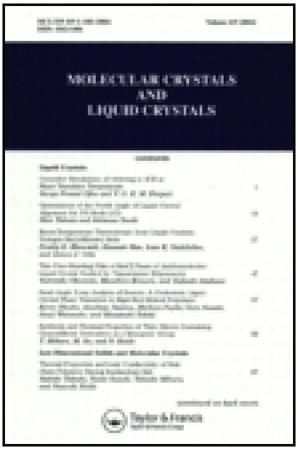

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Polarization-Dependence of Liquid Crystal Alignment on an Organic Insulation Thin Film with Ion Beam Irradiation Explained by Brewster's Law

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We used Brewster's Law to examine the mechanism of liquid crystal (LC) alignment on an organic insulation layer when subjected to ion-beam irradiation. Brewster's Law implies that the maximum rate polarized ray on a slanted insulation layers on the substrate and it illustrates the dependence of polarization and the mechanical structure on the ion beam irradiation process. The pretilt angle of nematic LCs on the organic insulation surface was about 1.13° for an ion beam exposure of 45° for 1 minute at 1800 eV. This shows the dependence of LC alignment on the polarization ratio in a slanted organic insulation layer. We also discussed the electro-optical characteristic of twisted nematic (TN) LCD using ion beam irradiation on organic overcoat layer.

Keywords: electro-optical characteristics; ion beam; liquid crystal alignment; polyimide; TN-LCD

INTRODUCTION

The alignment of the liquid crystal (LC) molecules on the substrate surface is an important process in liquid crystal display (LCD) manufacturing. Generally, rubbing has been used to align LC molecules on a polyimide (PI) surface [1–3]. Rubbed PI surfaces have suitable characteristics, such as uniform alignment and a stable pretilt angle.

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However, rubbing does have some drawbacks, such as the generation of an electrostatic charge [4] and the creation of contaminating particles. Since the LC cell must be cleaned to remove the electrostatic charge and particles, a non-contact alignment technique for future generations of high-resolution LCDs is highly desirable [5]. UV light exposure of the photopolymer layer has been studied as a non-contact alignment method and been shown to provide good LC alignment and thermal stability of the nematic liquid crystals (NLCs) [6]. The effects of UV exposure on LC-alignment on a PI surface have been reported [7]. Recent studies have addressed LC alignment and pretilt angle generation in various alignment layers using ion beam irradiation [8–10]. However, no study to date has used Brewster's Law to elucidate the polarization-dependence of LC alignment in ion beam irradiation.

EXPERIMENTAL

In this experiment, an organic insulation material (PIG-5411015, Chisso Co.) containing polyamic acid, epoxy resin, and methyl-3-methoxypropionate with solvent was used for the LC alignment layers. This material was uniformly prepared by spin-coating onto indium-tin-oxide (ITO) electrodes and imidized at 200°C for 60 min. The thickness of the organic overcoat film was set at 500 Å. The substrate surface was then exposed to ion-beam irradiation using a DuoPIGatron ion-beam system [10], which is well-suited to large-area exposure with high-density plasma generation. The ion-beam parameters were as follows: energy 600–3000 eV, exposure time 1 min, and ion beam current 1.84–2.51 mA/cm^2. A sandwich-type LC cell was fabricated with an anti-parallel structure and a thickness of 60 μm. The cell was then filled with a mixture of positive-type NLCs ($\Delta n = 0.0987$, MJ1001929, Merck Co.). We observed the alignment characteristics of the LCs with a photomicroscope. The NLC pretilt angle was measured using crystal-rotation (TBA 107 Tilt-Bias Angle Evaluation System, Autronic-Melchers Co., Germany) at room temperature. The annealing time was 10 min. And we also fabricated TN-LCD cell as above conditions. The TN-LCD was made for measurement of EO characteristics to verify the possibility of LCD application.

