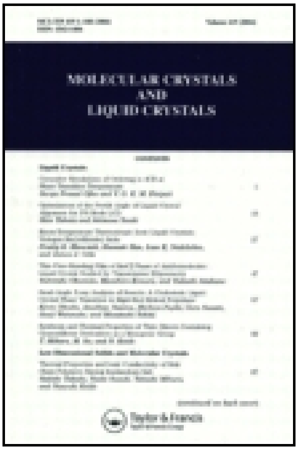

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Electro-optical Characteristics of a-TN-LCD on Polyimide Surfaces with Different Molecular Structure

Dae-Shik Seo [a] & Chang-Hoon Lee [a]

[a] Department of Electrical Engineering, College of Engineering, Soongsil University, 1-1, Sangdo 5-dong, Dongjack-ku, Seoul, 156-743, Korea

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Electro-optical Characteristics of a-TN-LCD on Polyimide Surfaces with Different Molecular Structure

DAE-SHIK SEO* and CHANG-HOON LEE

Department of Electrical Engineering, College of Engineering, Soongsil University, 1-1, Sangdo 5-dong, Dongjack-ku, Seoul 156-743, Korea

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We have investigated the electro-optical characteristics of amorphous (a)-twisted nematic (TN)-liquid crystal display (LCD) on two kinds of the polyimide (PI) surfaces. We obtained that the LC aligning capabilities is strongly dependent on molecular structure of the polymer. Also, we found that the domain size of a-TN-LCD on PI surface having CONH moiety is small compared to a-TN-LCD on PI surfaces with side chain. Also, we observed that the response time of a-TN-LCD on PI surfaces having CONH moiety is slow compared to a-TN-LCD on PI surfaces with side chain. It is considered that the response time of a-TN-LCD results from a surface effect between the substrate surface and the LC molecules. Finally, we obtained that the viewing angle of a-TN-LCD increases with decreasing the domain size.

Keywords: amorphous (a) TN-LCD; polyimide; pretilt angle; viewing angle; response time; microscopic photographs

1. INTRODUCTION

Information display devices are becoming key devices in recent multimedia age for indispensable human interfaces. Especially, LCDs are widely used for information equipment such as personal digital assistant (PDA), audio visual instruments, notebook computer and so on because of their low power consumption, compactness and full color. Conventional TN-LCDs, however, are need to improve their narrow viewing angle, response time,

*Corresponding author.

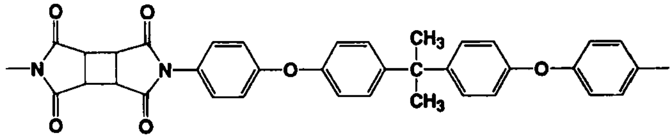
and contrast ratio when they are applied to high-quality information displays. To solve a problem of narrow viewing angle, several operation modes have been proposed such as optically compensated mode, multi-domain mode, a-TN-LCD mode, axially symmetric aligned microcell (ASM) mode, and in-plan switching (IPS) mode [1, 2].

Most commercial LCDs are TN and S (super) TN-LCDs, which utilize mechanically rubbed PI surfaces to achieve their high quality LC alignment and the suitability for mass production [3–5]. However this rubbing method has major drawbacks. This process leads to the development of not only dust particles but also static electricity that can cause cross-track shorts or failure of thin-film-transistors (TFTs). Hence a non-rubbing method is strongly desired to solve these problems without the need to make contact with the surface and to reduce production processing [6–9]. The narrow viewing angle characteristics of conventional TN-LCDs which applied TFT-LCD are due to the change of a retardation of LC layer (Δnd ; Δn is refractive index anisotropy of the LC, d is the thickness of LC cell), when the viewing direction changes in the "on" state. Recently, Y. Toko *et al.*, reported the electro-optical characteristics of a-TN-LCD on PI surfaces without rubbing [10, 11].

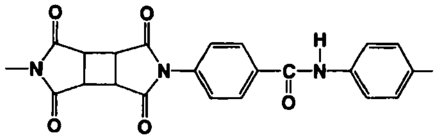
Most recently, we reported the electro-optical characteristics of a-TN-LCD on PI surfaces in order to improve viewing angle [12]. In this paper, we report the electro-optical characteristics of a-TN-LCD on two kinds of the PI surfaces with different molecular structure.

