Poster: Electro-Optical Characteristics of the Ion-Beam-Aligned FFS-LCD on a Diamond-Like-Carbon Thin Film

J. Y. Hwang, C. J. Park, and D. S. Seo*
Department of Electrical and Electronic Engineering (C-724), College of Engineering, Yonsei University, Korea
Y. H. Jeong
BOE-HYDIS Technology Co., LTD, Inchon, Kyubgki, Korea
K. C. Kim, H. J. Ahn, and H. K. Baik
Department of Metallurgical System Engineering, College of Engineering, Yonsei University, Korea
Phone: +82-2-2123-4617 , E-mail : dsseo@yonsei.ac.kr

Abstract
In this paper, we intend to make FFS mode cell with LC alignment used non-rubbing method, ion beam alignment method on the a-C:H thin film, to analyze electro-optical characteristics in this cell. We studied on the suitable inorganic thin film for FFS-LCD and the aligning capabilities of nematic liquid crystal (NLC) using the new alignment material of a-C:H thin film as working gas at rf bias condition. A high pretilt angle of about 5° by ion beam(IB) exposure on the a-C:H thin film surface was measured. An excellent voltage-transmittance (V-T) and response time curve of the ion-beam-aligned FFS-LCD was observed with oblique ion beam exposure on the DLC thin films.

1. Introduction
Recently, the representative LCD mode applied to TFT-LCD is normally white (NW) twisted nematic (TN) mode. But, it has narrow viewing angle because it has limitation of asymmetric phase retardation on polar angle.
Fringe Field Switching (FFS) mode [1] has the same phase retardation in every direction of polar angle, so it has wide viewing angle characteristic. But FFS mode has been homogeneous alignment state of normally black (NB) type in initial. Currently, we used rubbing aligninment method for LC alignment at FFS and at TN LCD. However, the rubbing method has some drawbacks, such as the generation of electrostatic charges, the creation of contaminating particles, rubbing scratch and rubbing track [2-3]. The FFS mode has more serious problem in rubbing method than that of TN mode because FFS mode adopt normally black mode. So FFS mode has demerit of narrow process margin in rubbing process. Recently, the LC alignment effects realized by photodimerization[4,5] and photodissociation[6] have been reported. Most recently, the LC aligning capabilities achieved by ion beam (IB) exposure on the diamond-like-carbon (DLC) thin film layer have been successfully studied by P. Chaudhari et al [7].

This article will report the electro-optical (EO) characteristics of the ion-beam-aligned Fringe-Field Switching (FFS) Mode-LCD with oblique ion beam exposure on the DLC thin films.

2. Experiment and Results
2.1 Experimental condition
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). Under a condition with 30W 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 30W 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 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 ion beam irradiation time was 0, 1, and 5 min at 200eV ion beam energy, respectively. The IB (Kaufman-type Ar ion gun) exposure system is shown in Fig. 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 nematic (N) LC without a chiral dopant ($\Delta\varepsilon$=8.4, from Merck Co., Ltd.). Also, the rubbing aligned cell was fabricated. LC alignment ability was observed using a photomicroscope. To measure FFS-LCD, the ion beam exposure direction was 83° to the electric field on the a-C:H thin film deposited at rf 30W bias condition. The FFS-LCDs were assembled by anti-parallel structure. The cell thickness was a 5.0μm. LCs used were positive dielectric anisotropy. Also, a rubbing-aligned FFS-LCD was fabricated. The cell thickness was a 4.0μm. The FFS-LCD fabricated was NB (normally black) mode. The pretilt angle of the anti-parallel cell was measured by a crystal rotation method. Electro-optic (EO) characteristics of the ion-beam-aligned FFS-LCD were measured by DMS (Display Measurement System, from Autronic) equipment. The residual DC voltage of the ion-beam-aligned FFS-LCD was measured by a capacitance-voltage hysteresis method.

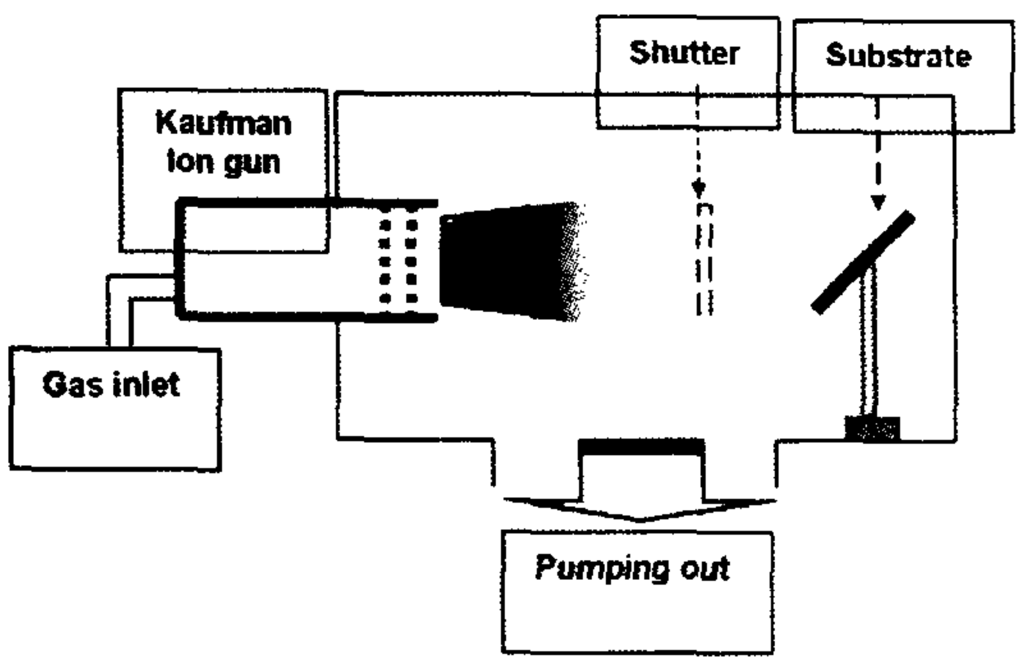


Fig. 1 IB exposure system used.

