Alignment of Nematic Liquid Crystals on Polyimide Surface Bombarded by Ar^+ Beam

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Abstract

We found that polyimide surfaces bombarded by a low energy argon ion beam align 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 corresponded to ion beam direction. By argon ion beam the pretilt angle of the liquid crystals was controlled between 0.5° and 4° for SE-3140 under the proper conditons. By the atomic force microscope (AFM), polyimide surfaces before and after bombarded by ion beam are compared.

1. Introduction

In liquid crystal display technology in order to align liquid crystals, anisotropy of a layer on the surface of a substrate is required to be induced. A number of alternative alignment techniques of inducing 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] and photo alignment[5] has been reported. Practically the most general technique used is rubbing a polyimide film with a velvet cloth. However, this technique has many disadvantages although it has been widely used in the actual production of liquid crystal displays for the last 20 years because of its high productivity. The rubbing method leaves the debris by the cloth during the rubbing process. Rubbing may also give rise to an electrostatic discharge that can influence the electronic circuitry just below the surface of the rubbed polyimide thin film. A multidomain structure significantly increases the viewing angle of the display[6]. However it is not easy to achieve multidomain structure by this technology because it is a contact method. Hence a non-contact alignment method would be highly desirable for future generations of large, high-resolution liquid crystal displays. In order to solve these problems, recently alignment by ion beam was reported by IBM[7],[8]. However the deep studies for this alignment mehod are required more strongly. Additionally, optical characteristics of the TN-LCD are determined by many parameters such as the gap of the LCD cell and the twist angle of the LC layer. The pretilt angle is one of the most important parameters. Twisted nematic displays, for example, prepared with low pretilt angles may show poor light scattering effects because of the formation of inversion walls in the nematic layer when the device is turned on. On the other hand, displays with large pretilt angles often show disturbing interference colors and have a reduced multiplexing capacity[9]. Therefore, in order to optimize display performance, it is necessary to control the pretilt angle suitable for each mode of LCDs. One of potential methods to control the pretilt angle can be the ion beam alignment technique.

2. Experiments and Results

Indium-Tin-Oxide (ITO) coated on glass substrates are used as electrodes for all of the cells. The substrates are spin coated with SE-3140 used as polyimide and prebaked at 80 ℃ for 10 minutes and cured at 180 ℃ for two hours. Then the polyimide are bombarded by a low energy argon ion beam. As an ion source, a cold hollow cathode (CHC) type is used to yield ion beam. In order to collimate ion beam, two perforated grids are used as elecrofocusing lenses. CHC represents a separate cooled chamber that is supplied with a magnetic system and is connected with discharge chamber through an orifice hole. Argon gas feeding into ion source is being carried out through the CHC only. A discharge ignition in the cathode takes place at nominal values of discharge voltages and at nominal gas flow rates. A neutralizer filament on the outside of the ion source serves as a source of electrons necessary for compensation of ion beam spatial charge and reduces the repulsive force among ions.

Parameters which influence on the surface of polyimide are maybe the energy, exposure angle, exposure time and current density with respect to the ion beam. In our experiment, these parameters were varied. After the substrates were bombarded by the ion beam, the two substrates were filled with a liquid crystal (Merck LC ZLI-1557).

The pretilt angle was measured by a crystal rotation method. Figure 1 shows a plot of the pretilt angle as a function of the angle of incidence of the ion beam with respect to the plane of the substrate, where ion beam energy and ion beam exposure thimes are 250 V and 20 sec respectively. Then a maximum pretilt angle is about 4° near exposure angle of sixty degree. The pretilt angle decreases with increasing exposure times for smaples exposed to 250 V ion beams and a 30° angle of incidence as shown in Fig. 2. Figure 2 shows a plot of transmission of light as a function of voltage for two TN cells, which were fabricated by ion beam alignment and by the conventional rubbing alignment. The transmission characteristics are very similar for the two processes. A little difference due to a difference in the cell gap and the pretilt angle for the two TN cells will exist. The thickness of the liquid crystal film was 9 μ m. The incidence angle, energy, exposure time and current of ion beam were 30° , 250 V, 20 s and 100 mA respectively. Figure 3 shows AFM images of the polyimide surface topography. Figure 3(a) is the picture taken before rubbing and ion beam exposure, Figs. 3(b) and 3(c) is the picture taken after rubbing and ion beam exposure, respectively. The image taken after rubbing in Fig. 3(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. 3(c) appear to have had very little effect on topography. It might be possible that grooves are present , but that the AFM tip is too