RESULTS AND DISCUSSION

Figure 1 shows the alignment of NLCs on an organic insulation thin-film surface subjected to ion beam irradiation at 45° for 1 min with various beam energies. Figure 2 shows the pretilt angles on an organic insulation surface under various ion-beam irradiation

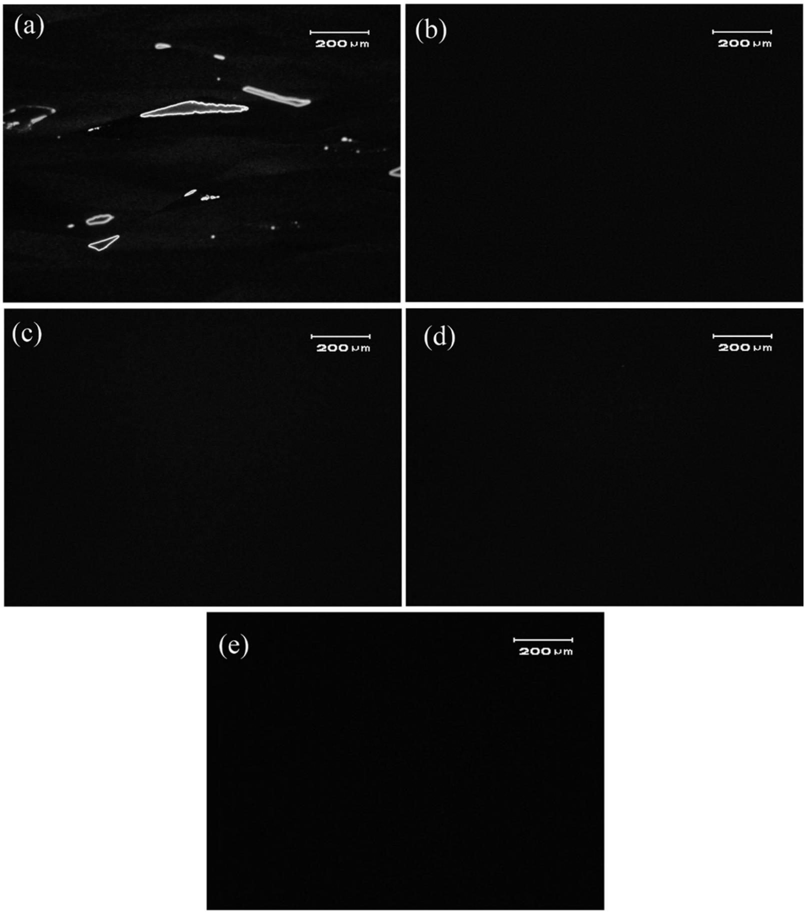


FIGURE 1 Microphotograph of NLCs after the organic thin film overcoat was exposed to ion-beam irradiation at 45° for 1 min with various ion beam energies (in crossed Nicols). (a) 600 eV, (b) 1200 eV, (c) 1800 eV, (d) 2400 eV, and (e) 3000 eV.

conditions. The pretilt angle was strongly related to the irradiation angle of the ion beam; irradiation angles of 45–60° produced the greatest pretilt angles. The figure shows that in the ion-beam irradiation process, NLC alignment is related to the anisotropy of the polarized optical wave, such as ultraviolet (UV) or other rays, and not to the energy of the ion beam, which is isotropic. UV and other waves are generated when ion-beam equipment is operated. According to Brewster's Law, p- and s-waves are generated by slanted reflections

