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Effects of Alignment Layer on Pretilt Angle and Electrical Characteristics for The Photo-Aligned Twisted Nematic Cell on Polyimide Surfaces

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The alignment layer effects on the pretilt angle generation and electrical characteristics of photoaligned twisted nematic (TN)-liquid crystal displays (LCDs) for a polyimide (PI) surface with side chains were studied. The generated pretilt angle of nematic liquid crystal (NLC) on the rubbed PI surface with one layer was almost the same as that on the PI surface with two layers. However, the generated pretilt angle of NLC on the photoinduced PI surface with two layers was larger than that on the PI surface with one layer generated by oblique UV exposure on the PI surface. The different mechanisms of pretilt generation in NLC in the rubbing- and photoalignment methods were examined. The pretilt angle of the NLC on the photoinduced PI surface is attributed to surface roughness and side chains due to photodissociation of the polymer with UV exposure on the PI surface. We observed the same characteristics of voltage–transmittance (V–T) and response time for one and two layers on the PI surface. We also observed the same voltage holding ratio (VHR) characteristics for one and two layers on the photoaligned TN-LCD. Finally, we suggest that the VHR of photoaligned TN-LCDs was higher than that of the rubbing-aligned TN-LCDs.

KEYWORDS: nematic liquid crystal, polyimide, photoalignment, TN-LCD, pretilt angle, response time, Voltage holding ratio

1. Introduction

The operation of liquid-crystal displays (LCDs) requires monodomain alignment and controll of the pretilt angle of LC molecules on the substrate surfaces. The majority of commercial LCDs utilize rubbed polyimide (PI) film to control LC alignment. The pretilt angle prevents the creation of reverse tilted disclinations in twisted nematic (TN) LCDs.[1)] Rubbed PI surfaces have been widely used to align LC molecules. The effect of surface alignment in nematic liquid crystal (NLC) on various alignment layers with unidirectional rubbing has been demonstrated and discussed by many researchers.[2–10)] However, the rubbing treatment creates several problems, such as the generation of electrostatic charges and the creation of contaminating particles. In a previous paper, we reported the generation of electrostatic charges produced during rubbing on various alignment layers.[9)] Rubbing-free techniques for LC alignment are required in thin-film transistor (TFT)-LCD technology.

More recently, the LC aligning capability achieved by a photodissociation method with polarized[11–17)] and nonpolarized[18–20)] ultraviolet (UV) exposure on a PI surface has been reported by some researchers. We have reported the pretilt generation of the NLC through oblique nonpolarized UV exposure on a PI surface.[19,20)] However, details of the mechanism of LC alignment by the photoalignment method have not yet been fully clarified.

In this work, we report the alignment layer effects on pretilt angle generation and electrical characteristics for the photo- and rubbing- aligned TN-LCDs on the PI surface with side chains.

2. Experimental

In this experiment, we used a polymer material with long alkyl chains (AL3046, supplied by JSR Co., Ltd.). The polymer was coated on indium-tin-oxide (ITO) coated glass substrates by spin-coating, and the substrates were imidized at 180°C for 1 h. The thickness of the PI layers was about 350. The oblique p-polarized UV (power: 1 kW) exposure system is shown in Fig. 1. The substrates were exposed using a UV light at a wavelength of 365 nm, and the energy density used was 52 mW/cm^2. The imidized PI surface was first treated with UV exposure, then the photoalignmnet of two layers was carried out, followed by a second UV exposure. Also, the imidized PI surface was first rubbed, and then the rubbing-aligned PI surfaces with two layers were assembled by a second. The definition of rubbing strength (RS) has been reported in previous papers.[4–6,10)] To measure the pretilt angle, the LC was assembled to sandwich-type cells with antiparallel to the UV exposure direction. All the sandwich-type cells had an LC layer thickness of 60. After assembly, the cells were filled with fluorinated-mixture-type NLC (T_c = 87°C) in the isotropic phase. Then the cells were annealed in the isotropic phase (97) for 10 min. To measure the electrical characteristics, the photoaligned TN-LCD was assembled with an oblique p-polarized UV exposure of 30° on the PI surface. The LC layer used for the photo- and rubbing-aligned TN-LCD was about 5 μm. To measure the pretilt angles, we used the crystal rotation method and measurements were performed at room temperature. Next, we measured the voltage–transmittance (V–T), response time, and voltage holding ratio (VHR) characteristics for the photo-

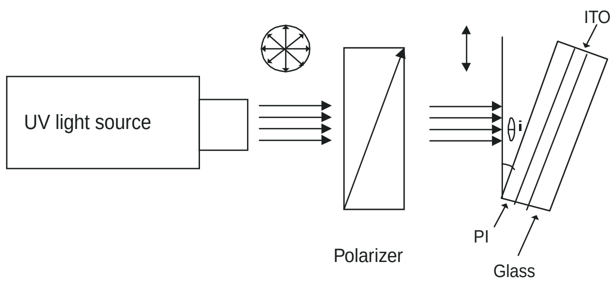


Fig. 1. Schematic diagram of the UV exposure system used.

