Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713926090

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Online publication date: 06 August 2010

To cite this Article Seo, Dae-Shik and Kim, Jin-Ho(1999) 'Effect of polymer polarity on transcription-aligned TN-LCDs for various polyimide surfaces', Liquid Crystals, 26: 12, 1813 — 1816
To link to this Article: DOI: 10.1080/026782999203445
URL: http://dx.doi.org/10.1080/026782999203445

LIQUID CRYSTALS, 1999, VOL. 26, NO. 12, 1813–1816

Effect of polymer polarity on transcription-aligned TN-LCDs for various polyimide surfaces

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(*Received 18 June 1999; accepted 11 August 1999*)

The effect of the polymer polarity of three types of polyimide (PI) on transcription-aligned twisted nematic liquid crystal display (TN-LCD) surfaces has been investigated. Monodomain alignment of the NLC was obtained in cells fabricated by the transcription alingment method on PI surfaces with medium polarity; the LC alignment is attributed to the polarity of the polymer. The threshold voltage of transcription-aligned TN-LCDs was found to decrease with increasing polarity of the polymer. The threshold voltage of a transcription-aligned TN-LCD on PI surfaces with high polarity was almost the same as that of a rubbing-aligned TN-LCD. The response time of transcription-aligned TN-LCDs decreased with increasing polymer polarity. The decay time of transcription-aligned TN-LCDs was long in comparison with rubbing-aligned TN-LCDs; this is attributed to the weak anchoring strength between the LC molecules and the PI surface.

1. Introduction

Currently, active matrix (AM)-liquid crystal displays (LCDs) are widely utilized in displays such as those for notebook computers, monitors, and televisions because of their high resolution image quality. The uniform alignment of liquid crystals (LCs) on polyimide (PI) surfaces is very important in achieving high resolution in LCD technology [1]. Rubbed PI surfaces have been widely used in organizing LC alignment layers because they are inert to the LC and provide excellent and stable LC alignment capability. LC alignment in NLCs by a unidirectional rubbing treatment on rubbed PI surfaces has been demonstrated and discussed by many investigators [2–11].

In a previous paper, we reported that the rubbing treatment method on PI surfaces creates several problems, such as the creation of dust and electro-static charges [12]. Thus, AM-LCDs require rubbing-free techniques for uniform LC alignment. The uniform alignment of the NLC in cells on PI-Langmuir–Blodgett (LC) surfaces has already been discussed in relation to rubbing-free techniques [13, 14]. Also, Toko has reported on the electro-optical (EO) performance and pretilt angle in cells fabricated by the transcription alignment method on PI surfaces [15]. Pretilt angles of 0.5° in NLC were generated on various PI surfaces with alkyl chains [15]. However, the pretilt angle needs to be 2° ~ 3° in order to avoid reverse tilt disclination in the practical operation of the TN-LCD. Recently, we have achieved high NLC pretilt angles by using the transcription alignment method on PI surfaces with side chains [16]. We also reported that the EO characteristics of the transcription-aligned TN-LCD are close to those of the rubbing-aligned TN-LCD [17].

In this study, we report on the effect of the polymer polarity of three kinds of PI surface on transcription-aligned TN-LCDs.

2. Experimental

In these experiments, we used three kinds of PI film; figure 1 shows their chemical structure. The order of the polymer polarity is PI-A> PI-B> PI-C. The precursors were coated on indium-tin oxide (ITO) coated glass substrates by spin-coating, and imidized at 250°C for 1 h. The thickness of the PI films used was 500 Å. The fabrication process for the transcription alignment cells was as given in previous papers [16, 17]. The original substrates (PI films) were unidirectionally rubbed using a machine equipped with a nylon roller (Y_0-15-N, Yoshikawa Chemical Industries Co., Ltd.); the definition of the rubbing strength, *RS*, has been given in previous papers [5, 6]. The transcribed substrates used un-rubbed PI films. The transcription alignment cells were fabricated with a rubbed PI surface (original substrate) and an un-rubbed PI surface (transcribed substrate), and were heated at 101°C (where the NLC shows an isotropic

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Journal of Liquid Crystals ISSN 0267-8292 print/ISSN 1366-5855 online © 1999 Taylor & Francis Ltd
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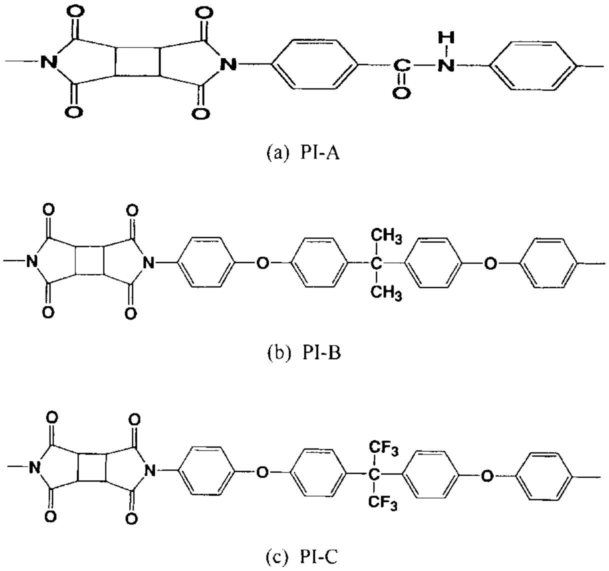


