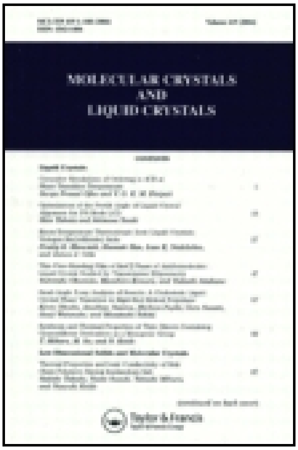

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A Study on Electro-Optical Characteristics of the Ion Beam Aligned Fringe-Field Switching (FFS) Cell on the Inorganic Thin Film

Jeoung-Yeon Hwang [a], Chang-Joon Park [a], Dae-Shik Seo [a], Youn-Hak Jeong [b], Han-Jin Ahn [c] & Hong Koo Baik [c]

[a] Department of Electrical & Electronic Engineering, College of Engineering, Yonsei University, Shinchon-dong, Seodaemoon-ku, Seoul, Korea

[b] Develop Department, BOE-HYDIS Technology Co., LTD, Ichon, Kyungki, Korea

[c] Department of Metallurgical System Engineering, College of Engineering, Yonsei University, Shinchon-dong, Seodaemoon-ku, Seoul, Korea

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Jeoung-Yeon Hwang
Chang-Joon Park
Dae-Shik Seo
Department of Electrical & Electronic Engineering, College of Engineering, Yonsei University, Shinchon-dong, Seodaemoon-ku, Seoul, Korea

Youn-Hak Jeong
Develop Department, BOE-HYDIS Technology Co., LTD, Ichon, Kyungki, Korea

Han-Jin Ahn
Hong Koo Baik
Department of Metallurgical System Engineering, College of Engineering, Yonsei University, Shinchon-dong, Seodaemoon-ku, Seoul, Korea

In this study, we investigated the electro-optical (EO) characteristic of fringe-field switching (FFS) mode cell by the ion beam alignment method on the a-C:H thin film. The suitable inorganic thin films for FFS cell and the aligning capabilities of nematic liquid crystal (NLC) using the new alignment material of a-C:H thin film were studied. An excellent voltage-transmittance (V-T) and response time curve of the ion beam aligned FFS cell was observed with oblique ion beam exposure on the a-C:H thin films. Also, the V-T hysteresis characteristics of the ion beam-aligned FFS cell with IB exposure on the a-C:H thin films is almost the same as that of the rubbing-aligned FFS cell on a polyimide (PI) surface.

Keywords: a-C:H thin films; fringe-field switching; ion beam alignment; response time; V-T curve; V-T hysteresis

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Address correspondence to Dae-Shik Seo, Department of Electrical and Electronic Engineering, College of Engineering, Yonsei University, 134 Shinchon-dong, Seodaemoon-ku, Seoul 120-749, Korea. E-mail: dsseo@yonsei.ac.kr

INTRODUCTION

A rubbing method has been widely used to align liquid crystal (LC) molecules on the polyimide (PI) surface. LCs are aligned due to the induced anisotropy on the substrate surface. Rubbed PI surfaces have suitable characteristics such as uniform alignment and a high pretilt angle. However, the rubbing method has some drawbacks; for example, the first, the rubbing method should generate electrostatic charges and the creation of contaminating particles because of contact alignment technique [1]. The second, the rubbing method has rubbing track and printing non uniformity of polymer film. It is difficult for these problems to make device of large size. Thus, rubbing-free techniques for LC alignment are strongly needed in liquid crystal display (LCD) technology. Up to date, the LC alignment effects by using the photodimerization [2–9] and photodissociation [10–15] have been reported. However, actually, these non-contact alignment techniques were not applied in industry. Most recently, the LC aligning capabilities by ion beam (IB) exposure on the diamond-like-carbon (DLC) as the alignment film have been successfully studied by P. Chaudhari *et al*. [16]. The other key technology is narrow viewing angle and slow response time of twisted nematic (TN) liquid crystal (LC). It has narrow viewing angle because it has limitation of asymmetric phase retardation on polar angle. Especially, multi domain vertical alignment (MVA) [17], in-plane switching (IPS) [18], and fringe-field switching (FFS) [19]. Among them, FFS mode has the advantage of higher transmittance comparing to MVA and IPS. Therefore, new alignment method using IB and DLC applied to FFS mode.

