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The effect of Ion Beam modification of Polyimide surface on alignment properties of liquid crystals

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Abstract

The alignment effect of liquid crystals on Polyimide surfaces bombarded by a low energy argon ion beam and the effect of pretilt angle on viewing characteristics of an LCD cell are discussed. The unidirectional out-of-plane liquid crystal tilt angle is varied with various ion beam irradiation conditions, such as the energy of the incident ions, the angle of incidence and exposure time. As low pretilt angle is profitable for wider viewing property, LCD cell with ion beam modified Polyimide layer show wider viewing characteristics.

Keywords : Polyimide film, Ion-beam modification

1. Introduction

The anisotropic nature of the alignment layer in Liquid Crystal display plays a crucial role to align liquid crystals to appropriate directions. Various techniques have been developed to induce anisotropy on the surface, such as rubbing [1], oblique angle deposition of SiO_2 [2], a grating structure produced by microlithography [3], stretching a polymer [4], photo alignment [5] and so on. The most common technique is rubbing a polyimide alignment film with a velvet cloth. Even though the technique has many disadvantages, the technique has been widely used more than 20 years because of its high productivity. The well known problems of rubbing method are leaving debris of the cloth during the rubbing process and generating electrostatic discharge that could influence to the electronic circuitry just below the surface of the rubbed polyimide thin film. And it is also reported that domain structures in the alignment layer of IPS(in plane switching) mode LCD are significantly related to the width of viewing angle of the display [6]. Using conventional rubbing method, it is almost impossible to make multi-domain structure which shows best view angle property. Hence a non-contact alignment method would be highly desirable for future generations of large, high-resolution LCDs. As a possible breakthrough for the requirement, ion beam modification method of the alignment layer was proposed by IBM researchers [7-8]. The detail mechanisms and characteristics for this alignment method are under actively studied. The ion beam alignment technique also could be the one of the potential methods to control the pretilt angle in order to optimize display performance such as having wider viewing angle and faster response time.

In this paper, by varying ion beam conditions, we investigate the change of the pretilt angle of LC on polyimide alignment layer in IPS cell. And also we study morphological change, chemical bonding and aligned state of polyimide surface after ion beam exposure through the atomic force microscope (AFM), and x-ray photoelectron spectroscopy (XPS), respectively.

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2. Experiments and Results

The alignment characteristics of liquid crystal and pretilt angle variations were checked for test cells fabricated using ion beam treatment. Spin coated SE-7492 on Indium-Tin-Oxide (ITO) substrates were prebaked at 80℃ for 10 minutes and cured at 250℃ for two hours to produce polyimide alignment layer. Then the polyimide are bombarded using cold cathode type low energy argon ion gun. Parameters which influence the surface of polyimide may be the energy, exposure angle, exposure time and current density with respect to the ion beam. The alignment directions of liquid crystals are quite different with cell fabrication methods, ion beam treated method and rubbing method. In two cases, the in-plane molecular direction of LC is the same, but the unidirectional out-of-plane LC tilt angle is opposite each other. This will be due to the following origin. At the rubbed polyimide, orientational order of LC is generated from the crystalline order of polymer chains [9]. However, for the ion beam-treated polyimides, orientational order of LC may be created by the selective destruction of π-bonds of imide ring in polyimide [10]. Figure 1 shows a plot of transmission of light as a function of voltage for four TN cells, which were fabricated by ion beam alignment and by the conventional rubbing alignment. The transmission characteristics are very similar for the two cases. Only a little difference due to a difference in the cell gap and the pretilt angle for the two TN cells exist. Fig. 2 shows AFM images of the polyimide surface topography. Fig. 2(a) show untreated polyimide surface, Figs. 2(b) and 2(c) represent the surfaces after

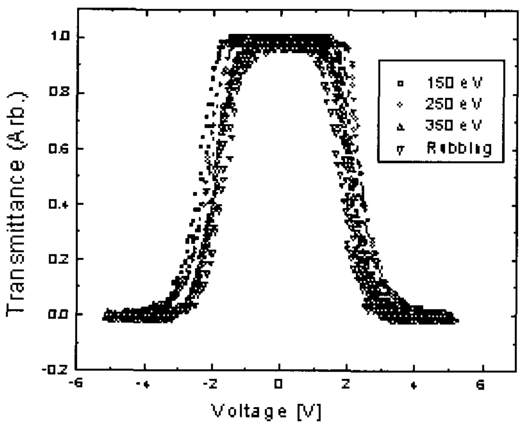

Fig. 1. The voltage-transmittance characteristics of TN cells fabricated by ion beam and rubbing methods.