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 Fig. 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 deposited at rf bias condition.

Figure 3 shows micrographs of the aligned LC with IB exposure on the a-C:H thin film deposited at rf bias condition for 1 min at various annealing temperatures (in crossed Nicols). In Fig. 3(a), good LC alignment with IB exposure on the a-C:H thin film deposited at rf bias condition was observed up to an annealing temperature of 250℃, and the alignment defects of LCs were observed above an annealing temperature of 300℃ [8].

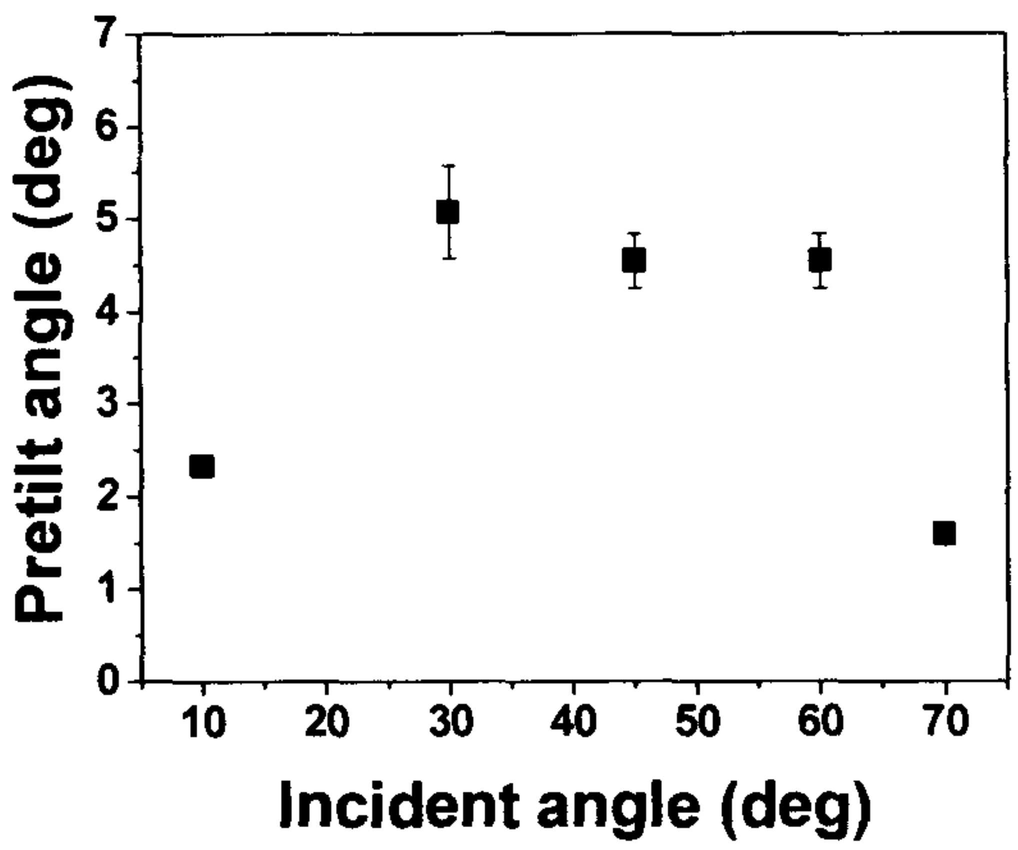


Fig. 2 Generation of pretilt angles in NLC with IB exposure on a-C:H thin films.

