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Effect of Liquid Crystal Alignment for Photo-Aligned VA-LCD on the Photo-Dimerized Polymer Surface

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A photopolymer, copoly (M4Ch-ChMA), copoly ((4-methacryloyloxy) chalcone-cholesteryl methacrylate), was synthesized in this study. The electro-optical (EO) characteristics for the photo-aligned vertical-alignment (VA)-liquid crystal display (LCD) were investigated. Excellent voltage-transmittance curves for the VA-LCD photo-aligned by polarized UV exposure on the copoly (M4Ch-ChMA) surfaces were observed. The response time for the photo-aligned VA-LCD decreased with increasing UV exposure time. Consequently, the photo-dimerized chalcone moiety increased with increasing UV exposure time, which then contributed to a low response time for the VA-LCD photo-aligned.

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I. INTRODUCTION

The rubbing process has been widely utilized to align LC molecules. Most LCDs with pretilted homogeneous LC alignment are prepared by rubbed polyimide (PI) surface. They have suitable characteristics such as high transparency, uniform alignment, and pretilt angle stability. 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 dust. 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]. 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 [9]. In this study, we report on the synthesis of a photo-polymer copoly (M4Ch-ChMA), copoly ((4-methacryloyloxy) chalcone-cholesteryl methacrylate), for homeotropic LC alignment and the EO characteristics of the VA-LCD photo-aligned.

II. EXPERIMENTAL

Fig. 1 shows the chemical structure of the copoly (M4Ch-ChMA) used in this study. The polymer is synthesized by copolymers of 4-methacryl chalcone (M4Ch) and cholestryl methacrylate (ChMA), which have photosensitivity on UV and vertical alignment ability. Polymers were coated on indium-tin-oxide (ITO) coated glass substrates by spin-coating, and were cured at 150°C for 1 h. The thickness of the

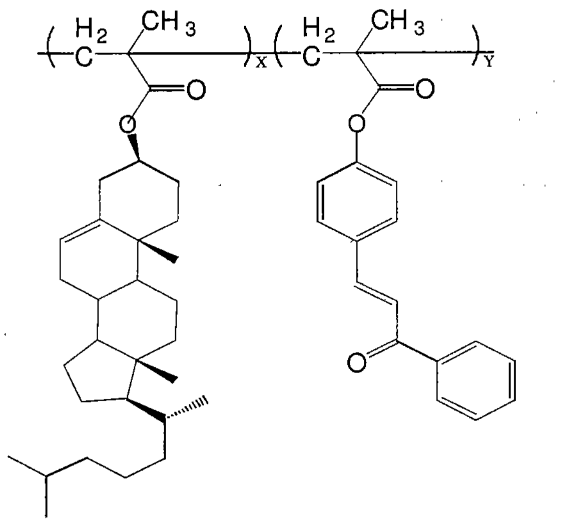


FIG. 1. Chemical structure of the copoly (M4Ch-ChMA) used.

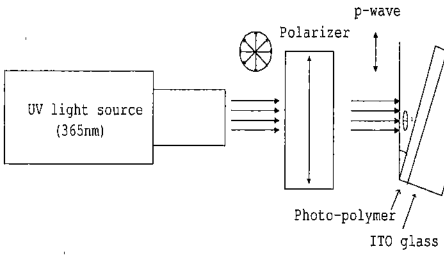
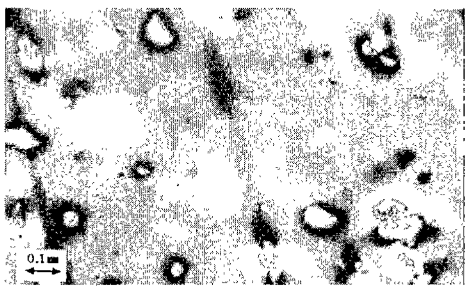


FIG. 2. UV exposure system used.

polymer layer was 400Å. Fig. 2 shows the UV expo sure system used in this study. The UV source used was a 500W Xe lamp. The UV light at a wavelength of 365nm was exposed to the substrates. The UV exposure time was 1 min, 3 min, and 7 min. To measure the EO characteristics of the VA-LCD photo-aligned, VA-LCDs photo-aligned were fabricated with an anti-parallel structure by linearly polarized UV exposure in the oblique polarized UV exposure of 30° on the copoly (M4Ch-ChMA). The VA-LCD rubbing-aligned was assembled at medium rubbing strength (164 mm)



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

(b) Off-state

FIG. 3. Microphotographs for the VA-LCD photo -aligned with linearly polarized UV exposure of oblique direction ($\theta_i = 30°$) on the copoly (M4Ch-ChMA) surfaces for 1 min. (in crossed Nicols)

