Molecular Crystals and Liquid Crystals

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

Electro-Optical Characteristics of Photoaligned TN Cell Using UV Alignment on the a-C:H Thin Film

Jeoung-Yeon Hwang [a] , Hyung-Ku Kang [a] , Chang-Joon Park [a] , Dae-Shik Seo [a] , Sung-Hoon Lim [b] , Kyu-Chang Park [b] & Jin Jang [b]

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

[b] Advanced Display Research Center, Kyung Hee University, Dangdaemoon-ku, Seoul, Korea

Version of record first published: 31 Jan 2007

To cite this article: Jeoung-Yeon Hwang, Hyung-Ku Kang, Chang-Joon Park, Dae-Shik Seo, Sung-Hoon Lim, Kyu-Chang Park & Jin Jang (2005): Electro-Optical Characteristics of Photoaligned TN Cell Using UV Alignment on the a-C:H Thin Film, Molecular Crystals and Liquid Crystals, 434:1, 151/[479]-161/[489]

To link to this article: http://dx.doi.org/10.1080/15421400590954696

Mol. Cryst. Liq. Cryst., Vol. 434, pp. 151/[479]–161/[489], 2005

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400590954696

Taylor & Francis
Taylor & Francis Group

Electro-Optical Characteristics of Photoaligned TN Cell Using UV Alignment on the a-C:H Thin Film

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

Sung-Hoon Lim
Kyu-Chang Park
Jin Jang
Advanced Display Research Center, Kyung Hee University,
Dangdaemoon-ku, Seoul, Korea

We studied the nematic liquid crystal (NLC) alignment capability by the UV alignment method on a a-C:H thin-film surface, and investigated electro-optical performances of the UV aligned twisted nematic (TN)- liquid crystal display (LCD) with the UV exposure on a-C:H thin film surface. A good LC alignment by UV irradiation on a a-C:H thin-film surface at a layer thickness of 200Å was achieved. Also, a good LC alignment by the UV alignment method on the a-C:H thin film surface was observed at an annealing temperature of 180°C. However, the alignment defect of the NLC was observed at an annealing temperature above 200°C. Monodomain alignment of the UV aligned TN-LCD can be observed. The best electro-optical (EO) characteristics of the UV aligned TN-LCD in the photoaligned TN-LCDs was observed with oblique ion beam exposure on the a-C:H thin film surface for 1 min.

Keywords: a-C:H thin film; electro-optical (EO) characteristics; nematic liquid crystal; UV exposure

This work was supported by National Research Laboratory program (M1-0203-00-0008) & the Ministry of Information & Communications of Korea under the Information Technology Research Center (ITRC) Program.

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

Liquid crystal displays (LCDs) have become one of the fastest growing information display devices in recent years. They are widely used in notebook computers, PC monitors, TVs and other devices. The uniform alignment of LC is one of the essential processes for LCD fabrication. The most conventional process for LC alignment employs a mechanically rubbed polyimide (PI) surface. LCs are aligned due to the induced anisotropy on the substrate surface. The rubbing alignment method has suitable characteristics such as uniform alignment and a high pretilt angle. However, rubbed PI surfaces involve some problems such as the generation of dust and static electricity [1–7], and a complicated process for multidomain LC alignment [8]. Thus, rubbing-free techniques for LC alignment are strongly required in LCD technology.

The LC alignment effected by the photodimerization [9–12] and photodissociation [13–17] has been reported. Most recently, the LC aligning capability achieved by ion beam (IB) exposure on the diamond-like-carbon (DLC) thin film layer has been successfully studied by P. Chaudhari *et al*. [18]. Also, our research group already studied IB alignment method using DLC thin film [19–21]. Thus, ion beam alignment using inorganic materials for LCDs is a promising technology among a variety of rubbing-free methods. However, the ion beam alignment method requires a vacuum chamber and has several problems; for example, LC orientation and pretilt angle is hard to reproducibility because of the high energy of ion beams. Also, UV alignment technique with polarizer for LC alignment has revealed good LC orientation by a simple process [16].

In this article, we report on LC alignment and pretilt angle generation with UV exposure on the DLC (a-C:H) thin-film surface, and EO characteristics of the ion beam aligned TN-LCD with oblique ion beam exposure on the DLC surface.

