Novel Alignment Layers for Ion Beam Method and the Orientations of Liquid Crystal

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Abstract

Various inorganic alignment layers of nematic liquid crystal (NLC) molecules were investigated. Ar ion beam (IB) irradiation was utilized for alignment method and homogenous and homeotropic orientations with tilt angle were obtained on the suitable inorganic thin films. Proper doping materials were added to diamond-like carbon (DLC) films. In the case of homogeneous alignment, nitrogen doping affected the increase of pretilt angle, while the fluorine bonding in the DLC films was induced the tilted homeotropic alignment cause its extreme hydrophobic property. These results showed that ion beam irradiation method could be applied to the various alignment mode of NLC such as IPS, TN and MVA.

1. Introduction

The alignment of liquid crystal (LC) molecules on a solid surface has become an important technique for the fabrication of LC device. Conventionally, mechanical rubbing technique has been employed to accomplish this function. However, several drawbacks are associated with this rubbing method such as generation of debris, damage of the surface and electrostatic discharge [1]. For the rub-free methods, UV irradiation technique has been proposed but it can not overcome the several problems such as the low anchoring energy and the poor thermal stability.

Recently, a new non-contact alignment method is reported utilizing accelerated Ar ion source [2]. DLC thin films are introduced by new inorganic alignment layer in this method. It is reported that the structural anisotropy of DLC films is induced by IB irradiation [3]. However, only few attempts have so far been made at this method and these studies have been studied only about planar alignment due to low pretilt angle [4].

In this study, we developed the new alignment layer, NDLC (amorphous carbon nitride) and FDLC (amorphous fluorinated carbon) thin films for IB irradiation method for the wide application of LC alignment. The alignment behavior of LC was changed by the selection of special alignment layer. We obtained the high pretilt angle on NDLC layer. This is suitable range in twisted nematic (TN) alignment mode. And we could align the LC molecules vertically or tilted vertically on FDLC layers. Low surface energy of alignment layer was induced by fluorinated bonding on the surface and it induced homeotropic or tilted homeotropic alignment, too.

2. Experiment

Each alignment films were deposited in remote plasma enhanced chemical vapor deposition (RPECVD) reactor at room temperature. In the case of

