Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Electro-Optical Characteristics of Vertical Alignment Cell by Ion-Beam Exposure on the SiC Thin Film Layer

Jeoung-Yeon Hwang [a], Sung-Ho Choi [a], Sang-Hoon Kim [a], Jin Jang [b] & Dae-Shik Seo [a]

[a] Department of Electrical Electronic Engineering, College of Engineering, Yonsei University, Seoul, Korea

[b] Advanced Display Research Center, Kyunghee University, Seoul, Korea

Version of record first published: 22 Sep 2010

To cite this article: Jeoung-Yeon Hwang, Sung-Ho Choi, Sang-Hoon Kim, Jin Jang & Dae-Shik Seo (2008): Electro-Optical Characteristics of Vertical Alignment Cell by Ion-Beam Exposure on the SiC Thin Film Layer, Molecular Crystals and Liquid Crystals, 480:1, 10-18

To link to this article: http://dx.doi.org/10.1080/15421400701821150

Mol. Cryst. Liq. Cryst., Vol. 480, pp. 10–18, 2008

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400701821150

Taylor & Francis
Taylor & Francis Group

Electro-Optical Characteristics of Vertical Alignment Cell by Ion-Beam Exposure on the SiC Thin Film Layer

Jeoung-Yeon Hwang[1], Sung-Ho Choi[1], Sang-Hoon Kim[1], Jin Jang[2], Dae-Shik Seo[1]
[1]Department of Electrical Electronic Engineering, College of Engineering, Yonsei University, Seoul, Korea
[2]Advanced Display Research Center, Kyunghee University, Seoul, Korea

We studied the electro-optical (EO) characteristics and nematic liquid crystal (NLC) aligning capabilities with the new alignment material of the Silicon Carbide (SiC) thin film using two kinds of ion beam (IB) gun. The SiC thin film exhibits good chemical and thermal stability. A vertical alignment of nematic liquid crystal by atomic beam exposure on the SiC thin film surface was achieved via all IB exposure system. The generated NLC tilt angle is about 87° using Kaufman type ion gun. The about 88° of stable tilt angle was achieved with incident angle of 10° using duoPIGatron type ion gun. An excellent voltage-transmittance (V-T) and response time curve of the IB-aligned VA-LCD using duoPIGatron type ion gun was observed. The V-T hysteresis characteristics of IB-aligned VA-LCD are almost the same as that of the rubbing-aligned VA-LCD. Consequently, the vertical alignment effect of liquid crystal and the good EO characteristics by the atomic beam alignment method on the SiC thin film layer can be achieved.

Keywords: DuoPIGatron ion gun; electro-optical (EO) characteristics; ion beam (IB) alignment; nematic liquid crystal (NLC); silicon carbide (SiC) thin film

INTRODUCTION

Liquid crystals (LCs) are aligned due to the induced anisotropy on the substrate surface [1–5]. Currently, a rubbing process has been widely used to align LC molecules on the polyimide (PI) surface. Rubbing process on the polyimide (PI) surfaces has the advantages of uniform

This work was supported by National Research Laboratory program (M1-0412-00-0008).

Address correspondence to D.-S. Seo, Department of Electrical and Electronic Engineering, Yonsei University, Shinchon-dong, Seodaemoon-gu, Seoul 120-749, Korea (ROK). E-mail: dsseo@yonsei.ac.kr

alignment and a high pretilt angle. However, the rubbing process has some drawbacks, such as the generation of electrostatic charges and the creation of contaminating particles [5]. Thus, rubbing-free method is strongly needed in the liquid crystal display (LCD).

Most recently, the LC alignment effects using atomic beam exposure on the diamond-like carbon (DLC) thin film layer have been studied [6–9]. Now, nitrogen doped DLC (NDLC), fluorinated DLC (FDLC), silicon carbide (SiC), and SiO thin film with optically transparent and insulating films has been used as alignment materials. Among these inorganic thin films, the structure of SiC is very similar to a diamond, which explains its great degree of hardness, and better thermal stability under high temperature situation will be achieved in comparison of existing LC alignment layer. We reported about the LC alignment effect using the ion beam (IB) beam exposure with Kaufman-type Ar ion gun on the SiC thin film. However, this system uses low IB energy. So, it is difficult to apply for large-scale manufacturing. And then none of these have so far been implemented in large-scale manufacturing. Thus we strongly recommend new type IB equipment (DuoPIGatron type Ar ion gun) [10–11] for large-scale manufacturing and high-resolution LCD. For new type (DuoPIGatron type) Ar ion gun, the plasma source should be capable of producing a quiescent, uniform, and dense plasma in order to produce a well collimated, high current density beam. Thus, new type (DuoPIGatron type) ion gun is suitable for large-scale area exposure with high uniformity. We also applied to the LC alignment on the ion beam irradiated polyimide [12], But, the specific reports about the mechanism of LC alignment using the DLC, NDLC and SiC thin film using DuoPIGatron IB system have not existed yet.