EXPERIMENTAL

The a-C:H thin films were grown on indium-tin-oxide (ITO)-coated glass substrates by an inductively coupled plasma chemical vapor deposition (ICP-CVD) System. The ICP-CVD system is shown in Figure 1. The a-C:H thin films were deposited using C_2H_2: He gas for 1–3 min. C_2H_2 and He gases were floated 3 sccm and 30 sccm in the chamber at room temperature, respectively. The thickness of the a-C:H layer was controlled to be 100–300 Å. Table 1 shows the deposition conditions of inorganic materials as a-C:H thin films. The UV exposure (Oriel Co.) system is shown in Figure 2. The UV source

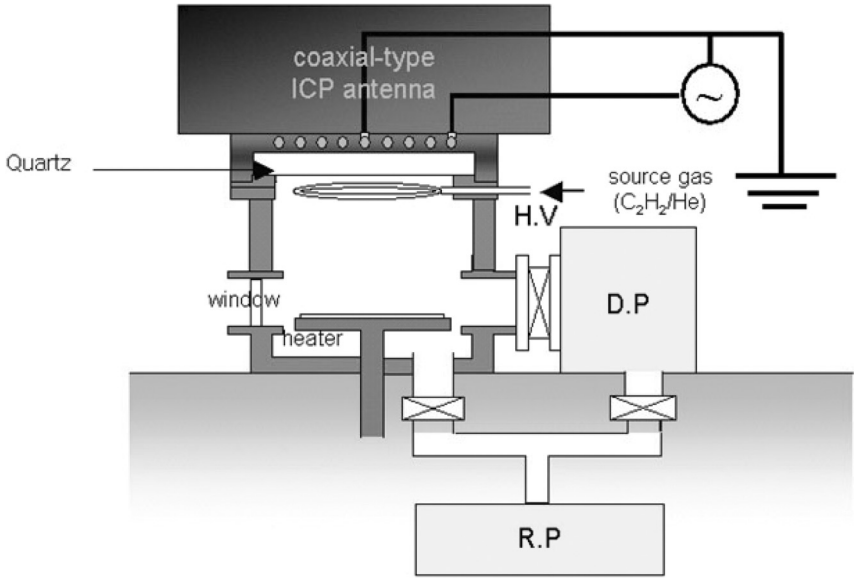


FIGURE 1 ICP-CVD system for a-C:H thin film.

was a 1 kW mercury lamp. The UV energy density used was 80 mW/cm^2. The LC cell was assembled in an antiparallel structure to measure the pretilt angle. In order to compare a new LC alignment using an inorganic thin film by UV light, an LC alignment using an organic film by the UV alignment method was investigated. Polyimide (PI) was uniformly coated on indium-tin-oxide (ITO) electrodes by a spin-coating method, and imidized at 250°C for 1 h. The molecular structure of the polymer used is shown in Figure 3. The thickness of the PI film was set at 500 Å. The substrate surfaces were irradiated by nonpolarized UV exposure. The same UV exposure system was used. The thickness of these LC layers was 60 μm, and the cell thickness of the Photoaligned TN-LCD was about 5 μm. Table 2 shows the

TABLE 1 Deposition Conditions as a-C:H Thin Films

Alignment layer	Deposition time (~1.7Å/sec)	Deposition pressure (mTorr)	C_2H_2: He ratio	Layer thickness (Å)
DLC_UV (1)	1 min	200	3:30	100
DLC_UV (2)	2 min	200	3:30	200
DLC_UV (3)	3 min	200	3:30	300

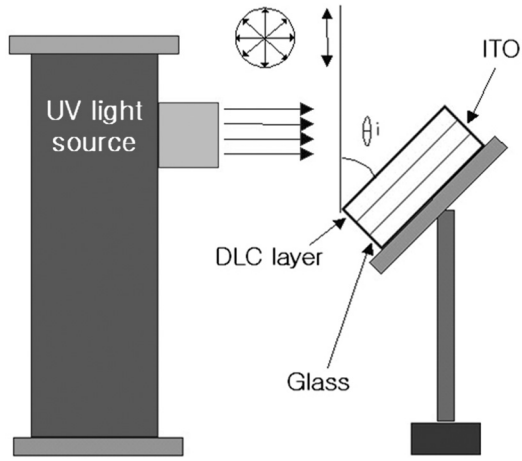


FIGURE 2 UV exposure system used.

experimental condition of Photoaligned TN-LCD as a-C:H thin films. The LC cells were filled with a fluorinated mixture type of NLC without a chiral dopant (Tc = 72°C, $\Delta\varepsilon = 9.4$, from Merck Co.). Also, the rubbing-aligned cell was fabricated. The LC alignment ability was observed using a photomicroscope. Lastly, the pretilt angle of an antiparallel cell was measured by a crystal rotation method, and V-T and response time characteristics of the ion beam aligned TN-LCD were measured by a LCD-700 (LCD Evaluation System, from Otsuka Electronics Co.) equipment.

