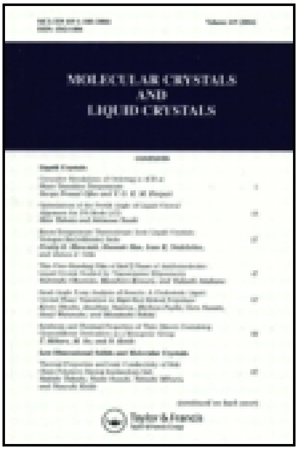

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The Alignment Effect of Nematic Liquid Crystal on NDLC Thin Films Surface

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We studied the nematic liquid crystal (NLC) aligning capabilities using the new alignment material of Nitrogen doped diamond-like carbon (NDLC) thin film. The NDLC thin film exhibits high electrical resistivity and thermal conductivity that are similar to the properties shown by diamond-like carbon (DLC) thin films. The diamond-like properties and nondiamond-like bonding make NDLC an attractive candidate for applications. A high pretilt angle of about 9.9° by ion beam (IB) exposure on the NDLC thin film surface was measured. A good LC alignment is achieved by the IB alignment method on the NDLC thin film surface at annealing temperature of 200°C. The alignment defect of the NLC was observed above annealing temperature of 250°C. Consequently, the high pretilt angle and the good LC alignment by the IB alignment method on the NDLC thin film surface can be achieved.

Keywords: annealing; ion Beam (IB); nematic liquid crystal (NLC); nitrogen doped diamond-like carbon (NDLC); pretilt angle

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INTRODUCTION

Liquid crystal displays (LCDs) are widely used as information display devices such as monitors in notebooks, desktops, and LCD-TVs. A rubbing method has been widely used to align liquid crystal (LC) molecules on the polyimide (PI) surface. LCs are aligned due to the induced anisotropy on the substrate surface [1–6]. 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 [7–9]. 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*. [10]. They deposited DLC thin films using plasma enhanced chemical vapor deposition (PECVD) method and the surface of the deposited thin films was irradiated by Ar ion beam. Also, our research group already studied IB alignment method using DLC thin film [11,12]. In addition, another research group also studied about LC alignment using the non-rubbing method on the NDLC thin film [20]. They used the plasma irradiation method. However, our research group used the ion-beam irradiation method.

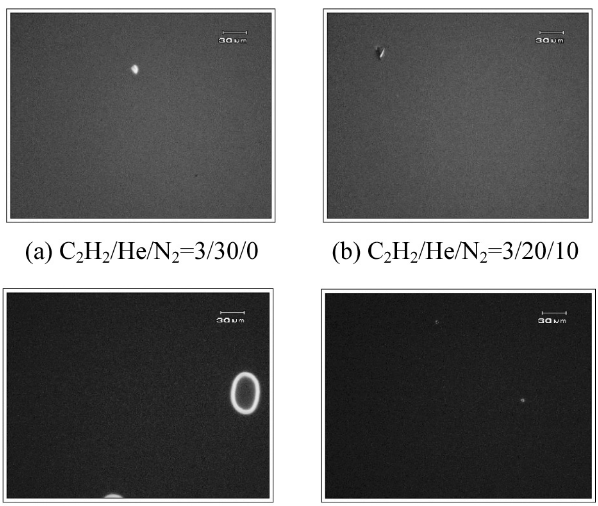
DLC thin films have properties of high mechanical hardness, high electrical resistivity, low friction coefficient, optical transparency and chemical inertness [10]. NDLC exhibits similar properties shown by DLC films. Significantly, this diamond-like transport property in NDLC comes in a material consisting of sp^2-bonded carbon versus the sp^3-carbon of DLC. When NDLC thin films have higher nitrogen contents, Raman spectra shows remarkable I_D/I_G and ω_G increase and a Γ_G decrease, as reported by Jacobsohn *et al*. [13]. Such behavior of the Raman parameters, have been ascribed to the increase of the number or/and the size of sp^2-bonded carbon clusters in the film. Thus nitrogen incorporation at concentrations high results in the increase of the fraction of carbon atoms with sp^2 hybridization. In other words, nitrogen incorporation strongly affects the hybridization state of carbon atoms by increasing the sp^2 fraction [13–16]. Preparation of the NDLC thin films can be carried out at low substrate temperature and with high deposition rates using PECVD [17].

