Liquid Crystal Alignment Effects on Nitrogen-doped Diamond like Carbon Layer by Ion Beam Alignment Method

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We have studied the nematic liquid crystal (NLC) alignment effects on a nitrogen-doped diamond-like carbon (NDLC) thin film layer with ion beam irradiation. The pretilt angle for NLC on the NDLC surface with ion beam exposure was observed below 1 degree. Also, we had the good LC alignment characteristics on the NDLC thin films with ion beam exposure of 1800 eV. In thermal stability experiments, the alignment defect of the NLC on the NDLC surface with ion beam irradiation above annealing temperature of 250 ℃ can be observed. Therefore, the good thermal stability and LC alignment for NLC by ion beam aligned NDLC thin films can be achieved.

Keywords : NDLC, Ion beam exposure, Alignment, PECVD, Nematic liquid crystal

1. INTRODUCTION

Recently, liquid crystal displays (LCDs) are widely used as information display devices such as mobile equipment, notebook PC, desktop, and LCD-TV. A rubbing method has been widely used to align liquid crystal (LC) molecules on the polyimide (PI) surface[1-3]. Rubbed polyimide surfaces have suitable characteristics such as uniform alignment and a high pretilt angle. However, the rubbing method has some drawbacks, such as the generation of electrostatic charges and the creation of contaminating particles[4,5]. Thus we strongly recommend a non-contact alignment technique for future generations of large, high-resolution LCD.

Most recently, the LC aligning capabilities achieved by ion beam (IB) exposure on the diamond like carbon (DLC) thin film layer have been successfully studied by P. Chauhari et al. DLC thin films have a high mechanical hardness, a high electrical resistivity, optical transparency and chemical inertness[6]. NDLC thin films exhibit properties similar to those of DLC films and better thermal stability than DLC films. Because C:N bonding in the NDLC film is stronger against thermal stress than C:H bonding in the DLC thin films.

In this study, we report on pretilt angle generation, LC alignment, atomic force microscopy (AFM) image analysis, and thermal stability of the LC cell on the nitrogen doped diamond like carbon (NDLC) surface as a-C:H:N thin-film[7-9] deposited by plasma-enhanced chemical vapor deposition (PECVD) with ion beam exposure.

2. EXPERIMENTAL

The NDLC thin films were deposited on indium-tin-oxide (ITO) coated glass substrates by PECVD. Prior to the film deposition, pre-sputtering was performed for 10 min to remove any contamination on the target surface. The NDLC thin films were deposited using C_2H_2 : 3 sccm, N_2 : 30 sccm for 1 min. The thicknesses of films were 18 nm. The used DuoPIGatron type ion beam system is shown in Fig. 1 which can be advantageous in a large area with high density plasma generation[10]. The ion beam parameters were as follows: energy of 1200~2100 eV, and exposure time 1min and ion beam current of 4 mA/cm² at an exposure angle of 45°. The NDLC thin films were bombarded with an Ar ion beam. After irradiation, test samples were fabricated in anti-parallel configuration with a cell gap of 60 μm. The test samples were assembled together and filled with a nematic liquid crystal (NLC) (TC = 72 ℃, $\Delta\varepsilon$ = 8.2,