RESULTS AND DISCUSSION

Figure 4 shows micrographs of LC cells with nonpolarized UV exposure on a-C:H thin film for 30 min and on the polyimide layer film

TABLE 2 The Experimental Condition of Photoaligned TN-LCD as a-C:H Thin Films

Cell number	UV exposure time (min)	UV incident angle (deg)	Cell gap measured (μm)
TN-1 (1 min)	1	45°	5.1
TN-2 (5 min)	5	45°	5.2
TN-3 (10 min)	10	45°	4.9
TN-4 (20 min)	20	45°	5.0

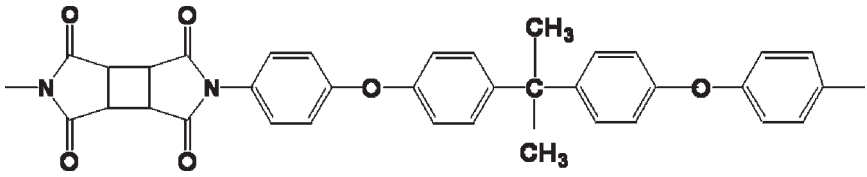


FIGURE 3 Chemical structure of the polymers.

for 30 min. In Figure 4(a), a uniform LC alignment was observed via nonpolarized UV exposure on the a-C:H thin film (200 Å). However, the LC alignment defect was observed via nonpolarized UV exposure on the polyimide layer as shown in Figure 4(b). It is considered that weak aligning capability is due to strong UV energy. This strong UV energy can help to form good alignment on the inorganic thin film. However, in the organic film, this strong UV energy can affect to decrease LC alignment. As a result, the LC alignment capability on the inorganic thin film was higher than that on the organic thin film using UV light. It is considered, therefore, that a stable LC alignment can be obtained on the a-C:H thin film.

Figure 5 shows micrographs of an LC cell with linearly polarized and nonpolarized UV exposure on a-C:H thin film (200 Å) for 30 min. All UV irradiation used the same UV dose. An excellent LC alignment was observed by nonpolarized UV exposure with an incidence angle of 45° on the a-C:H thin film for 30 min, as shown in Figure 5(a). However, many dislocations were observed by linearly polarized UV exposure on the a-C:H thin film for 30 min, as shown in Figure 5(b). The LC alignment achieved by nonpolarized UV exposure was better than that achieved by linearly polarized UV exposure. Therefore, it is considered

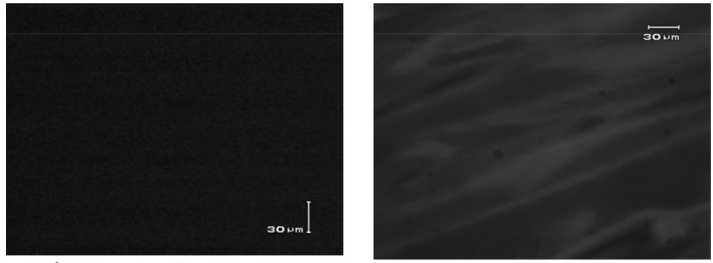
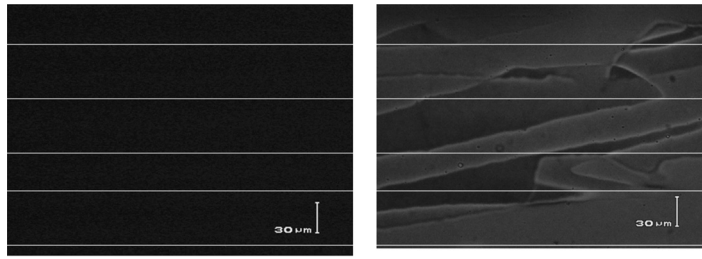


FIGURE 4 Micrographs of LC cell with nonpolarized UV exposure on polymer film and a-C:H thin films (in crossed Nicols).



(a) nonpolarized UV light **(b) polarized UV light**

FIGURE 5 Micrographs of LC cell with nonpolarized UV or linearly polarized UV exposure on a-C:H thin films (in crossed Nicols).

that an inorganic material for LCD was used by non-polarized UV light as superior LC alignment, but an organic material for LCD was used by linearly polarized UV light as superior LC alignment [11]. These results show that inorganic film needs strong UV energy.

