Liquid crystal alignment effects for the photo-aligned VA-LCD on the photo-polymer

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In this study, the new photo-alignment material, copoly (PM4Ch-ChMA) (copoly (poly (4-methacryloyloxy) chalcone - cholesteryl methacrylate)), was synthesized. Also, the liquid crystal (LC) aligning capabilities and the electro-optical (EO) characteristics for the photo-aligned vertical-aligned (VA)-LC display (LCD) were studied. The monodomain alignment of the NLC for the photo-aligned VA-LCD by linearly polarized UV exposure on the photo-dimerized copoly (PM4Ch-ChMA) surfaces was observed. Excellent voltage-transmittance characteristics for the VA-LCD photo-aligned by polarized UV exposure on the copoly (PM4Ch-ChMA) surfaces for 1 min was achieved. The response time of the VA-LCD photo-aligned with UV exposure on the copoly (PM4Ch-ChMA) surfaces for 1 min was about 39.3 ms. We suggest that the photo-dimerized chacone group increased with increasing UV exposure time, which then contributes to a low response time for the photo-aligned VA-LCD on the copoly (PM4Ch-ChMA) surfaces

Keywords: copoly (PM4Ch-ChMA) (copoly (poly (4-methacryloyloxy) chalcone - cholesteryl methacrylate)), vertical alignment, photo-alignment.

1. INTRODUCTION

Surface alignment effects by unidirectional rubbing in nematic (N) LC on various PI layers have been demonstrated by many investigators. (1,2) However, the rubbing method creates several problems, such as the generation of electro-static charges and the contaminating particles. Thus rubbing-free techniques for LC alignment are required in LC technologies. Many investigators have proposed photo-alignment such as photo-dimerization (2-6) and photo-dissociation method. (7,8) Recently, the synthesis of photo-alignment materials such as PMCh (poly (4'-methacryloyloxy chalcone)), PMCh-F (poly (4-fluoro-4'-methacryloyloxy chalcone)), PVCi (poly (vinyl) cinnamate), and PMCi (poly (2-methacryloyloxy ethyl cinnamate)) has been reported by Y. Makita et al. (9) More recently, we have reported on the synthesis of photo-alignment material PM4Ch (poly (4-methacryloyloxy chalcone)), and the EO performance of the photo-aligned TN-LCD on the PM4Ch surfaces. (10)

In this study, we report on the synthesis of a new photo-alignment material copoly (PM4Ch-ChMA), copoly (poly (4-methacryloyloxy chalcone - cholesteryl methacrylate), and the EO characteristics of the photo-aligned VA-LCD.

2. EXPERIMENTAL

Figure 1 shows the chemical structure of the copoly (PM4Ch-ChMA) used. The copoly (PM4Ch-ChMA) was synthesized by chalconyl moiety for homogeneous alignment and cholesteryl moiety for homeotropic alignment as side chain. The polymers were coated on indium-tin-oxide (ITO) coated glass substrates by spin-coating, and were cured at 150℃ for 1 h. The thickness of the polymer layer was 400 Å. Figure 2 shows the UV exposure system used in this study. The UV source used was a 500W Xe lamp. The UV light at a wavelength of 365nm was exposed on the substrates. The UV exposure time was 1 min, 3 min, and 7 min. To measure the EO characteristics of the photo-aligned VA-LCD, the cell was fabricated with anti-parallel structure with polarized UV exposure in the oblique direction of 30° on the copoly (PM4Ch-ChMA) surfaces. The rubbing-aligned VA-LCD was assembled at medium rubbing strength (164mm) for comparison with photo-aligned VA-LCD. The thickness of the LC layer used for the photo-aligned VA-LCD was 4.25 μm. Also, the cell thickness was used 60μm for pretilt angle measurements. The NLC was used in negative-type dielectric anisotropy ($\Delta\varepsilon = -3.8$). The pretilt angle, voltage-transmittance (V-T), and response time measurements for the photo-aligned VA-LCD were performed at room temperature.

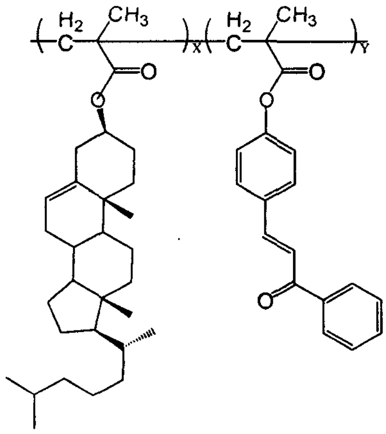

Fig. 1. Chemical structure of the copoly (PM4Ch-ChMA) used in this study.