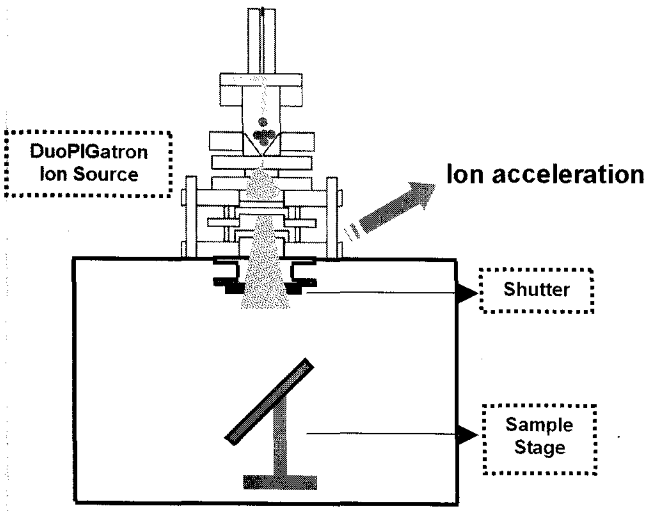


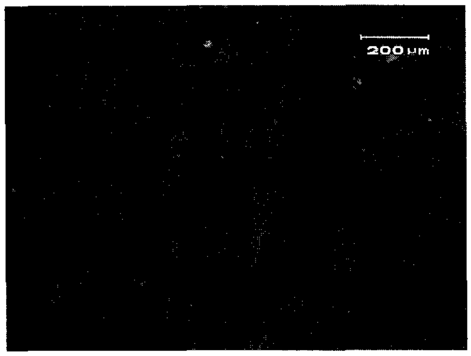
Fig. 1. Ion beam exposure system.

Δ n = 0.0987, MJ001929 from Merck Co.). To determine LC alignment, a polarized microscope was used and pretilt angle was measured by crystal rotation method (TBA 107, Tilt-Bias Angle Evaluation, from Autronic Co.) at room temperature. To measure the LC anchoring energy indirectly, thermal stability experiment was carried out. Each LC cells was heated up to specific temperature on the hot plate for 10 min and LC cells were cooled down gradually. For identifying the NDLC thin films surfaces topography, atomic force microscopy (AFM) was introduced.

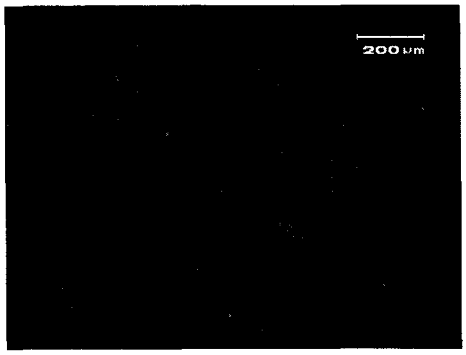
3. RESULTS AND DISCUSSION

The microphotograph (polarizer is crossed Nicols) of ion beam aligned LC cells on the NDLC thin films with ion beam exposure are shown in Fig. 2. The good LC alignment without light leakage of the NDLC thin films with ion beam exposure was measured at ion beam energy of 1800 eV.

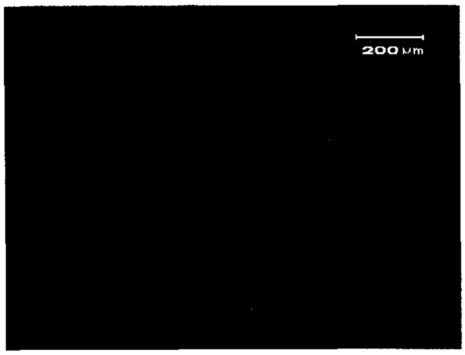
Figure 3 shows the relationship between the transmittance and the incidence angle for NLC on the NDLC surface with ion beam exposure by measuring the pretilt angle using the crystal-rotating method. A shift of symmetric point from point 0 was measured on the NDLC thin films with ion beam exposure at the various ion beam energy. The calculation shows that the pretilt angles are (a): 0.496, (b): 0.745, (c): 0.995, (d): 0.785, which is considered to be a very low pretilt angle. In the result LC cell which was irradiated ion beam on the NDLC thin films shows homogeneous alignment.



