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## Alignment Properties and EO Performances of Flexible TN-LCD Using *In-Situ* Photoalignment Method with the Polymer Film

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*We have investigated the generation of pretilt angle for a nematic liquid crystal (NLC) alignment with in-situ photoalignment method on polyimide (PI) surfaces using polymer films. Especially, we studied in-situ photoalignment changing heating temperature from 50°C to 120°C on the polymer film. The LC aligning capabilities and pretilt angle on the polymer substrates were better than those on the glass substrate using in-situ photoalignment method. It is considered that this increase in pretilt angle may be attributed to the roughness of the micro-groove substrate induced by the in-situ photoalignment. As temperature of heated substrate and UV exposure time increases, pretilt angle of the cell used polymer film increased. It is considered that the heating temperature of substrate is attributed to generate pretilt angle. Also, EO performances of the in-situ photoaligned TN cell using the polymer substrate are almost the same as that of the TN cell using the glass substrate.*

**Keywords:** *in-situ* photoalignment method; nematic liquid crystal; polymer film; pretilt angle

## INTRODUCTION

Flexible display based on polymer substrates for liquid crystal displays (LCDs) has several advantages compared to display using glass

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substrates. They exhibit only 1/6 of the weight of glass substrate. Flexible displays are virtually unbreakable and their flexibility allows the designer to do elegant styling [1–5].

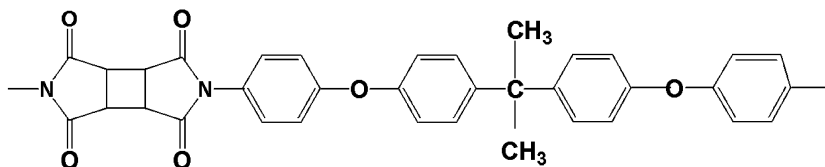
Flexible display has many problems yet in spite of that fact the display has these advantages; for example, the first, polymer films have low thermal stability below 180°C. The second, a liquid crystal (LC) alignment on polymer film followed by cloth rubbing has several problems [6–8]. Most general polyimide (PI) layer need high curing temperature to form alignment layer. However, polymer films are difficult to apply this manufacturing line because polymer films are thermally unstable. Also, the control of rubbing strengths is difficult because film thickness is thin like 0.2 mm.

Therefore, a rubbing-free method for LC alignment is required for the fabrication of a flexible LCD. Many researchers have reported a rubbing-free method for LC alignment [13–16]. Most recently, the LC alignment and pretilt angle generation using the *in-situ* photoalignment method on a PI surface for homogeneous alignment have been reported [17]. The *in-situ* photoalignment method produces a higher thermal stability of LC alignment than that produced using the conventional photoalignment method. We have investigated *in-situ* photoalignment method on the glass substrate [18,19]. However, the effect of the nematic liquid crystal (NLC) pretilt angle and electro-optical (EO) performance by using the *in-situ* photoalignment method on the polymer film have not been reported yet.

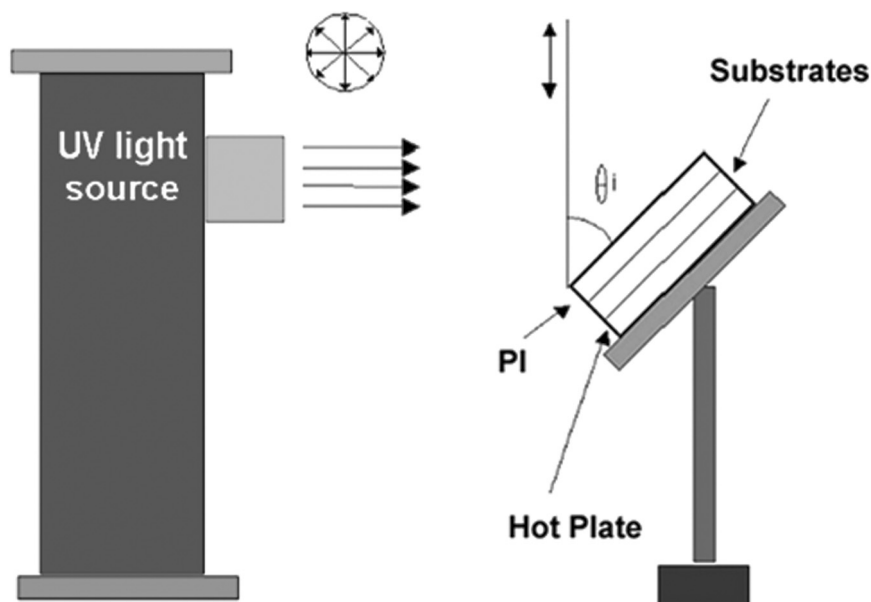
In this study, we studied LC alignment effects and the electro-optical (EO) characteristics of *in-situ* photoaligned TN cell on the polymer film.