*Author for correspondence. E-mail address: dsseo@bbuble.yonsei.ac.kr and rubbing- aligned TN-LCD on the PI surface.

3. Results and Discussion

Figure 2 shows the pretilt angle of NLC on the PI surface with side chains as a function of RS. The pretilt angle of NLC on the rubbed PI surface with two layers was almost the same as that on the PI surface with one layer. Generally, the LC alignment on the rubbed PI surface with one layer is achieved at 100. Therefore, the alignment layer effect was not observed. The behavior of pretilt generation on a rubbed PI surface with one layer is the same as the previously reported result.[4] Therefore, the generated pretilt angle of NLC is attributed to the side chains of the polymer. The pretilt angle of NLC with polarized UV exposure on the PI surface with side chain as a function of exposure time is shown in Fig. 3. The pretilt angle of NLC on the PI surface with two layers was larger than that on the PI surface with one layer; a different behavior was observed. Therefore, the LC alignment is attributed to surface roughness and side chains due to photodissociation of the polymer upon UV exposure on the PI surface. Generally, the rubbing process forms the groove structure,[21] but the generation of the pretilt angle in NLC was not attributed to the groove structure. We consider that the surface ordering of photoaligned NLC was low compared to that of the rubbing-aligned NLC. It is considered that the pretilt angle of NLC obtained on the PI surface with two layers using a photoalignment method increases with increasing the surface roughness. Similar behavior of decreasing of the pretilt angle with increasing UV exposure time was observed in previous studies.[19,20]

Figure 4 and Table I show the V–T characteristics for the photo- and rubbing-aligned TN-LCD on the PI surfaces. The threshold voltage of the photo-aligned TN-LCD was larger than that of the rubbing-aligned TN-LCD. This effect is al-

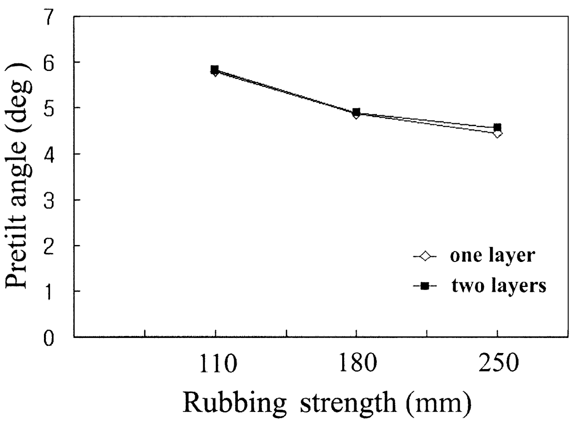


Fig. 2. Pretilt angle of the NLC on a PI surface with side chain as a function of RS.

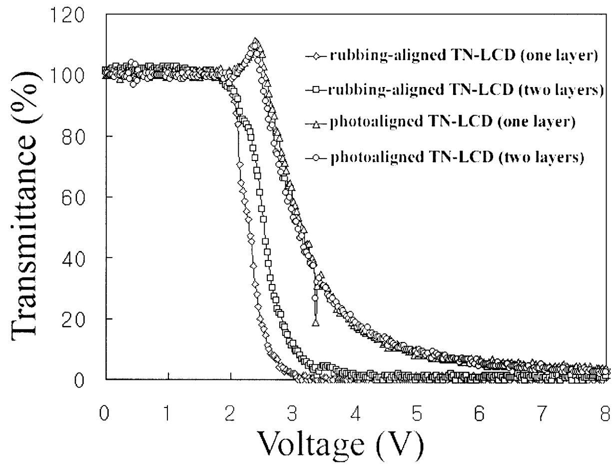


Fig. 4. V–T characteristics for the photo- and rubbing-aligned TN-LCD on the PI surfaces.

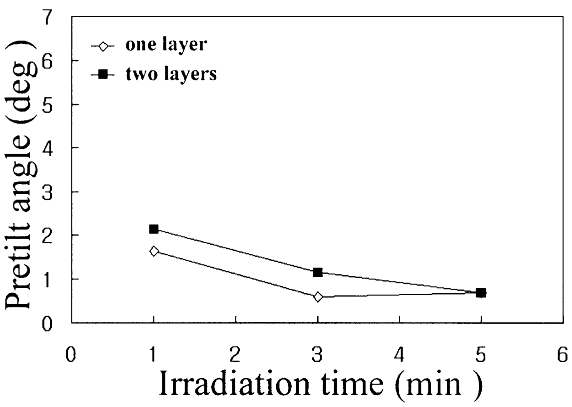


Fig. 3. Pretilt angle of NLC with polarized UV exposure on the PI surface with side chains as a function of UV exposure time.