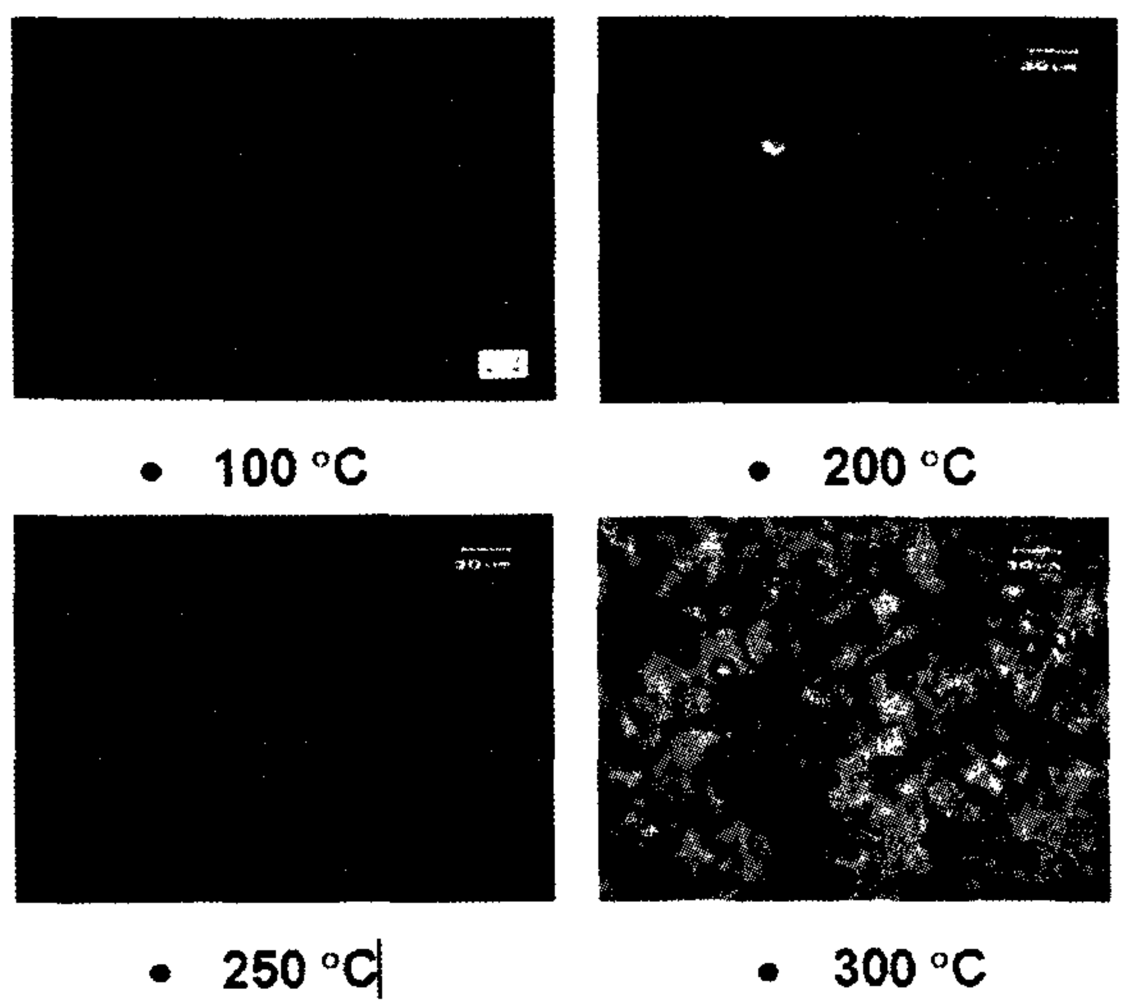
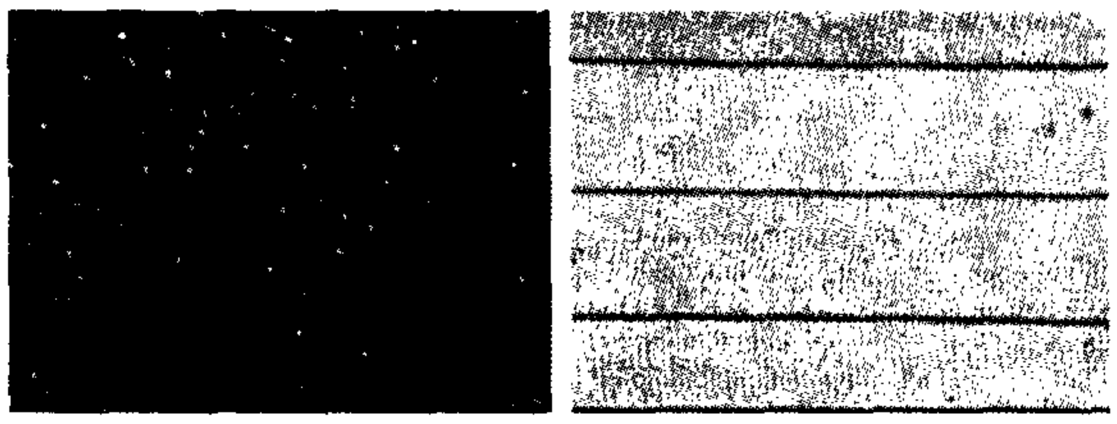


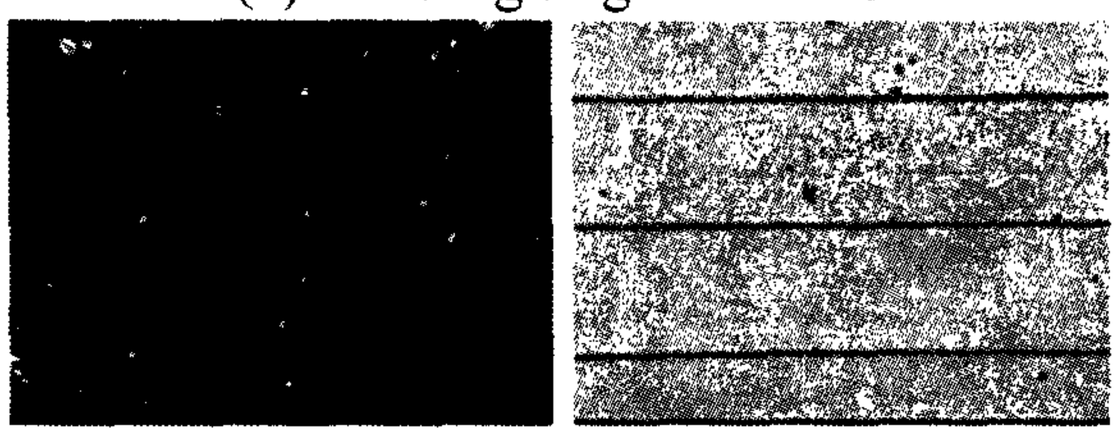
Fig. 3 Microphotographs of aligned NLC with IB exposure on the a-C:H thin film surfaces for 1 min as a function of annealing temperature (in crossed Nicols)

Figure 4 shows micrographs of rubbing-aligned FFS-LCD on the polyimide surface and the ion-beam-aligned FFS-LCD with oblique ion beam exposure on DLC thin films deposited at rf bias condition (in crossed Nicols). Monodomain alignment of the rubbing-aligned FFS-LCD and ion-beam-aligned FFS-LCD can be observed.