## EXPERIMENTAL

Figure 1 shows the chemical structure of the polyimide (PI) used in this study (from Nissan Chemical industries). We used a polycarbonate (PC) film (200  $\mu\text{m}$ ) as the substrate. In the conventional photoalignment method, the polymers were soft-baked at 80°C for 10 min and baked at 120°C for 1 h. The thickness of the PI layer was set at 500 Å.



**FIGURE 1** Chemical structure of the polymer.

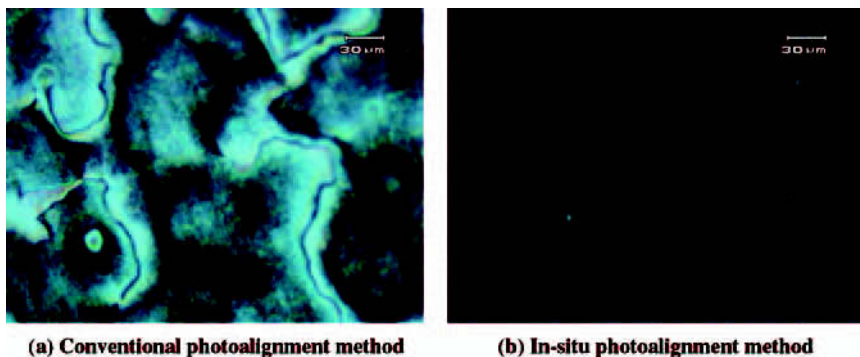


**FIGURE 2** UV exposure system used.

The UV exposure system is shown in Figure 2. The UV source was a 1000 W Xe lamp. In the *in-situ* photoalignment method, polymers were exposed to obliquely polarized UV during imidization of polyimide at  $50 \sim 120^\circ\text{C}$ . To measure tilt angle, the cell was fabricated as a sandwich type, and the thickness of the cell was  $60\ \mu\text{m}$ . A nematic liquid crystal (NLC) ( $T_c = 72^\circ\text{C}$ ,  $\Delta\epsilon = 8.2$ , from Merck Co.) of positive type NLC ( $\Delta\epsilon = 8.2$ , from Merck Co.) was injected to the isotropic phase. The other is the twisted nematic (TN) cell, which is used for Electro-Optical measurement. The thickness of the liquid crystal cells for TN cell was  $5\ \mu\text{m}$ . The crystal rotation method was used to measure pretilt angle (from Autronic Co.). LC alignment effects were observed by using a polarized microscope. In addition Voltage-Transmittance and response time characteristics of *in-situ* photoaligned TN cell were measured by LCD EOMS (Electro-Optical Measurement, from Sesim Photonics Technology) equipment.

## RESULTS AND DISCUSSION

Figures 3 show the microphotographs of aligned NLC using the conventional and *in-situ* photoalignment method with obliquely

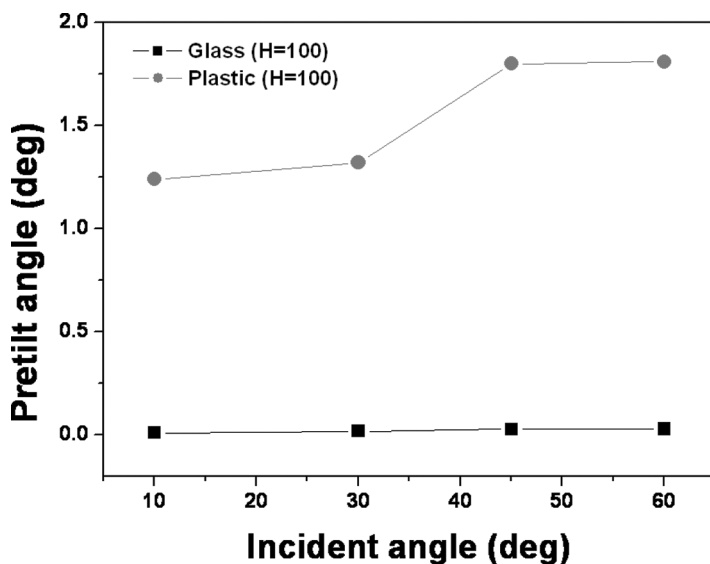


**FIGURE 3** Microphotographs of photoaligned LC cell using general and *in-situ* photo-alignment method on the glass and plastic substrate (incrossed Nicols).