This article will report the electro-optical (EO) characteristics of the Ion beam aligned FFS cell with oblique Ion beam exposure on the a-C:H thin films.

EXPERIMENTAL

a-C:H thin films were deposited on various substrates such as indium-tin-oxide (ITO), single crystalline Si, and glass by the remote plasma enhanced chemical vapor deposition (RPECVD). All substrates were cleaned ultrasonically before deposition; ITO and glass were cleaned with trichloroethylene (TCE), acetone and alcohol, and single crystalline Si was cleaned with TCE, acetone, alcohol, buffered oxide etchant (BOE), and DI water. Then the samples were sputter cleaned for 10 min by argon plasma. Under first condition without rf bias, a-C:H thin films were deposited using a mixture of C_2H_2 (3 sccm) and He (30 sccm) as working gases. C_2H_2 and He gases were introduced into the chamber through the separate gas lines and the deposition was performed for 10 min at 100 W rf power and with a gas pressure of 30 Pa. Under Second condition with 30 W rf bias, a-C:H thin films were deposited using a mixture of C_2H_2 (3 sccm) and He (30 sccm) as working gases at 30 W rf bias condition. C_2H_2 and He gases were introduced into the chamber through the separate gas lines and the deposition was performed for 10 min at 100 W rf power and with a gas pressure of 30 Pa. The surface properties of a-C:H thin films were controlled by Ar ion beam irradiation. The Kaufman ion gun was used for the irradiation of a-C:H thin films. The argon IB irradiation time was 0, 1, and 5 min at 200 eV ion beam energy, respectively. The IB (Kaufman-type Ar ion gun) exposure system is shown in Figure 1.

The LC cell was assembled in an anti-parallel structure to measure the pretilt angle. The thickness of the LC layer was 60 μm. The LC cell was filled with a fluorinated mixture type of NLC without a chiral dopant ($\Delta\varepsilon = 8.4$, from Merck Co., Ltd.). Also, the rubbing aligned cell was fabricated. LC alignment ability was observed by using a photomicroscope. To measure EO characteristics for FFS cell, the IB exposure direction was 83° to the electric field on the a-C:H thin film as shown in Figure 1. The FFS cells were assembled by anti-parallel structure.

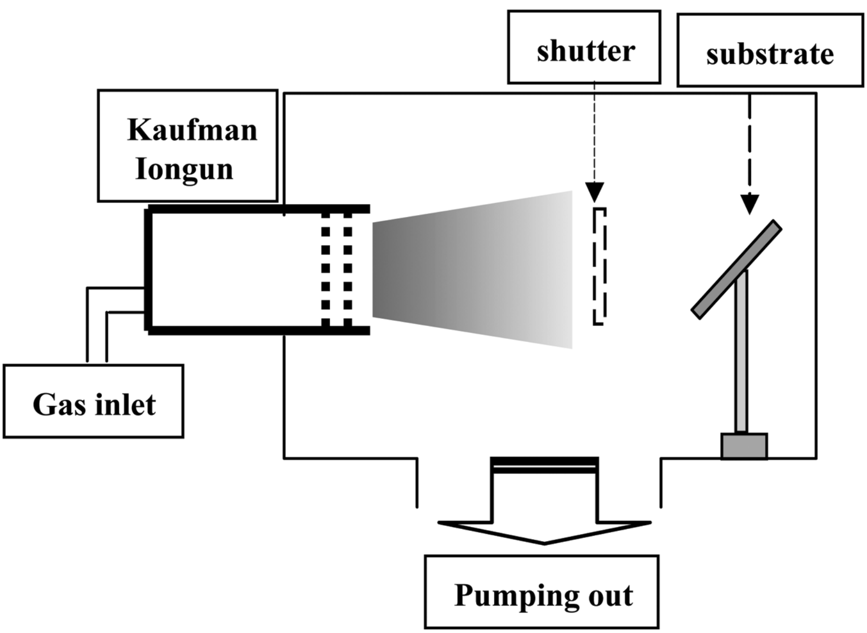

FIGURE 1 Ion beam exposure system.

