Liquid Crystal Orientation Properties on Homogeneous Polymer Surface by Various Alignment Methods

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We have studied the liquid crystal alignment properties for various alignment methods on the homogeneous polyimide surface. Suitable liquid crystal alignment for one-side alignment cell on the polyimide surface by all alignment method was observed. Highly pre-tilt angle of the NLC for both-side rubbing cell was measured. But, low pre-tilt angle of the NLC for one-side ion beam and UV irradiation cell was observed. We consider that the pre-tilt angle of NLC for one-side ion beam and UV irradiation on the PI surface is lower than that of the PI surface with rubbing. Also, the suitable transmittance-voltage curves for the one-side rubbing TN-LCD on the PI surface with one-side UV irradiation were measured. Also, good response time characteristics of the one-side rubbing TN-LCD on the polyimide surface with one-side UV irradiation can be measured.

Keywords: Homogeneous polymer, Ion beam, UV, Pretilt angle, Liquid crystal alignment

1. INTRODUCTION

Currently, the rubbing technique on the polymer-coated glass substrate surface has been widely used to align liquid crystal (LC) molecules[1-5]. Polyimide (PI) is widely adopted as an alignment layers they have appropriate properties such as uniform alignment and stable thermal stability. But, rubbing technique has several disadvantages, such as generation of electrostatic charge and creation of contaminating particles. Also this technique has a difficulty of applying for large and flexible substrates. Thus, we have recommended rubbing free alignment techniques such as UV[6] and ion beam (IB)[7] for getting rid of disadvantages of rubbing technique. Recently, we reported LC alignment effects of the ion beam aligned homogeneous PI surface[8] and inorganic thin film surface[9-11]. However, LC alignment effects of NLC on the PI surface using IB and UV irradiation were insignificant. The LC molecules which are in contact with an alignment layer are oriented with a certain angle from substrate surface. This angle formed by the axis of the LC director and the alignment layer is defined as the pretilt angle. The pretilt angle of LCs on the substrate surface is most important parameter in LC-device properties.

In this study, we report on the LC aligning capabilities and pretilt angles for NLC in a cell with one-side aligned on the PI surface by the rubbing, IB irradiation, and UV irradiation method. In addition, we describe the EO characteristics of the one-side rubbing TN-LCD on the PI surface with one-side UV irradiation.

2. EXPERIMENTAL

In this experiment, the polymer for the homogeneous (SE-7492 from Nissan Chemical Engineering Co.) was used. The polymers were uniformly prepared by the spin coating on indium-tin-oxide (ITO) electrodes and imidized at 250 ℃ for 1 hour. The thickness of the PI film was set at 500 Å. Rubbing strength is set up by the follow equation[12]:

$$RS = NM(2\pi rn/V - 1), \quad (1)$$

where N is the number of the times for the rubbing, M is the depth of the fibers (millimeter), n is the rotation rate of the drum, V is the translating speed of the substrate, and r is the radius of the drum.

Figure 1(a) shows the high-energy-density IB system, DuoPIGatron-type used in this experiment. The IB energy intensity was 1500 eV and the incident angle of ion beam

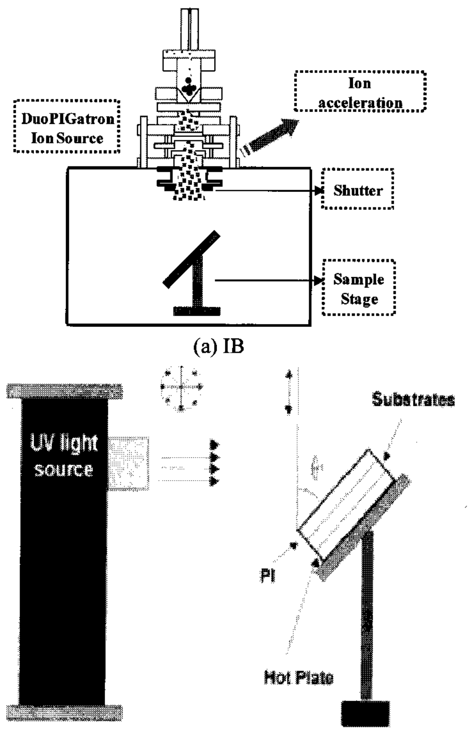
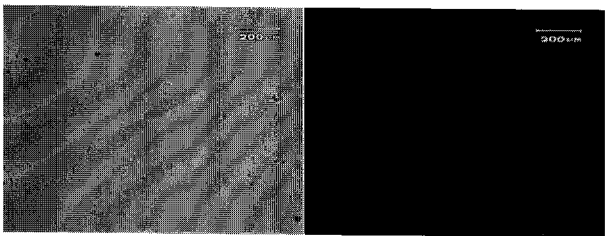


Fig. 1. Schematic diagram of DuoPIGatron-type IB and UV system used.