Figure 6 shows micrographs of an LC cell with non-polarized UV exposure on three kinds of a-C:H thin film for 30 min. In Figure 6 (a), the LC cell via UV exposure on the a-C:H thin film (100 Å) showed dark state except from clearly imperfections in the center. Also, excellent LC alignment was observed via non-polarized UV exposure on the a-C:H thin film (200 Å) as shown in Figure 6(b). However, the many LC alignment defects were observed with non-polarized UV exposure on the a-C:H thin film (300 Å) as shown in Figure 6(c). It is contended that stable LC alignment can be obtained on the a-C:H thin film with 200 Å of layer thickness. Therefore, it is considered that LC aligning capability depends on a-C:H thin film thickness.

The alignment direction of LC was parallel to the incident direction of the nonpolarized UV light. A unidirectional LC alignment on the a-C:H thin film was generated by UV exposure which selectively

(a) 100 Å **(b) 200 Å** **(C) 300 Å**

FIGURE 6 Micrographs of an LC cell with non-polarized UV exposure on three kinds of a-C:H thin film for 30 min.

destroyed unfavorably oriented rings of atoms, and the planes of the remaining rings induced LC molecules to align in the direction of UV exposure [14].

The LC pretilt angle observed with nonpolarized UV exposure on the a-C:H thin film (200 Å) for 30 min as a function of incident angle are shown in Figure 7. It is shown that the LC pretilt angle generated was below 1° in the all-incident angle on the a-C:H thin film. Also, the pretilt angle increased with increasing incident angle. It is considered that the generation of the LC pretilt angle in nonpolarized UV exposure is attributable to the high incident angle by UV exposure [12].

Figure 8 shows micrographs of the aligned LC with non-polarized UV exposure on the a-C:H thin film for 30 min at various annealing temperatures (in crossed Nicols). A superior LC alignment on the inorganic thin film was observed up to an annealing temperature of 180°C, and the alignment defects of the LCs were observed at an annealing temperature above 200°C. From these results, LC azimuthal deformation which implies the relationship of spatial orientation between LC and the alignment director, in spite of high temperature, was uniform and thermal stability of LC alignment with UV exposure on the a-C:H thin film layer up to 180°C was obtained. Therefore, a superior LC alignment capability and thermal stability can be achieved via non-polarized UV exposure on the a-C:H thin film.

Figure 9 shows the V-T curves of the photoaligned TN-LCDs with oblique non-polarizer exposure on the a-C:H thin film. All of the V-T cures exhibited backflow bounce effect, as shown in Figure 8. Especially, we used the NLC without a chiral dopant to observe

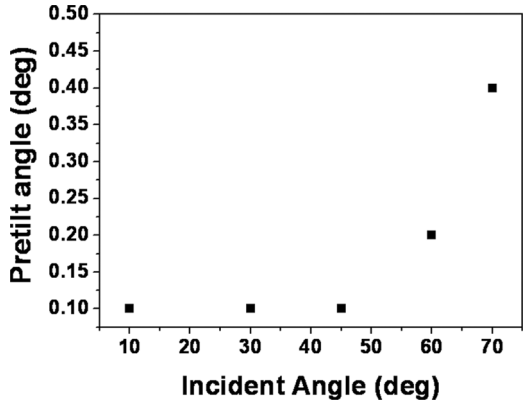


FIGURE 7 LC pretilt angle with nonpolarized UV exposure on the a-C:H thin film for 30 min as a function of incident angle.

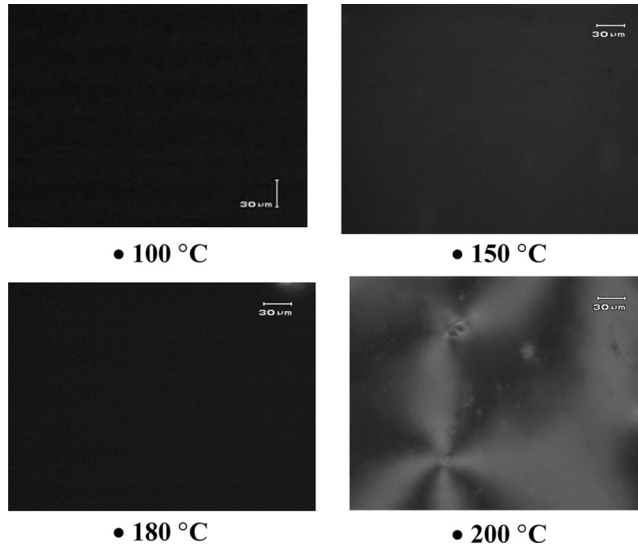


FIGURE 8 Micrographs of aligned LC with non-polarized UV exposure on the a-C:H thin film surface for 1 min at various annealing temperatures (in crossed Nicols).

