Homeotropic Alignment Effect of a Nematic Liquid Crystal on Oblique Deposited SiO_x Thin-film with e-beam Evaporation

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In this study, liquid crystal (LC) aligning capabilities for homeotropic alignment on the SiO_x thin film by electron beam evaporation method were investigated. Also, the control of pretilt angles and thermal stabilities of the nematic liquid crystal (NLC) treated on SiO_x thin film were investigated. A high pretilt angle of about 86.5 ° was obtained, and also the suitable pretilt angle of the NLC on the SiO_x thin film at 10~50 nm thickness with e-beam evaporation can be achieved. The uniform LC alignment and good thermal stabilities on the SiO_x thin film surfaces with electron beam evaporation can be achieved. It is considered that the LC alignment on the SiO_x thin film by electron beam evaporation is attributed to elastic interaction between LC molecules and micro-grooves at the SiO_x thin film surface created by evaporation.

Keywords : SiO_x thin film, LC alignment, Pretilt angle, Annealing, Thermal stability, Response time, Voltage-transmittance

1. INTRODUCTION

The uniformity of LC alignment is very important in LC devices. Currently, a rubbing method which rubs polyimide (PI) surface to align LC has been widely used to mass-produce wide LCD panels. LCs are aligned due to the induced anisotropy on the substrate surface[1-4]. Rubbed polymer 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 from rubbing fabric and substrate[5,6]. Also, difficulties in applying for large glass substrate have been reported. Thus we strongly recommend a non-contact alignment technique for future generations of large, high-resolution LCD. Also, in micro-display panel, due to the changes in alignment by strong UV irradiation or some other reasons with the inorganic alignment method is strongly required[7,8].

Most recently, the LC aligning capabilities achieved by ion beam (IB) exposure on the diamond-like carbon (DLC) thin film layer and SiO_x vacuum evaporation method have been successfully studied[9-11].

The alignment mechanism of LC molecules on the SiO_x thin film by electron beam evaporation is an important issue for both scientific research and LC device application[16]. Two possible mechanisms were proposed to explain the alignment of LC molecules on rubbed polymer films. One is based on an elastic interaction between LC molecules and the micro-grooves on the polymer film surface created by rubbing. The other is based on an intermolecular interaction between LC molecules and polymer chains in the underlying film. LC molecules in contact with electron beam evaporation system are on average oriented along the evaporation direction with a certain tilt angle. The tilt angle on homogenous alignment measured from the substrate surface is called the pretilt angle. Also the pretilt angle on homeotropic alignment is measured from normal direction on substrate surface.

The pretilt angle is a very important parameter that characterizes surface-induced alignment of LC molecules and also an important variable in the fabrication of LC. The pretilt angle controls of 2 ° ~ 3 ° are required to apply to display modes. However, the control of pretilt angles for homeotropic alignment of the NLC on the SiO_x thin film surface by electron beam evaporation have not been reported yet.

In this research, we reported the LC alignment effects and the thermal characteristics on the SiO_x thin film with oblique electron beam evaporation.

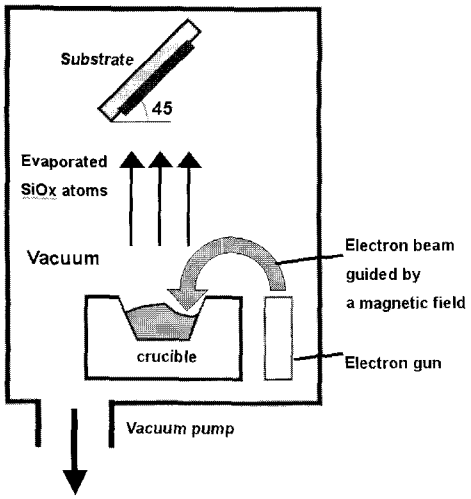

Fig. 1. Electron beam evaporation system.

2. EXPERIMENTAL

The SiO_x thin films were evaporated on indium-tin-oxide (ITO)-coated glass substrates by 45 ° oblique electron beam evaporation. ITO coated substrates with dimensions of 307 mm × 217 mm × 1.1 mm were used for all measurements reported here. Before being evaporated, the ITO-coated glass substrates were cleaned in TCE (trichloroethylene), acetone, alcohol solutions respectively by supersonic wave for 10 minutes, and then were blown with N_2 gas. After that they were evaporated by electron beam equipment under the condition of 30 °C.