• Dark state •White state

(a) rubbing aligned FFS-LCD



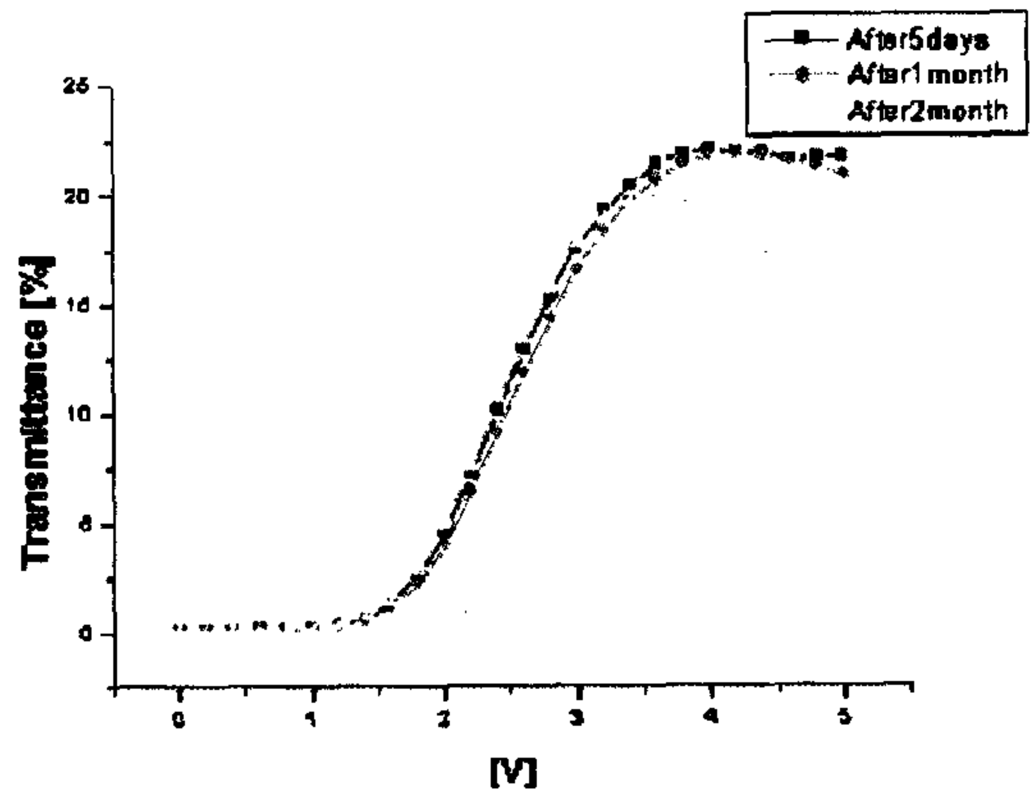
• Dark state •White state

(b) ion beam aligned FFS-LCD

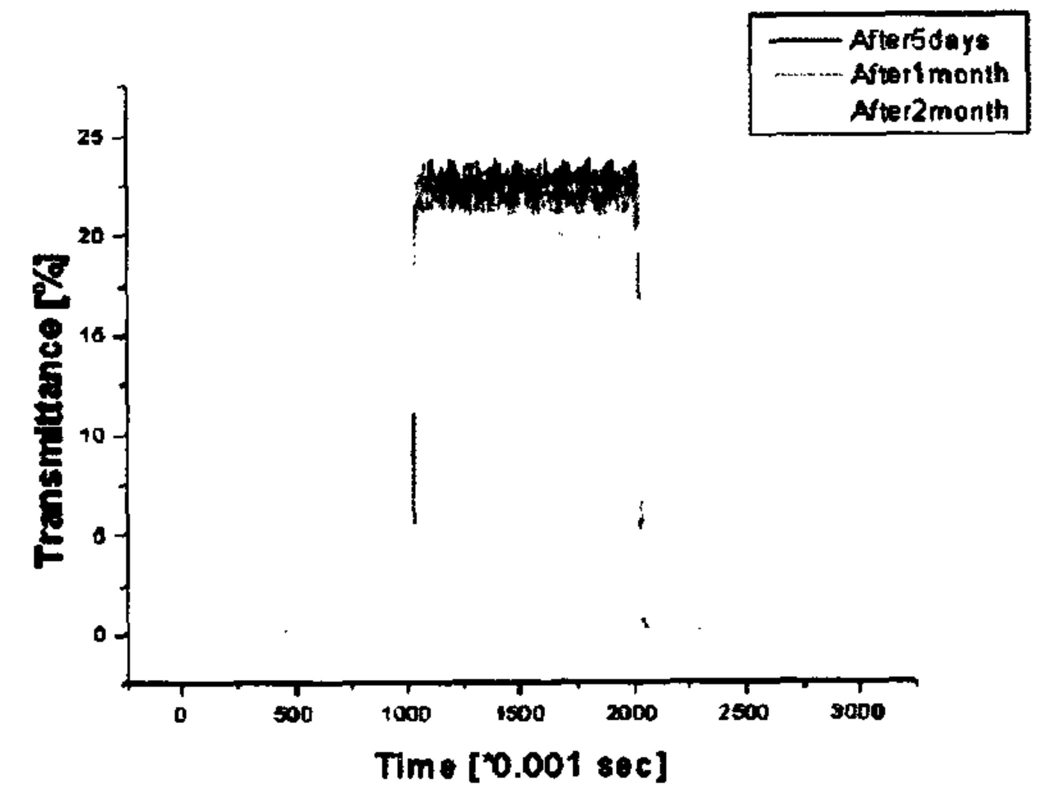
Fig. 4. Microphotographs of the dark & the white state of rubbing aligned FFS-LCD cells (in crossed Nicols).

Figure 5 shows voltage-transmittance (V-T) and response time (RT) curves of the rubbing-aligned FFS-LCDs. A stable V-T and RT curve on the rubbing-aligned FFS-LCD can be achieved. Stable V-T and RT characteristics of the rubbing-aligned FFS-LCD were achieved after five days and one month. However, drop of steep VT curve of the rubbing-aligned FFS-LCD was achieved after two moths.

Figure 6 shows VT and RT characteristics of the ion-beam-aligned FFS-LCD with ion beam exposure on the DLC thin films. A stable VT and RT curve on the the ion-beam-aligned FFS-LCD can be achieved as shown in Fig 6. Also, stable V-T characteristics of the ion beam aligned FFS-LCD was achieved after two moths. From these results, it is contended, herein, that the ion beam alignment method can be to achieve a good V-T curve and good response time characteristics, as shown in Figs. 5 and 6. Consequently, the VT performance of the ion-beam-aligned FFS-LCD on the DLC thin film surface is almost the same as that of the rubbing-aligned FFS-LCD on the PI surface.