surface energy between surface and LC, and can observe anchoring energy indirectly. Therefore, it was considered that these backflow bounce effect of the photoaligned TN-LCDs was caused to weak anchoring energy. As a result, we support that weak anchoring energy

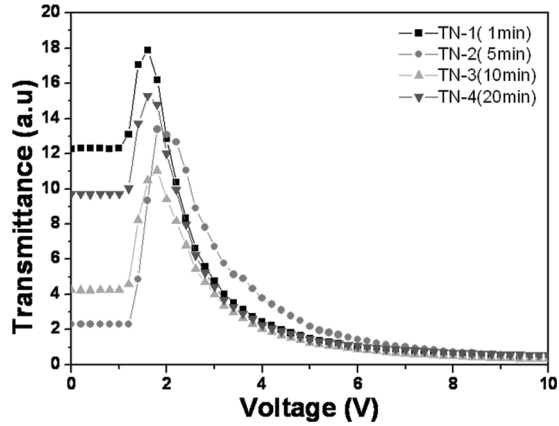


FIGURE 9 V-T curves of the photoaligned TN-LCDs with oblique non-polarizer exposure on the a-C:H thin film.

generated by non-polarized UV exposure on the a-C:H thin film gave birth to sharp bounce curves. Also, excellent V-T curve of photoaligned TN-LCD with oblique non-polarizer exposure on the a-C:H thin film for 1 min was measured. However, the photoaligned TN-LCD with oblique non-polarizer exposure on the a-C:H thin film for 5 min showed the worst V-T characteristic among photoaligned TN-LCDs, and afterwards the V-T characteristics of the photoaligned TN-LCDs increased with increasing UV exposure time. It indicates that LC aligning capability was decreased when UV light irradiates for 5 min, and increased with increasing UV exposure time. Therefore, it considers that initial alignment may be changed by strong UV exposure because strong UV energy gives rise to rearrange LC alignment. Consequently, this system suggests that the best non-polarizer exposure time needed to achieve good V-T characteristics of the photoaligned TN-LCD is about 1 min.

Figure 10 shows the response time characteristics of the photoaligned TN-LCDs with oblique non-polarizer exposure on the a-C:H thin film. High backflow bounce effect on all photoaligned TN-LCDs was observed. The best performance for photoaligned TN-LCD (1 min) of the four kinds of photoaligned TN-LCDs was shown. However, the photoaligned TNLCD (5 min) was the worst response time characteristic, and measured a lowest transmittance level in photoaligned TN-LCDs. It reveals that the response time characteristics of the photoaligned TN-LCD on a-C:H thin film improved by increasing UV exposure time over 5 min.

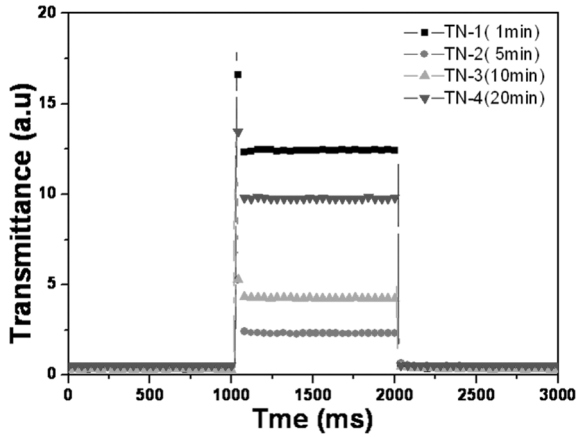


FIGURE 10 Response time characteristics of the photoaligned TN-LCDs with oblique non-polarizer exposure on the a-C:H thin film.