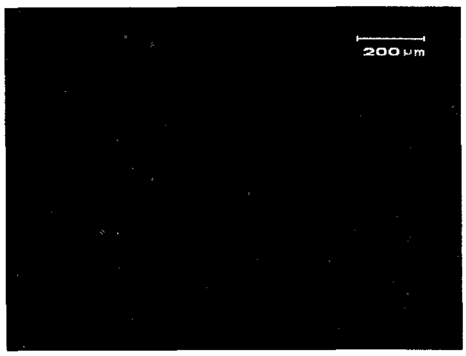
(a) 1200 eV



(b) 1500 eV

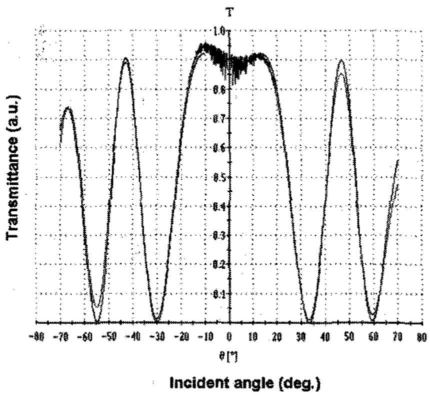


(c) 1800 eV

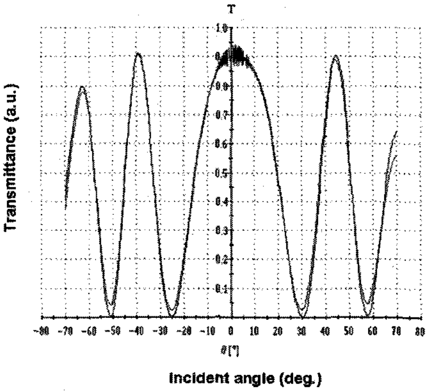


(d) 2100 eV

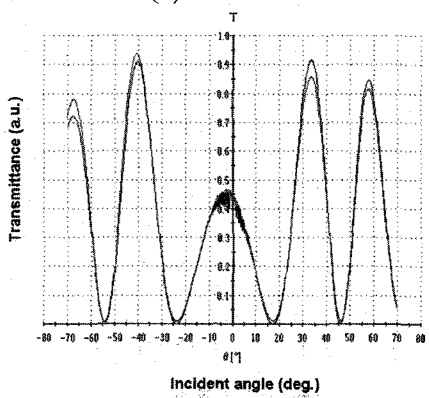
Fig. 2. Microphotograph of the LC cells on the NDLC thin films with ion beam exposure at various ion beam energy (in crossed Nicols).



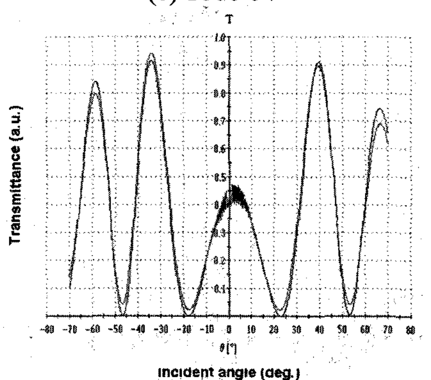
(a) 1200 eV



(b) 1500 eV

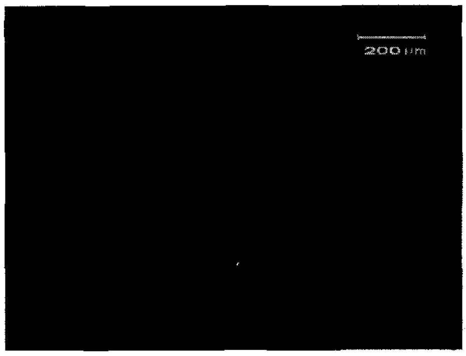


(c) 1800 eV

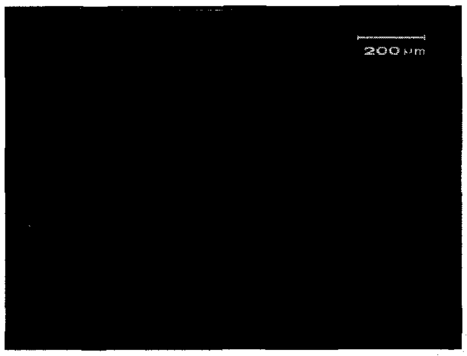


(d) 2100 eV

Fig. 3. The relationship between transmittance and incidence angle for NLC on the ion beam irradiated NDLC thin films at the various ion beam energy.