Therefore, in this research, we studied LC alignment effects and the electro-optical (EO) performances of the ion-beam-aligned vertical alignment (VA)-LCD with oblique ion beam exposure on the SiC thin film using new-type IB system.

EXPERIMENTAL

The SiC thin films were deposited on indium-tin-oxide (ITO)-coated glass substrates by plasma enhanced chemical vapor deposition (PECVD). The glass substrates were pre-sputtered for 10 min using the Ar plasma in the chamber. The SiC thin film was deposited using C_2H_2: He : SiH_4 gas for 20 s at 300°C. The flow amount of C_2H_2, He and SiH_4 gas is 30 sccm, 600 sccm and 60 sccm each at the PECVD.

The thickness of the SiC thin film layer was about 15 nm. The general type (Kaufman type Ar ion gun) and new type (DuoPIGatron

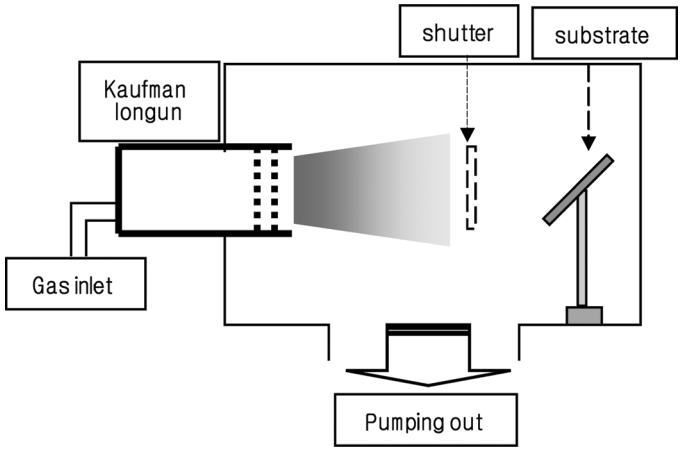

FIGURE 1 Schematic diagram of the IB exposure system using Kaufman type Ar ion gun.

type Ar ion gun) IB exposure system are shown in Figure 1, and Figure 2, respectively. The IB energy with Kaufman type Ar ion gun was 200 eV, and the IB energy with new-type Ar ion gun was 2200 eV. The gap of the atomic beam aligned LC cell was 60 μm. The thickness of the liquid crystal cells for VA test sample was 4 μm.

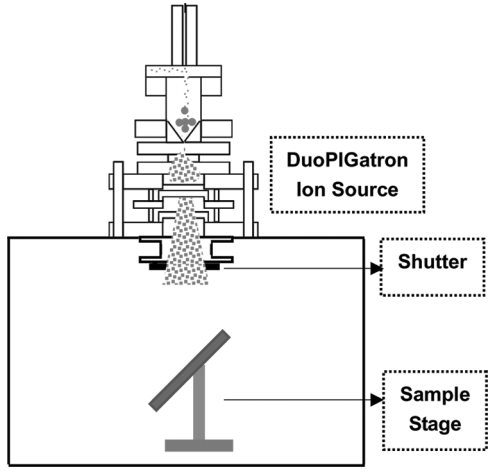

FIGURE 2 Schematic diagram of the IB exposure system using DuoPIGton type Ar ion gun.

The LC cell was filled with a nematic liquid crystal (NLC) ($\Delta\varepsilon = -4.1$, from Merck Co.). To determine LC alignment condition, a polarization microscope was used and pretilt angle was measured crystal rotation method at room temperature. In addition Voltage-Transmittance and response time characteristics of ion-beam aligned VA-LCD using new ion beam system were measured by LCMS-200 (Electro-Optical Measurement, from Sesim Photonics Technology) equipment. Also the residual DC voltage properties of ion-beam aligned VA-LCD using new ion beam system were measured by a Capacitance-Voltage hysteresis method.

