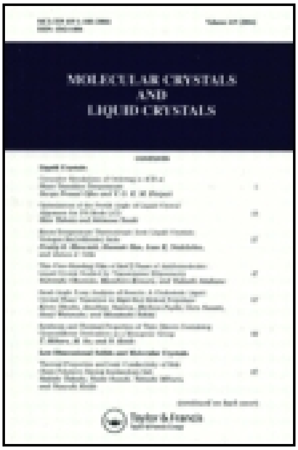

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Investigation of Liquid Crystal Alignment on the Photo-Alignment Material PM4Ch Surfaces

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We synthesized the new photo-alignment material, PM4Ch (poly (4-methacryloyloxy chalcone)). Good thermal stabilities of synthesized PM4Ch were obtained by TGA (Thermogravimetric Analysis) measurement. The electro-optical (EO) characteristics of the photo-aligned twisted nematic (TN)-LC display (LCD), with linearly polarized UV exposure of normal direction on the PM4Ch surface were investigated. Monodomain alignments of the NLC by polarized UV exposure of normal direction on the PM4Ch surface were observed. The excellent voltage-transmittance curves for the photo-aligned TN-LCD on the PM4Ch surfaces were successfully obtained. Also, a fast response time for the photo-aligned TN-LCD on the PM4Ch surface can be achieved. Reduction of the DC voltage for the photo-aligned TN-LCD decreases with increasing UV exposure time on the PM4Ch surfaces.

Keywords: photo-alignment; PM4Ch; electro-optical performance; nematic liquid crystal; TN-LCD

INTRODUCTION

Liquid crystal displays (LCDs) are widely used in various display fields. Most LCDs require controlled monodomain LC alignment. LCDs with pre-tilted homogeneous LC alignment are mostly prepared by rubbed polyimide (PI) surfaces. Rubbed PI surfaces have been widely used to align LC molecules. The effect of surface alignment in nematic (N) LC on various alignments layers by unidirectional rubbing has been demonstrated and discussed by many investigators. [1-6] However, the rubbing treatment creates several problems, such as generation of electro-static charges and creation of contaminating particles. In a previous paper, we reported the generation of electro-static charges produced on various alignment layers during

Rubbing.[7] Thus rubbing-less techniques for LC alignment are required in LCD fabrication. The photo-alignment method for LC alignment is the most promising rubbing-free method. Photo-alignment methods being proposed thus far have been photo-dimerization,[8-11] and photo-dissociation.[12-15]

Recently, some researchers [8-11] have reported the LC alignment with polarized UV exposure on poly (vinyl) cinnamate surfaces has been reported. It is seem that the photo-dimerized reaction of a photo-polymer with polarized UV exposure has been observed to induce uniaxial orientation of NLCs on poly (vinyl) cinnamate surfaces. Recently, the synthesis of photo-alignment materials such as PMCh (poly (4'-methacryloyloxychalcone)), PMCh-F (poly (4-fluoro-4'-methacryloyloxy chalcone)), PVCi (poly (vinyl) cinnamate), and PMCi (poly (2-metha-cryloyloxy ethyl cinnamate)) has been reported by Y.Makita et al.[16] Most recently, we have reported the synthesis of the photo-alignment material PCEMA (poly (cinnamoly ethylmethacrylate), and the EO performance of photo-aligned TN-LCD on PCEMA surfaces.[17] The polar anchoring strength of NLC on photo-dimerized alignment layers and rubbed PI surfaces has been reported by D.Shenoy et al.[18] However, the detailed mechanism of LC alignment by photo-alignment method is not yet well understood.

In this work, we report on the synthesis of the photo-alignment material of PM4Ch and EO performance of photo-aligned TN-LCD, with polarized UV exposure of normal direction on the PM4Ch surfaces.

EXPERIMENTAL

Figure 1 shows the chemical structure of the PM4Ch used in this study. The polymer is synthesized by the following method. In a 250ml round bottom flask, 4-hydroxy chalcone and triethylamine were dissolved in 2-butanone and cooled to between –5 and 0℃ in an ice bath. Methacryloyl chloride solution in 2-butanone was then added dropwise while stirring and keeping the temperature at between –5 and 0℃. After stirring at room temperature for 4 hr the precipitated ammonium salt was filtered off. The organic layer was washed successively with 5% aqueous sodium hydroxide solution and distilled water, dried over anhydrous magnesium sulfate and the 2-butanone was evaporated.