2. EXPERIMENTAL

The alignment films used in this experiment were the two kinds of PI films with different molecular structure. The chemical structure of the two kinds of the polymers are shown in Figure 1. It is shown that PI-A and PI-B film have side chain and CONH moiety of high polarization, respectively. We spin-coated these polyamic acid solutions on indium tin oxide (ITO) glass substrates. The coated substrates were soft baked at 80°C for 30 min. and hard baked 250°C at 1 hr. To estimate the LC aligning capabilities we used a cell fabricated with antiparallel rubbed surfaces. The thickness of LC layers is controlled about 6 μm and 60 μm to measure electro-optical characteristics and LC aligning capabilities, respectively. In fabrication of a-TN-LCD, the NLC of fluorinated type mixture containing a chiral dopant (S-811; supplied from Merck Japan, Co., Ltd.) was injected into the cells in the isotropic phase and then the cells were cooled down to room temperature. The



(a) PI-A



(b) PI-B

FIGURE 1 The molecular structure of used two kinds of the polymer.

concentration of chiral dopant was chosen to give the ratio $d/p = 1/4$, where d and p stand for the thickness of the LC cell and the chiral pitch. Also, we used the NLC, 4-*n*-pentyl-4′-cyanobiphenyl (5CB), to measure the pretilt angle.

We used a polarization microscope to measure characteristics of aligned NLC and estimated the characteristics of transmission-voltage, response time, and viewing angle. The pretilt angles in 5CB were measured by using the crystal rotation method at room temperature.

3. RESULTS AND DISCUSSION

3.1. LC Aligning Capabilities

Figure 2 shows the rubbing strength dependence of induced optical retardation on the two kinds of the rubbed PI surfaces. The definition of rubbing strength, RS, is given previous papers [3, 4]. The induced optical retardation of the rubbed PI surfaces increases with increasing rubbing strength RS. The induced optical retardation on rubbed PI-A surface is larger than that of the rubbed PI-B surface. Figure 3 shows the pretilt angle generation in 5CB on rubbed PI surfaces. The measured pretilt angle occurring in 5CB on rubbed PI surfaces increases with the rubbing strength RS. However, the pretilt angle in 5CB decreases with the rubbing strength RS on PI-A surfaces. It is believed that the pretilt angle in 5CB is strongly influenced by steric interaction between the substrate surfaces and the LC

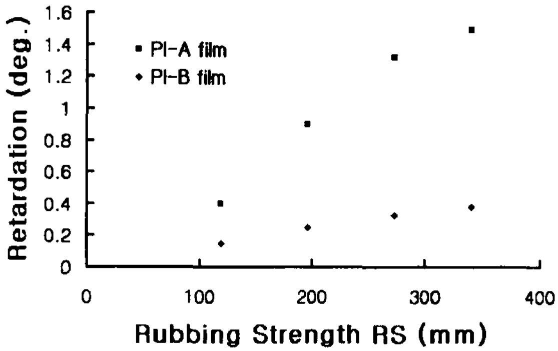


FIGURE 2 Induced optical retardation on rubbed PI surfaces.

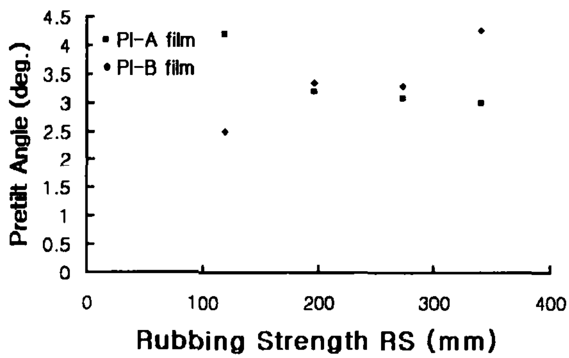
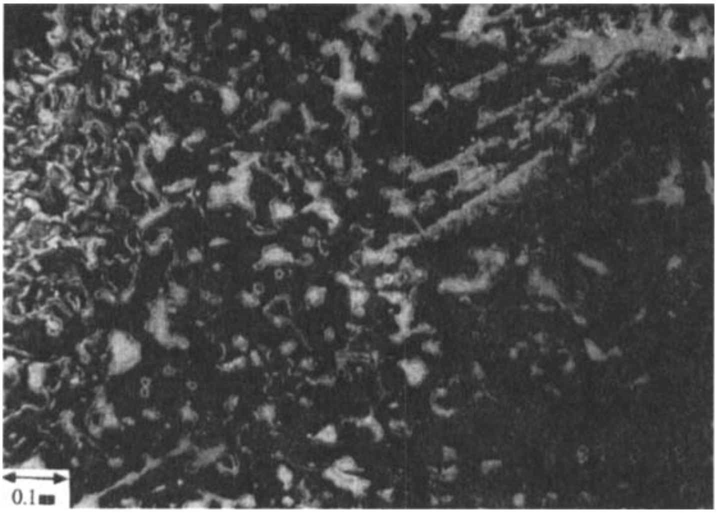


