Tilted Homeotropic Alignment using Ion Beam Process: Development of Novel Inorganic thin films

*Byoung Har Hwang, Kyung Chan Kim, Han Jin Ahn, Jong Bok Kim, Hong Koo Baik**

Dept. of Metallurgical Engineering, Yonsei University, 134 Shinchon-dong, Seodaemoon-ku, Seoul, 120-749, Korea

thinfilm@yonsei.ac.kr
Phone: +82-2-2123-2838
Fax: +82-2-312-5375

Abstract

The ion beam alignment technique is one of the potential and fascinating methods. However, there are merely a few reports about aligning nematic liquid crystals (NLCs) horizontally for in-plane switching mode (IPS) by means of low energy ion beam exposure on inorganic materials such as DLC. In this study, we have investigated the tilted vertical alignment of NLC by the ion beam technique on the thin films of various amorphous silicon compounds as new inorganic alignment materials. Appropriate pretilt angles of NLC with preferred orientation on these thin films were achieved. And the electro-optic property of vertically aligned single-domain cells has been investigated.

1. Objective and Background

It is indispensable to make multi-domain structure in tilted homeotropic (TH) alignment mode since multi-domain structure leads to wide-viewing angle. Therefore, recently, many new wide viewing angle technologies such as SE, RFFMH, and PVA mode have developed for large, high resolution TFT-LCD monitors. However, each technology has its own limitation either in the complex process or the insufficient performance. Therefore, the new method for solving wide-viewing problem is necessary.

The ion-beam alignment technique is one of the potential methods for controlling the pretilt angle. Chaudhari et al.[1] and Stohr et al.[2] proposed ion beam (IB) irradiation method as a new substitute for making great size panel. It is a non-contact alignment type and prevents generation of the debris or electrostatic discharges which are shortcomings of conventional rubbing method. Although it has such a good advantage and is a simple process, however, only few attempts have so far been made at this method. For instance, there are a few reports about aligning nematic liquid

crystals (NLCs) horizontally for in-plane switching mode (IPS) by means of low energy ion beam exposure on inorganic materials such as DLC.[3]

In this study, we have investigated the TH alignment by irradiating IB on various amorphous silicon compound thin films such as a-Si:H, a-SiO_x:H, a-SiN_x and a-SiC_x:H. We have showed that pretilt angles with preferred orientation on such those films can be obtained and controlled by the condition of ion beam irradiation. Pretilt angles on those films after ion beam exposure revealed good uniformity. For the practical application to the industry, we have investigated electro-optical properties and thermal stability of the cells made of ion beam irradiated amorphous silicon compound thin films.

2.1 Vertical alignment on the various amorphous silicon compound thin films

We have investigated the vertical alignment of nematic liquid crystal (NLC) on a-Si:H, a-SiO_x:H, a-SiN_x and a-SiC_x:H thin films as new inorganic materials for the alignment layer. All the films were prepared by plasma enhanced chemical vapor deposition (PECVD). We obtained the vertical alignment of NLC on the various amorphous silicon compound thin films without IB irradiation and with low energy ion beam irradiation from Kaufman type ion gun.

The pretilt angles of NLC on these films without IB irradiation showed around 90 degree from the substrate. However, the homogeneity of vertical alignment was not good. That means the direction of director of NLC is different, individually. However, the cells made of ion beam irradiated amorphous silicon compound thin films showed the excellent vertical alignment of NLC with good uniformity of the director direction of NLC. In other words, appropriate ion beam exposure condition gives rise to the good uniformity of the director direction of NLC, which seems to be caused by the reinforcement of anchoring energy.

The pretilt angles of NLC in those cells are dependent mainly on the incident angle of ion beam. The lower incident angle of ion beam, the lower pretilt angle of NLC can be achieved. The ion beam irradiation time has tiny effect on the homogeneity of vertical alignment of NLC. The pretilt angle variation with ion beam irradiation is in the range of 88~90 degree.

2.2 Characteristics of amorphous silicon compound thin films

Alignment of NLC on the specific substrate is achieved by morphological effect and the physico-chemical interaction between substrates and nematic liquid crystal molecules. To find what brings about vertical alignment of NLC on amorphous silicon compound thin films with ion beam irradiation and without ion beam irradiation, we performed several experiments.

In order to see the physico-chemical interaction, we examined the surface energy of thin films by means of contact angle measurement and checked the chemical bonding species by X-ray photoelectron spectroscopy (XPS) before irradiating ion beam and after

irradiating ion beam. Meanwhile, we performed atomic force microscope (AFM), X-ray reflectivity (XRR), photo-elastic modulator (PEM), optical birefringence measurement to see the morphological effect on the vertical alignment of NLC.

Finally, in order to evaluate the possibility whether amorphous silicon compound thin films with ion beam irradiation can be applied to the new vertical alignment layer, we examined the electro-optical properties and thermal stability of the cells. The thin films were investigated in terms of respond time, I-V characteristics, transmittance for the electro-optical properties and the cells showed the good thermal stability.

3. Impact

We have investigated the homeotropic alignment of NLC on various inorganic materials using ion beam exposure technique. The ion beam irradiation alignment technique is one of the potential and fascinating methods for controlling the pretilt angle with preferred orientation. It is a non-contact alignment method and a simple process. In addition, it is free from the debris or electrostatic discharges which are occurred in rubbing method. Meanwhile, it is noticeable that the materials for alignment layer in this study are inorganic materials. Organic materials such as polyimide need high thermal process for polymerization, however, inorganic materials such as amorphous silicon compounds used in this study don't need any high thermal process. Also, the process for the deposition of inorganic materials is simpler than that for polymerization of polyimide.

We obtained the tilted homeotropic alignment of NLC on various amorphous silicon compound thin films by means of low energy ion beam exposure. In vertical mode of LCD, it is indispensable to make the multi-domain structure, which leads the angle of viewing to being wide. Rubbing process, being macroscopic process, can not readily induce aligning liquid crystals having different direction of their directors. However, ion beam process can easily induce multi-domain structure using a simple mask. Therefore ion beam irradiation technique is a prospective method for the multi-domain tilted homeotropic alignment of NLC. Not only in multi-domain vertical alignment but also in single vertical alignment, tilted homeotropic alignment can be adopted to various applications. One of them is the light valve for projection display where single domain is required for higher optical throughput.

4. References

[1] P. Chaudhari et. al. "Atomic-beam alignment of inorganic materials for liquid-crystal displays", Nature, Vol. 411, pp. 56, 2001.

[2] J. Stohr et. al. "Liquid Crystal Alignment on Carbonaceous Surfaces with Orientational Order", science, Vol. 292, pp. 2299, 2001.

[3] D. K. Lee et. al. "Study on Liquid Crystal Alignment Characteristics by the Surface Treatment of Hydrogenated Amorphous Carbon Thin Films", J. Jpn. Appl. Phy., Vol. 41, pp. L1399, 2002.