As the thin film thickness, four kinds of samples were evaporated. The thicknesses of the SiO_x thin film layer were 10 nm and 20 nm with the evaporation speed of 1~2 nm / sec. After being evaporated, two types of test samples were fabricated. One type of cells was arranged in an anti-parallel configuration, which was used for pretilt angle measurements and thermal stability. The others were the test sample, which were used for electro-optical measurement. To determine LC alignment condition, a polarized microscope was used and pretilt angles were measured by a crystal rotation method at room temperature.

3. RESULTS AND DISCUSSION

The microphotographs of vertical aligned LC cells by 45 ° oblique evaporation with electron beam system on the SiO_x thin film surface are shown in Fig. 1. From all conditions of the microphotographs, the excellent LC alignment states without any impurities, defects generated during the evaporation process and cell assembly processes

Fig. 2. Microphotographs of the aligned LC cells on the 10 nm thickness of SiO_x thin film by 45 ° obliqued electron beam evaporation (in crossed Nicols).

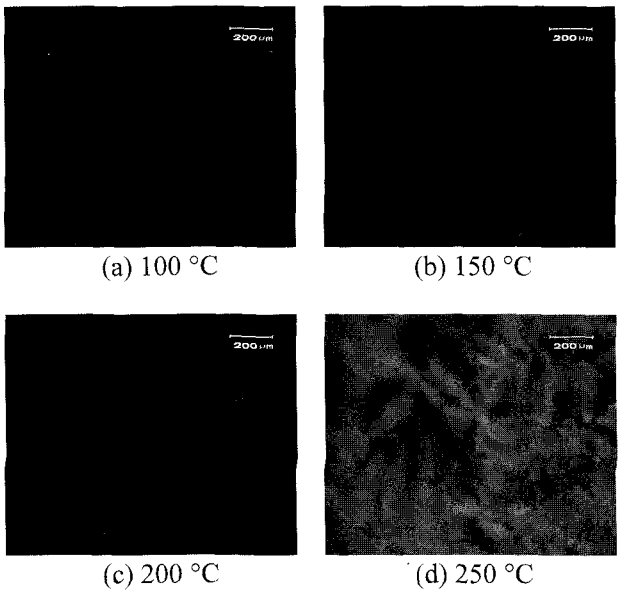

Fig. 3. Microphotographs of the aligned LC cells on the SiO_x thin film by 45 ° electron beam evaporation as a function of annealing temperature for 60 min (in crossed Nicols).

are shown. From these results, we consider that the LC alignment on SiO_x thin film by 45 ° electron beam evaporation is attributed to elastic interaction between LC molecules and micro-grooves at the SiO_x thin film surface created by evaporation[8].

Figure 2 shows the microphotographs of the LC cells with the film thickness of 10 nm alignment effect. The pretilt angle is 89.9 °.

Figure 3 shows the thermal stability of the LC cells with the film thickness of 10 nm respectively. The LC alignment states of each cell were maintained with the annealing temperature from 100 °C to 250 °C. However, some defects begun to appear from the annealing condition of 250 °C. The LC alignment states are maintainable to the temperature almost 250 °C.

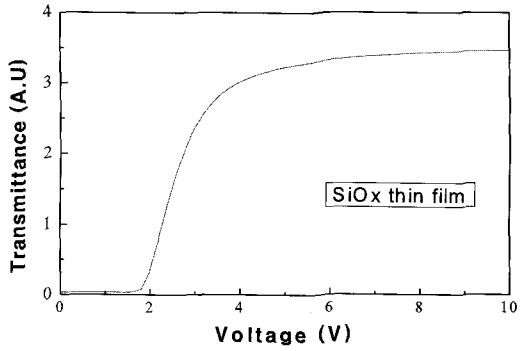

Fig. 4. Microphotographs of *V-T* of the aligned LC cells on the SiO_x thin film by 45 ° electron beam evaporation (in crossed Nicols).