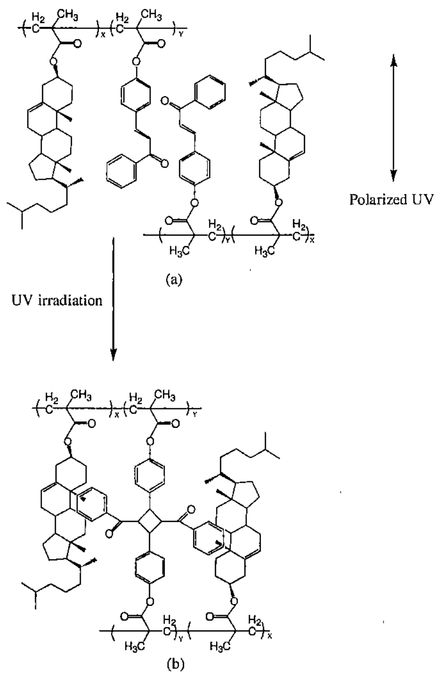


FIG. 4. Photodimerization reaction of the copolymers.

for comparison with VA-LCD photo-aligned. The thickness of the LC layer used for the photo-aligned VA-LCD was 4.25 μm. The NLC was used in negative-type dielectric anisotropy. The voltage-transmittance (V-T) and response time measurements of the VA-LCD photo-aligned were performed at room temperature.

III. RESULTS AND DISCUSSION

Fig. 3 shows the microphotographs for the VA-LCD photo-aligned with linearly polarized UV exposure in oblique direction ($\theta_i = 30°$) on the copoly (M4Ch-ChMA) surfaces for 1 min. Monodomain alignment of the NLC for the VA-LCD photo-aligned was observed. Also, homeotropic alignments of the NLC on the copoly (M4Ch-ChMA) surfaces were achieved.

The mechanism of LC alignment using obliquely polarized UV exposure on the copolymers is attributed to the photodimerization of the chalcone group side chains, as shown in Fig. 4. During the obliquely polarized UV exposure, the chalcone groups are crosslinked through photodimerization.

The V-T characteristics for the VA-LCD's photo-aligned with polarized UV exposure in oblique direc-

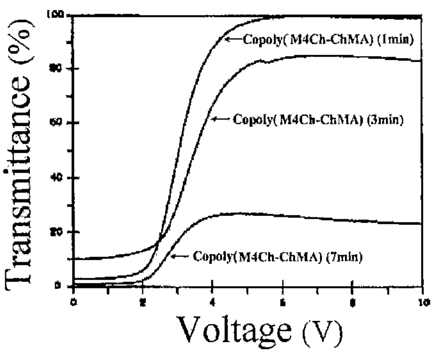


FIG. 5. V-T characteristics for the photo-aligned VA-LCD's with linearly polarized UV exposure of oblique direction ($\theta_i = 30°$) on the copoly (M4Ch-ChMA) surfaces.

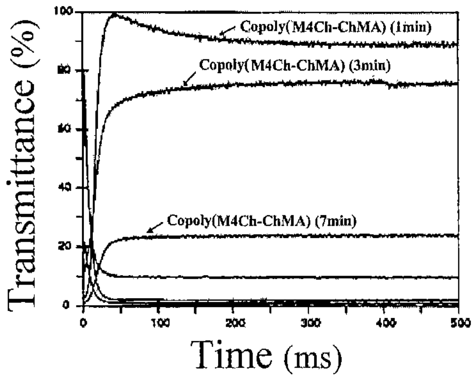


FIG. 6. Response time characteristics for the photo-aligned VA-LCD's with linearly polarized UV exposure of oblique direction ($\theta_i = 30°$) on the copoly (M4Ch-ChMA) surfaces.

tion ($\theta_i = 30°$) on the copoly (M4Ch-ChMA)surfaces is shown in Fig. 4. As shown in Fig. 5, excellent V-T characteristics of the VA-LCD photo-aligned on the copoly (M4Ch-ChMA) surfaces for 1 min were observed. Also, there is no difference in V-T curve characteristics for the photo-aligned VA-LCD within 1min of UV exposure time.

Poor V-T characteristics for the VA-LCD photo-aligned with UV exposure on the copoly (M4Ch-ChMA) surface for 3 min and 7 min were measured. Therefore, the transmittances of the VA-LCD photo-aligned decreased by increasing of UV exposure time on the copoly (M4Ch-ChMA) surfaces. Consequently, the UV exposure time to achieve good V-T characteristics for the VA-LCD photo-aligned was about 1 min in this system.

Table 1 shows the threshold voltages for various VA-LCD's photo-aligned on copoly (M4Ch-ChMA) surfaces and VA-LCD rubbing-aligned on a polyimide (PI) surface. The threshold voltages for the VA-LCD photo-aligned with UV exposure for 1min on the copoly (M4Ch-ChMA) surfaces for 1min were about 2.34 (v). It is shown that the threshold voltage for the VA-LCD photo-aligned was almost the same as that of the VA-LCD rubbing-aligned.