Figure 2 shows the FT-IR (Fourier Transform Infrared Spectrophotometer) spectrum of M4Ch. Good synthesis capabilities were obtained as shown in Figure 2. The product was purified by recrystallizatinon from ethylacetate/ethanol (1:1) mixture. Polymerization of monomers was carried out as solution in toluene using 2,2'-azoisobutyronitrile(AIBN)(2 mol%) as initiator at 70℃. The required amounts of monomers, initiator and toluene were mixed in a flask, and flushed with oxygen free nitrogen for 30min. After reacting for 48 hr at 70℃, the polymer was precipitated in excess methanol. The crude polymer was purified by reprecipitation in methanol from chloroform solution, and was finally dried under a vacuum. The polymers were coated on indium-tin-oxide (ITO) coated glass substrates by spin-coating, and were cured at 150℃ for 1 hr. The thickness of the monomer layers was 400Å. The linearly polarized UV (Xe lamp of 500W) exposure system is shown in Figure 3.

The substrates were exposed using a UV at a wavelength of 365nm for 30sec. ~ 2 min. To measure the EO characteristics, the photo-aligned TN-LCD was assembled with linearly polarized UV exposure of normal direction on the PM4Ch surfaces. LC layer of photo-aligned TN-LCD used was 5μm. NLC used is a fluorinated type mixture (T_c=87℃). The rubbing-aligned TN-LCD was fabricated at medium rubbing strength (RS=187mm) for comparison with photo-aligned TN-LCD. Measurement of the voltage-transmittance, response time, and voltage-capacitance of the photo-aligned TN-LCD were done at room temperature.

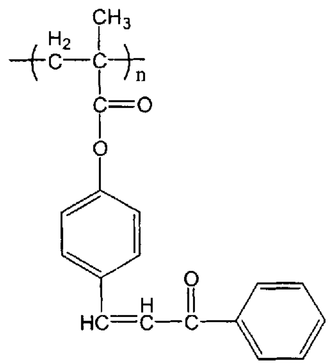


FIGURE 1 Chemical structure of PM4Ch.

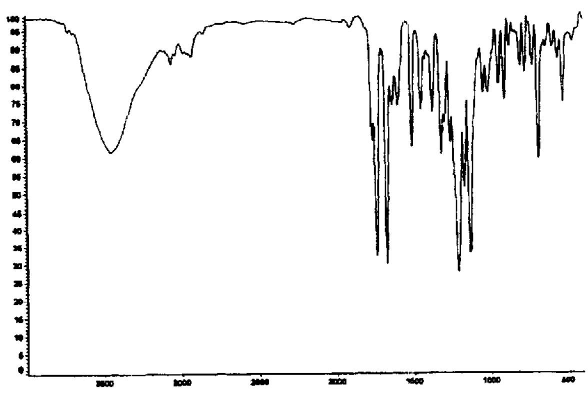


FIGURE 2 FT-IR spectrum of M4Ch.

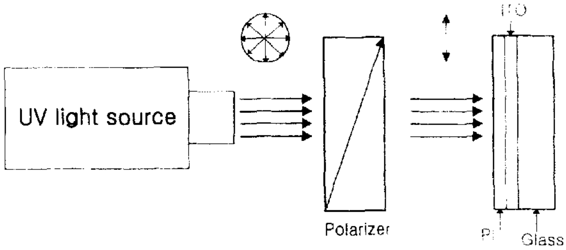


FIGURE 3 Schematic diagram of UV exposure system.

RESULTS and DISCUSSION

Figure 4 shows the TGA (Thermogravimetric Analysis) characteristics of the PM4Ch. Good thermal stabilities of synthesized PM4Ch are obtained by TGA measurement.

The microphotographs of photo-aligned TN-LCD with polarized UV exposure of normal direction on the PM4Ch surface for 1 min (in crossed Nicols) are shown in Figure 5. It is shown that the aligned NLC was relatively uniform.