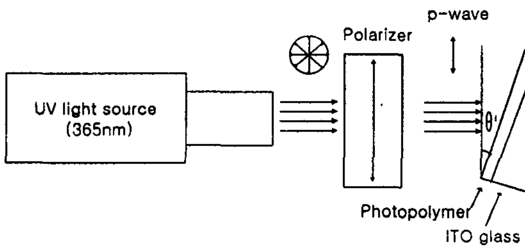

Fig. 2. UV exposure system used.

3. RESULTS AND DISCUSSION

Figure 3 shows the TGA (Thermogravimetric Analysis) characteristics of the copolymer. TGA measurement yielded satisfactory thermal stabilities of synthesized copolymers.

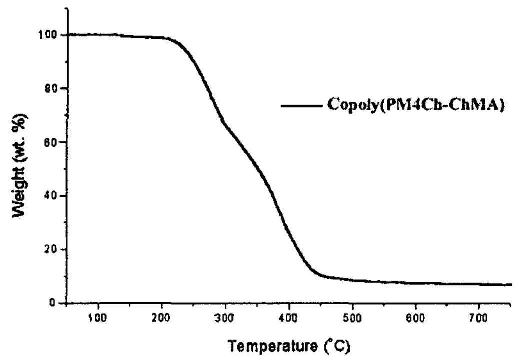

Fig. 3. TGA characteristics of three copolymer types.

Figure 4 shows the microphotographs for the photo-aligned VA-LCD by linearly polarized UV exposure in oblique direction (Θ_i=30°) for 1 min on the copoly (PM4Ch-ChMA) surfaces. Monodomain alignment of the NLC for the photo-aligned VA-LCD was observed. Also, homeotropic alignments of the NLC on the copoly (PM4Ch-ChMA) surfaces can be achieved.

(a) on-state (V=5(V))

(b) off-state

Fig. 4. Microphotographs for the photo-aligned VA-LCD with linearly polarized UV exposure of oblique direction (Θ_i=30°) for 1 min on the copoly (PM4Ch-ChMA) surfaces (in crossed Nicols).

The V-T characteristics for the photo-aligned VA-LCD's by linearly polarized UV exposure in oblique direction (Θ_i=30°) on the copoly (PM4Ch-ChMA) surfaces is shown in Fig. 5. As shown in Fig. 5, excellent V-T characteristics of the photo-aligned VA-LCD on the copoly (PM4Ch-ChMA) surfaces for 1 min were observed. Poor V-T characteristics for the VA-LCD photo-aligned with UV exposure on the copoly (PM4Ch-ChMA) surface for 3 min and 7 min were measured. Therefore, the transmittances of the photo-aligned VA-LCD decreased by increasing of UV exposure time on the copoly (PM4Ch-ChMA) surfaces. Consequently, the UV exposure time to achieve good V-T characteristics for the photo-aligned VA-LCD was about 1 min in this system.

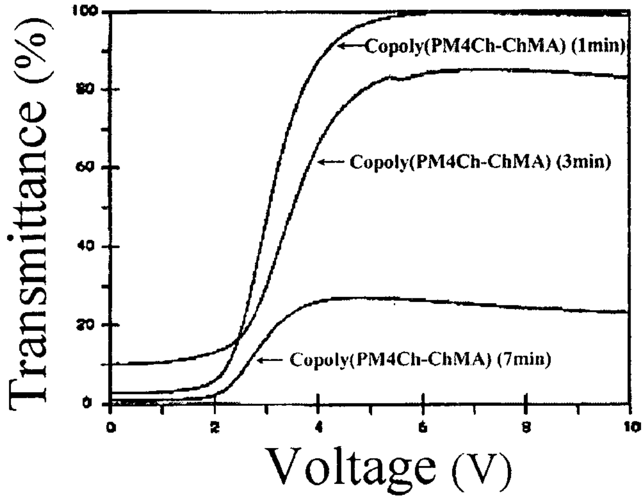

Fig. 5. V-T characteristics for the photo-aligned VA-LCD's with linearly polarized UV exposure of oblique direction (Θ_i=30°) on the copoly (PM4Ch-ChMA) surfaces.

Table 1 shows the threshold voltages for various photo-aligned VA-LCD's on copoly (PM4Ch-ChMA) surfaces and rubbing-aligned VA-LCD on a PI surface. The threshold voltages for the VA-LCD photo-aligned with UV exposure for 1min on the copoly (PM4Ch-ChMA) surfaces were about 2.34 (v). It is shown that the threshold voltage for the photo-aligned VA-LCD was almost the same as that of the rubbing-aligned VA-LCD.