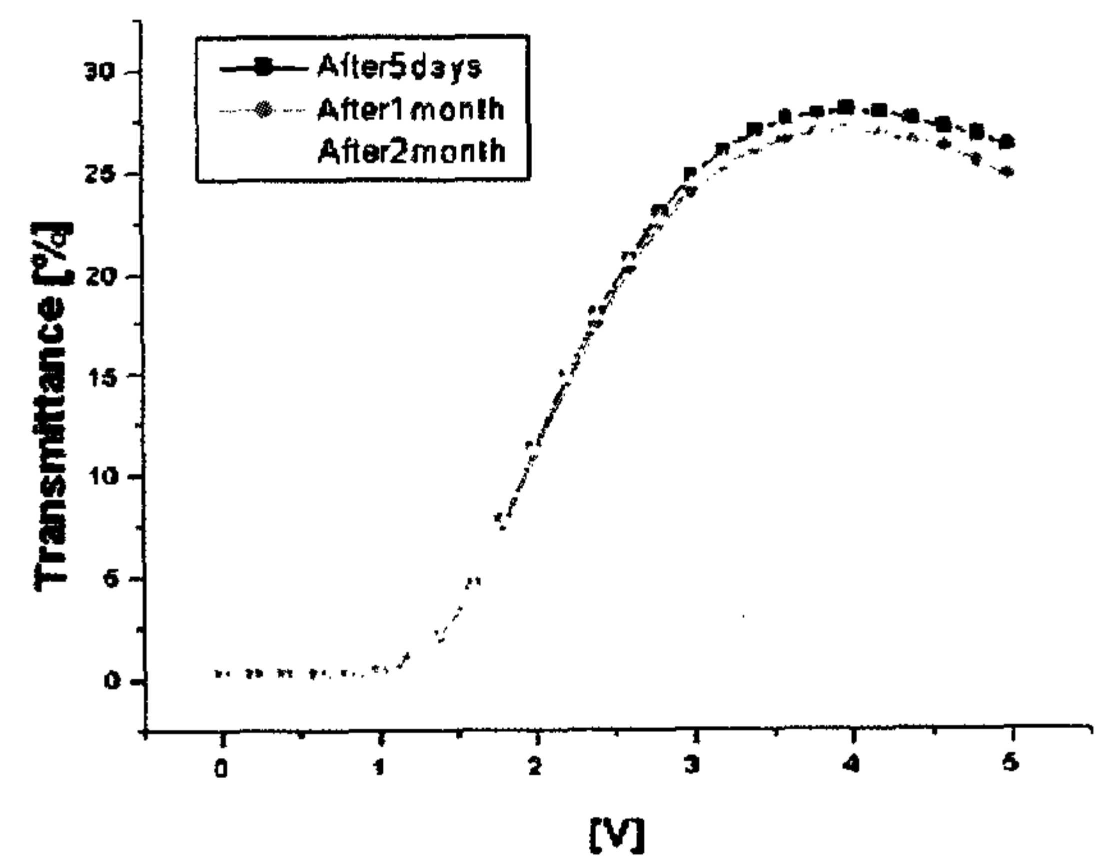


(a) V-T curve

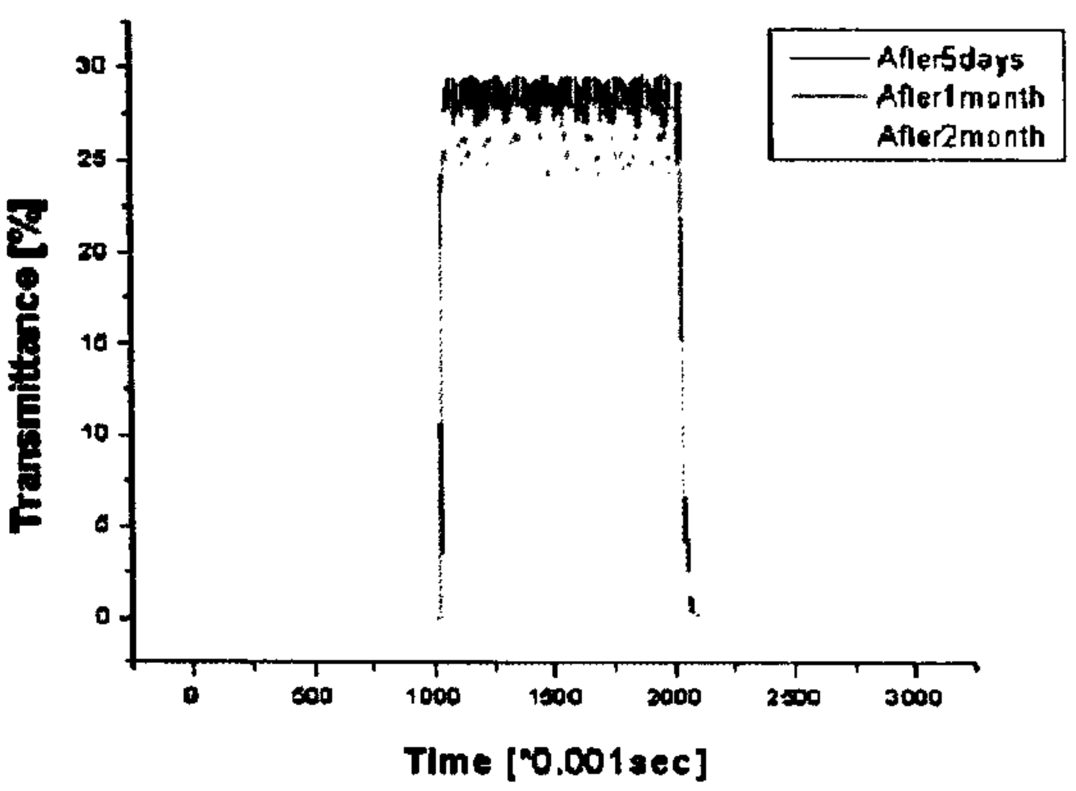


(b) R-T curve

Fig. 5. V-T and response time curves of the rubbing-aligned FFS-LCDs on a PI surface.



