Annealing Behavior of Pretilt Angles on Polyimide Surface with Rubbing and Ion Beam Irradiation

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We have studied the liquid crystal (LC) alignment, the pretilt angle generation, and the annealing behavior for a nematic liquid crystal (NLC) on the homogeneous polyimide (PI) surfaces by using the rubbing method and the ion beam (IB) method. An excellent LC alignment of the NLC on the PI surface with rubbing and IB irradiation were observed. The pretilt angle of NLC on the homogeneous PI surface for the rubbing method is decreased from 4.5 ° to 3.5 ° as rubbing time is increased, that of the for the IB irradiation method is decreased from 0.5 ° to 0.1 ° as the time of IB irradiation is increased. After the annealing, the pretilt angles of the rubbed PI surfaces increased up to 4 °, these of the IB irradiated PI surfaces little increased. It is considered the side chain of the rubbed PI show the its abilities of the original capacities, while the side chain of the IB irradiated PI cannot show the its abilities of the original capacities due to the IB has already destroyed the side chain of the PI.

Keywords : Polyimide (PI), Rubbing, Ion beam (IB), Pretilt angle, Annealing

1. INTRODUCTION

There are various ways to achieve planar alignment of liquid crystal (LC) molecules on the substrate surface, including rubbed polyimide (PI) film, oblique evaporation SiO film, and photo-aligned polymer film with ultra violet irradiation. LC alignment consisting of rodlike molecules on the rubbed PI surface is widely used to obtain uniform alignment it is relatively simple and reliable[1-4]. The rubbing methods on the PI surface have a several disadvantages, such as electrostatic charge generation and creation of contaminating particles by the rubbing[5,6].

Recently, the LC orientation effects on ion beam (IB) aligned polymer[7-11] and inorganic[12-14] surface are demonstrated. Hwang et al. have been reported that the LC orientation on the PI surface with IB irradiation is attributed to the C-O bonds of the PIs broken of the C=O bonding[11]. Also, the dipole-dipole interaction between the LC molecules and the PI surface by IB irradiation is discussed. Recently, we reported the LC alignment properties of the nematic liquid crystal (NLC) on the PI surface with IB irradiation[7]. It indicates that the tilt angle of NLC on the PI surface could be controlled by IB irradiation.

In this paper, we report on the LC orientation properties and control of pretilt angle for NLC on the PI surface with IB irradiation. The LC alignment texture of NLC, pretilt angle measurements, and annealing behavior were discussed.

2. EXPERIMENT

In this experiment, we used SE7492 (from Nissan Chemical Industries, Ltd.) polymer for the homogeneous alignment. The polymers were uniformly deposited by the spin coating on indium-tin-oxide (ITO) electrodes, prebaked at 100 °C for 10 minutes and imidized at 230 °C for 1 hour. The thickness of the PI film was set at 100 nm. The PI surfaces were rubbed with rubbing machine. The rubbing strength (RS) fixed 120 mm. The RS has been defined in previous paper[1,4].

Figure 1 shows the high-energy-density ion beam system, DuoPIGatron-type used in this experiment. The ion beam energy intensity was fixed at 800 eV and an IB current density of 1.5 mA/cm^2. The incident angle of the IB irradiation was also fixed at 45 °. The IB irradiation times were set to 10 and 30 s.

The LC cells were assembled as a sandwich type with

anti-parallel structure, and the thickness of the cell was 60 ㎛. After fabricating the cell, the positive type NLCs (T_c = 72 °C, $\Delta\varepsilon$ = 8.2; MJ1929, from Merck Co.). The LC alignment characteristics were observed by using a photomicroscope (BXP51; Olympus). The pretilt angle of the NLCs was measured by the crystal-rotation method (TBA 107 tilt-bias angle evaluation device; Autronic Melchers) at room temperature. Also, the LC cells were annealed at 92 °C for 1 hour, for measuring annealing behavior.

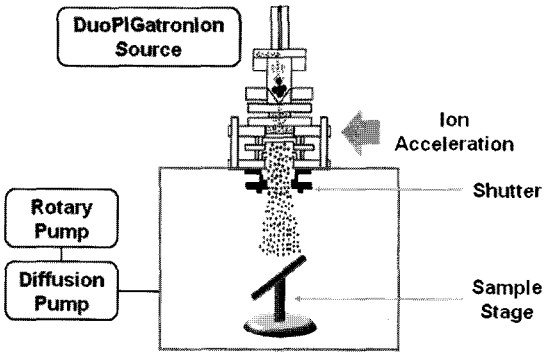
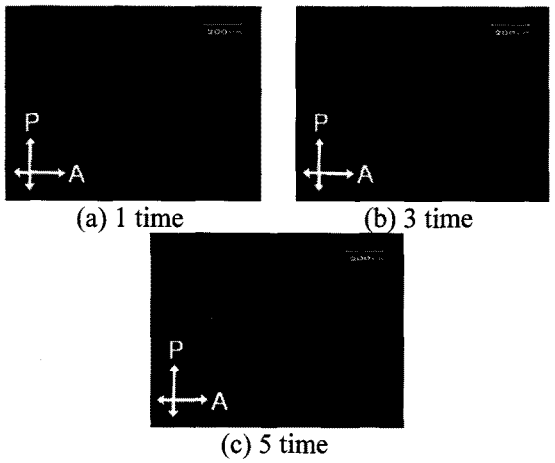


Fig. 1. DuoPIGatron-type ion beam system.