Figure 1. Chemical structures of the three types of polymer.

phase) for LC injection. The NLC used in this experiment was a fluorinated type mixture with a clearing temperature of $T_C = 87°C$. The cell was cooled to room temperature, and the LC configured from the isotropic phase into the nematic phase. The NLC molecules were aligned along the rubbing direction of the original substrate of rubbed PI surface. The original substrate was then separated from the transcribed substrate. The transcribed substrate was stacked upon another film of transcribed substrate to form the transcription alignment cell, and the nematic phase of the LC material was injected into the completed transcription alignment cell. To measure its EO characteristics, the transcription-aligned TN-LCD was assembled with a 90° twist angle of the LC conformation, without a chiral dopant on the PI surface; LC layers were about 5 μm thick. The LC orientation capability was evaluated from optical microscopic textures. The EO characteristics of the transcription-aligned TN-LCD on the three kinds of PI surfaces were measured, together with those of a rubbing-aligned TN-LCD.

3. Results and discussion

Figure 2 shows micrographs of the NLC aligned in cells fabricated by transcription alignment on the three types of PI surface (in crossed Nicols). The NLC molecules were aligned along the transcribed direction by the memory effect of the NLC on all the PI surfaces. This phenomenon is the same as that observed by Toko [15]. The monodomain alignment of the NLC obtained on a PI-B surface is shown in figure 2 (*b*). In figure 2 (*a*), for PI-A, a small domain of LCs was observed. The large domain of LCs was measured for PI-C is attributed to

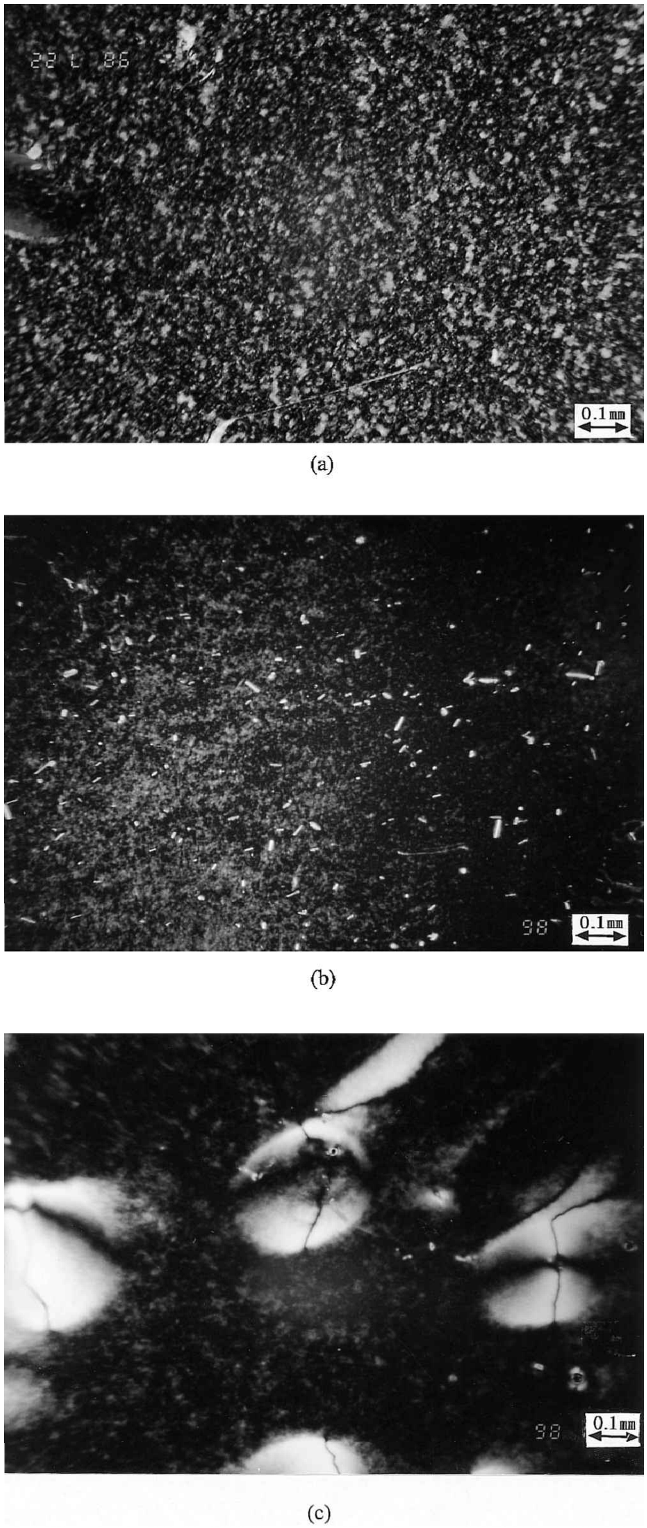
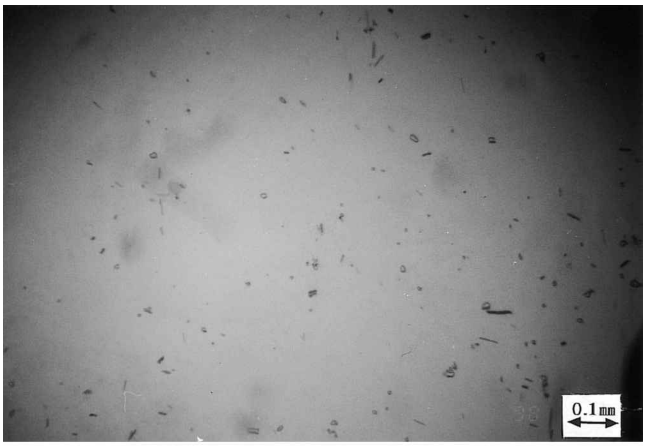