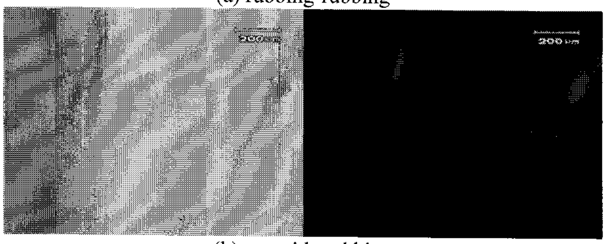
*Author to whom corresponding should be addressed: electronic mail: dsseo@yonsei.ac.kr exposure was used 45 ° incident angle. The IB irradiation time is used for 1 min. UV irradiation system used is shown in Fig. 1(b). The UV irradiation time is used for 1 min. and the incident angle of UV irradiation was 45 °. Here, the UV energy intensity was 30 mW/cm^2 for 1 min. The LC cell was fabricated as a sandwich type with anti-parallel structure, and the thickness of the cell was 60 μm. After fabricating the cell, a mixture of the positive type NLC (Δn = 8.2, MJ1001929, from Merck Co.). LC alignment characteristics were observed by using the photomicroscope. The tilt angle of the NLC was measured by crystal-rotation method (TBA 107, Tilt-Bias Angle Evaluation, from Autronic Co.) at room temperature. And, the cell gap was used 5 μm to fabrication of TN cell. In addition Voltage-Transmittance (V-T) and response time characteristics for the TN-LCDs were measured by LCD EOMS(Electro-optical Measurement) equipment.

3. RESULTS AND DISCUSSION

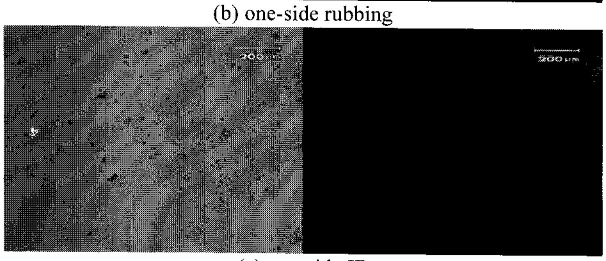
Figure 2 shows the microphotograph of NLC on the homogeneous PI surface by various alignment methods (under crossed Nichols). Suitable LC alignment for one-side alignment cell on a PI surface by all alignment method was observed.



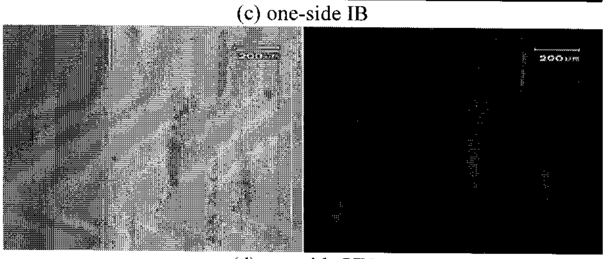
(a) rubbing-rubbing



(b) one-side rubbing



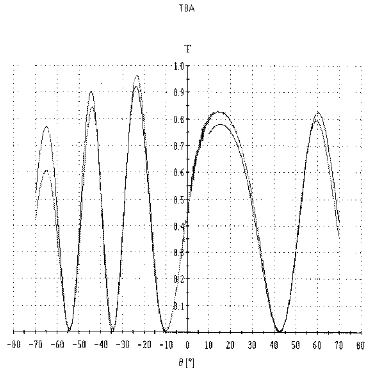
(c) one-side IB



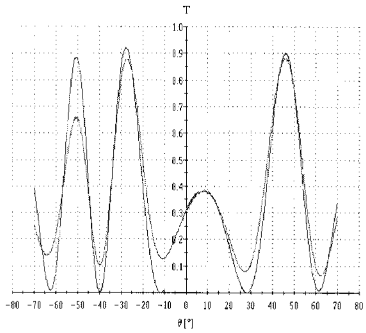
(d) one-side UV

Fig. 2. Microphotograph of NLC on the homogeneous PI surface by various alignment methods (under crossed Nichols).