In this article, we studied the alignment effect of nematic liquid crystal and control of high pretilt angle using the ion-beam alignment method on the NDLC thin films surface.

EXPERIMENTAL

The NDLC thin films were deposited on indium-tin-oxide (ITO)-coated glass substrates by plasma enhanced chemical vapor deposition (PECVD). Prior to film deposition substrates were cleaned ultrasonically; in case of ITO and glass cleaning was carried out with trichloroethylene (TCE), acetone and alcohol. The glass substrates were pre-sputtered for 10 minutes using the Ar plasma in the chamber. The NDLC thin film was deposited using C_2H_2:He:N_2 gas for 30 seconds in order to settle the working pressure the total flux was 33 sccm. Namely, as the flow amount of N_2 was increased, that of He was correspondingly decreased. However the quantity of C_2H_2 was fixed. The deposition was performed for 30 seconds at 30 W r.f. power.

The thickness of the NDLC thin film layer was about 10 nm. The ion-beam (Kaufman type) exposure system was shown in Figure 1. The ion-beam energy used was 200 eV and incident angle of the ion-beam was range from 20° to 70°. The gap of the ion-beam-aligned LC cell was 60 μm. The LC cell was filled with a nematic liquid crystal (NLC) (MJ001929, from Merck Co.). To determine LC alignment condition, a polarization microscope was used and pretilt angle was measured crystal rotation method at room temperature.



(a) C_2H_2/He/N_2=3/30/0 (b) C_2H_2/He/N_2=3/20/10

(c) C_2H_2/He/N_2 =3/10/20 (d) C_2H_2/He/N_2=3/0/30

FIGURE 1 Microphotographs of IB-aligned LC cell on the four kinds of the NDLC thin film (in crossed Nicols).

RESULTS AND DISCUSSION

Figure 2 shows the microphotographs of LC cell deposited for 30 seconds according to the portions of $C_2H_2/He/N_2$ gas ion-beam irradiation to 1 minute on the NDLC thin films surface. Figure 2 (a) shows the microphotograph of LC cell deposited for 30 seconds when the portions of $C_2H_2/He/N_2$ gas is 3/30/0 deposited for 10 minutes at the PECVD and ion-beam irradiation to 1 minute on NDLC thin films surface. Figure 2 (d) shows the microphotograph of LC cell deposited for 30 seconds when the portions of $C_2H_2/He/N_2$ gas is 3/0/30 at the PECVD and ion-beam irradiation to 1 minute. As shown in Figure 2, the excellent LC alignment of the NDLC thin film when the quantity of C_2H_2, He and N_2 gas is 3 sccm, 0 sccm and 30 sccm each at the PECVD among the four conditions for forming the NDLC thin film was achieved.

Figure 3 shows the LC pretilt angle variation according to ion beam incident angle on the NDLC thin film. The NDLC thin film was deposited for 30 seconds when the portions of $C_2H_2/He/N_2$ gas is 3/0/30 deposited at the PECVD and ion-beam irradiation to 1 minute. The LC pretilt angle had the maximum value at 45° about 9.9°, and the pretilt angle gradually decreased with increasing ion beam incident angle. In other words, it shows that incident angle of 45° is the best condition for generating the high pretilt angle.

LC pretilt angle dependancy according to ion-beam irradiation time on the NDLC thin film was measured as shown in Figure 4. The NDLC thin film was deposited for 30 seconds when the portions of $C_2H_2/He/N_2$ gas is 3/0/30 at the PECVD. The LC pretilt angle has

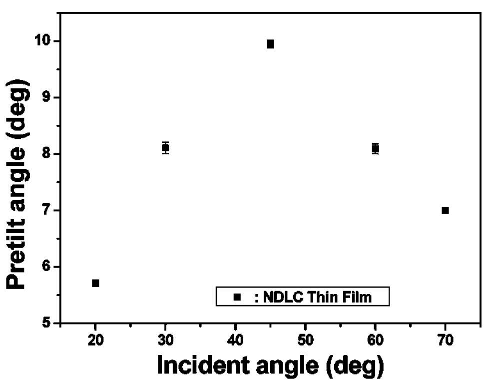


FIGURE 2 Generation of pretilt angles in NLC with IB exposure on the NDLC thin film surfaces for 1 minute as a function of incident angle.