3. RESULTS AND DISCUSSION

Figure 2 shows the microphotographs of the NLC on the rubbed PI surfaces (in crossed Nicols). The black states show the uniform alignments in the crossed polarizer and analyzer. Excellent LC alignments were observed on the homogeneous PI surfaces without reference to the rubbing time.

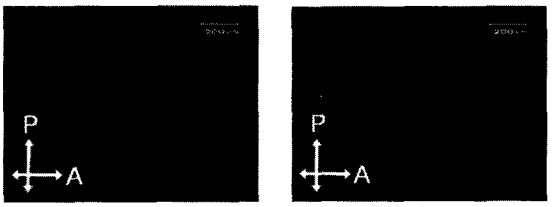


(a) 1 time (b) 3 time

(c) 5 time

Fig. 2. Microphotographs of NLC on the rubbed PI surfaces to the rubbing time (in crossed Nicols).

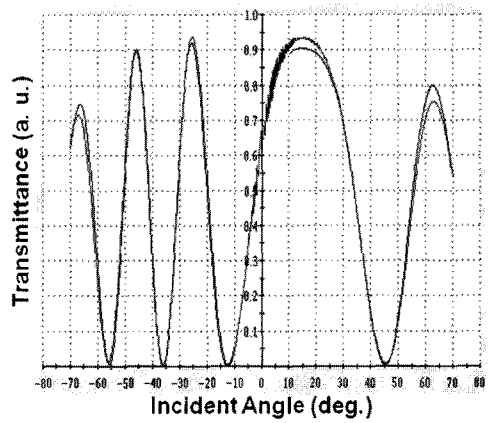
Figure 3 shows the microphotographs of the NLC on the IB aligned PI surfaces (in crossed Nicols). Excellent LC alignments were also observed on the homogeneous PI surfaces without reference to the IB irradiation time.



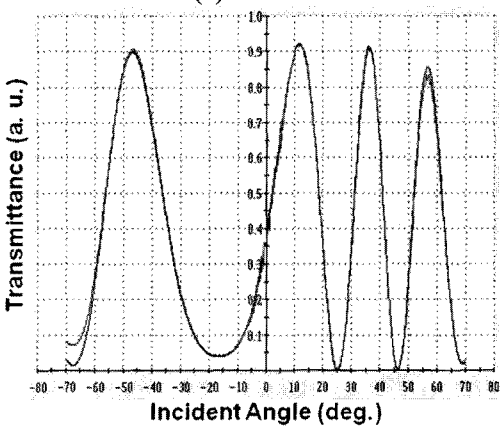
(a) 10 s (b) 30 s

Fig. 3. Microphotographs of NLC on the IB aligned PI surfaces to the duration of IB irradiation (in crossed Nicols).

Figure 4 and 5 show the results of the pretilt angle of the NLC on the rubbed PI surfaces and IB aligned PI surfaces by crystal-rotation method. A shift of symmetric point from point 0 was measured on the PI surface with all incident angles. The pretilt angles of NLC on the rubbed PI surfaces were measured the range of 3.5~4.5 degrees and these of the NLC on the IB aligned PI surfaces were measured between 0.1~0.5 degrees.



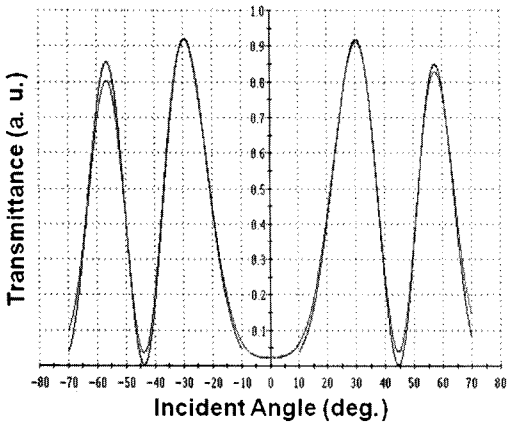
(a) 1 time



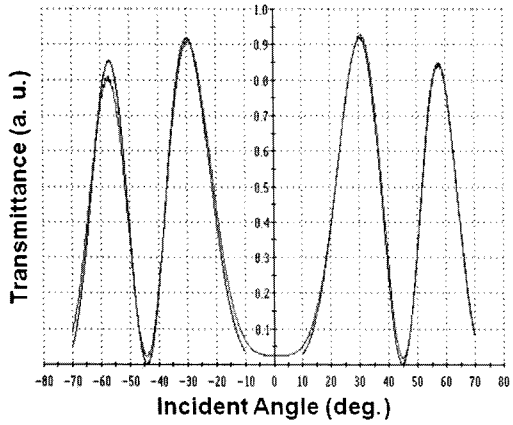
(b) 5 time

Fig. 4. Relationship between transmittance and incident angle in LC cells on the rubbed PI surfaces.