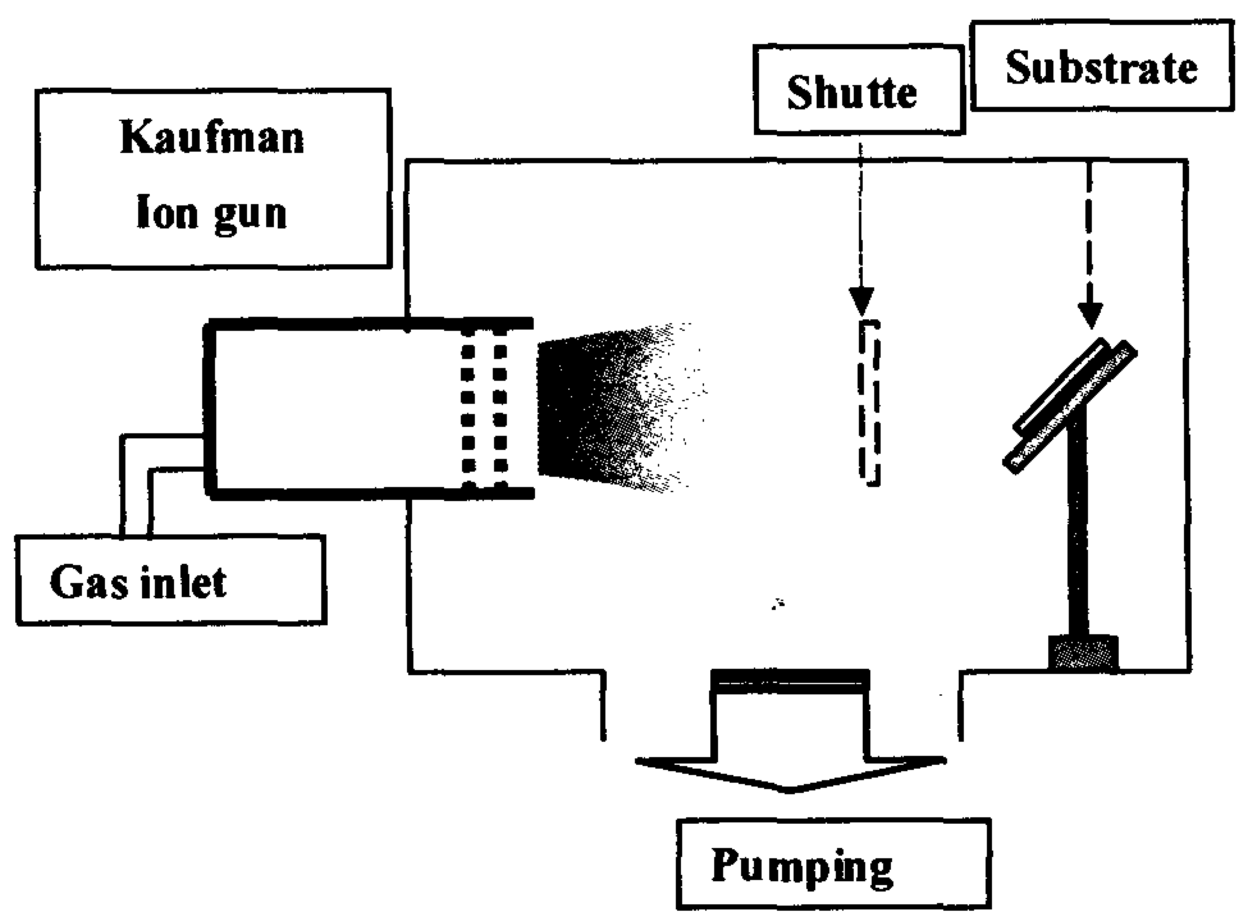

Fig.1 Ion beam exposure system

NDLC, mixture of acetylene (C_2H_2), Nitrogen (N_2) and helium (He) was used as working gases, while the mixture of acetylene (C_2H_2), tetrafluoromethane (CF_4) and helium (He) was used in the case of FDLC thin films. In order to change the film property, the reactive gases such as N_2 and CF_4 were varied at constant Mr. (13.56MHz) plasma power density. Following the deposition, the samples were irradiated with the argon ion beam at 200eV energy during 1 minute with Kaufman-type ion source. The ion beam current density was fixed by 12.12 μA/㎠. Particular ion beam irradiation angle was existed, which homogeneous alignment was achieved at 45° from the surface and homeotropic alignment was shown at 70° of incident angle from the substrate. The detailed configuration of the system used for the irradiation is shown in Fig.1.

NLC test cells were fabricated by setting the substrates in such a way that the IB directions were anti-parallel with the thickness of 50 μm. For homogeneous alignment, the NLC which had positive dielectric anisotropy (MJ97359, from Merck Co.) was injected into the cells by capillary flow at about 75℃ and the NLC which had positive dielectric anisotropy ($\Delta\varepsilon$ = -4, from Merck Co.) was filled in the cells for the homeotropic alignment. The major component of the surface alignment ("vertical" or "parallel") was determined by observing the sample in a microscope between cross polarizers in the transmission mode and checking for the presence or absence of birefringence. And the pretilt angle was obtained by crystal rotation method with Autronic TBA 107.

3. Results and discussion

NDLC and FDLC thin films were studied for appropriate liquid crystal orientations. We considered the variation of binding state and surface energy of deposited thin films for suitable interaction with liquid crystals. Each dopant material performed the generation of pretilt angle at parallel and vertical alignment.