(a) V-T curve



(b) R-T curve

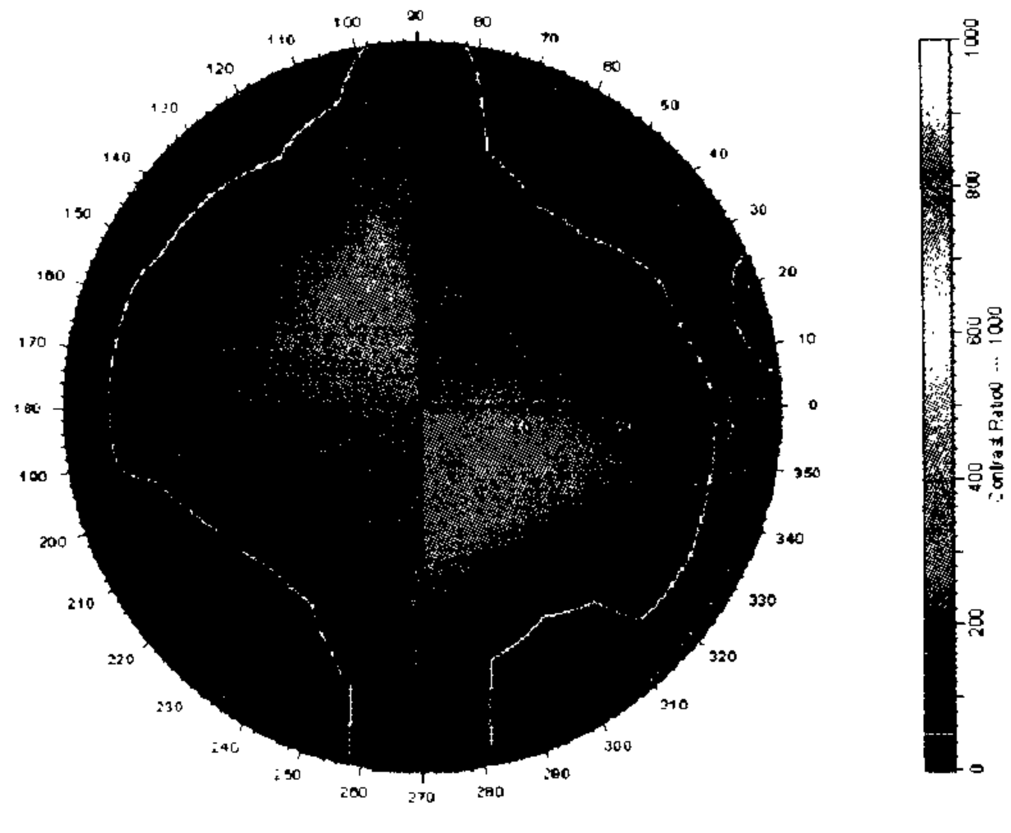
Fig. 6. V-T and response time characteristics of the ion-beam-aligned FFS-LCDs with oblique ion beam exposure on the DLC thin film .

Table I shows the response times of rubbing-aligned and the ion-beam-aligned FFS-LCD. A stable response time of the rubbing-aligned and ion-beam-aligned FFS-LĈD can be achieved after two moths. However, the slow response time of the ion-beam-aligned FFS-LCD was optically measured than rubbing-aligned FFS-LCD. It is considered that the slow response time in the ion-beam-aligned FFS-LCD (d=5μm) is due to higher cell gap than rubbing-aligned FFS-LCD (d=4μm).

Table I. Response time characteristics of the ion beam aligned FFS-LCD on the a-C:H thin film surface and rubbing aligned FFS-LCD on the PI surface.

Alignment Film	a-C:H (RF power 30W)			Rubbed PI		
Time / RT	5days	1month	2months	5days	1month	2months
Rising time (τ_r)	13.49	15.85	15.73	13.49	13.82	13.04
Decay time (τ_f)	21.50	21.25	20.70	12.54	13.51	13.53
Response time τ (ms)	34.99	37.10	36.43	26.03	27.33	26.57

Figure 7 shows the viewing angle characteristics of the rubbing-aligned and the ion-beam-aligned FFS-LCD. It is shown that the iso-viewing angle characteristics of the rubbing-aligned and the ion-beam-aligned FFS-LCD can be achieved.