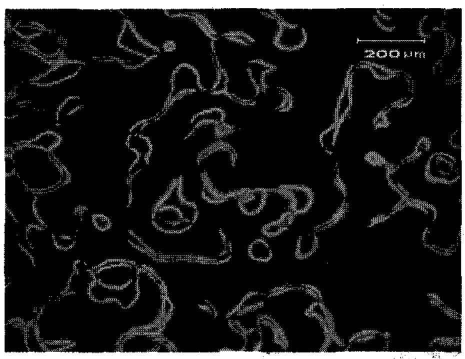


(a) 100 ℃



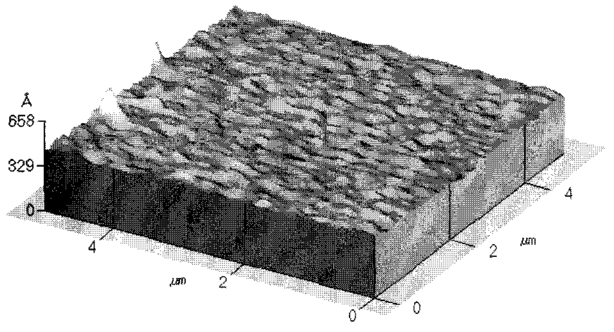
(b) 150 ℃

(c) 200 ℃

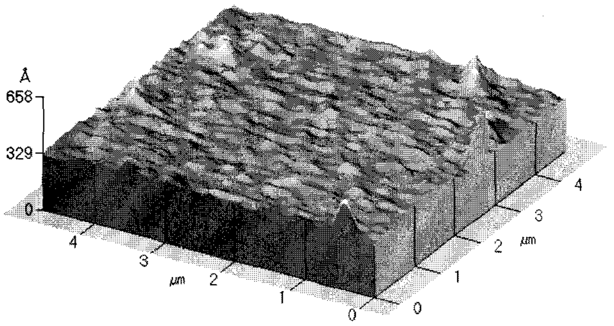


(d) 250 ℃

Fig. 4. Microphotographs of ion beam-aligned LC cells on the NDLC thin films for 10 min at various heating temperature (in crossed Nicols).



(a) Before ion beam exposure (rms : 18.3 Å)



(b) After ion beam exposure (rms : 17.8 Å)

Fig. 5. AFM images on the NDLC thin films.

Figure 4 shows the microphotographs of LC cells cooled gradually after heating for 10 min at 100 ℃, 150 ℃, 200 ℃, and 250 ℃ on the ion beam irradiated NDLC thin films. As shown in Fig. 4, the LC alignment is good when the heating temperature is 100 ℃ to 200 ℃. However, the LC alignment is destroyed at 250 ℃. As a result, the ion beam-aligned LC cell on the NDLC thin films can maintain a stable LC alignment up to 200 ℃.

Figure 5 shows AFM images of the NDLC thin films. Figure 5 (a) is before ion beam exposure. On the other hand Fig. 5(b) is after ion beam exposure. Before and after the ion beam exposure, the NDLC thin films surface rms roughness was equivalent (before: 18.1 Å, after: 17.8 Å). Therefore, it is concluded that the alignment by ion beam is due to the breakdown of π-bonds of imide rings, phenyl rings and carbonyl groups regardless of surface formation variation. When ion beam exposure, Ion beam destroy π-bonds that have larger cross section than others[11,12]. Therefore, LC is aligned parallel to the ion beam exposure direction.

4. CONCLUSION

The LC alignment capabilities, pretilt angle generation, AFM image analysis, and thermal stability of the ion beam exposed NDLC thin films deposited by PECVD were studied. We measured very low pretilt angle and good LC alignment on the NDLC surface with ion beam exposure. AFM images can be seen NDLC thin films surface roughness variation after ion beam exposure. Finally, the superior thermal stability of LC alignment for NLC on the ion beam exposed NDLC thin films can be achieved. As a result, good characteristics can be achieved on NDLC thin films as a new LC alignment layers.

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