3.1 Alignment behavior on NDLC layer

Figure 2 represents the polarized optical microscopic image of NDLC alignment layers. We varied the N_2 flux for variation of nitrogen contents in the thin films. As the figure was shown, all of samples showed uniform homogeneous alignment behavior. In

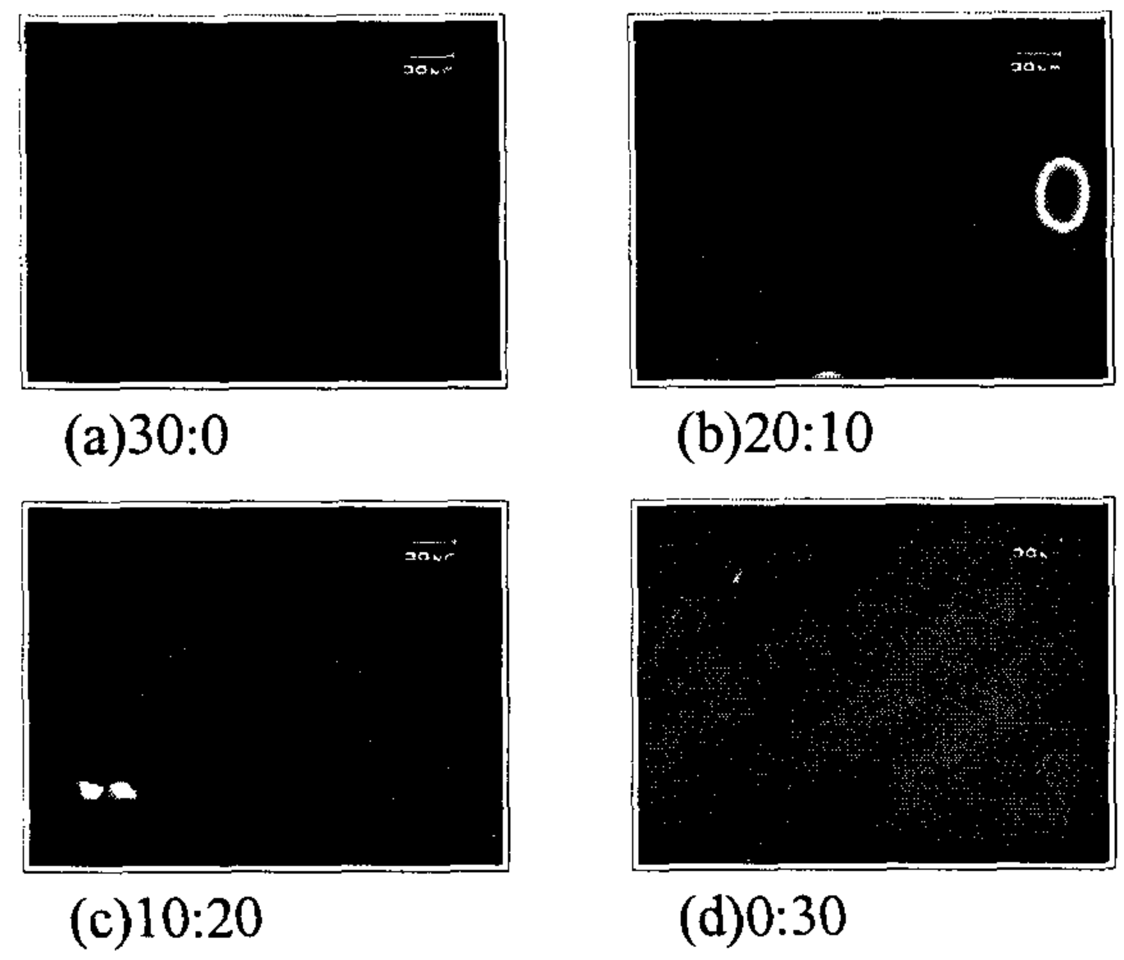

Fig.2 Microphotographs of aligned LC with ion beam exposure on three kinds of NDLC layers as a function of He: N_2 flow ratio (in crossed Nicols)

order to distinguish each case of NDLC thin films, the pretilt angle was measured as a function of nitrogen composition and the result was shown in Figure 3. As increase the ratio of nitrogen to carbon, high pretilt angles were obtained. In addition, we were measured pretilt angle by changing an IB incident angle and IB irradiation time for constant ion dose and NDLC composition. It was shown the same tendency with the DLC layers, which had the maximum value for optimum condition of each parameter [5], but the average pretilt angle was higher than DLC thin films on the whole.