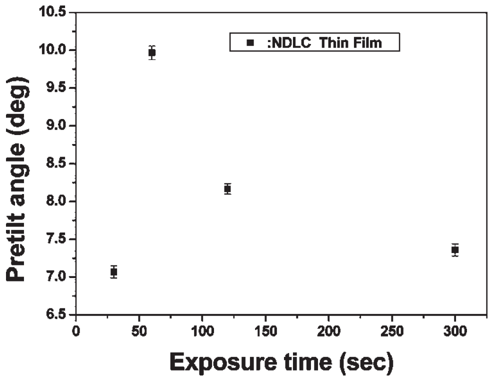


FIGURE 3 Generation of pretilt angle in NLC by IB exposure on the NDLC thin film surfaces as a function of exposure time.

the maximum value at 1 minute, and the pretilt angle rapidly decreases with increasing ion beam exposure time. Because ion-beam irradiation causes the increase of sp^2-fraction and the decrease of the thickness of the NDLC thin films. In addition, surface roughness of the NDLC was increased on a large scale according to increasing ion beam

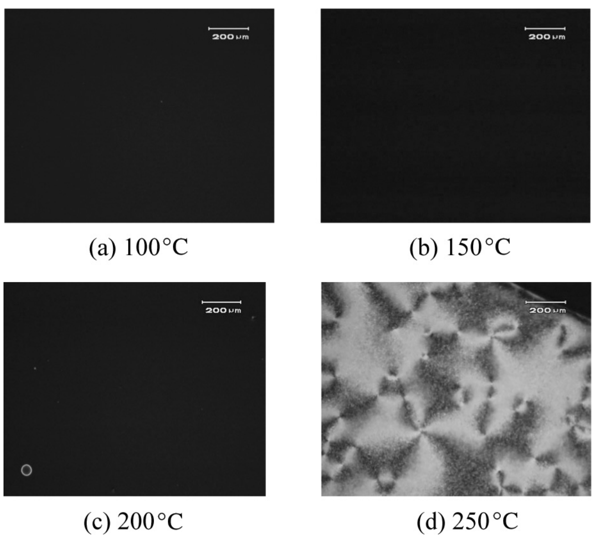


FIGURE 4 Microphotographs of aligned NLC with IB exposure on the NDLC thin film surfaces for 1 minute as a function of annealing temperature (in cross Nicols).

irradiation time over 2 minutes [18,19]. Ion-beam irradiation contributes to the generation of the pretilt angle and that value of the pretilt angle is more affected by surface roughness than sp^2-fraction of the NDLC thin films. Therefore, control of pretilt angle is possible using the ion-beam alignment method.

Figure 5 shows alignment microphotograph of LC cell which was cool gradually after annealing for 10 min at four kinds of temperature. The conditions were 100°C, 150°C, 200°C and 250°C on the NDLC thin film. The NDLC thin films were deposited for 30 seconds when the portions of $C_2H_2/He/N_2$ gas is 3/0/30 deposited at the PECVD and ion-beam irradiation to 1 minute. As shown in Figure 5, LC alignment was good when the annealing temperature was from 100°C up to 200°C. However LC alignment was destroyed at 250°C. In other words, because C:N bonding of the NDLC thin film was caused unstable at 250°C, LC alignment was destroyed at 250°C. In general LC alignment using the DLC thin film was destroyed at 220°C. However in case using the NDLC thin film was destroyed at 250°C. That is the reason why NDLC thin film has more nitrogen gases, stronger bonding and another factors related to LC alignment than DLC thin film. However, more specific theory and evidence related thermal stability was not reported yet. Finally we could make sure of a thermal stability up to 200°C of IB alignment method on the NDLC thin films surface.

CONCLUSION

In this paper, we studied about LC alignment effect and control of pretilt angle using the ion beam alignment method in new alignment layer the NDLC thin film. We achieved a good alignment characteristic using the IB alignment method on the NDLC thin film when the quantity of C_2H_2, He and N_2 gas is 3 sccm, 0 sccm and 30 sccm each at the PECVD. Especially, we achieved the high pretilt of about 9.9° when ion beam conditions were irradiation time of 1 minute and incident angle of 45°. Also, IB alignment method using the NDLC thin film had thermal stability up to 200°C. As a result, IB alignment method using the NDLC thin film was achieved the control of pretilt angle and good thermal stability.

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