RESULTS AND DISCUSSION

Momodomain alignment of the NLC can be obtained via IB exposure using Kaufman-type (200 eV) and new type Ar ion gun (2200 eV); the LC aligning capability using the new type Ar ion source is the same as that using Kaufman-type Ar ion source. In a previous, we reported that IB energy used 500 eV for LC alignment on a PI surface using New IB exposure system using DuoPIGatron ion source. However, to align on the SiC thin film, new IB exposure system is required of high IB energy like 2200 eV. It is considered that inorganic material like SiC thin film is due to stronger hardness than organic material like a PI surface, and source plasma of DuoPIGatron ion gun is composed of a cathode plasma and PIG plasma. A cathode plasma works as an electron source, supplying ionizing electrons to the PIG discharge, and PIG plasma works as an ion source, supplying ions to the extraction electrodes for forming a useful ion beam as shown Figure 3(a) [10–11]. Thus, it controls the density and uniformity of PIG plasma and influences source reliability. Also, the DuoPIGatron ion gun for alignment process uses high-energy ($\sim$40 keV). Therefore, DuoPIGatron ion gun is available to apply large-size substrate. On the other hand, Kaufman ion gun is basically consists of screen and accelerator. An ions passing through a screen aperture are attracted to the nearest edge of accelerator aperture thereby defecting the trajectories in this direction as shown in Figure 3(b) [13–14]. Thus, low energy (300 eV $\sim$ 1000 eV) is used by Kaufman ion gun as alignment process. From these results, the DuoPIGatron ion gun is higher energy than the Kaufman ion gun. Namely, the two kinds of ion beam systems use high and low energy respectively because of their original ion source design.

Figure 4 shows generation of tilt angle in NLC with oblique IB exposure as a function of incident angle using two kinds of IB systems. In the Kaufman ion gun, the LC pretilt angle is about 87° with incident angle from 30° to 45°, and the pretilt angle gradually decreases with

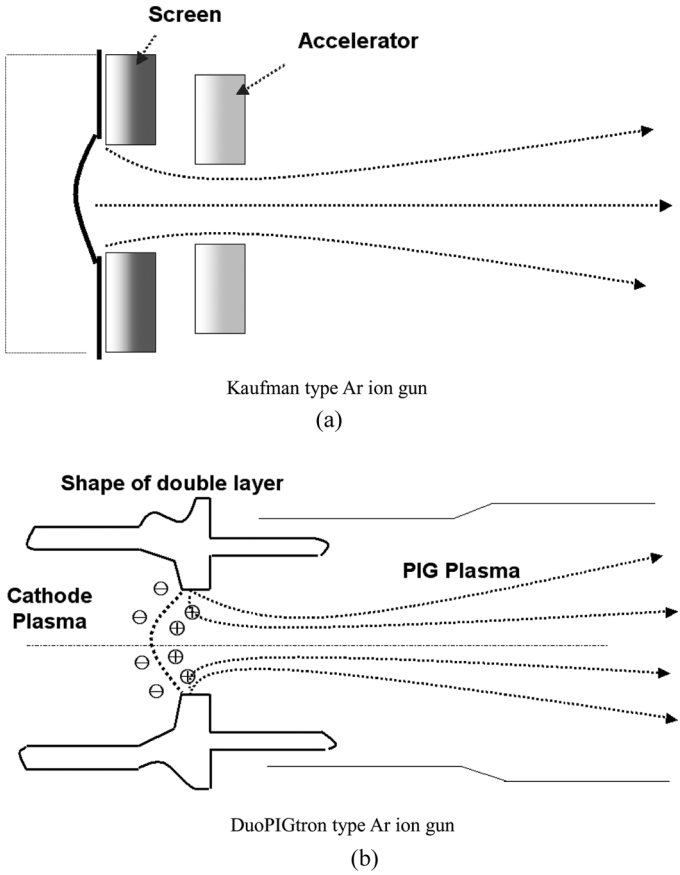

FIGURE 3 A operation principle of IB Ar gun: (a) Kaufman type Ar ion gun (b) DuoPIGton type Ar ion gun.

increasing incident angle. However, in the DuoPIGatron ion gun is about 88° with incident angle of 10°. NLC tilt angle increase with increasing angle of incidence of IB exposure. It is considered that difference of IB energy used influence on NLC tilt angle generation. As a result, vertical alignment of NLC and the control of tilt angle were achieved by IB irradiation on the SiC thin film.

We also investigated the EO characteristics of the ion-beam-aligned VA-LCD with IB exposure using DuoPIGatron ion gun on the SiC thin film. Figure 5 shows micrographs of the ion-beam-aligned VA-LCD with IB exposure using DuoPIGatron ion gun on the SiC thin film.