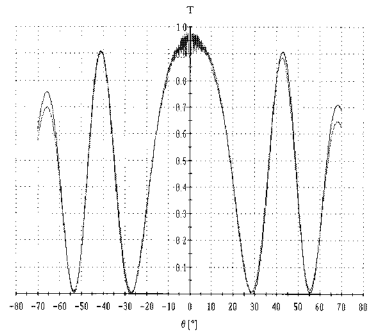
Figure 3 shows the transmittance characteristics as a function of incident angle in various LC cell on the PI surfaces by a crystal-rotation method. A shift of symmetric point from point 0 was measured on the PI surface with all incident angles. The pretilt angle of NLC on the PI surfaces with IB and UV irradiation was measured below 1 degree.



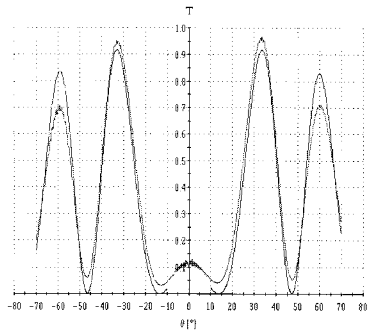
(a) rubbing-rubbing



(b) one-side rubbing



(c) one-side IB



(d) one-side UV

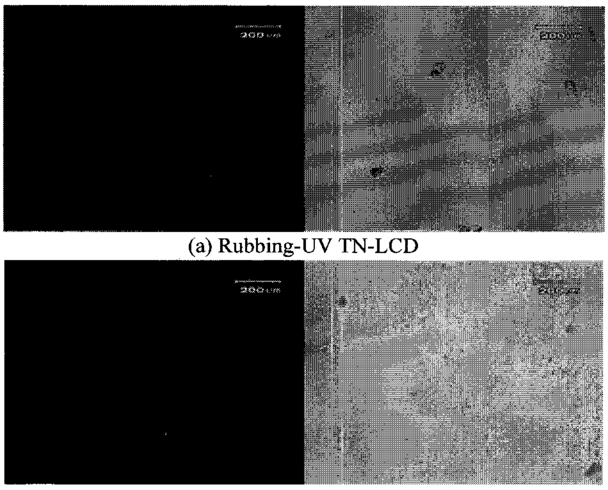
Fig. 3. Relationship between the transmittance and the incident angle in various LC cell on the PI surface for measuring pretilt angles.

Table 1 shows the pretilt angle of NLC on the PI surfaces by various alignment methods. High pretilt angle of NLC for both-side rubbing cell on the PI surface was measured. The half pretilt angle of NLC for one-side rubbing on the PI surface was measured. But, low pretilt angle of NLC for one-side IB and UV irradiation cell on the PI surface was observed. Therefore, we consider that the generated pretilt angle of NLC for one-side IB and UV irradiation on the PI surface is lower than that of the PI surface with rubbing.

Table 1. Pretilt angles of NLC on the PI surface by various alignment methods.

	Pretilt angle(°)	Cell gap(μm)	error
rubbing-rubbing	4.87	56.4	0.004163
one-side rub	2.59	55.8	0.00957
one-side IB	0.23	57.4	0.001647
one-side UV	0.09	55.2	0.00697

Figure 4 shows the microphotographs of the TN-LCDs on the PI surface (under crossed Nichols). The applied voltage is used 5 V. As shown in Fig. 4(a), the monodomaine texture for the one-side rubbing TN-LCD on the PI surface with one-side UV irradiation was observed. The monodomaine LC alignment for the both-side rubbing TN-LCDs on the PI surface can be achieved as shown in Fig. 4(b).



(a) Rubbing-UV TN-LCD

(b) Rubbing-rubbing TN-LCD

Fig. 4. Microphotographs of the TN-LCDs on the PI surface (under crossed Nichols). TN-LCDs prepared by (a) one-side rubbing TN-LCD on the PI surface with UV irradiation and (b) Both-side rubbing TN-LCD.