FIGURE 3 The generation of the pretilt angles in 5CB on rubbed PI surfaces.

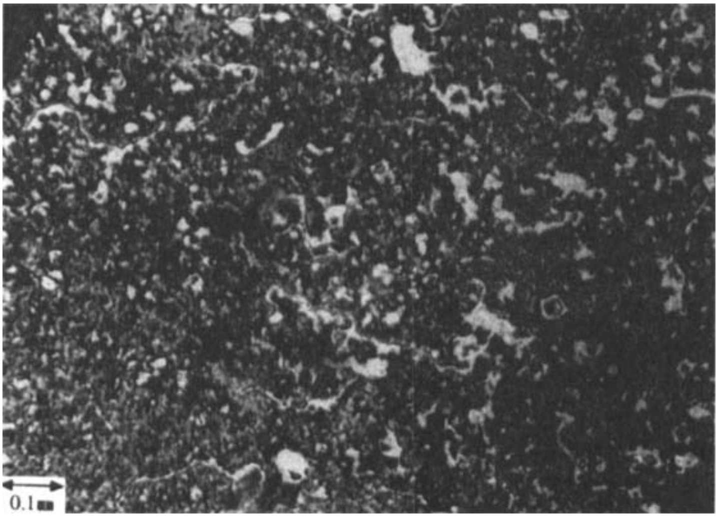
molecules. Therefore, we suggest that the LC aligning capabilities are strongly dependent on molecular structure of the polymer on these PI surfaces.

3.2. Electro-optical Characteristics of a-TN-LCD

Figure 4 shows the microscopic photographs of a-TN-LCD on the two kinds of PI surfaces with different molecular structure. It is shown that the textures of a-TN-LCD display a typical schlieren texture indicating random orientation of the LC directors at the surface. It is shown that the domain size of a-TN-LCD on PI-B surface is smaller then that of PI-A surface. The domain size of a-TN-LCD on PI-B surface is measured about 0.09 mm. Several of these domains are included in a conventional pixel size 0.3×0.3 mm. We consider that the electro-optical characteristics are strongly dependent on this domain of LC molecules in a-TN-LCD.



(a) PI-A film



(b) PI-B film

FIGURE 4 The microscopic photographs of a-TN-LCD on the two kinds of PI surfaces. (See Color Plate I).

Figure 5 shows the transmission *vs.* applied voltage characteristics for a-TN-LCD on PI surface having CONH moiety. Table I shows the applied voltage values *versus* the optical transmission of a-TN-LCD on the two kinds of the PI surface with different molecular structure. It is shown that

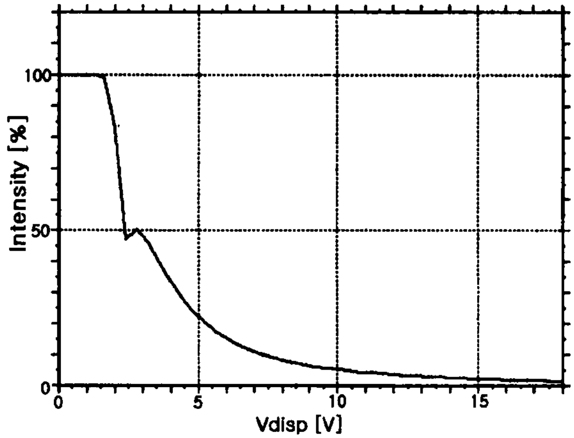


FIGURE 5 The transmission *vs.* applied voltage characteristics for a-TN-LCD on PI-B surface.

