilt angle of NLC is about 0.8° and then increases with increasing the oblique angle at the irradiation time of 10 min. It is shown that the pretilt angle in NLC decreases with increasing the oblique angle at above 70°. We consider that the pretilt angle is low because photo-polymerization of polymer is generated much more at low oblique angle of second irradiation. Also, the obtained pretilt angle is about 1.5° at incident angle of 60°. It is considered that the pretilt angle decreased as decreasing the photo-polymerization of polymer at above 70°. We consider that the high pretilt angle generated to the interaction between the LC molecules and the polymer surface due to photo-depolymerization of polymer with polarized UV light irradiation of oblique angle of 60°.

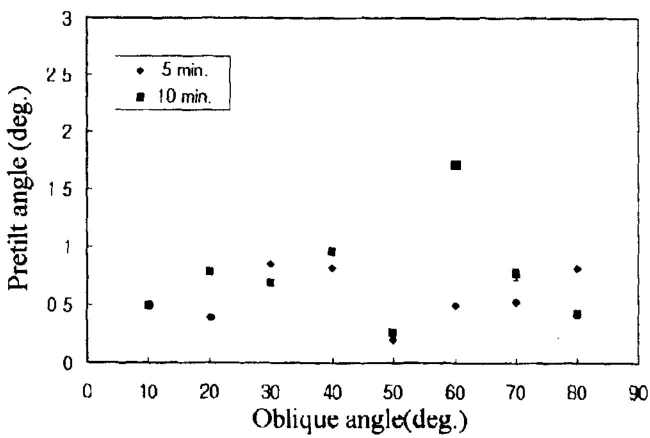


FIGURE 6 The oblique angle dependence of pretilt angle in NLC in the cell with oblique polarized UV light is irradiated on PI surfaces rotated by 90° after it is normally irradiated on PI surface for 30min.

Figure 7 shows the irradiation time dependence of pretilt angle in the cell which the polarized UV light of oblique angle of 60° is irradiated on PI surface rotated by 90° after it is normally irradiated on PI surface for 30 min. It is shown that the pretilt angle in NLC increases with increasing the irradiation time and then decreases at above 10 min. It is considered that the generation of pretilt angle in NLC depends on photo-polymerization reaction of polymer.

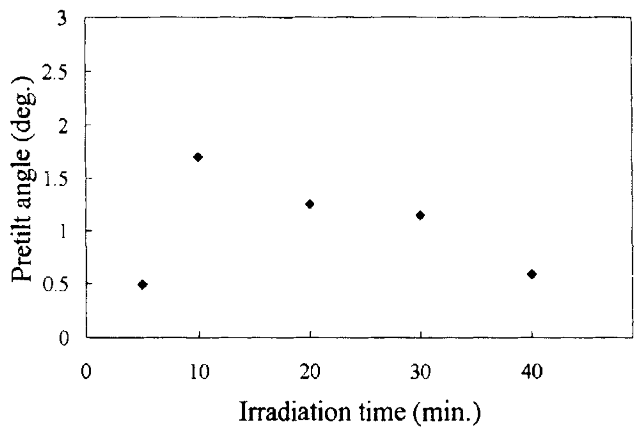
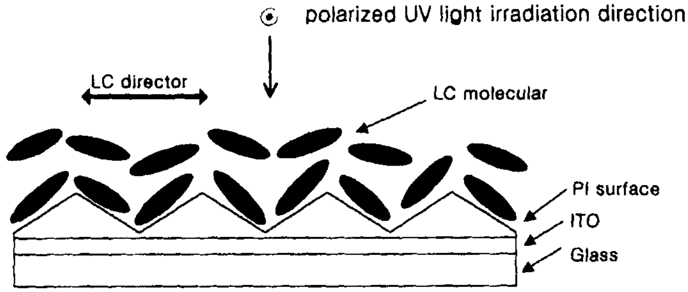


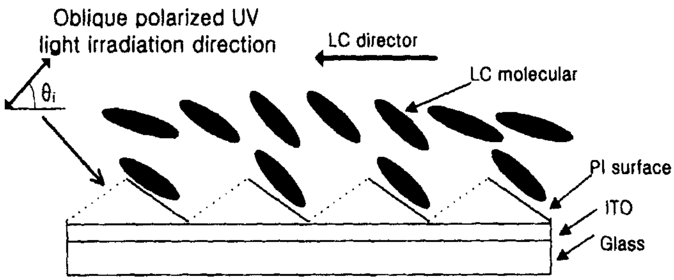
FIGURE 7 The irradiation time dependence of pretilt angle in the cell with polarized UV light of oblique angle of 60° is irradiated on PI surface rotated by 90° after it is normally irradiated on PI surface for 30min..