Figure 5 shows the *V-T* characteristics for two kinds of TN-LCDs on the PI surface. Excellent *V-T* curve for the rubbing TN-LCD on the PI surface was obtained. Also, good *V-T* curves for the one-side rubbing TN-LCD on the PI surface by one-side UV irradiation was obtained. Table 2 shows the threshold voltage for two kinds of TN-LCDs on the PI surface. The threshold voltage of the one-side rubbing TN-LCD on the PI surface with one-side UV irradiation was about 1.40 V. The threshold voltage of the one-side rubbing TN-LCD on the PI surface with one-side UV irradiation is large than that the both-side rubbing TN-LCD on the PI surface. It is suggested that the high threshold voltage is attributed to low pretilt angle.

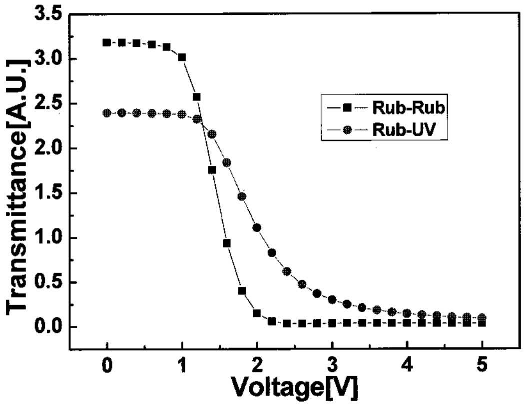


Fig. 5. Light transmittance characteristics as a function of applied voltage for two kinds of TN-LCDs on the PI surface.

Table 2. Threshold voltages for two kinds of TN-LCDs on the PI surface.

	Threshold voltage (V)
Rub-UV TN-LCD	1.40
Rub-Rub TN-LCD	1.07

Figure 6 shows the response time characteristic for two kinds of TN-LCDs on the surface. The good response time characteristics for two kinds of the TN-LCDs on the PI surfaces were measured. Table 3 shows the response time of the two kinds of the TN-LCDs on the PI surface.

The rising time was 1.56 ms and the decay time was 6.72 ms, for one-side rubbing TN-LCD with UV irradiation. But, the rising time was 1.21 ms, and the decay time was 12.3 ms for the both-side rubbing TN-LCD. The fast rising time was measured in the both-side rubbing TN-LCD on the PI surface. However, fast decay time can be achieved by one-side rubbing TN-LCD on the PI surface with one-side UV

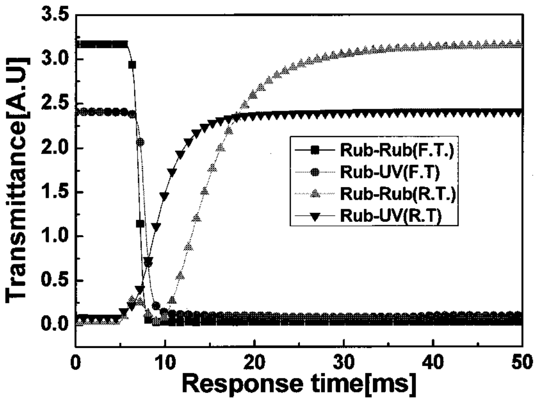


Fig. 6. Response time characteristics for two kinds of TN-LCDs on the PI surface.

irradiation. We suggest that the rising response time is attributed to the pretilt angle on the PI surface, and the decay time is strongly attributed by anchoring strength between the LC molecules and the PI surface.

Table 3. Response times for two kinds of TN-LCDs on the PI surface.

	Rising Time (ms)	Decay time (ms)	Response Time (ms)
Rub-UV TN-LCD	1.56	6.72	8.28
Rub-Rub TN-LCD	1.21	12.3	13.5

4. CONCLUSION

In conclusion, we have studied the LC alignment and pretilt angle generation for the one-side alignment cell on the PI surface by the rubbing, IB irradiation, and UV irradiation method. Suitable LC alignment for one-side alignment cell on the PI surface by all alignment method was observed. The high pretilt angle of NLC for both-side rubbing cell on the PI surface was measured. But, low pretilt angle of NLC for one-side IB and UV irradiation cell on the PI surface was observed. Therefore, we consider that the pretilt angle of NLC for one-side IB and UV irradiation on the PI surface was lower than that of the PI surface with rubbing. In addition, the EO characteristics of the two kinds of the TN-LCD on the PI surface were investigated. The suitable V-T curves for the one-side rubbing TN-LCD on the PI surface with one-side UV irradiation were measured. Also, the good response time characteristics of the one-side rubbing TN-LCD on the PI surface with one-side UV irradiation were measured. We assumed that the response time is attributed by the anchoring strength between the LC molecules and the PI surface.

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