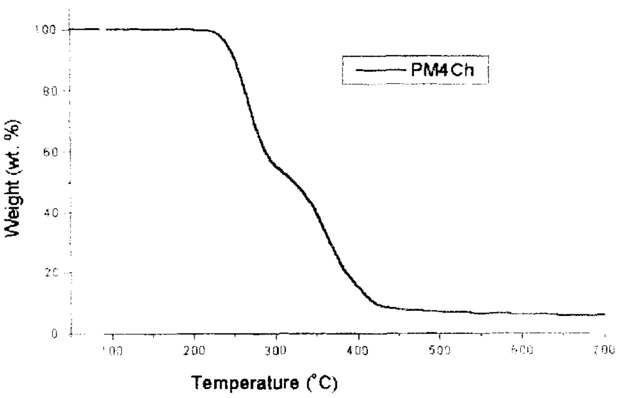
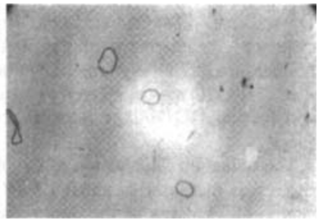


FIGURE 4 TGA characteristics of the three kinds of copolymer.

(a) on-state (V=6(V))



(b) off-state (V=6(V))

FIGURE 5 Microphotographs of photo-aligned TN-LCD with polarized UV exposure of normal direction on the PM4Ch surface for 1 min (in crossed Nicols).

Figure 6 shows the voltage-transmittance (V-T) curves of photo-aligned TN-LCD with polarized UV exposure of normal direction on the PM4Ch surfaces. Poor V-T curves for the photo-aligned on the PM4Ch (30 sec) and PM4Ch (2 min) were obtained. Excellent V-T curves of photo-aligned TN-LCD on the PM4Ch surface (1 min) were measured. Suitable V-T curve of photo-aligned TN-LCD on the PM4Ch surfaces was obtained by a UV exposure time of 1 min. Table 1 shows the threshold voltages for the photo-aligned TN-LCD with polarized UV exposure of normal direction on the PM4Ch surfaces and rubbing-aligned TN-LCD. The low threshold voltage of the photo-aligned TN-LCD on the PM4Ch surfaces was also measured. The threshold voltage of the photo-aligned TN-LCD was almost the same as the rubbing-aligned TN-LCD.

The response time characteristics of photo-aligned TN-LCD with polarized UV exposure of normal direction on the PM4Ch surfaces are shown in Figure 7. An excellent curve for photo-aligned TN-LCD on the PM4Ch surfaces is shown. No backflow bounce effect on photo-aligned TN-LCD was observed. Table 2 shows the response time for the photo-aligned TN-LCD with polarized UV exposure of normal direction on the PM4Ch surfaces, and rubbing-aligned TN-LCD. It is shown that a fast response time of photo-aligned TN-LCD on the PM4Ch surfaces was obtained. The response time for the photo-aligned TN-LCD on the PM4Ch (1 min) surface was about 23.9ms. Additionally, It is shown that the response time of the photo-aligned TN-LCD was faster than that of the rubbing-aligned TN-LCD. In a previous paper, D.Shenoy et al. reported that the polar anchoring energy of NLC on a photo-dimerized monolayer is about 4.9×10^{-3} (J/m^2), indicating a relatively strong anchoring strength.[18] From these results, we can consider that the fast response time for the photo-aligned TN-LCD on a photo-dimerized surface can be attributed to a strong anchoring energy between the LC molecules and the substrate surfaces. Consequently, we suggest that the EO characteristics of the photo-aligned TN-LCD with polarized UV exposure of normal direction on the PM4Ch surfaces, depend on the UV exposure condition and materials.

Figure 8 shows the voltage-capacitance (V-C) curves of the photo-aligned TN-

LCD on the PM4Ch surfaces. In Figure 8(a), the asymmetric voltage-capacitance characteristics of the photo-aligned TN-LCD on the PM4Ch (30 sec) were measured. The asymmetric voltage-capacitance characteristics of the photo-aligned TN-LCD are considered to be dependent on the inner ions of the LC cell. The reduction DC voltage was observed about 3.5 (V) on the PM4Ch (30 sec) surfaces.

The reduction DC voltage of the photo-aligned TN-LCD (2 min) on the PM4Ch surfaces was measured at about 1.5 (V) as shown in Figure 8(b). It is clear that the reduction DC voltage of the photo-aligned TN-LCD decreases with increasing UV exposure time. Therefore, the reduction DC voltage depends on the alignment layer and cell conditions.