The pretilt angles of the rubbed PI surfaces were decreased as the rubbing time was increased, these of the IB aligned PI surfaces were also decreased as the time of IB irradiation was increased. This means that the pretilt angle can be controlled by the rubbing time and IB irradiation time.



(a) 10 s



(b) 30 s

Fig. 5. Relationship between transmittance and incident angle in LC cells on the IB aligned PI surfaces.

Figure 6 shows the relationship between pretilt angle and the rubbing time in LC cells on the rubbed PI surfaces before and after annealing. As the rubbing time is increased, the pretilt angle is decreased for the not annealed cells. It is due to the side chain of the PI is layed down on the PI surface by the rubbing. For the annealed cells, the pretilt angle is increased. It is considered the side chain of the PI is stabilized and shows its abilities of the original capacities.

Figure 7 shows the relationship between pretilt angle and the times of IB irradiation in LC cells on the IB aligned PI surfaces before and after annealing. As the time of IB irradiation is increased, the pretilt angle is decreased for the not annealed cells. For the annealed cells, the pretilt angle is little changed. Due to the side chain of the PI is already destroyed by the IB, the side chain cannot show its ability of the original capacities.

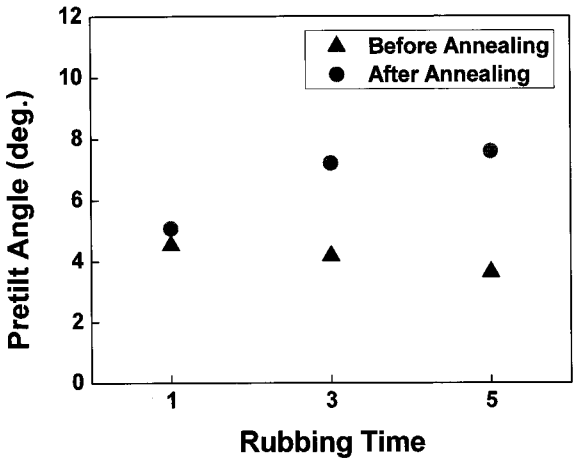


Fig. 6. Pretilt angles in NLC on the rubbed PI surfaces before and after annealing as a function of rubbing time.

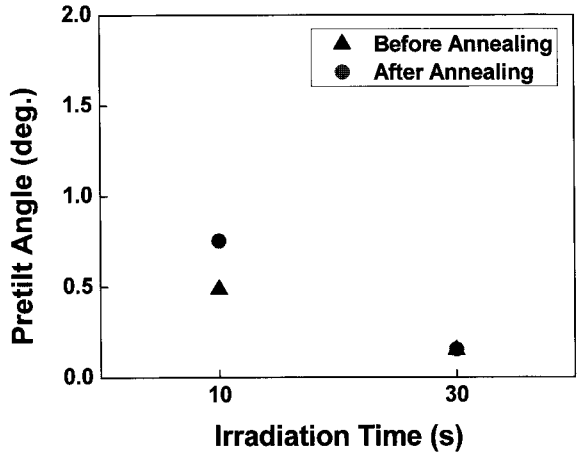


Fig. 7. Pretilt angles in NLC on the IB aligned PI surfaces before and after annealing as a function of IB irradiaton time.

4. CONCLUSION

In conclusion, we have studied the pretilt angle generation and the annealing behavior for NLC on the PI surfaces by the rubbing method and the IB method. The pretilt angle of NLC on the PI surface for the rubbing method is decreased as the rubbing time is increased, that of the IB irradiation method is decreased as the time of IB irradiation is increased. After the annealing, the pretilt angles of the rubbed PI surfaces increased up to

4 °, these of the IB irradiated PI surfaces little increased. It is considered the side chain of the rubbed PI shows its abilities of the original capacities, while the side chain of the IB irradiated PI cannot shows its abilities of the original capacities due to the destroyed side chain on the PI irradiated IB device. Therefore, the annealing effects of the PI surfaces were clearly observed.