Generally, it had been reported about the

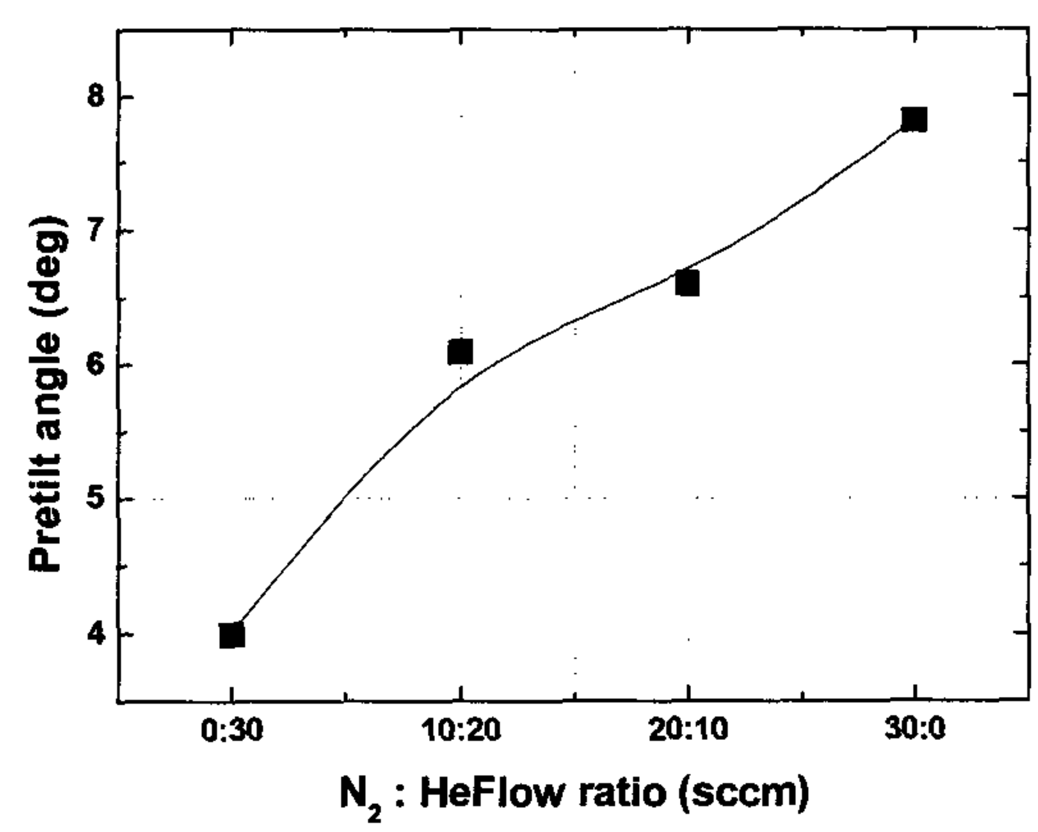

Fig.3. Measured pretilt angle depend on the N2 flow. The ion dose is constant throughout the range

variation of atomic binding states in the DLC layer by addition of nitrogen dopant [6-7]. Even though hydrogen composition was not changed by increase of nitrogen composition, hydrogen bonded to carbon atoms would be decreased and hydrogen bonded to nitrogen atoms would be increased. Hence it caused the increase of sp^2 bonding fraction of carbon. In the IBM's reports [3], the carbon cluster rings which were constructed by sp^2 bonding fraction, played an important part as the LC alignment factor. As the result, it was concluded that the change of sp^2 bonding fraction was inversely proportional to the change of pretilt angle.

The twist angle was measured using spectral analysis for a measure of the binding force of the liquid crystal to the substrate [8]. It was also found to exhibit the same dependency as the pretilt angle. It was correspondingly decreased as increase of the pretilt angle.

3.2 Alignment behavior on FDLC layer

Figure 4 shows the contact angle of FDLC thin films as a function of CF_4 percentage in the feed. High contact angle and hydrophobic property were obtained by increase fluorine bonding in the thin films. FDLC thin films had various carbon – fluorine bonding such as C-F, $C\text{-}F_2$, $C\text{-}F_3$ and hydrophobic property was induced by $C\text{-}F_2$, $C\text{-}F_3$ bonding cause these non-polar property [9].

Generally, LC alignment could be influenced such as parallel or vertical behavior by changing the wetting property of alignment layer.