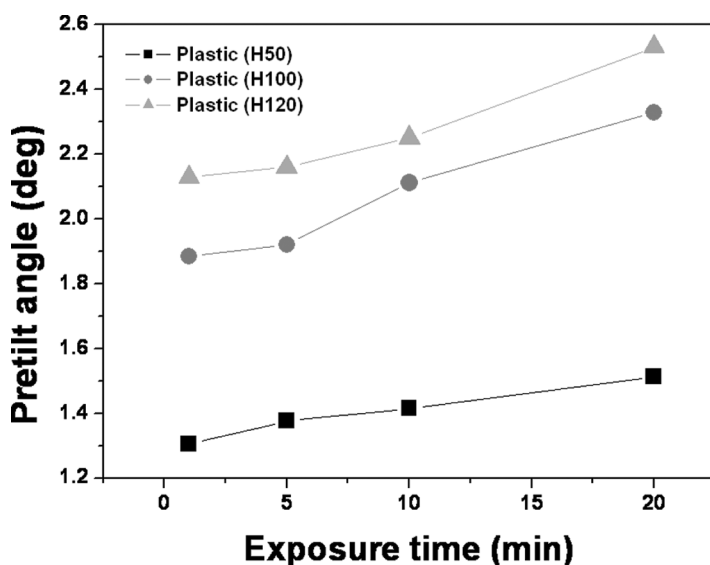
non-polarized UV exposure of  $45^\circ$  on the PI surfaces using polymer film. The large disclinations of NLC were observed by conventional photoalignment method. However, good alignment with *in-situ* photoalignment was obtained. It is considered that the better aligning capability of NLC is attributed to the high temperature of polymer substrate. The LC aligning capability of *in-situ* photoalignment method is better than that of the conventional alignment method.

The pretilt angles in NLC with non-polarized *in-situ* UV exposure on the glass and polymer substrate as a function of incident angle are shown in Figure 4. The high pretilt angle generated in NLC was observed by *in-situ* UV exposure on the polymer substrate for 1 min. The pretilt angle of NLC increases with increasing UV exposure angle. However, the low pretilt angle in NLC on the glass substrate was measured below  $1^\circ$  for all UV exposure angle. Therefore, the pretilt angle on the polymer film is higher than that on the glass using *in-situ* photoalignment method. The surface roughness of the polymer substrate is higher than that of the glass substrate. It is considered that this increase in pretilt angle may be attributed to the roughness of the micro-groove substrate induced by the *in-situ* photoalignment. These results demonstrate the theory that the topographical structure of the alignment layer contributes to the LC alignment [20].

Figure 5 shows NLC pretilt angles with obliquely non-polarized *in-situ* UV exposure of the plastic substrate as a function of UV exposure time and heating temperature. The pretilt angle of NLC increases with increasing UV exposure time and substrate's heating temperature. Moreover, increasing of heat temperature that is



**FIGURE 4** Generation of pretilt angles in NLC on the glass and plastic substrate as a function of non-polarized *in-situ* UV incident angle.

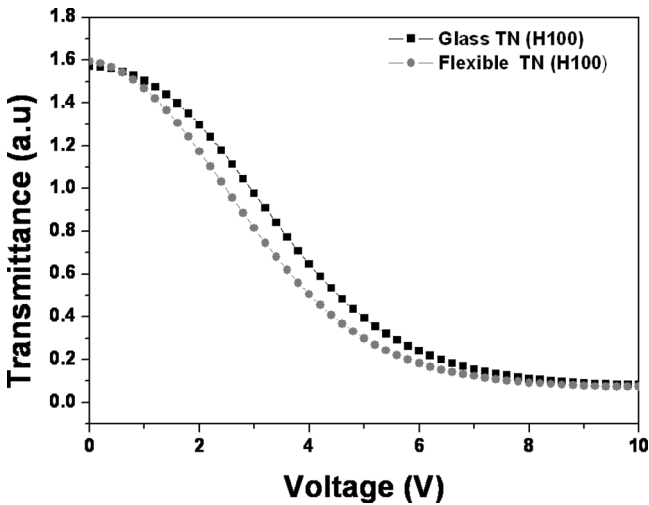


**FIGURE 5** Generation of pretilt angles in NLC as a function of substrate's heating temperature and UV exposure time on the *in-situ* photoalignment method.

imposed on polymer substrate can give important influence on moving molecules and surface topography of the micro-roughness of the substrate. So, it is considered that the heating temperature of substrate is attributed to generate pretilt angle. These results in polymer substrate show that heating effect on the PI surface can promote photodissociation action. Therefore, we suggest that *in-situ* alignment method contribute to the high pretilt angle for NLC on the polymer substrate.