TABLE I The applied voltage *vs.* transmission for a-TN-LCD on the two kinds of PI surfaces with different molecular structure and conventional TN-LCD

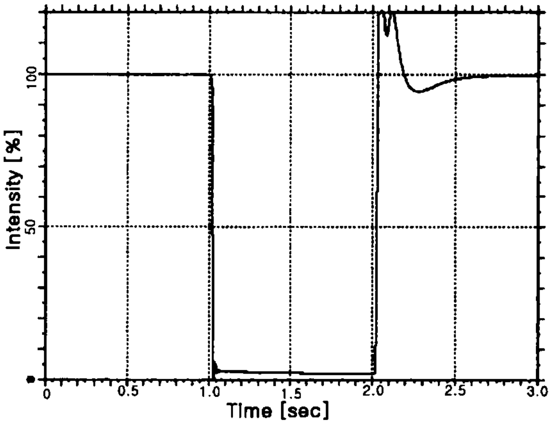
Transmission \ *film*	*PI-A film (V)*	*PI-B film (V)*	*Conventional TN-LCD (V)*
V_{10}	2.40	1.83	2.62
V_{90}	8.81	6.95	4.92
V_{sa}	25.00	18.00	8.40

V_{10}, V_{90} and V_{sa} are 10%, 90% and saturation of transmission respectively.

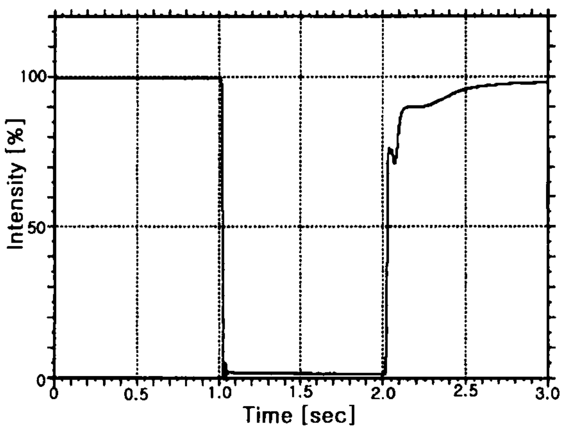
the threshold voltage of a-TN-LCD on PI-B surface is small compared to a-TN-LCD on PI-A surface.

Figure 6 shows the response time characteristics for a-TN-LCD on the two kinds of PI surfaces with different molecular structures. The calculated values of response time for a-TN-LCD are shown in Table II. We observed that the response time of a-TN-LCD on PI-B surface is slower then PI-A surface. The response time of a-TN-LCD on PI-B surface is slower than that of PI-A surface in τ_d decay time of LC molecules. However, the rise time τ_r of a-TN-LCD is almost the same on PI-A and PI-B surface. In general, the response time of LCDs is due to bulk parameters. From the results, we suggest that surface effects between the substrate surfaces and the LC molecules contributes to the response time of a-TN-LCD.

The viewing angle characteristics of a-TN-LCD on two kinds of the PI surfaces are shown in Figure 7 and Table III. As shown in Figure 7 and Table III, the viewing angle of a-TN-LCD on PI-B surface is wide compared to PI-A surface. The viewing angle of a-TN-LCD on PI-B surface is a little