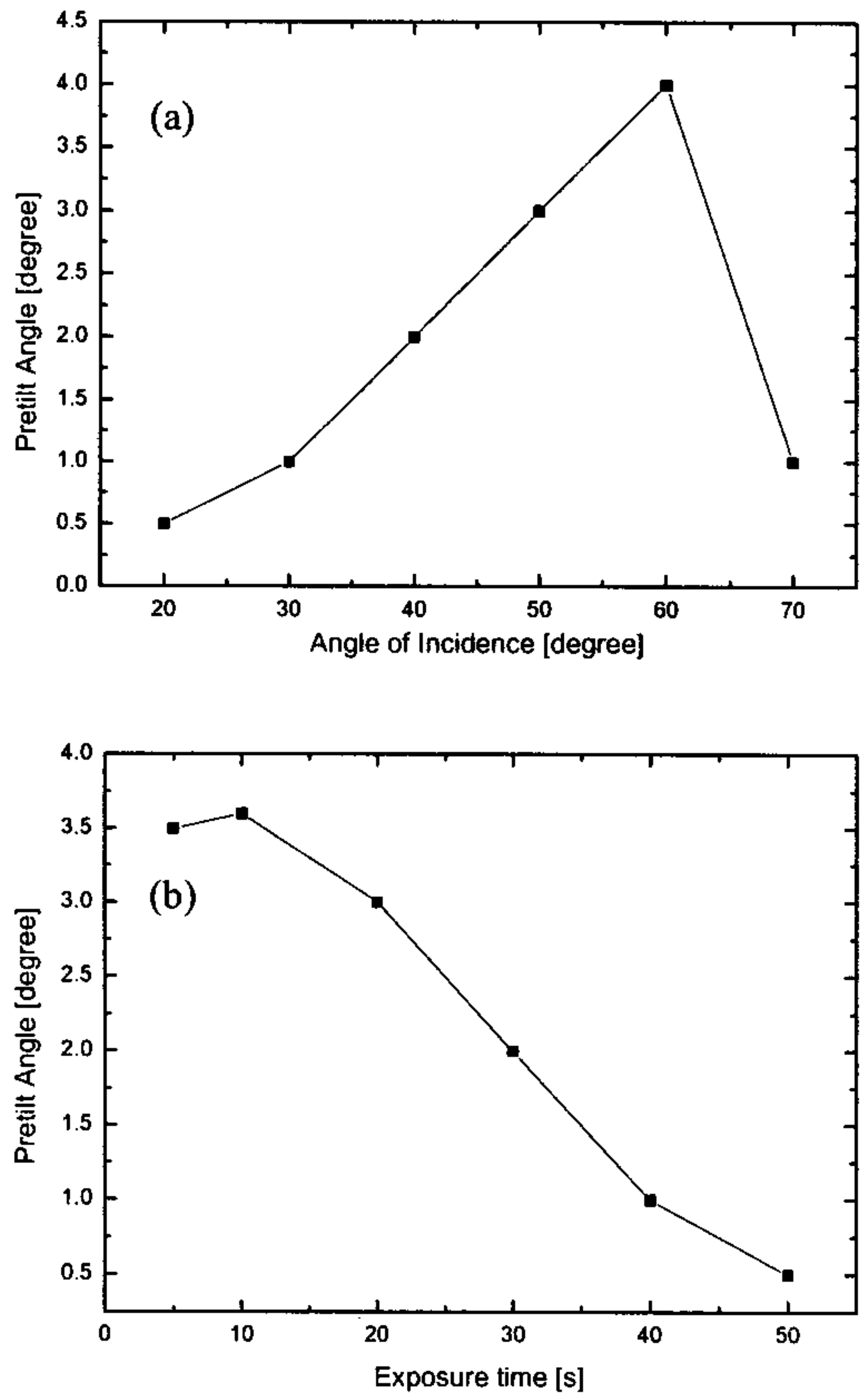

Figure 1. The pretilt angle as (a) a function of the incident ion beam angle and (b) a function of the exposure time of ion beam.