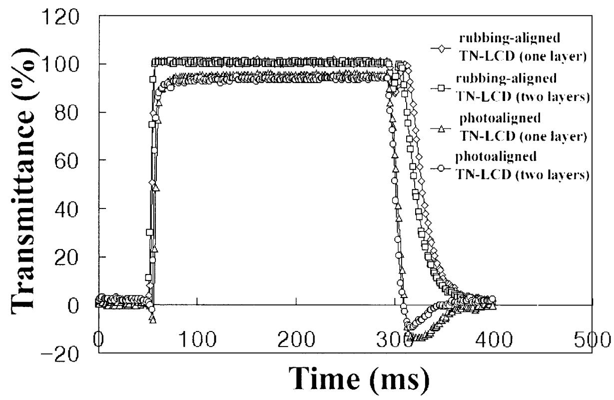


Fig. 5. Response time characteristics for the photo- and rubbing-aligned TN-LCDs on PI surfaces.

Table I. Threshold voltages for photo and rubbing-aligned TN-LCDs on the PI surfaces.

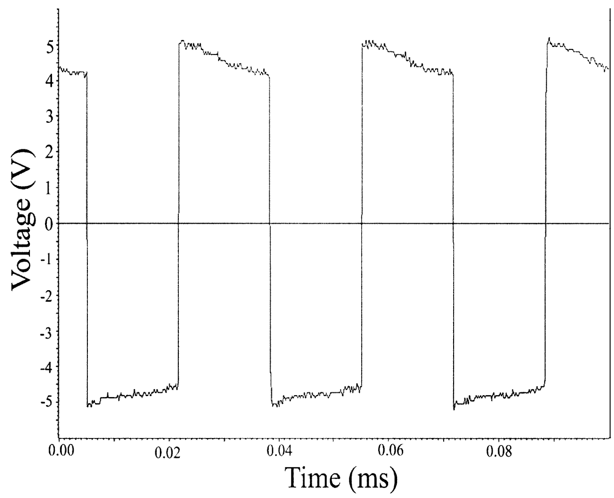
	Rubbing-aligned TN-LCD (one layer)	Rubbing-aligned TN-LCD (two layers)	Photoaligned TN-LCD (one layer)	Photoaligned TN-LCD (two layers)
V_{90}	2.06	2.13	2.63	2.57
V_{10}	2.60	3.00	4.40	4.50

Table II. Response times for photo and rubbing-aligned TN-LCDs on PI surfaces.

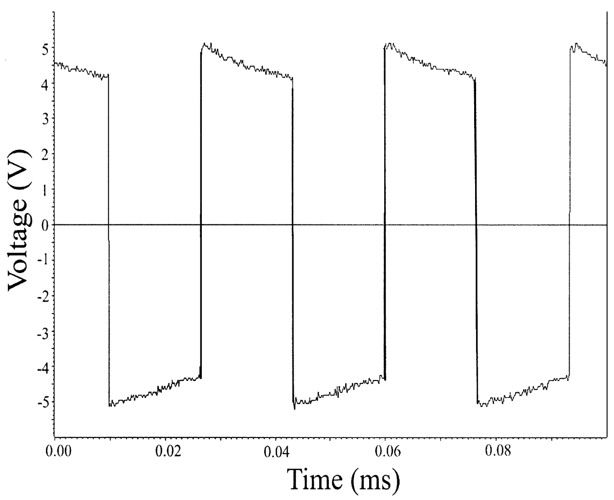
	Rubbing-aligned TN-LCD (one-layer)	Rubbing-aligned TN-LCD (two layers)	Photoaligned TN-LCD (one layer)	Photo-aligned TN-LCD (two layers)
Rise time τ_r (ms)	4.30	5.00	7.00	7.60
Decay time τ_d (ms)	62.0	53.2	14.4	13.2
Response time τ (ms)	66.3	58.2	21.4	20.8

most the same as that observed in the previous results.[20] Also, the effect of the alignment layer was not observed. Therefore, the V–T curve of the photo-aligned TN-LCD is not dependent on the number of alignment layers.