The cell thickness was 5.0 μm. LCs used were positive dielectric anisotropy. Also, a rubbing-aligned FFS-LCD was fabricated. The cell thickness was 4.0 μm. The FFS cell fabricated was NB (normally black) mode. The pretilt angle of the anti-parallel cell was measured by a crystal rotation method. EO characteristics of the IB-aligned FFS cell were measured by the LCD-700 (LCD Evaluation System, from Otsuka Electronics Co.) equipment. The residual DC voltage of he IB-aligned FFS-LCD was measured by a capacitance-voltage hysteresis (C-V) method.

RESULTS AND DISCUSSION

The LC pretilt angles observed with IB exposure on a-C:H thin film for 1 min as a function of the incident angle are shown in Figure 2. It is shown that the LC pretilt angle generated was about 5.0° with an IB exposure of 30 ~ 65° on the a-C:H thin film. The LC pretilt angle had the maximum value at 30° about 5.5°, and the pretilt angle gradually decreased with increasing ion beam incident angle. In other words, it shows that incident angle of 30° is the best condition for generating the high pretilt angle.

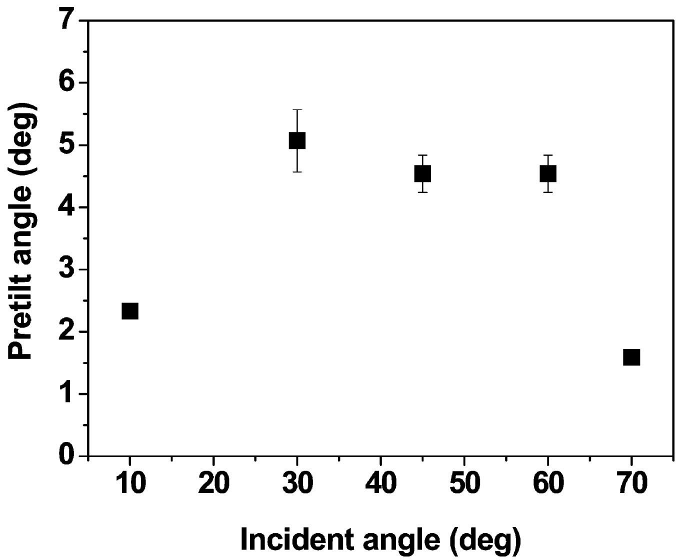

FIGURE 2 Generation of pretilt angles in NLC with IB exposure on a-C:H thin films.

Figure 3 shows micrographs of rubbing-aligned FFS cell on the polyimide surface and the ion-beam-aligned FFS cell with oblique ion beam exposure on a-C:H thin films (in crossed Nicols). Monodomain alignment of the rubbing-aligned FFS-LCD and ion beam aligned FFS cell can be observed (Magnification of a microscope: 100×).

Figure 4 shows voltage-transmittance (V-T) curve of rubbing-aligned FFS cell on the PI surface and ion beam aligned FFS cell on the a-C:H thin film. All stable V-T curves of rubbing-aligned and ion beam aligned FFS cell can be achieved. The light transmittance of ion beam aligned FFS cell starts to occur at the saturated at 4 V. Furthermore, the maximum-transmitted value of ion beam aligned FFS cell in intensity is higher than that of rubbing-aligned FFS cell