(a) ion-beam-aligned FFS-LCD

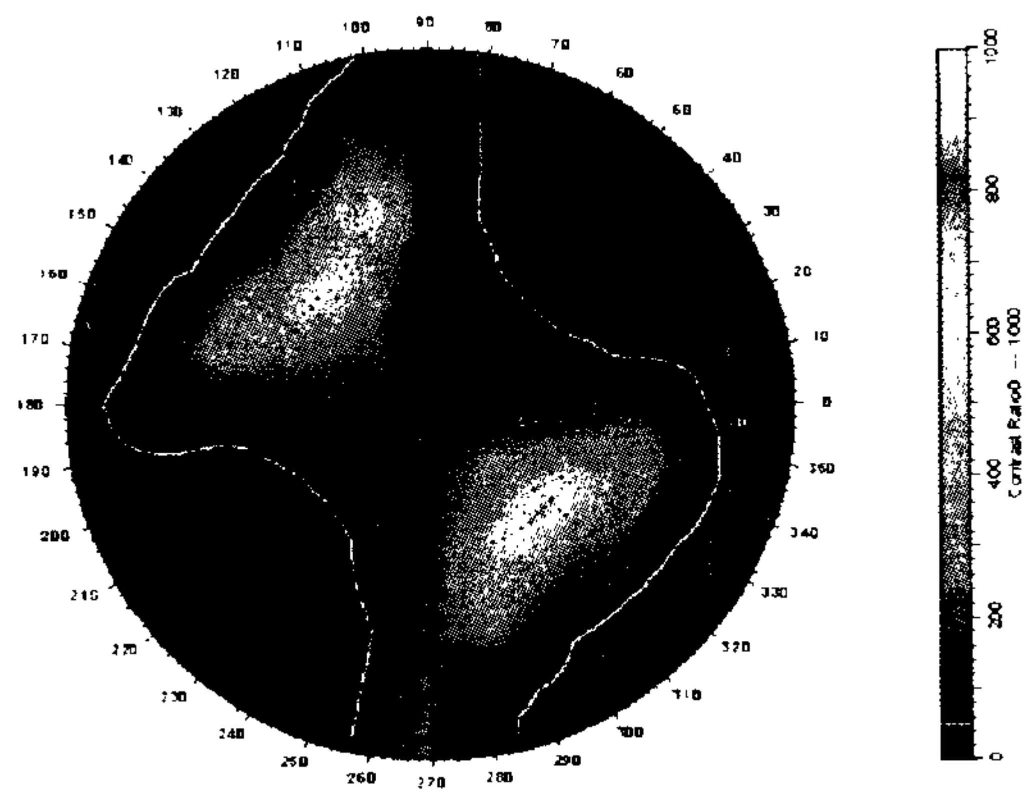
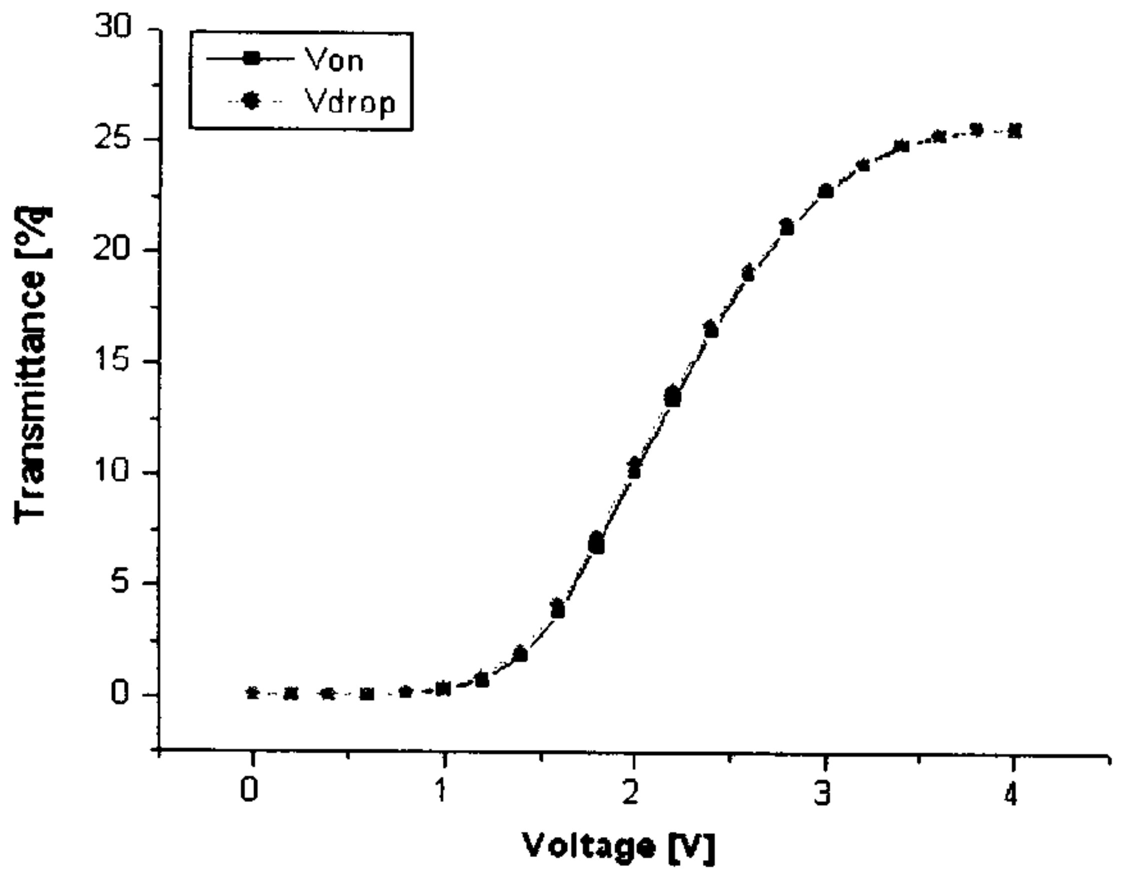
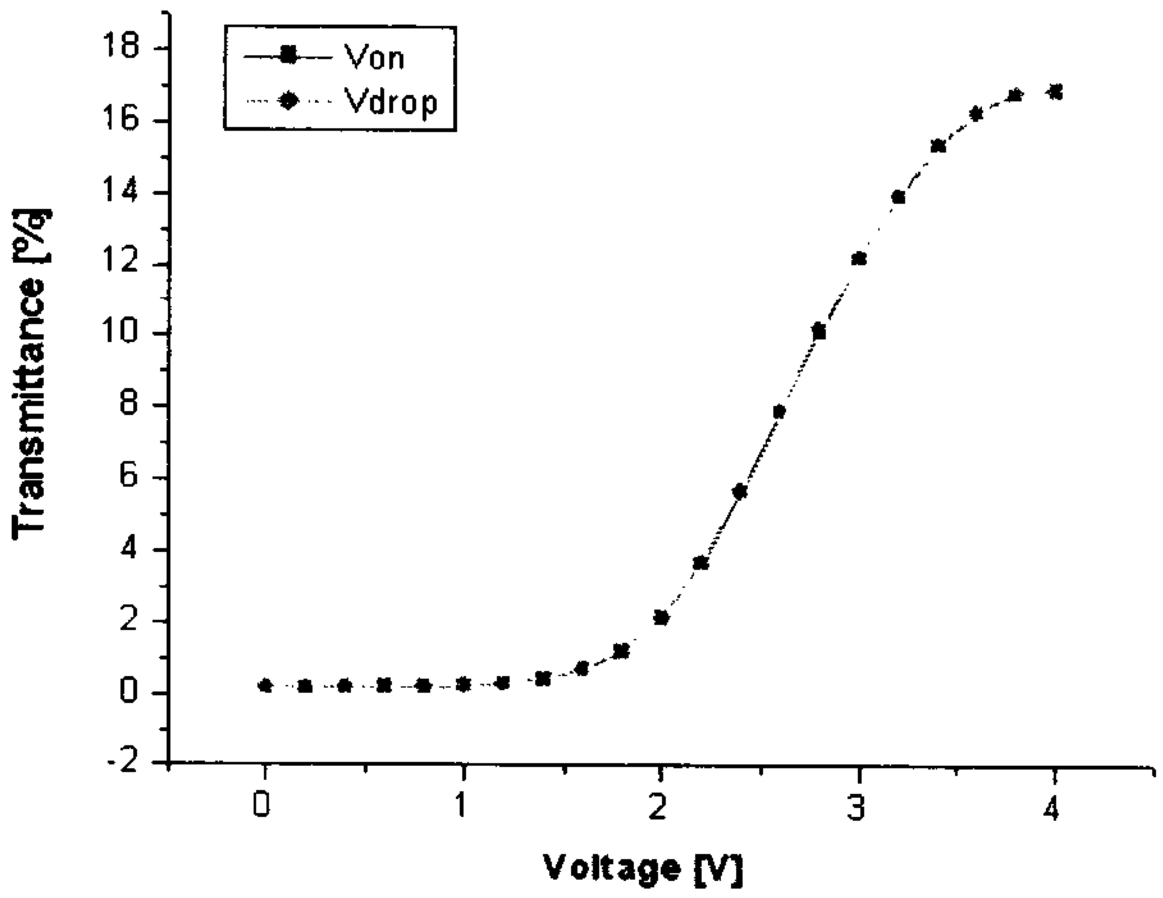