Figure 2. Microphotographs on the aligned NLC on three kinds of the PI surfaces in a cell fabricated by the transcription alignment method: (*a*) PI-A, (*b*) PI-B, (*c*) PI-C.

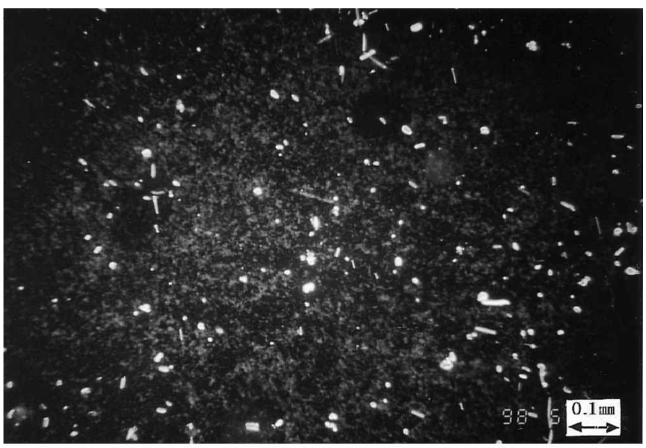
the low surface energy of the polymer. These results, indicate that the monodomain alignment in the NLC is attributed to relatively high polymer polarity.

We next investigated the EO characteristics of transcription-aligned TN-LCDs on the three kinds of PI surface. Micrographs of the transcription-aligned TN-LCD on a PI-B surface with medium polarity are shown in figure 3. This shows that reverse tilt disclinations were not formed in the on-state. Thus, excellent contrast was successfully achieved.

Figure 4 shows the voltage-transmittance (*V–T*) characteristics for the transcription-aligned TN-LCD on the three PI surfaces, and for the rubbing-aligned TN-LCD on a PI-B surface with $RS = 164$ mm. Excellent voltage-transmittance characteristics are seen for a rubbing-aligned TN-LCD on a PI surface with medium polarity. Good voltage-transmittance characteristics for a transcription aligned TN-LCD on a PI-A surface with high polarity were also obtained, almost the same as those for the rubbing-aligned TN-LCD. However, a bad



(a) off-state



(b) on-state

Figure 3. Microphotograph of the transcription-aligned TN-LCD on a PI-B surface.

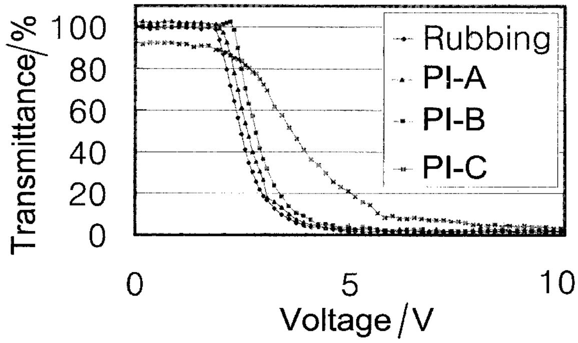


Figure 4. Voltage-transmission characteristics for the transcription-aligned TN-LCDs on three kinds of PI surfaces and the rubbing-aligned TN-LCD on PI-B surface.