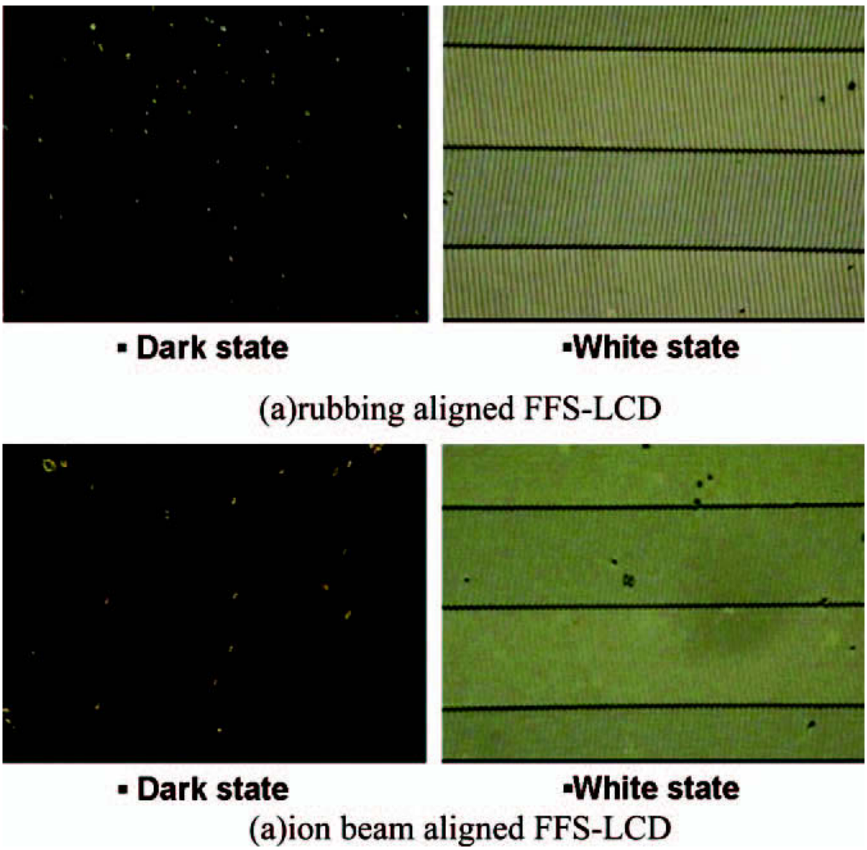

FIGURE 3 Microphotographs of the dark & the white state of rubbing aligned FFS cells (in crossed Nicols).

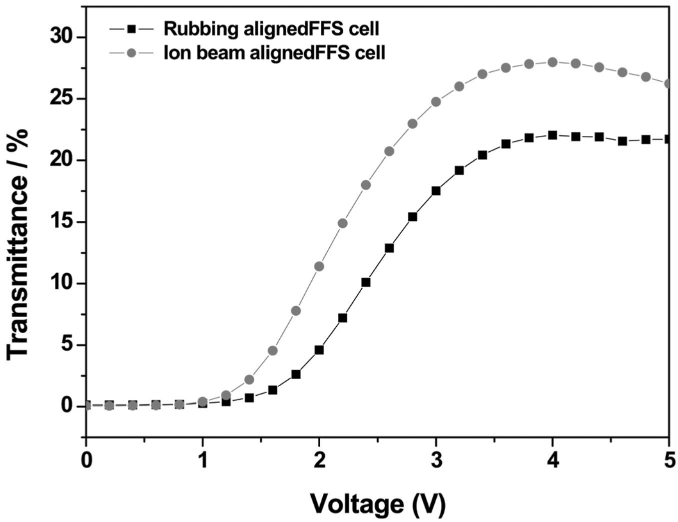

FIGURE 4 Voltage-transmittances curve of rubbing-aligned FFS cell on the PI surface and ion beam aligned FFS cell on the a-C:H thin film.

though the transmission-saturation voltage is the same. As a result, more transmittance level of ion beam aligned FFS cell was obtained than that of rubbing-aligned FFS cell. It is consider that better LC aligning capability give rise to higher transmittance level. Defects caused by the rubbing process could decrease transmittance in the manufacturing process. However, ion beam alignment process should make it better to improve aligning capability. The reason is that ion beam alignment method is the non contact alignment and uniform film technology. Therefore, this indicated that LC aligning capability generated by ion beam treatment is stronger than that by rubbing treatment. The new alignment technique has many advantages to apply large size display.

Figure 5 shows response time (RT) characteristics of rubbing-aligned FFS cell on the PI surface and ion beam aligned FFS cell on the a-C:H thin film. All stables curve on the the rubbing-aligned and ion beam aligned FFS cell were achieved as shown in Figure 5. However, the transmittance level of ion-beam-aligned FFS cell is higher than that of rubbing-aligned FFS cell. From these results, it was contended, herein, that the ion beam alignment method achieved a good V-T curve and good response time characteristics, as shown in Figure 4 and Figure 5. Consequently, the V-T performance of the ion beam aligned FFS cell on the a-C:H thin film surface is almost the same as that of the rubbing-aligned FFS cell on the PI surface.