Fig. 6 shows the response time characteristics for the VA-LCD's photo-aligned with linearly polarized UV exposure in oblique direction ($\theta_i = 30°$) on the copoly (M4Ch-ChMA) surfaces. Good response time characteristics for the VA-LCD photo-aligned with UV exposure for 1min on the copoly (M4Ch-ChMA)surfaces were measured. Also, there is no difference in response time characteristics for the photo-aligned VA-LCD within 1min of UV exposure time.

The transmittances of the VA-LCD photo-aligned decreased by increasing 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 Figs. 5 and 6.

Table 2 shows the response times for the three the kinds of VA-LCD's photo-aligned on copoly (M4Ch-ChMA) surfaces and a VA-LCD rubbing-aligned on a PI surface. It is shown that the response time for the VA-LCD photo-aligned with UV exposure on the copoly (M4Ch-ChMA) surfaces for 1 min was about 39.3 ms. The response time of the VA-LCD photo-aligned was almost the same as that of the VA-LCD rubbing-aligned on a PI surface. However, slow response times for the VA-LCD photo-aligned with UV exposure on the copoly (M4Ch-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 to a low response time for the VA-LCD photo-aligned on the copoly (M4Ch-ChMA) surfaces.

Table 3 shows the response times for the three the kind of VA-LCD's photo-aligned on copolymer surfaces as a function of ransmittance. T_{10} and T_{50} were the same as the response time for the VA-LCD photo-

TABLE 1. Threshold voltages for various photo-aligned VA-LCD's on the copoly (M4Ch-ChMA) surfaces and rubbing-aligned VA-LCD on a PI surface.

Orientation Film	Voltage	
	V_{10}	V_{90}
Copoly(MCh-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

TABLE 2. Response times for three kinds of photo-aligned VA-LCD's on copoly (M4Ch-ChMA) surfaces and rubbing-aligned VA-LCD on a PI surface.

Orientation Film	Time		
	τ_r(ms)	τ_d(ms)	τ(ms)
Copoly(MCh-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

TABLE 3. Response times for three kinds of the photo-aligned VA-LCD's on the copoly(M4Ch-ChMA) surface as a function of transmittance.

Time Orientation	τ	Transmittance		
		T_{10}	T_{50}	T_{90}
Copoly(M4Ch-ChMA) (1 min)	τ_r	8.0	16.0	23.1
	τ_d	1.5	6.6	16.2
	τ	9.5	22.6	39.3
Copoly(PMCh-ChMA) (3 min)	τ_r	4.5	18.0	50.4
	τ_d	1.5	6.0	16.1
	τ	6.0	24.0	66.5
Copoly(PMCh-ChMA) (7 min)	τ_r	9.0	20.5	40.3
	τ_d	1.5	6.9	18.4
	τ	10.5	27.4	58.7

aligned with UV exposuret on the copolymer surfaces. However, in the case of T_{90}, it is shown that slow response times for the VA-LCD photo-aligned with UV exposure on the copolymer surfaces for 3 min and 7 min were achieved. It was known that slow response time was particularly achieved in raising time (τ_r). The cholesteryl groups contribute to the homeotropic alignment and the photodimerized chalcones contribute to the LC direction on the new synthesized copolymer. The LC aligning capabilities decreased with increasing UV exposure time because the photodimerized chalcones dissolved into the ester linkage (-COO-) of weak combinations in the photodimerized chalcones by high energy density. Also, the glass temperature (T_g: 110°C) of copolymer was low due to the flexible chains of acrylate in the backbone structure. Therefore, the LC aligning capabilities decreased due to the fluctuation of the backbone of the copolymer by heating with a long UV exposure time. Therefore, the decrease of the LC aligning capabilities decreased the response time.

IV. CONCLUSION

In conclusion, the photo-polymer copoly (M4Ch-ChMA) was synthesized and the EO performances for the VA-LCD photo-aligned were studied. Uniform alignment of the NLC for the VA-LCD photo-aligned with UV exposure on the photo-dimerized copoly (M4Ch-ChMA) surfaces was observed. Excellent V-T characteristics for the VA-LCD photo-aligned with UV exposure for 1min on the copoly (M4Ch-ChMA) surfaces for 1min were achieved. The response time of the VA-LCD photo-aligned was almost the same as that of the VA-LCD rubbing-aligned. Finally, we suggested that slow response times of the VA-LCD photo-aligned was related to increasing photo-dimerized chalcone groups by increasing UV exposure time on the copoly (M4Ch-ChMA) surfaces.

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