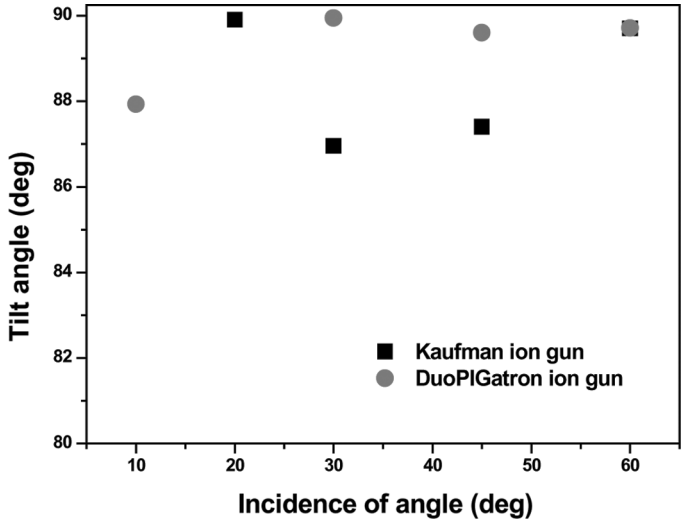

FIGURE 4 Generation of tilt angle in NLC with oblique IB exposure on SiC thin films as function of incidence angle.

Monodomain alignment of ion beam aligned VA-LCDs on the SiC thin film can be observed.

Figure 6 shows the voltage-transmittance (V-T) characteristics the ion-beam-aligned VA-LCD with oblique IB exposure using DuoPIGatron ion gun on the SiC thin film. An excellent voltage-transmittance (V-T) curve can be achieved in the ion beam aligned VA-LCD with oblique IB exposure using DuoPIGatron ion gun on the SiC thin

(a) (b)

FIGURE 5 Micrographs of the IB-aligned VA-LCDs with oblique IB exposure on a SiC thin film for 1 min (in crossed Nicols).

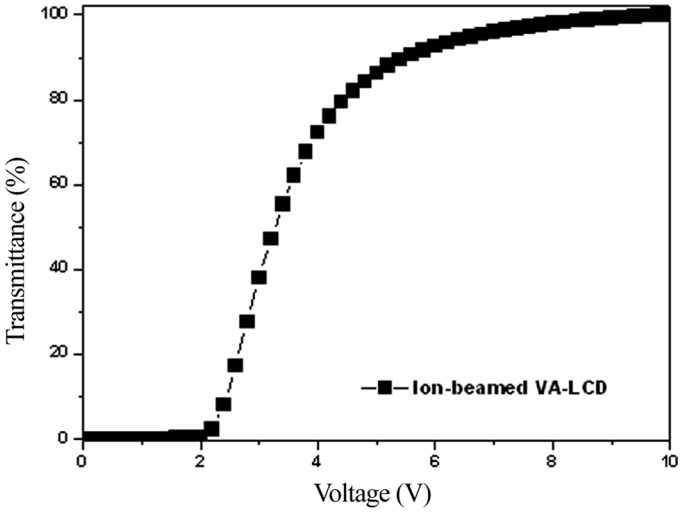

FIGURE 6 Voltage-transmittance (V-T) characteristics of the IB-aligned VA-LCDs with oblique ion beam exposure on a SiC thin film.

film as shown Figure 6. The threshold voltage of ion-beam VA-LCD is about 2.4(V). Consequently the new type ion beam system can be achieved good V-T characteristics of the ion beam aligned VA-LCD on the SiC thin film.

Image sticking was also very important factor for the functioning of displays. This arises from residual charges that accumulate in a local region as the voltage is left on. When the voltage is removed, the image survives and gradually fades away with time as the charge is dissipated. We show in Figure 7 the Capacitance-Voltage characteristics of the IB-aligned VA-LCD made of ion beam exposure on a SiC thin film. The residual charge characteristics of IB-aligned VA-LCD have a little; the increased value of the residual charge was very small. We evaluated the residual DC voltage characteristics using capacitance-voltage characteristics. That method is the same as used by Nissan chemical. Nissan chemical, alignment layer manufacturing company of Japan, uses capacitance-voltage characteristics as evaluation method. That method measures residual DC voltage by changing DC bias voltage which was measured electrical capacity of liquid crystal panel from the gap of C-V hysteresis curve. As a result, a good characteristic was achieved on the new type ion beam system, as a new ion beam source using alignment method. Consequently the stable EO characteristic of the IB-aligned VA-LCD using DuoPIGatron type ion gun was obtained.