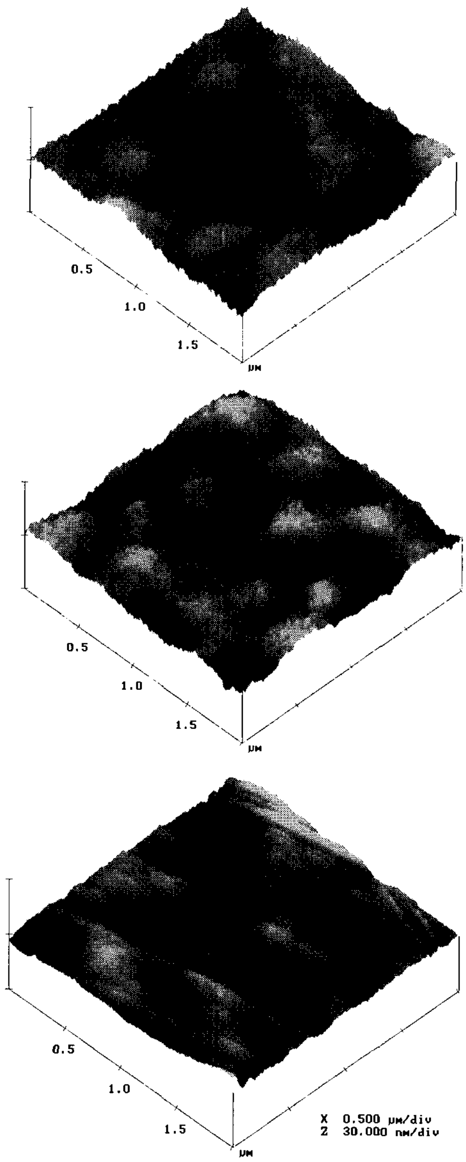

Fig. 2. AFM images on polyimide surface : (a) Without both rubbing and ion beam exposure, (b) after rubbing and (c) after ion beam exposure.

rubbing and ion beam exposure, respectively. The image taken after rubbing in Fig. 2(b) shows obviously the trace of grooves. The alignment of liquid crystal which is influenced strongly by the effect of these grooves already had been reported [3]. Then, the alignment of liquid crystal is parallel to the direction of rubbing. However, the polyimide surfaces bombarded by the ion beam as shown in Fig. 2(c) appear to have had very little effect on directional topography. It might be possible that the homogeneous alignment on the surfaces bombarded by ion beam could be considered to be due to statistically parallel alignment of molecules of the orientation layer. Anyway, the mechanism of alignment by using ion beam might be different with that of rubbing and it needs more study. Fig. 3 shows fitted curves of C_{1s} with XPS (X-ray Photoelectron Spectroscopy) for SE-3140. The peak of 288.5 eV corresponds to carbonyl carbon (C=O) in imide ring [11]. After rubbing, the intensities of this peak is almost the same. However, after ion beam exposure, the intensities are decreased. This spectral shape agrees well with one shown in reference [11]. The probability of interaction between ion beam and π -electrons will have large value with the ion beam normal than parallel to the plane of the p orbital. Ion beam will destroy π-bonds perpendicular to the incident ion beam which have larger cross-section. In consequence, the pretilt angle of the liquid crystal will be created by the remaining π-bonds parallel to the incident ion beam. As the result of XPS measurements, the out-of-plane pretilt angle and in-plane alignment of the liquid crystal is thought to originate from the remaining-bonds without destruction by atomic beam. That the alignment direction of liquid crystal on polyimide substrate is parallel to the direction of ion beam supports this assumption. Fig. 4 shows a plot of the pretilt angle as a function of the angle of incidence of the atomic beam with respect to the plane of the substrate, where ion beam energy and ion beam exposure times are 200 V and 30 sec respectively. The pretilt angle was measured by a crystal rotation method.