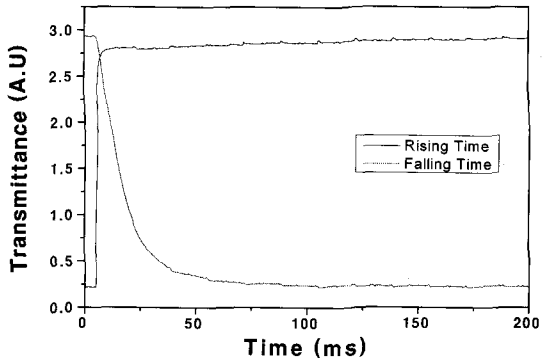

Fig. 5. Microphotographs of response time of the aligned LC cells on the SiO_x thin film by 45 ° electron beam evaporation (in crossed Nicols).

Figure 4 shows the *V-T* characteristic of the aligned LC cells on the SiO_x thin film by 45 ° electron beam Evaporation. A good *V-T* curve for the aligned LC cells on the SiO_x thin film by 45 ° electron beam evaporation was obtained. The threshold voltage for the aligned LC cells on the SiO_x thin film by 45 ° electron beam evaporation was about 2 V.

Figure 5 shows the response time characteristic of the aligned LC cells on the SiO_x thin film by 45 ° electron beam evaporation. The rising time was 5.0 ms, and the decay time was 33.7 ms. Generally, response time is depnded on the cell gap.

4. CONCLUSION

In conclusion, LC alignment effects and generation of pretilt angles treated on the SiO_x thin film with 45 ° oblique electron beam evaporation were studied. Good alignment characteristics could be achieved using 45 ° oblique evaporation method with electron beam system. We consider that the LC alignment on the SiO_x thin film is attributed to elastic interaction between LC molecules and micro-grooves at the SiO_x thin film surface created by evaporation. The thermal stability characteristic was good. And considerable EO characteristics could be achieved for VA-LCD.

E-beam evaporation method can be feasible for micro display manufacturing - less than the size of 10 inch. The productivity and less cost are important factors for the micro sized LCD. Without rubbing process, the productivity of the micro LCD will be increased.

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] D.-S. Seo, T. Oh-ide, and S. Kobayashi, "Observation of the surface structure on as stacked and rubbed polyimide (PI)-LB films with an atomic force microscope and their anchoring capability for nematic liquid crystals", Mol. Cryst. Liq. Cryst., Vol. 214, p. 97, 1992.

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

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

[5] 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.

[6] 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.

[7] 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.

[8] D.-H. Kang, S.-H. Kim, B.-Y. Kim J.-Y. Kim, C.-H. Ok, Y.-H. Kim, J.-W. Han, J.-H. Kim, J.-Y. Hwang,

B.-Y. Oh, J.-M. Han, S.-K. Lee, J,-W. Lee, B.-M. Moon, J.-H. Kim, and D.-S. Seo, "Liquid crystal alignment effects for nematic liquid crystal on homeotropic polyimide surface using new ion-beam source", Jpn. J. Appl. Phys., Vol. 46, p. 6601, 2007.

[9] J.-M. Han, S.-H. Choi, B.-Y. Kim, J.-W. Han, J.-Y. Hwang, C.-H. Ok, and D.-S. Seo, "Homeotropic alignment effects for nematic liquid crystal on the SiOx thin film layer by new ion beam exposure", Trans. EEM, Vol. 7, No. 6, p. 293, 2006.

[10] Y.-M. Jo, J.-Y. Hwang, D.-S. Seo, and S.-K. Lee, "Alignment effects for nematic liquid crystal on a new diamond-like carbon layer", Trans. EEM, Vol. 3, No. 2, p. 1, 2002.

[11] J.-H. Kim, H.-K. Kang, J.-W. Han, S.-H. Kang, Y.-H. Kim, J.-Y. Hwang, and D.-S. Seo, " LC aligning properties for homeotropic alignment of NLC on the SiO_x thin film as incident angle of electron beam evaporation angle", Trans. EEM, Vol. 7, No. 1, p. 21, 2006.