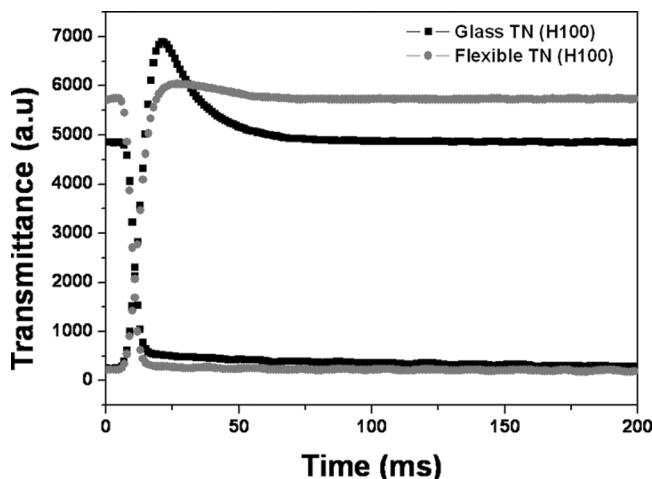
Figure 6 shows the voltage-transmittance (V-T) characteristics of the *in-situ* photoaligned TN cell on glass and polymer substrates when heating temperature of two substrates is 100°C. All stable curves of the *in-situ* photoaligned TN cell on glass and polymer substrates were achieved; The TN cells show a good transmission of light as a function of applied voltage across TN cells made by glass and polymer films, for using liquid crystal display. Therefore, V-T characteristics of the *in-situ* photoaligned TN cell using the polymer substrate are almost the same as those of the *in-situ* photoaligned TN cell using the glass substrate.

Figure 7 shows the response time (RT) characteristics of the *in-situ* photoaligned TN cell on glass and polymer substrates when heating temperature of two substrates is 100°C. The two RT curves have a difference as shown Figure 7. The response time-transmittance characteristics of the *in-situ* TN cell with the polymer film exhibited a



**FIGURE 6** The voltage-transmittance (V-T) characteristics of the *in-situ* aligned TN cell on glass and polymer substrates when heating temperature of two substrates is 100°C.





**FIGURE 7** The response time (RT) characteristics of the *in-situ* aligned TN cell on glass and polymer substrates when heating temperature of two substrates is 100°C.

more stable quality than those of the *in-situ* photoaligned TN cell with the glass substrate. Especially, RT curve of *in-situ* TN cell with the glass substrate showed big backflow bounces. It is considered that LC aligning capability generated film by *in-situ* photoalignment method with the polymer film is stronger than that by the *in-situ* photoalignment method with the glass substrate. Also, the response time of the *in-situ* photoaligned TN cell using the polymer substrate was measured to be about 15 ms.

When a polymer film is used in the *in-situ* photoalignment method, the pretilt angle characteristics were higher than those obtained when the glass substrates were used, and the EO performances of the TN cell using the polymer substrate is almost the same as that of the TN cell using the glass substrate.

## CONCLUSION

In conclusion, LC alignment effects and generation of pretilt angles with *in-situ* photoalignment irradiation changing heating temperature from 50°C to 120°C on the polymer film were investigated, and the EO performances of the *in-situ* photoaligned TN-LCD with polymer film were studied. LC aligning capability with the polymer substrate was obtained the better than that on glass substrate using

*in-situ* photoalignment method. The pretilt angles of the polymer substrates by *in-situ* photoalignment method were higher than those of the glass substrate by *in-situ* photoalignment method. As temperature of heated substrate and UV exposure time increase, pretilt angles of the cell using polymer film increased. It is considered that the heating temperature of substrate is attributed to generate pretilt angle. In the *in-situ* photoalignment method, the EO performances of the TN cell using the polymer substrate is almost the same as those of the TN cell using the glass substrate.

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