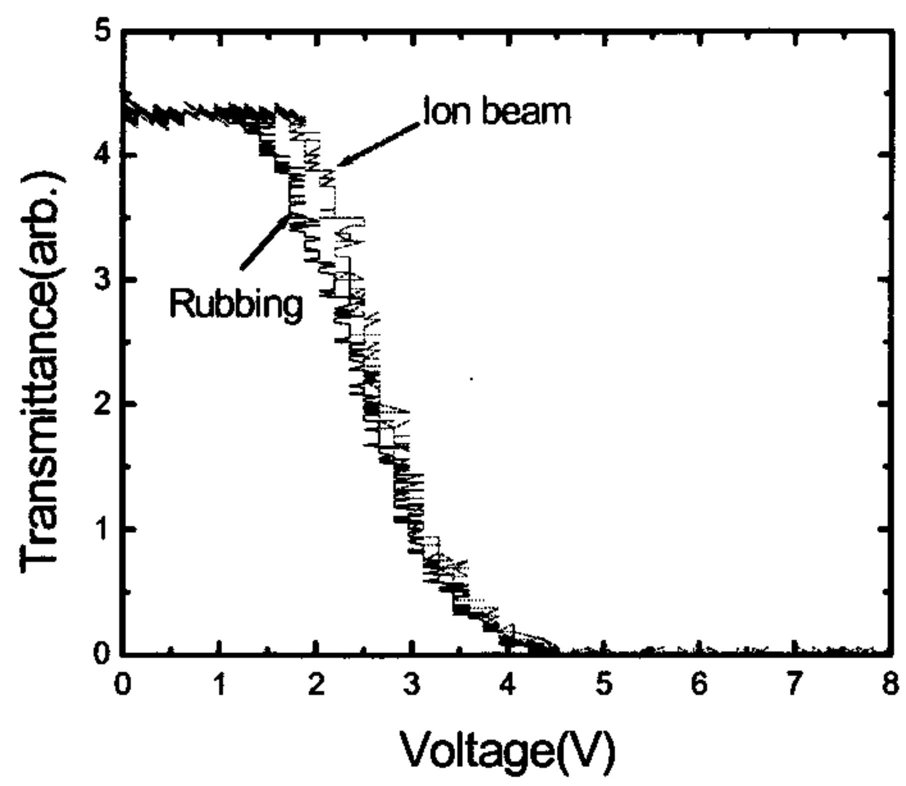

Figure 2. The transmission curve under an applied voltage for twisted nematic (TN) cell with the rubbing and the ion beam exposure.

blunt to image them clearly or 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.