(a) PI-A film

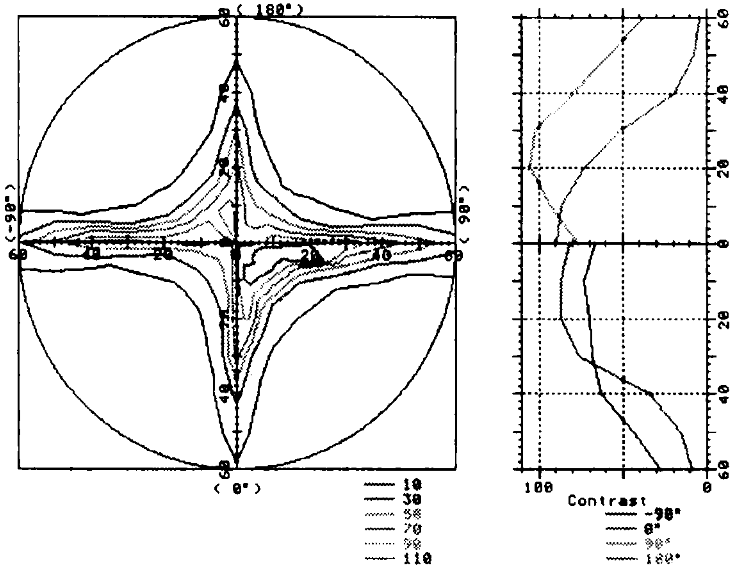


(b) PI-B film

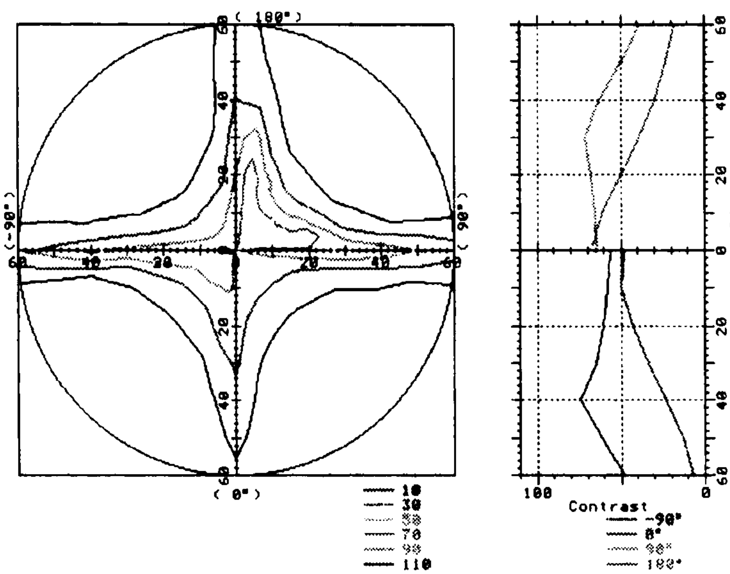
FIGURE 6 The response time characteristics for a-TN-LCD on the two kinds of PI surfaces.

TABLE II The response time of a-TN-LCD on the two kinds of PI surfaces with different molecular structures and conventional TN-LCD

film / *Time*	*PI-A film*	*PI-B film*	*Conventional TN-LCD*
Rising Time τ_r (msec)	8.00	8.20	13.16
Decay Time τ_d (msec)	8.60	124.30	4.41
Response Time τ (msec)	16.60	132.50	17.57



(a) PI-A film



(b) PI-B film

FIGURE 7 The viewing angle of a-TN-LCD on the two kinds of PI surfaces. (See Color Plate II).

TABLE III The viewing angle of a-TN-LCD on the two kinds of PI surfaces with different molecular structures and conventional TN-LCD

film / *Direction*	*PI-A film* (°)	*PI-B film* (°)	*Conventional TN-LCD*
Up	50	over 60	53
Down	60	56	15
Left	over 60	over 60	40
Right	over 60	over 60	40

wider in comparison to the PI-A surface when contrast ratio is 10. Therefore, we suggest that viewing angle of a-TN-LCD is governed in part by the domain size of LC molecules as shown in Figure 4. In particular, a-TN-LCD has extremely wide viewing angle characteristics in comparison with conventional TN-LCD. It is concerned that the LC molecules, which are randomly orientated in one pixel, compensate the viewing angle in each those directions, and then the viewing angle characteristics are improved in all directions.

4. CONCLUSION

In this paper, we have investigated the electro-optical characteristics of a-TN-LCD on two kinds of the PI surface with different molecular structure. We found that the domain size of LC molecules of a-TN-LCD on PI surface having CONH moiety is smaller than PI surface with side chain. It is considered that the electro-optical characteristics are strongly dependent on this domain size in a-TN-LCD. Also, we observed that the response time of a-TN-LCD on PI surface having CONH moiety is slow. We believe that the response time of a-TN-LCD is governed in part by the surface effect between the substrate surfaces and the LC molecules. Finally, we observed that the a-TN-LCD on PI surface having CONH moiety has wider viewing angle characteristics over 60 degrees in many directions, which is due to the domain size of LC molecules.

Acknowledgements

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