V–T curve was observed for a transcription-aligned TN-LCD with low polarity. The characteristics of the transcription-aligned TN-LCD thus depends on the polarity of the polymer. Table 1 shows the threshold voltages for the transcription and rubbing-aligned TN-LCDs, clearly indicating that the threshold voltage of the transcription-aligned TN-LCD decreases with decreasing polymer polarity. The threshold voltage of the transcription-aligned TN-LCD on a PI-A surface (with high polarity) is about 2.18 V, i.e. relatively low. Thus the low threshold voltage is obtained with high polymer polarity. Also, the threshold voltage of the transcription-aligned TN-LCD is relatively high compared with that for the rubbing-aligned TN-LCD.

The response time characteristics for both the transcription-aligned TN-LCD on three kinds of PI surfaces, and the rubbing-aligned TN-LCD on a PI surface, are shown in figure 5. It can be seen that the decay time curves of the transcription-aligned TN-LCD are less sharp (especially for PI-B and PI-C) than that of the rubbing-aligned TN-LCD. The response time characteristics of the transcription-aligned TN-LCD increased with increasing polymer polarity. Also, no backflow effect was observed on the transcription-aligned TN-LCD on PI-A and PI-B surfaces. Table 2 shows the response times for all types of cell. The response time of the transcription-aligned TN-LCD decreased with increasing

Table 1. Threshold voltages for transcription-aligned TN-LCDs on three kinds of PI surface and the rubbing-aligned TN-LCD on a PI-B surface V_{10}: 10% of transmittance; V_{90}: 90% of transmittance.

Cell type	V_{10}/V	V_{90}/V
PI-A surface	3.58	2.18
PI-B surface	3.74	2.39
PI-C surface	5.90	4.20
Rubbing-aligned TN-LCD	3.40	1.99

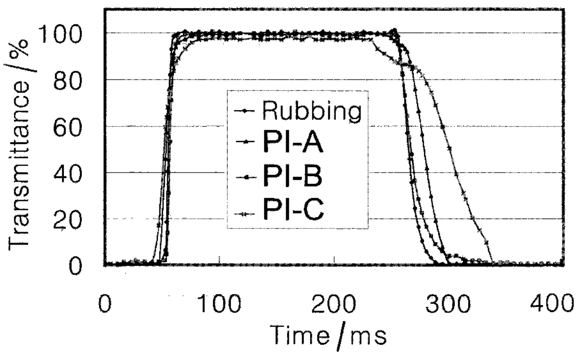


Figure 5. Response time characteristics for the transcription-aligned TN-LCD on three kinds of PI surfaces and the rubbing-aligned TN-LCD on a PI-B surface.

Table 2. Response time characteristics for the transcription-aligned TN-LCD on three kinds of PI surfaces and the rubbing aligned TN-LCD on a PI-B surface.

Cell type	Rise time τ_r/ms	Decay time τ_d/ms	Response time τ/ms
PI-A surface	9.4	29.6	39.0
PI-B surface	8.4	33.8	42.4
PI-C surface	13.8	100.0	113.8
Rubbing-aligned TN-LCD	8.4	26.0	34.4

polymer polarity. Also, slow response time characteristics for the transcription-aligned TN-LCD was clearly observed, in comparison with the rubbing-aligned TN-LCD. Previously, Toko reported that the azimuthal anchoring energy of NLC was about 5×10^{-5} J m^{-2} in a cell fabricated by the transcription alignment method on a PI surface [15]. In a previous work, a NLC azimuthal anchoring energy of about 1×10^{-4} J m^{-2} on a rubbed PI surface with side chains was reported by Kobayashi and Iimura [18]. Therefore the anchoring strength of NLC in a cell constructed by the transcription alignment method on PI surfaces is relatively low compared with a rubbing-aligned cell. From these results, we suggest that the slow response time of the transcription-aligned TN-LCD can be attributed to weak anchoring between the LC molecules and the polymer surface.

4. Conclusion

In summary, the effect on transcription-aligned TN-LCDs of the polymer polarity of three kinds of PI surface was investigated. Monodomain alignment of NLC was obtained in cells with medium polarity PI surface. The LC alignment, using the transcription alignment method, is attributed to the polymer polarity. The threshold voltage of transcription-aligned TN-LCDs decreased with increasing polarity of the polymer. The threshold voltage of transcription-aligned TN-LCDs on high polarity PI surfaces was almost the same as that of a rubbing-aligned TN-LCD. The response time of transcription-aligned TN-LCDs decreased with increasing polymer polarity. The response time of transcription-aligned TN-LCDs were slow compared with a rubbing-aligned TN-LCD; they are attributed to low anchoring strength between the LC molecules and the PI surface.

This research was supported by a Grant of the G7 Project for Flat Panels from the Ministry of Science and Technology and the Ministry of Industry and Energy of Korea.

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