Figure 8 shows the schematic diagram of pretilt angle generation in NLC with polarized UV light irradiation on PI surface. In Figure 8 (a), the low pretilt angle generated with normally polarized UV light irradiation on PI surface; it is attributed to anisotropic dispersion force due to photo-depolymerization of polymer. It is shown that the high pretilt angle generated with oblique polarized UV light irradiation on PI surface rotated by 90 after it is normally irradiated (in Fig. 8 (b)).

The pretilt angle of NLC is attributed to polymer surface due to photo-polymerization of polymer with oblique polarized UV light irradiation. We, therefore considered that the high pretilt angle of NLC is attributed to oblique polarized UV light irradiation.



(a) with normal polarized UV light irradiation on polimided surface.



(b) with oblique polarized UV is irradiated on PI surface rotated by 90° after it is normally irradiated.

Figure 8 The generation of pretilt angle with polarized UV light irradiation on PI surface.

The microphotographs of three kinds of the photo-aligned TN-LCD with normally polarized UV light irradiation on PI surface is shown in Fig. 9. It is shown that the LC alignment capability increased with increasing the irradiation time. Also, the reverse tilt disclinations formed due to low pretilt angle.

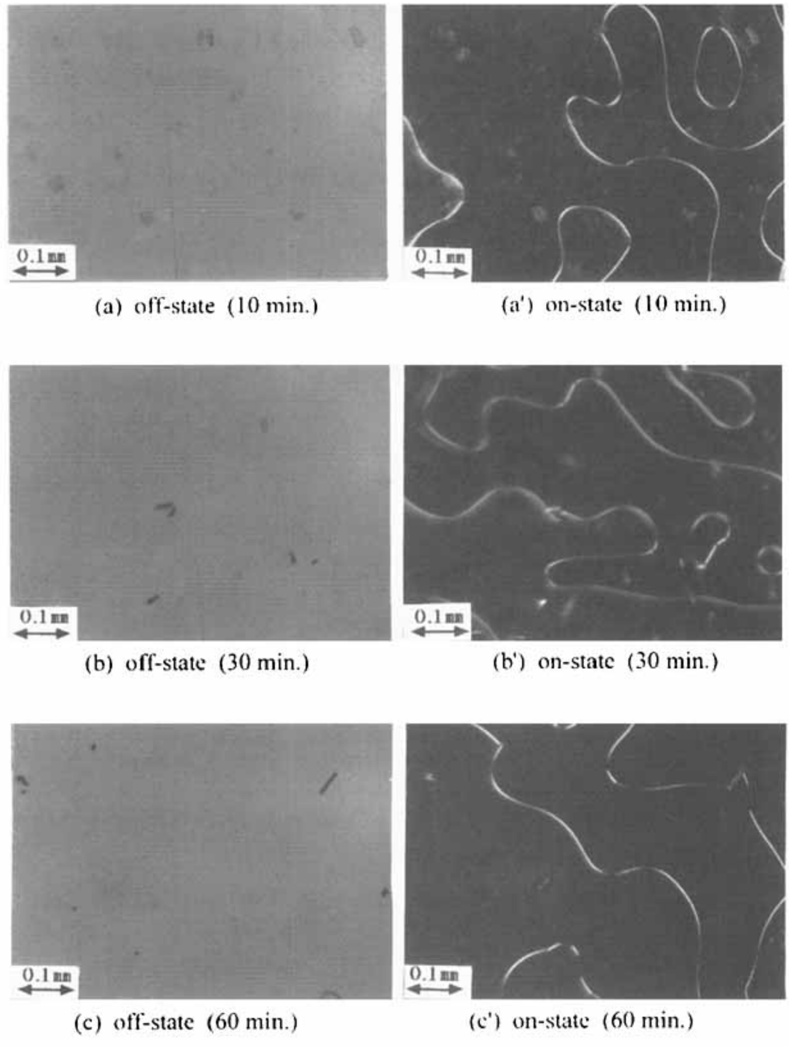


FIGURE 9 The microphotographs of photo-aligned TN-LCD with polarized UV light irradiation on PI surface (in crossnicols).

(See color plate XI at the back of this issue)

Next, we investigate the EO characteristics of photo-aligned TN-LCD with polarized UV light irradiation on PI surface. Figure 10 shows the voltage-transmittance (V-T) characteristics of photo-aligned TN-LCD with polarized UV light irradiation on PI surface and rubbing-aligned TN-LCD. Table I shows the applied voltage versus transmission for photo-aligned TN-LCD and rubbing aligned TN-LCD on PI surface. It is shown that the V-T characteristics of photo-aligned TN-LCD with polarized UV light irradiation time of 60min. on PI surfaces is almost the same compared to rubbing-aligned TN-LCD.