Table 1. Threshold voltages for various photo-aligned VA-LCD's on the copoly (PM4Ch-ChMA) surfaces and a rubbing-aligned VA-LCD on a PI surface.

Alignment layer	Voltage	
	V_{10}	V_{90}
Copoly (PMCh-ChMA) (1 min)	2.34	4.17
Copoly (PMCh-ChMA) (3 min)	2.52	4.65
Copoly (PMCh-ChMA) (7 min)	2.18	3.66
Rubbing-aligned	2.56	4.39

Figure 6 shows the response time characteristics for the VA-LCD's photo-aligned with linearly polarized UV exposure in oblique direction (Θ_i=30°) on the copoly (PM4Ch-ChMA) surfaces. Good response time characteristics for the VA-LCD photo-aligned with UV exposure for 1min on the copoly (PM4Ch-ChMA) surfaces were measured. The transmittances of the photo-aligned VA-LCD decreased by increasing of UV exposure time. From these results, we consider that the UV exposure time needed to achieve good V-T curve and response time characteristics was about 1 min as shown in Fig. 5 and Fig. 6.

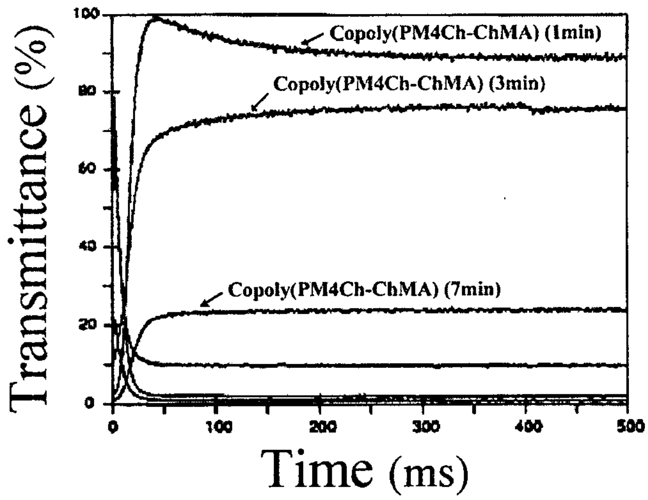

Fig. 6. Response time characteristics for the photo-aligned VA-LCD's with linearly polarized UV exposure of oblique direction (Θ_i=30°) on the copoly (PM4Ch-ChMA) surfaces.

Table 2 shows the response times for the three the kinds of photo-aligned VA-LCD's on copoly (PM4Ch-ChMA) surfaces and a rubbing-aligned VA-LCD on a PI surface. It is shown that the response time for the photo-aligned VA-LCD with UV exposure on the copoly (PM4Ch-ChMA) surfaces for 1 min was about 39.3 ms. The response time of the photo-aligned VA-LCD was almost the same as that of the rubbing-aligned VA-LCD on a PI surface. However, slow response times for the photo-aligned VA-LCD with UV exposure on the copoly (PM4Ch-ChMA) surfaces for 3 min and 7 min were measured. We consider that the photo-dimerized chalcone groups increase with increasing UV exposure time, which contributes a low response time for the VA-LCD photo-aligned on the copoly (PM4Ch-ChMA) surfaces.

Table 2. Response times for three kinds of photo-aligned VA-LCD's on copoly (PM4Ch-ChMA) surfaces and a rubbing-aligned VA-LCD on a PI

surface.

Alignment layer	Time		
	τ_r(ms)	τ_d(ms)	τ (ms)
Copoly (PMCh-ChMA) (1 min.)	23.1	16.2	39.3
Copoly (PMCh-ChMA) (3 min.)	50.4	16.1	66.5
Copoly (PMCh-ChMA) (7 min.)	40.3	18.4	50.7
Rubbing-aligned	18.2	18.5	36.7

4. CONCLUSIONS

In conclusion, the monodomain alignment of the NLC for the VA-LCD photo-aligned with UV exposure on the photo-dimerized copoly (PM4Ch-ChMA) surfaces was observed. Excellent V-T characteristics for the photo-aligned VA-LCD with UV exposure for 1min on the copoly (PM4Ch-ChMA) surfaces were achieved. The response time of the photo-aligned VA-LCD was almost the same as that of the rubbing-aligned VA-LCD. The response time for the photo-aligned VA-LCD decreases with increasing UV exposure time. We suggest that slow response times of the photo-aligned VA-LCD are related to increasing of photo-dimerized chalcone moieties by increasing of UV exposure time on the copoly (PM4Ch-ChMA) surfaces.

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