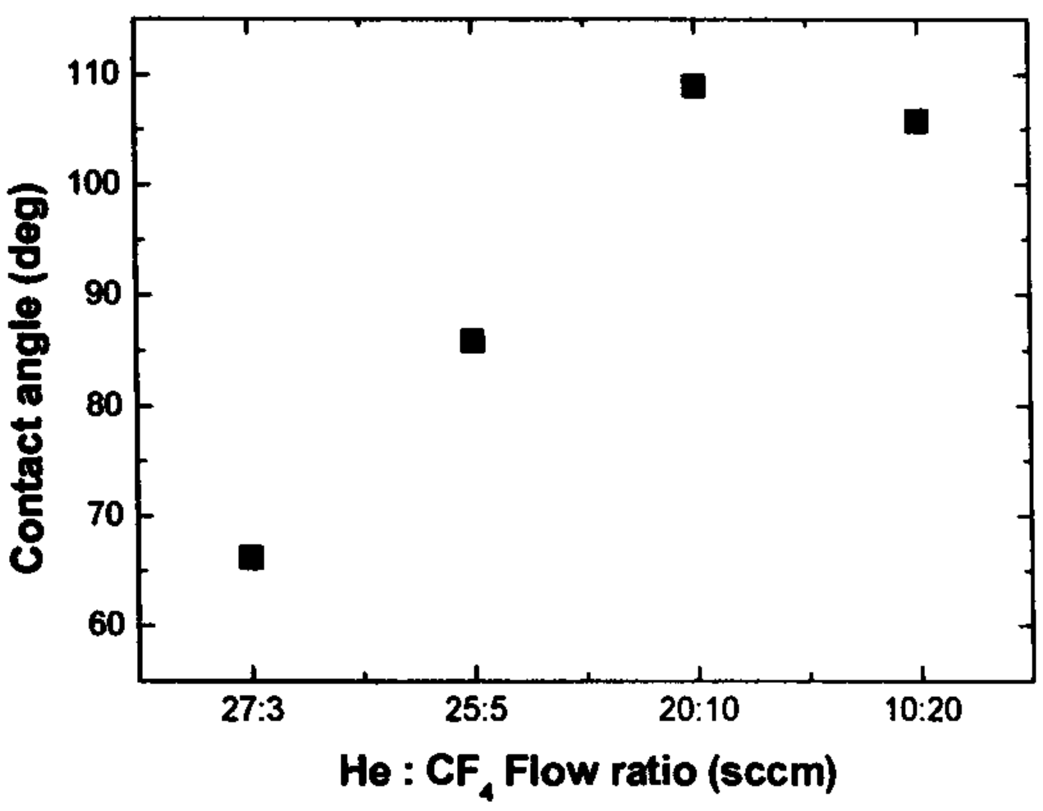

Fig.4. Surface energy of FDLC layer as a function of fluorine concentration

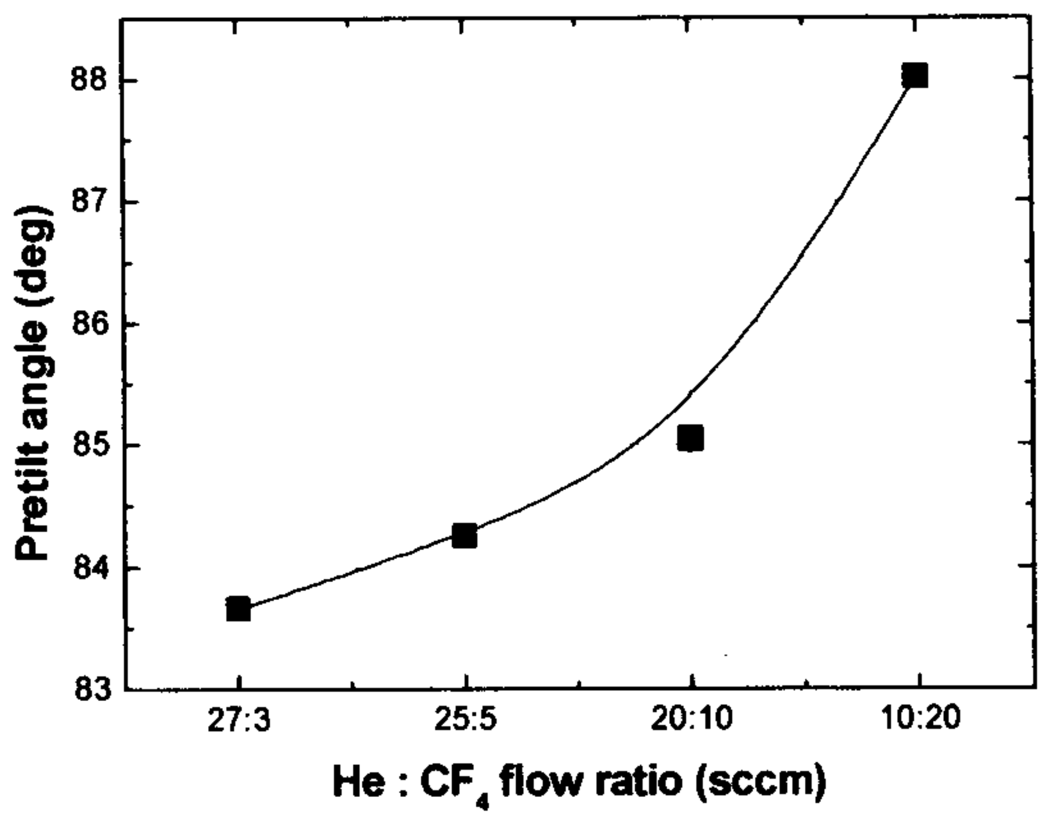

Fig.5. Measured pretilt angle depend on the CF4 flow. The incidence angle is constant throughout the range

Conventionally, rubbed polyimide containing trifluoromethyl moiety has been used by vertical alignment material [10]. And oblique evaporation method or LPUV irradiation method could be obtained homeotropic alignment using similar mechanism. However, the pretilt angle is not very sensitive to the external variables. We have examined the IB-induced liquid crystal alignment on the hydrophobic thin film. Unlike the previous methods there are two major advantages in this method. First, IB irradiation method is the novel alignment method which is free from damage of alignment layer. Secondly it is easy to perform the hydrophobic surface by plasma treatment. Figure 5 shows the variation of the pretilt angle for various fluorine concentrations in alignment layers. Uniform tilted homeotropic alignments were achieved even though the fluorine concentration was changed. Pretilt angle were generated by increasing fluorine concentration and hydrophobic property of FDLC layer. Below the 50% of $CF_4/(CF_4 + C_2H_2)$, we were not able to obtain the uniform alignment behavior. In addition, exact homeotropic alignment could be achieved at the condition of high fluorine concentration but alignment layer was not stable because of poor adhesion with substrate. Within these two limits, pretilt angles were generated between 83.6 degree and 88 degree.