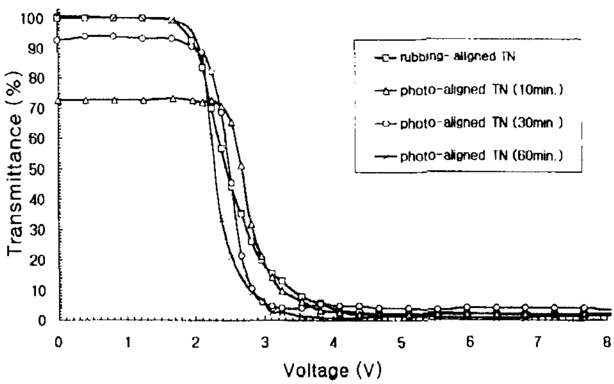


FIGURE 10 The voltage-transmittance characteristics of photo-aligned TN-LCD with polarized UV light irradiated on PI surface and rubbing-aligned TN-LCD.

TABLE I The applied voltage versus transmission for photo-aligned TN-LCD and rubbing-aligned TN-LCD on PI surface.

TN / Voltage	photo-aligned TN-LCD (10 min.)	photo-aligned TN-LCD (30 min.)	photo-aligned TN-LCD (60 min.)	rubbing-aligned TN-LCD
V_{90}	×	2.02	2.07	1.99
V_{10}	3.28	2.82	2.76	3.39

The response time characteristics of photo-aligned TN-LCD with polarized UV light irradiation on PI surface is shown in Fig. 11. It is shown that the characteristics of response time on photo-aligned TN-LCD increases with increasing irradiation time. Also, the backflow bounce effect is observed during the decay time for photo-aligned TN-LCD with irradiation time of 10 and 30 min. Table II shows the response time for photo-aligned TN-LCD and rubbing-aligned TN-LCD on PI surface. It is shown that the response time of photo-aligned TN-LCD with polarized UV light irradiation on PI surface at 60 min. is almost the same compared to rubbing-aligned TN-LCD.

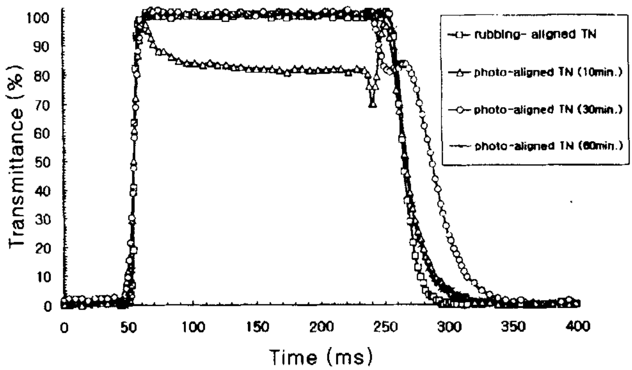


FIGURE 11 The response time characteristics of photo-aligned TN-LCD with polarized UV light irradiated on PI surface and rubbing-aligned TN-LCD.

TABLE II The response time for photo-aligned TN-LCD and rubbing-aligned TN-LCD on PI surface

TN / Time	photo-aligned TN-LCD (30 min.)	photo-aligned TN-LCD (60 min.)	rubbing-aligned TN-LCD
rising time τ_r (ms)	11.4	10.1	8.4
decay time τ_d (ms)	73.6	38.8	26.0
response time τ (ms)	85.0	48.9	34.4

Consequently, we suggest that the EO characteristics of photo-aligned TN-LCD with polarized UV light irradiation on PI surface strongly depends on UV light irradiation time.

CONCLUSIONS

In conclusion, we measured that the LC alignment capability increases with increasing the UV irradiation time. In case of the fact that the polarized UV light of oblique angle of 60° irradiated on PI surface rotated by 90° at 10 min. after it is normally irradiated on PI surface at 30 min., the generated pretilt angle of NLC is about 1.5°. Also, we obtained that the pretilt angle in NLC strongly depends on oblique angle and UV light irradiation time. For pretilt angle generation, we considered that the polarized UV light normal irradiation is attributed to LC alignment capability and then polarized UV light oblique irradiation is attributed to the generation of pretilt angle.

In a consequence, we suggest that the EO characteristics of photo-aligned TN-LCD is almost same in comparison with rubbing-aligned TN-LCD on PI surface.

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