Figure 5 and Table II show the response time characteristics for the photo- and rubbing-aligned TN-LCD on the PI surfaces. Good response time characteristics of the rubbing-aligned TN-LCD were measured at 66.3 ms and 58.2 ms for one layer and two layers respectively. However, the reverse twist behavior for the photoaligned TN-LCD was measured on decay time characteristics. The reverse twist behavior is caused by nonchiral dopant. Therefore, the reverse twist behavior strongly depends on the twist force of the NLC in TN-LCD. Also, the effect of the alignment layer was not observed. It may be that the large decay time (58 ms) of rubbing-aligned TN-LCD is attributed to the thickness of the cells, while the fast response time of the photoaligned TN-LCD is due to the reverse twist.

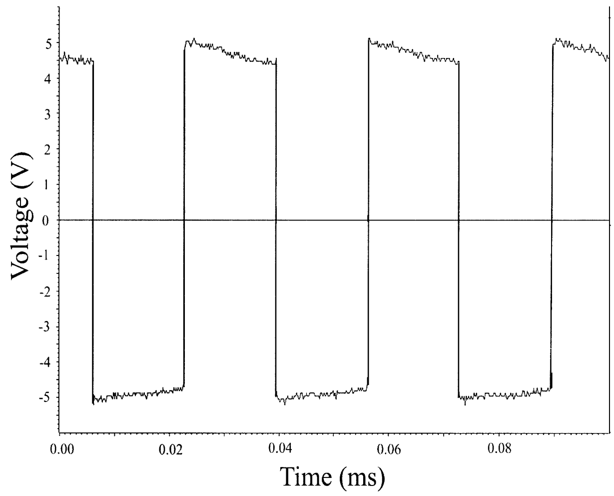


(a)

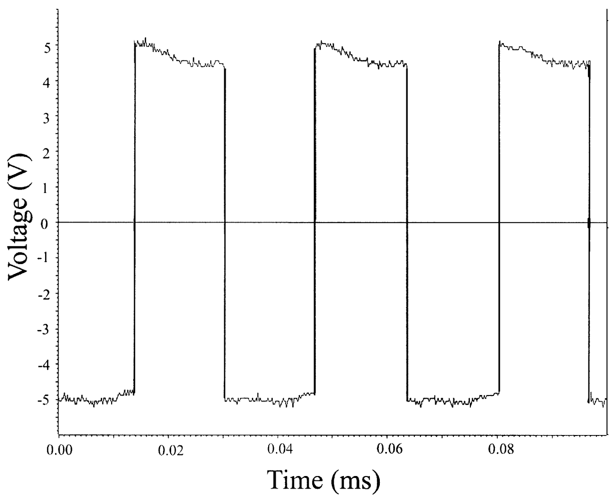


(b)

Fig. 6. VHR measurements for rubbing-aligned TN-LCDs on PI surfaces. (a) one layer; (b) two layers.



(a)



(b)

Fig. 7. VHR measurements for photo-aligned TN-LCDs on PI surfaces using a photodissociation method. (a) one layer; (b) two layers.

Table III. VHRs for photo and rubbing-aligned TN-LCDs on PI surfaces.

	Rubbing-aligned TN-LCD (one layer)	Rubbing-aligned TN-LCD (two layers)	Photoaligned TN-LCD (one layer)	Photoaligned TN-LCD (two layers)
VHR (%)	88	86	92	92

Figures 6(a) and (b) show the results of VHR measurement of the rubbing-aligned TN-LCD on the PI surface. The VHR characteristics of the two layer rubbing-aligned TN-LCD are almost the same as those of the one layer rubbing-aligned TN-LCD. Figures 7(a) and 7(b) show the results of VHR measurement of the photoaligned TN-LCD on the PI surface using a photodissociation method. The VHR characteristics of the two-layer photoaligned TN-LCD are almost the same as those of the one-layer photoaligned TN-LCD. The same VHR characteristics of the photoaligned TN-LCD were measured on one- and two-layer PI surfaces.

Table III shows the VHR for the photo and rubbing-aligned TN-LCDs on PI surfaces. The obtained VHR of the photoaligned TN-LCD on the PI surface was about 94%. The VHR of the photoaligned TN-LCD was larger than that of the rubbing-aligned TN-LCD.

4. Conclusions

In conclusion, the alignment layer effects on the pretilt angle generation and electrical characteristics of photoaligned TN-LCDs on the PI surface with side chains were successfully evaluated. The generated pretilt angle of NLC on the photoinduced PI surface with two-layers was larger than that on the PI surface with one-layer. Different mechanisms of pretilt generation were observed for NLC on the rubbing- and photoalignment method. We observed the same characteristics of V–T and response time for one- and two-layers on the PI surface. Finally, we suggest that the VHR of the photoaligned TN-LCD was higher than that of the rubbing-aligned TN-LCD.

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