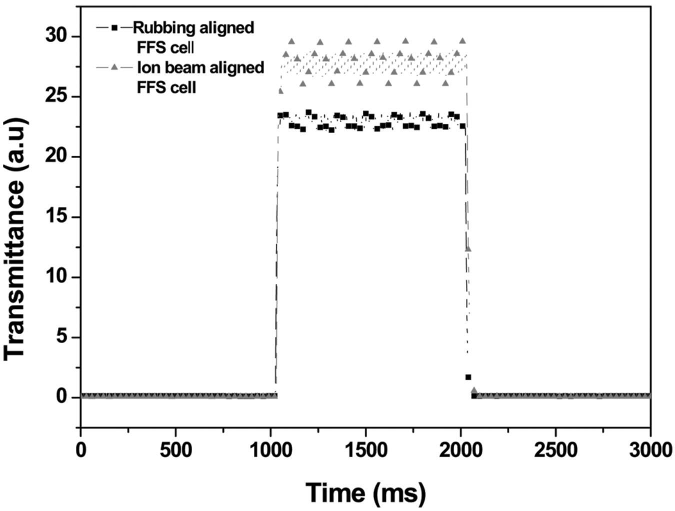

FIGURE 5 Response time curve of rubbing-aligned FFS cell on the PI surface and ion beam aligned FFS cell on the a-C:H thin film.

Figure 6 shows the V-T hysteresis characteristics of the rubbing-aligned and ion beam aligned FFS cell. V-T characteristics were measured by applied voltage from 0 V to 4 V. Without time delay, transmittances were measured by applied from 4 V to 0 V. If a display has hysteresis, a display produces image sticking. Therefore, 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. Few hysteresis characteristics of rubbing-aligned and ion beam aligned FFS cell were measured. Also, the residual charge characteristics between the ion bean aligned and rubbing aligned FFS cell have a little differences. However, the increased value of the residual charge was very small. It is concluded that the ion-beam-aligned FFS cell produce a few inner ion in spite of ion beam exposure. As a result, a good characteristic was achieved on a-C:H thin films, as a new alignment layer.

CONCLUSION

In conclusion, LC alignment capabilities and the variation of pretilt angles with ion beam irradiation on the a-C:H thin films, and the EO characteristics of the ion-beam-aligned FFS cell with oblique ion beam exposure on the a-C:H thin films were studied. We achieved

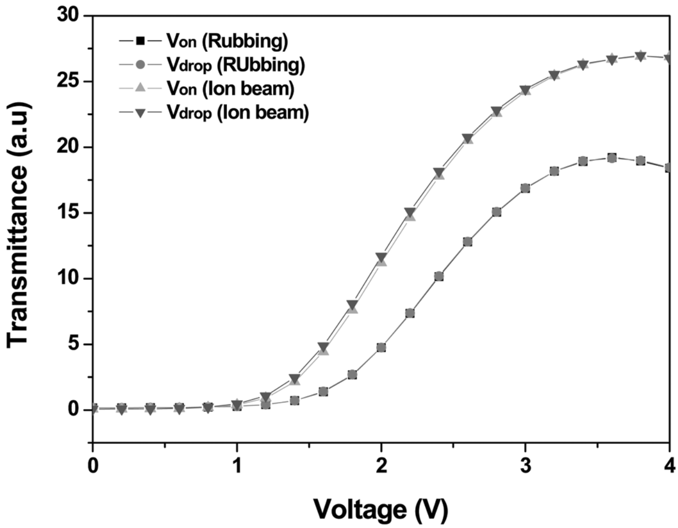

FIGURE 6 V-T hysteresis characteristics of the ion-beam-aligned FFS cell with oblique ion beam exposure on the a-C:H thin film surface and the rubbing-aligned FFS cell on a PI surface.

the high pretilt of about 5.5° when ion beam conditions were irradiation time of 1 minute and incident angle of 30°. Stable V-T and RT curve were observed for the ion-beam-aligned FFS cell with ion beam exposure on the a-C:H thin films for 1 min. Especially, the value of transmittance of the ion beam aligned FFS cell is higher than that of the rubbing aligned FFS cell. It is considered that high transmittance is due to higher LC aligning capability by non-contact alignment technology. Also, few hysteresis characteristics of rubbing-aligned and ion-beam-aligned FFS cell were measured. The Finally, the EO characteristics of the ion-beam-aligned FFS cell with ion beam exposure of 1 min on the DLC thin film surface is almost the same as that of the rubbing-aligned FFS cell on the PI surface. We can expect that FFS technology by using new method produces higher-quality displays, especially at higher resolutions.

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