(b) rubbing-alined FFS-LCD

Fig. 7 Viewing angle characteristics of the ion-beam-aligned FFS-LCDs with oblique ion beam exposure on the DLC thin film surface and the rubbing-aligned FFS-LCD on a PI surface.

Figure 8 shows the AC V-T hysteresis characteristics of the rubbing-aligned and ion-beam-aligned FFS-LCD. Few hysteresis characteristics of rubbing-aligned and ion-beam-aligned FFS-LCD were measured. It can be concluded that inner ion in the ion-beam-aligned FFS-LCD can't produce for AC operation. Therefore, the EO characteristics of the ion-beam-aligned FFS-LCD with oblique ion beam exposure on the DLC thin films for 1 min are almost the same as those of the rubbing-aligned FFS-LCD on the PI surface.



(a) ion-beam-aligned FFS-LCD



(b)rubbing-alined FFS-LCD

Fig. 8. AC V-T hysteresis characteristics of the ion-beam-aligned FFS-LCDs with oblique ion beam exposure on the DLC thin film surface and the rubbing-aligned FFS-LCD on a PI surface.

3. Conclusion

In conclusion, LC alignment capabilities and the variation of pretilt angles with ion beam irradiation on the DLC thin films, and the EO characteristics of the ion-beam-aligned FFS-LCD with oblique ion beam exposure on the DLC thin film surface were studied. A high pretilt angle of on the a-C:H thin film deposited at 30W rf bias condition was measured. A good LC alignment by the IB alignment method on the a-C:H thin film deposited at rf bias condition was observed at annealing temperature of 250℃, and the alignment defect of the NLC was observed above annealing temperature of 300℃. A good V-T and RT curve was observed for the ion-beam-aligned FFS-LCD with ion beam exposure on the DLC thin films for 1 min. Also, a good iso-viewing angle characteristic can be achieved for the ion-beam-aligned FFS-LCD. Finally, the AC V-T hysteresis characteristics of the ion-beam-aligned FFS-LCD with ion beam exposure of 1 min on the DLC thin film surface is almost the same as that of the rubbing-aligned FFS-LCD on the PI surface.

4. Acknowledgement

This work was supported by National Research Laboratory program (M1-0203-00-0008).

5. References

[1] S. H. Lee, S. L. Lee, and H. Y. Kim: Appl. Phys. Lett., **73**, (1998) p.2881.
[2] J. M. Geary, J. W. Goodby, A. R. Kmetz and J. S. Patel: J. Appl. Phys. **62** (1987) 4100.
[3] D.-S. Seo, K. Muroi and S. Kobayashi: Mol. Cryst. & Liq. Cryst. **213** (1992) 223.
[4] M. Schadt, K. Schmitt, V. Jozinkov and V. Chigrinov: Jpn. J. Appl. Phys. **31** (1992) 2155.
[5] S. Furumi, M. Nakagawa, S. Morino, K. Ichimura and H. Ogasawara: Appl. Phys. Lett. **74** (1999) 2438.
[6] J. L. West, X. Wang, Y. Ji and J. R. Kelly: SID' 95 (1995) p.703.
[7] P. Chaudhari, 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: Nature **411** (2001) 56.
[8] J.-Y. Hwang, Y.-M. Jo, D.-S. Seo, S.- J. Rho, D. K. Lee and H. K. Baik: Jpn. J. Appl. Phys. **41** (2002) L654.