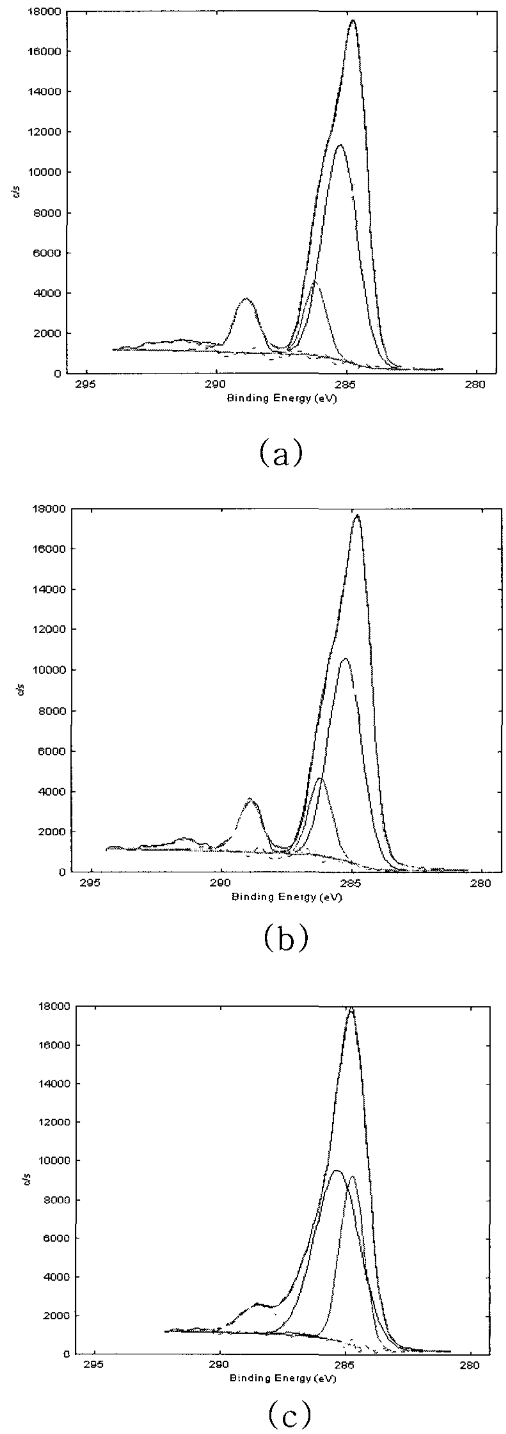

Fig. 3. Curve fitting of XPS data for SE-3140 as PI : (a) Before rubbing (b) after rubbing, and (c) after argon ion beam exposure.

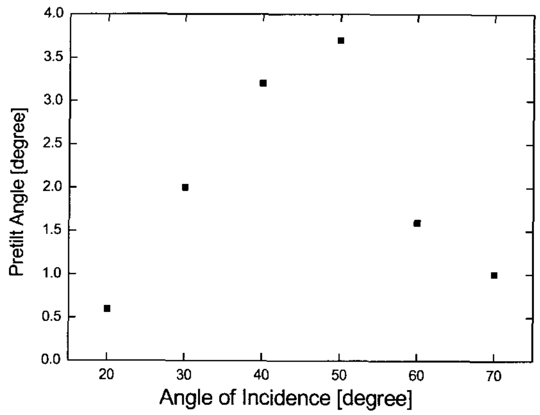

Fig. 4. The pretilt angle as a function of the incident ion beam angle.

Then a maximum pretilt angle is about 3.5° at exposure angle of 50. In general, the pretilt angle is detemined by the polymer surface orientation and the chemical composition of the alignment surface12. For the rubbed polymer surfaces, the alignment of polymer chain give rise to orientational order of LC as referred in above. For polymer surfaces exposed by atomic beam, the orientational order of LC is originated from selective destruction and bond formation with respect to the atomic beam direction [8,10].

IPS mode of LCD would be designed with NB (Normally Black) mode because very good dark state could be obtained at field off state. With crossed polarizer, we need to set the LC directors to same direction with transmission axis of the polarizer. This configuration allows very good dark state irrespective of retardation of the LC cell in the normal direction. In the case of the oblique incident light, however, we can predict that the retardation should be dependent on pretilt angle, so that it may cause the variation of their contrast and equ-contrast characteristics. To calculate the viewing angle performance, optical calculation has been performed by LCD-master shintech simulator. We assumed 2.36um cell gap. The interdigital electrode distance was 10 um and the electrode width was 5 um. ZLI-1557 produced in Merk was used as LC material. Fig. 5 shows calculated equ-contrast