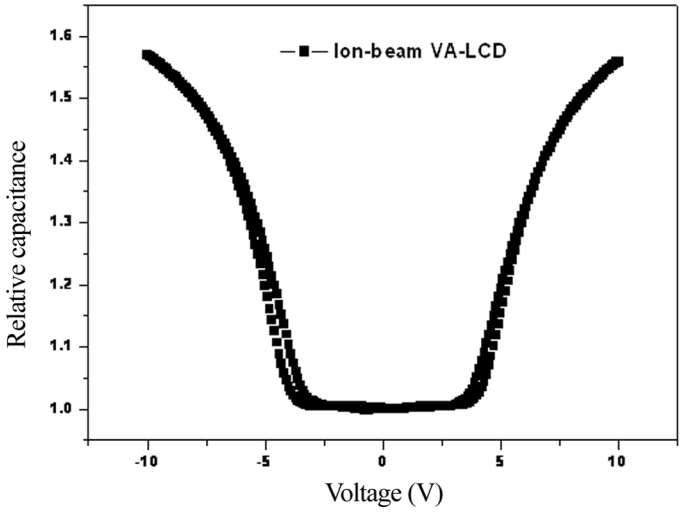

FIGURE 7 Capacitance-voltage characteristics of the IB-aligned VA-LCDs with oblique ion beam exposure on a SiC thin film.

CONCLUSIONS

In conclusion, LC alignment effects and generation of pretilt angles with ion beam irradiation the ion beam aligned VA-LCD on SiC thin films using two kinds of ion gun source were studied. Also, the EO performances of the ion beam aligned VA-LCD on SiC thin films using new type ion gun source were studied. It was found that mondomain alignment of the NLC is obtained with Kaufman and duoPiGatron type on gun, and then the generated NLC tilt angle is about 87°, and 88°, respectively. The stable V-T characteristics of the IB-aligned VA-LCD on a SiC thin film with duoPiGatron type on gun were observed. Finally, the residual DC voltage of the IB-aligned VA-LCD on a SiC thin film was good. Therefore, it was found from the result that new type ion gun is suitable for liquid crystal alignment and large-scale application.

REFERENCES

[1] Geary, J. M., Goodby, J. W., Kmetz, A. R., & Patel, J. S. (1987). *J. Appl. Phys.*, *62*, 4100.
[2] Seo, D.-S., Muroi, K., & Kobayashi, S. (1992). *Mol. Cryst. & Liq. Cryst.*, *213*, 223.
[3] Seo, D.-S., Araya, K., Yoshida, N., Nishikawa, M., Yabe, Y., & Kobayashi, S. (1995). *Jpn. J. Appl. Phys.*, *34*, L503.

[4] Iimura, Y., Kobayashi, S., Hashimoto, T., Sugiyama, T., & Katoh, K. (1996). *IEICE Trans. Electron*, *E79-C*(8), 1040.
[5] Nishikawa, M., Taheri, B., & West, J. L. (1998). *SID'98*, *131*.
[6] Chaudharl, P., Lacey, J., Doyle, J., Galligan, E., Alan, S. C., Callegarl, A., Hougham, G., Lang, N. D., Andry, P. S., John, R., Yang, K. H., Lu, M., Cal, C., Speidell, J., Purushothaman, S., Ritsko, J., Samnt, M., Stohrt, J., Nakagawa, Y., Katoh, Y., Saitoh, Y., Saka, K., Satoh, H., Odahara, S., Nakano, H., Nskshski, J., & Shiota, Y. (2001). *Nature*, *411*, 56.
[7] Jo, Y.-M., Hwang, J.-Y., Rho, S.-J., Baik, H.-K., & Seo, D.-S. (2004). *Mol. Cryst. & Liq. Cryst.*, *410*, 319.
[8] Park, C.-J., Hwang, J.-Y., & Seo, D.-S., Ahn, H.-J., Kim, K.-C., & Baik, H.-K. (2002). *Transactions on Electrical and Electronic Materials*, *3*(2), 11.
[9] Jo, Y.-M., Hwang, J.-Y., Seo, D.-S., & Lee, S.-K. (2004). *Transactions on Electrical and Electronic Materials*, *5*(1), 15.
[10] Jiang, S. F. & Wang, G. J. (1994). *Rev. Sci. Instrum.*, *65*(4).
[11] Tsai, C. C., Stirling, W. L., & Ryan, P. M. (1977). *Rev. Sci. Instrum.*, *48*(6).
[12] Kim, S.-H., Hwang, J.-Y., Kim, J.-H., & Seo, D.-S. *Mol. Cryst. & Liq. Cryst.* (in printed).
[13] Kaufman, H. (1985). *J. Vac. Sci. Technol.*, *A3*(4), 1774.
[14] Kaufman, H. (1986). *J. Vac. Sci. Technol.*, *A4*(3), 764.