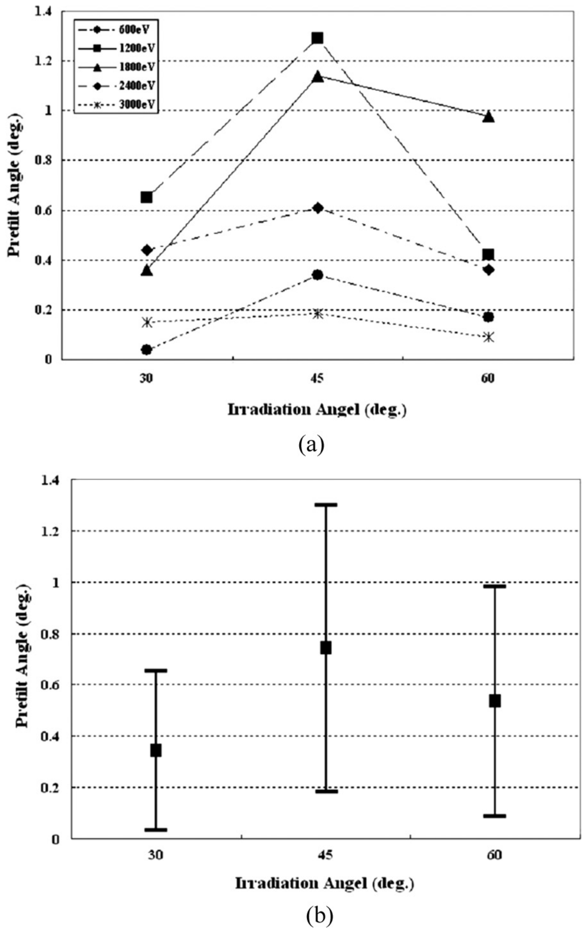


FIGURE 2 Pretilt angles as a function of ion beam intensity and irradiation angle. (a) Pretilt angles at various ion beam strengths and irradiation angles. (b) Pretilt angles generated with three different irradiation angles.

from materials. Other research has examined NLC alignment on the insulation layer using non-polarized UV light. Therefore ion-beam irradiation is a more effective method because unidirectional corrosion is driven by ion beam energy more rapidly than using only polarized long waves such as UV light. This is a very significant result in view of possible applications in mass-production processes.

We calculated Brewster's angle in specimens consisting of two layers [11]. One was the insulation layer, with a refraction ratio of

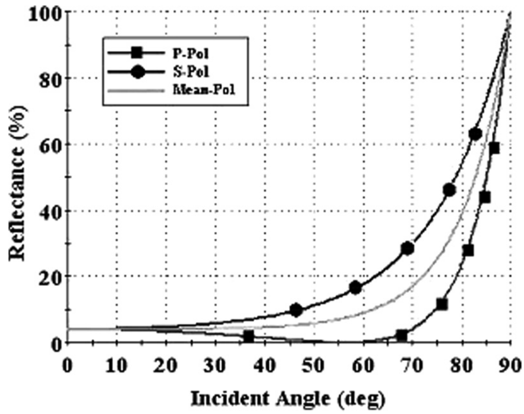


FIGURE 3 Calculated optical anisotropy generated at various irradiation angles.

1.62, and the other was ITO glass with a refraction ratio of 1.5. Figure 3 shows that separation of the p- and s-waves started at ion-beam irradiation angles of about 30° and they were highly