In order to investigate the relationship between pretilt angle and surface property of alignment layer, surface tension and polar surface energy were computed by Owens-Wendt Geometric model. Hydrophobic surface with high contact angle showed low surface energy. Additionally, total and polar surface energies were found to decrease steadily with increasing fluorine concentration. Typically, the strength of electronic interactions is one factor affected the pretilt angle of NLC molecules. As the interaction forces between LC and substrate was stronger, LC would not tilt from alignment layer and the non-polar surface gave a large pretilt angle than the polar surface probably due to the weaker electronic interaction between LC molecules and the FDLC surface. From these results, it can be reasonably concluded that the hydrophobic property of alignment layer due to the fluorine content is an important factor for pretilt angle generation.

4. Conclusion

We investigated two kinds of LC orientation depending on the substrates. By using IB irradiation method, it had been reported only homogeneous or tilted orientation with 1° or less of pretilt angle on various substrates. However, we obtained suitable tilted orientation with high pretilt angle or vertical alignment layer with XDLC layer. This tendency was dependent on X component of DLC layers. Especially, the pretilt angle to the substrate normal was controlled well as we varied the IB condition or the ratio of fluorine to carbon. This class of vertical alignment layers is necessary for making multi-domain LC displays which give better electro-optic characteristics than the conventional mono-domain LC displays.

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