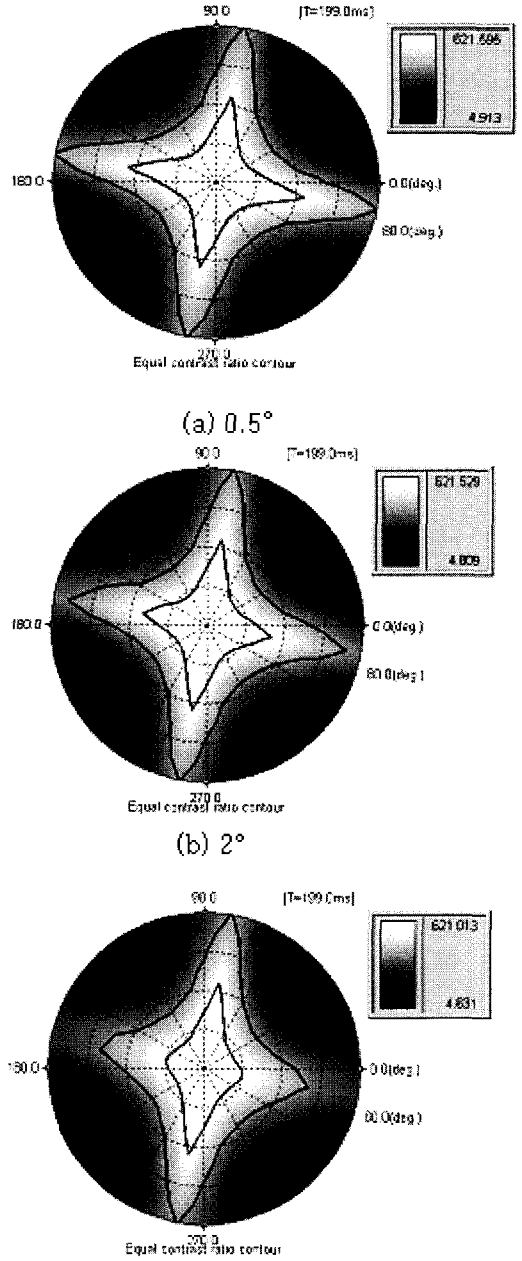

Fig. 5. Equal contrast ratio contours for (a) pretilt angle of 0.50 (b) 20 (c) 40. The solid lines in figure represent contrast ratio of 400, 100, 15 respectively, from inside

as a function of the pretilt angle.

Applied pretilt angles in calculation are 0.5°, 2° and 4°, respectively. And each line shows equ-contrast

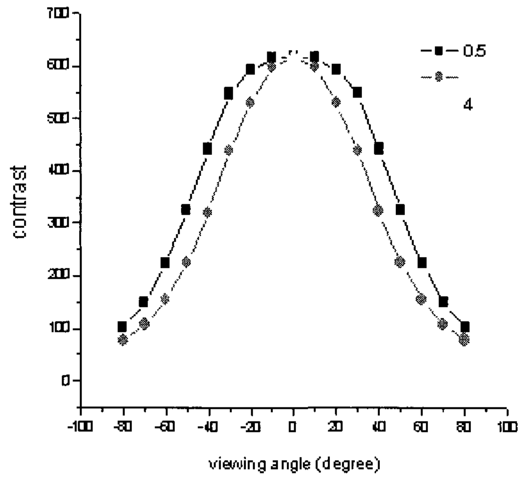

Fig. 6. View angle and contrast ratio dependance as pretilt angle varies

contour of 400, 100 and 15 from the inside. The lower pretilt angle liquid crystal has, the wider viewing angle-dependent-contrast ratio is. The relatively low contrast ratio line is insensitive to viewing angle. However, the highest contrast ratio line(400) shape is different for pretilt angle variation. From the fig. 6, we confirm that the lower pretilt angle in the liquid crystal is needed for better viewing angle characteristics. When azimuthal angle of the viewing angle direction is fixed on axis of analyzer, the dark state of the cell aligned high pretilt is not as good as that with low pretilt. When the oblique incident light is perpendicular to optic axis of liquid crystal, retardation at high pretilt aligned liquid crystal is larger than the one with low pretilt in liquid crystal layer. These viewing angle characteristics can be caused dark state. Difference of dark states is affected by the birefringence of the liquid crystal layer. Because retardation as inclined incident light is not zero. retardation at high pretilt aligned liquid crystal is larger than that of low pretilt aligned liquid crystal. As a result, it is necessary to generate low pretilt angle for wide viewing angle performance. In general, however, we cannot make very low pretilt angle by using conventional rubbing method. Pretilt characteristic of polyimides to align liquid crystal is higher than 1o for the present. One of methods to be able to generate low pretilt angle and control the pretilt angle is ion beam alignment technique [3,4]. The ion beam alignment method is non-contact method which exposure ion beam on the polyimide surface with suitable energy, so that we can obtain very low and stable pretilt angle even below 0.5°.

3. Conclusions

Polyimide surfaces bombarded by a low energy argon ion beam align liquid crystals and create a pretilt angle of liquid crystals. The pretilt angle of the liquid crystals is controlled by ion beam parameters, such as the energy of the incident ions, the angle of incidence, exposure time and current density. The alignment direction of liquid crystal on substrates is parallel to the direction of ion beam. By the analysis of the AFM images, at polyimide surface exposed by atomic beam, directional topography not appears like the rubbing. The mechanism of atomic beam alignment can be considered to be different with that of rubbing mechanism. As a result of curve fittings with XPS, ion beam bombarded on polyimide surfaces destroys π-bonds of polymers. The pretilt angle and alignment of the liquid crystal by atomic beam will be produced by the remaining π-bonds. Therefore we support a model by which LC alignment originates from overlap of the anisotropic p orbital between polymer surface and LC. The viewing angle of an IPS cell was calculated as function of pretilt angle from 0.5 to 4. We find that the viewing angle characteristic of an IPS which has low petilt angle is better than that of an IPS which has high pretilt angle. The low pretilt angle angle was achieved by exposing ion-beam on glass substrate.

Acknowledgement

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