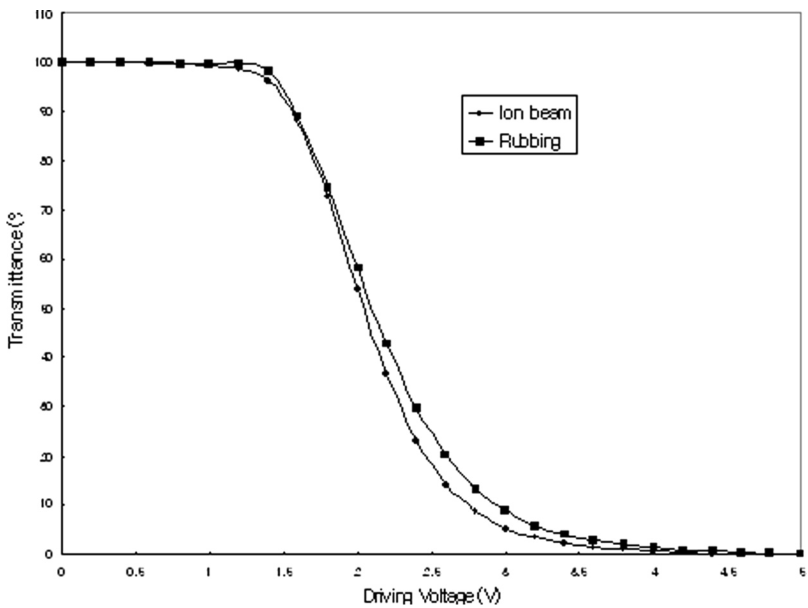
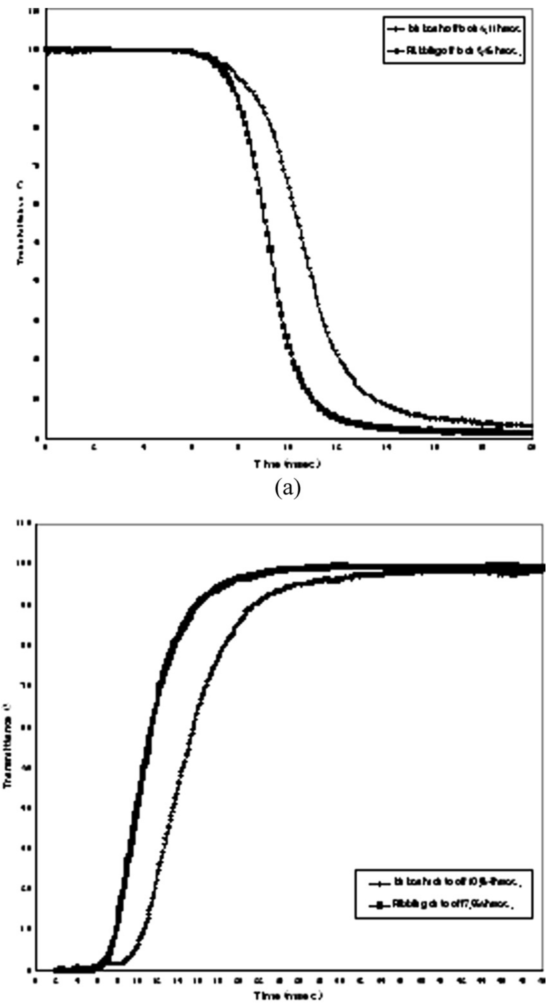


FIGURE 4 Voltage-transmittance (VT) characteristics of TN LCD with rubbing and ion beam treatment.

separated at 56.56–56.93°. Although this calculation does not match the experimental data exactly, it does provide a good foundation for explaining the experimental results. Figure 4 shows almost same result as conventional rubbing treated TN-LCD in V-T measurement results. And as shown in Figure 5, on-time is 5.11 msec, and off-time



(a)

(b)

FIGURE 5 Response time characteristics of TN LCD with rubbing and ion beam treatment. Response time characteristics during off state to on state (NW mode), Response time characteristics during on state to off state (NW mode).

is 10.98 msec. It is larger than conventional rubbing treated sample but it is good result without any chiral dopant.

CONCLUSIONS

We have successfully studied LC alignment and the mechanism of ion beam irradiation on the surface of an organic insulation thin film for the first time. Good LC alignment can be achieved on an organic insulation thin film surface irradiated by ion beams at 45°for 1 min with ion beam energies greater than 1200 eV. We have suggested the relationship between the irradiation angle and the direction of LC alignment using Brewster's Law. The pretilt angle of NLCs on an organic insulation thin film surface for an ion beam exposure of 1800 eV was measured to be about 1.13°. However, low pretilt angles were observed for NLCs on an organic insulation thin-film surface with ion beam exposure energies of 600, 1200, 2400, and 3000 eV.

We fabricated the TN-LCD for measurements of the V-T characteristics and the response time characteristics. The V-T characteristics were almost same characteristics between ion beam treated specimen and rubbing treated specimen. Both of two types are linearly changed at 1.5 volt, and saturated at 3.5 volt. The Response time characteristics 5.11 msec in on time, and off time is 10.98 msec showed a possibility of LCD application. It was a good result without any chiral dopant.

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