CONCLUSION

In conclusion, the LC alignment capability and the generation of pretilt angle with nonpolarized UV exposure on the a-C:H thin-film surface were investigated. A good LC alignment by UV exposure on the a-C:H thin-film surface at a layer thickness of 200 Å was observed. A superior LC alignment ability via non-polarized UV exposure on the a-C:H thin film surface was observed up to an annealing temperature of 180°C. Therefore, a good LC alignment capability and superior LC alignment thermal stability can be achieved via the non-polarized UV alignment method on the a-C:H thin film surface. Finally, The best electro-optical (EO) characteristics of the UV aligned TN-LCD in the photoaligned TN-LCDs was observed with oblique ion beam exposure on the a-C:H thin film surface for 1 min.

REFERENCES

[1] Geary, J. M., Goodby, J. W., Kmetz, A. R., & Patel, J. S. (1987). *J. Appl. Phys.*, *62*, 4100.
[2] Sugiyama, T., Kuniyasu, S., Seo, D.-S., Fukuro, H., & Kobayashi, S. (1990). *Jpn. J. Appl. Phys.*, *29*, 2045.
[3] Seo, D.-S., Muroi, K., & Kobayashi, S. (1992). *Mol. Cryst. Liq. Cryst.*, *213*, 223.
[4] Seo, D.-S., Kobayashi, S., & Nishikawa, M. (1992). *Appl. Phys. Lett.*, *61*, 2392.
[5] Seo, D.-S., Matsuda, H., Oh-ide, T., & Kobayashi, S. (1993). *Mol. Cryst. Liq. Cryst.*, *224*, 13.
[6] Seo, D.-S., Oh-ide, T., Matsuda, H., Isogami, T., Muroi, K., Yabe, Y., & Kobayashi, S. (1993). *Mol. Cryst. Liq. Cryst.*, *231*, 95.
[7] Kuniyasu, S., Fukuro, H., Maeda, S., Nakaya, K., Nitta, M., Ozaki, N., & Kobayashi, S. (1988). *Jpn. J. Appl. Phys.*, *27*, 824.
[8] Seo, D.-S., Araya, K., Yoshida, N., Nishikawa, M., Yabe, Y., & Kobayashi, S. (1995). *Jpn. J. Appl. Phys.*, *34*, L503.
[9] Schadt, M., Schmitt, K., Jozinkov, V., & Chigrinov, V. (1992). *Jpn. J. Appl. Phys.*, *31*, 2155.
[10] Furumi, S., Nakagawa, M., Morino, S., Ichimura, K., & Ogasawara, H. (1999). *Appl. Phys.*, *L74*, 2438.
[11] Seo, D.-S. & Hwang, J.-Y. (2000). *Jpn. J. Appl. Phys.*, *39*, L816.
[12] Ichimura, K., Akita, Y., Akiyama, H., Kondo, K., & Hayashi, Y. (1997). *Macromolecules*, *30*, 903.
[13] Hasegawa, M. & Taira, Y. (1994). *IDRC, 94*, 213.
[14] West, J. L., Wang, X., Ji, Y., & Kelly, J. R. (1995). *SID'95*, 703.
[15] Lee, K.-W., Lien, A., Stathis, J. H., & Paek, S.-H. (1997). *Jpn. J. Appl. Phys.*, *36*, 3591.
[16] Seo, D.-S. & Han, J.-M. (1999). *Liq. Cryst.*, *26*, 959.
[17] Hasegawa, M. (2000). *Jpn. J. Appl. Phys.*, *39*, 1272.
[18] Chaudhari, P., Lacey, J., Doyle, J., Galligan, E., Lien, S.-C. A., Callegari, A., Hougham, G., Lang, N. D., Andry, P. S., John, R., Yang, K. H., Lu, M., Cal, C., Speidell, J., Purushothaman, S., Ritsko, J., Samant, M., Stohr, J., Nakagawa, Y.,

Katoh, Y., Saitoh, Y., Sakai, K., Satoh, H., Odahara, S., Nakano, H., Nakagaki, J., & Shiota, Y. (2001). *Nature*, *411*, 56.

[19] Hwang, J.-Y., Jo, Y.-M., Seo, D.-S., Rho, S. J., Lee, D. K., & Baik, H. K. (2002). *Jpn. J. Appl. Phys.*, *41*, L654.

[20] Hwang, J.-Y., Jo, Y.-M., Rho, S. J., Baik, H. K., & Seo, D.-S. (2002). *Jpn. J. Appl. Phys.*, *41*, L992.

[21] Park, C.-J., Hwang, J.-Y., Seo, D.-S., Ahn, H.-J., Kim, K.-C., & Baik, H.-K. (2004). *Trans. Electric. Electro. Mater.*, *5*, 15.