REFERENCES

[1] D.-S. Seo, K. Muroi, and S. Kobayashi, "Generation of pretilt angle in nematic liquid crystal, 5CB, media aligned polyimide films prepared by spin coating and LB techniques: effects of rubbing", Mol. Cryst. Liq. Cryst., Vol. 213, p. 223, 1992.

[2] B. O. Myrvold and K. Kondo, "A population distribution model for the alignment of nematic liquid crystals", Liq. Cryst., Vol. 17, p. 437, 1994.

[3] R. Arafune, K. Sakamoto, S. Ushioda, S. Tanioka, and S. Murata, "Importance of rubbing-induced inclination of polyimide backbone structure for determination of the pretilt angle of liquid crystals", Phys. Rev. E., Vol. 58, p. 5914, 1998.

[4] D.-S. Seo, K. Araya, N. Yoshida, M. Nishikawa, Y. Yabe, and S. Kobayashi, "Effect of the polymertilt angle for generation of pretilt angle in nematic liquid crystal on rubbed polyimide surfaces", Jpn. J. Appl. Phys., Vol. 34, p. L503, 1995.

[5] H. Matsuda, D.-S. Seo, N. Yoshida, K. Fujibayashi, and S. Kobayashi, "Estimation of the static electricity and optical retardation produced by the rubbing polyimide and polyamide films with different fabrics", Mol. Cryst. Liq. Cryst., Vol. 264, p. 23, 1995.

[6] D.-S. Seo, S. Kobayashi, D.-Y. Kang, and H. Yokoyama, "Effects of rubbing and temperature dependence of polar anchoring strength of homogeneously aligned nematic liquid crystal on polyimide Langmuir-Blodgett orientation films", Jpn. J. Appl. Phys., Vol. 34, p. 3607, 1995.

[7] B.-Y. Oh, K.-M. Lee, B.-Y. Kim, Y.-H. Kim, J.-W. Han, J.-M. Han, S.-K. Lee, and D.-S. Seo, "Surface reformation and electro-optical characteristics of liquid crystal alignment layers using ion beam irradiation", J. Appl. Phys., Vol. 104, p. 064502, 2008.

[8] C.-H. Ok, D.-H. Kang, K.-M. Lee, J.-W. Han, B.-Y. Kim, B.-Y. Oh, Y.-H. Kim, J.- Y. Hwang, S.-K. Lee, J.-M. Han, and D.-S. Seo, "LC aligning capabilities of a nematic liquid crystal on homeotropic polyimide surface by new ion-beam irradiation", Trans. EEM, Vol. 8, No. 6, p. 265, 2007.

[9] S.-K. Lee, D. -S. Choi, and D. -S. Seo, "Tilt angle generation in NLC on homeotropic polymer surface with ion beam irradiation as a function of incident angle", Trans. EEM, Vol. 9, No. 3, p. 120, 2008.

[10] J.-M. Han, B.-Y. Kim, J.-Y. Kim, Y.-H. Kim, J.-W. Han, J.-Y. Hwang, S.-K. Lee, D.-H. Kang, C.-H. Ok, and D.-S. Seo, "Liquid crystal aligning capabilities treated on organic overcoat thin film by ion beam irradiation method", J. of KIEEME(in Korean), Vol. 20, No. 3, p. 245, 2007.

[11] C.-Y. Lee, Y.-L. Liu, K. Y. Wu, M.-Y. Chen, and J.-C. Hwang, "Argon plasma beam scanning processes on polyimide films for liquid crystal alignment", Jpn. J. Appl. Phys., Vol. 47, p. 226, 2008.

[12] P. Chaudharl, J. Lacey, J. Doyle, E. Galligan, S. C. Alan, A. Callegarl, G. Hougham, N. D. Lang, P. S. Andry, R. John, K. H. Yang, M. Lu, C. Cal, J. Speidell, S. Purushothaman, J. Ritsko, M. Samnt, J. Stohrt, Y. Nakagawa, Y. Katoh, Y. Saitoh, K. Saka, H. Satoh, S. Odahara, H. Nakano, J. Nskshski, and Y. Shiota, "Atomic-beam alignment of inorganic materials for liquid-crystal displays", Nature, Vol. 411, p. 56, 2001.

[13] J.-Y. Kim, B.-Y. Oh, B.-Y. Kim, Y.-H. Kim, J.-M. Han, and D.-S. Seo, "Compositional investigation of liquid crystal alignment on tantalum oxide via ion beam irradiation", Appl. Phys. Lett., Vol. 92, p. 043505, 2008.

[14] S.-K. Lee, J.-H. Kim, B.-Y. Oh, B.-Y. Kim, J.-W. Han, Y.-H. Kim, J.-M. Han, J.-Y. Hwang, C.-H. Ok, and D.-S. Seo, "Liquid crystal alignment effects treated on SiN_x thin film layers using ion beam irradiation", Jpn. J. Appl. Phys., Vol. 46, p. 7711, 2007.