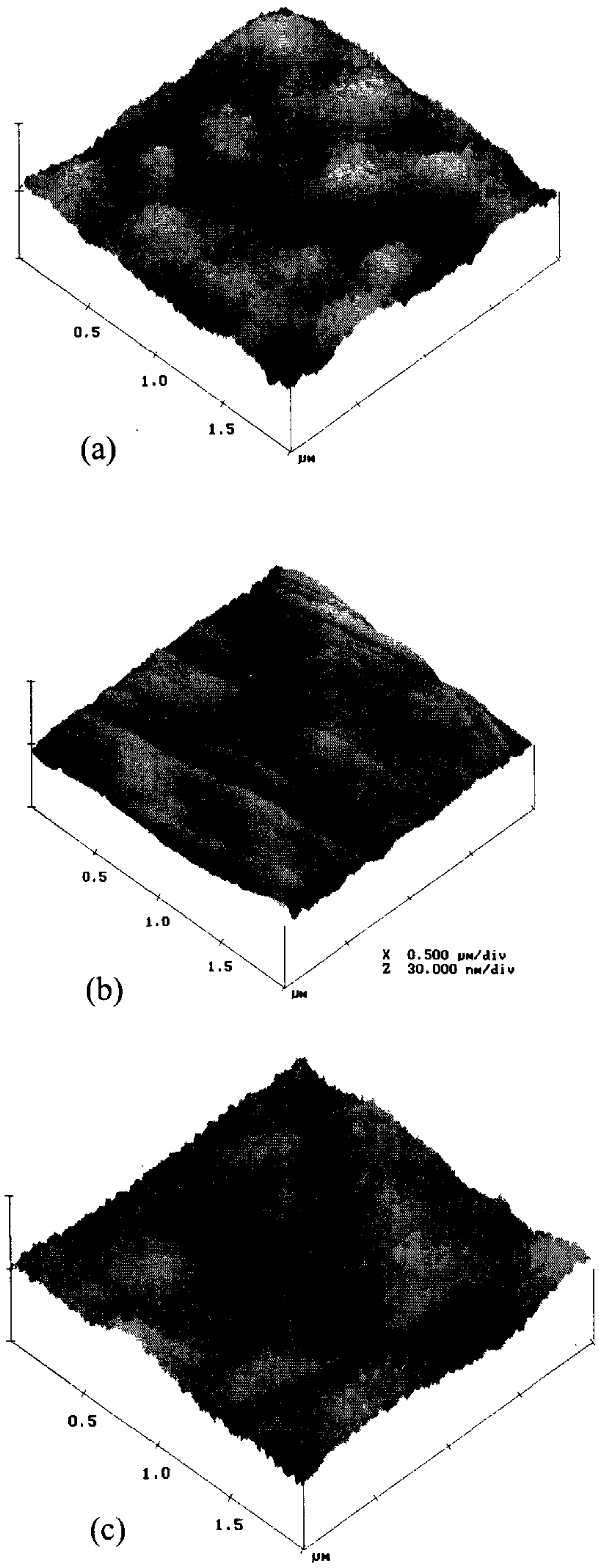

Figure 3. AFM images on polyimide surface : (a) Without both rubbing and ion beam exposure , (b) after rubbing and (c) after ion beam exposure.

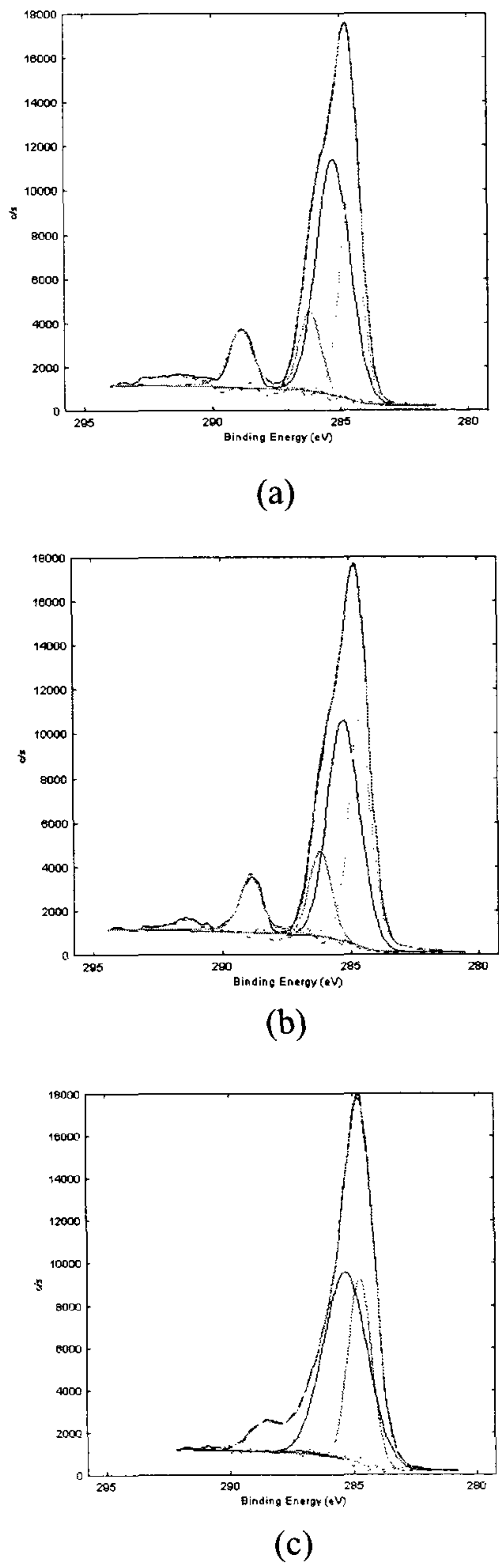

Figure 4. Curve fitting of XPS data for SE-3140 as PI : (a) Before rubbing and ion beam exposure, (b) after rubbing, and (c) after argon ion beam exposure.

Figure 4 shows fitted curves of C 1s with XPS (X-ray Photoelectron Spectroscopy) for SE-3140. Figure 4(a) is a picture taken before rubbing and ion beam exposure, Fig. 4(b) is after rubbing and Fig. 4(c) is after ion beam exposure (ion beam energy : 250eV, exposure time : 40 sec). The peak of 288.4 eV is due to carbonyl carbon in imide ring. After rubbing, the intensities of this peak is almost the same. However, after ion beam exposure, the intensities are decreased. This may be due to break- down of π-bonds in imid ring. 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 which have larger cross-section than others. The pretilt angle and alignment of the liquid crystal will be created by the remaining π-bonds.

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, the mechanism of ion 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 using ion beam will be produced by the remaining π-bonds.

4. Acknowledgements

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5. References

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