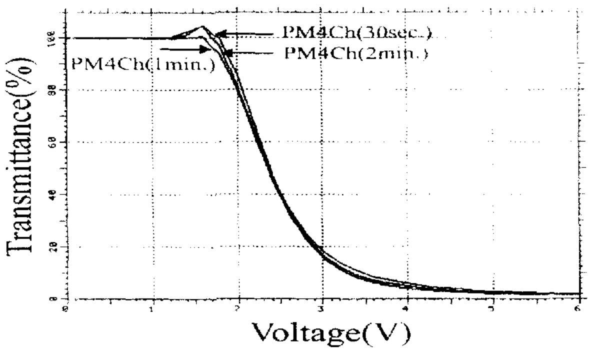


FIGURE 6 Voltage-transmittance curves for the photo-aligned TN-LCD with linearly polarized UV exposure of normal direction on the PM4Ch surfaces.

TABLE 1 Threshold voltages for photo- and rubbing-aligned TN-LCDs.

Orientation Film \ Voltage	V_{90}	V_{10}
PM4Ch (30 sec)	1.87	3.22
PM4Ch (1 min)	1.84	3.19
PM4Ch (2 min)	1.83	3.31
Rubbed PI	1.99	3.39

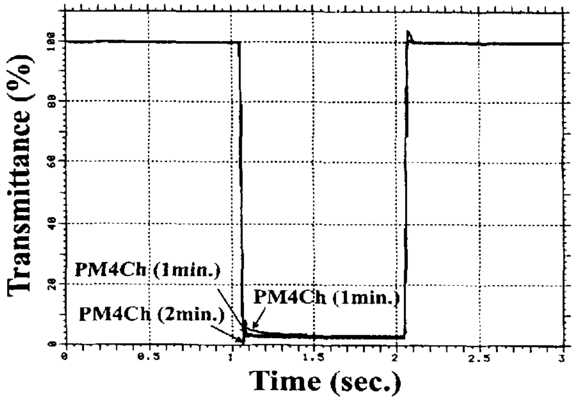
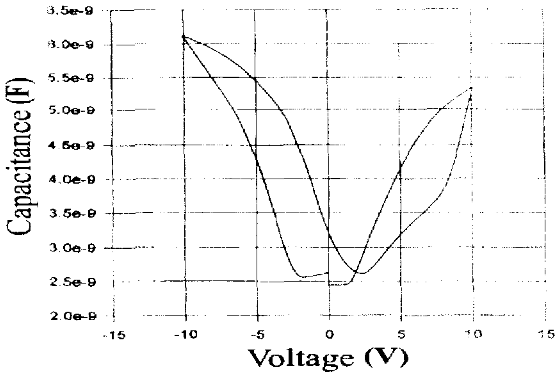


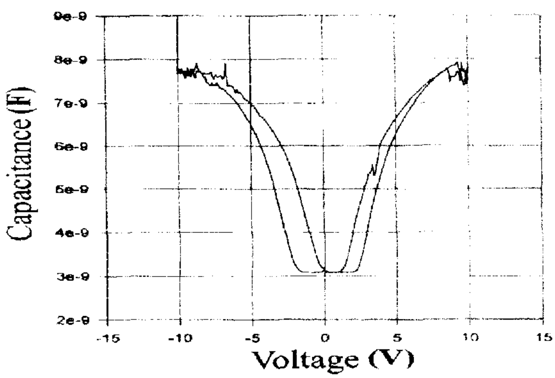
FIGURE 7. Response time characteristics of photo-aligned TN-LCD with polarized UV exposure of normal direction on the PM4Ch surfaces.

TABLE 2 Response times for photo- and rubbing-aligned TN-LCDs.

Time / Orientation Film	Rising time τ_r (msec)	Decay time τ_d (msec)	Response time τ (msec)
PM4Ch (30 sec)	10.7	13.1	23.8
PM4Ch (1 min)	10.9	13.0	23.9
PM4Ch (2 min)	10.0	12.6	22.6
Rubbed PI	8.4	26.0	34.4



(a) PM4Ch (30 sec)



(b) PM4Ch (2 min)

FIGURE 8 Voltage-capacitance characteristics of photo-aligned TN-LCD with polarized UV exposure of normal direction on the PM4Ch surfaces.

CONCLUSIONS

In conclusion, we have synthesized the photo-alignment material of PM4Ch. The EO performance for the photo-aligned TN-LCD, with polarized UV exposure of normal direction on the PM4Ch surface, was studied. Good thermal stabilities of synthesized PM4Ch are obtained by TGA measurement. We had the uniform alignment of the NLC by polarized UV exposure on the PM4Ch surface. Excellent V-T characteristics of the photo-aligned TN-LCD on the PM4Ch surfaces were obtained. Additionally, fast response times for photo-aligned TN-LCD on the PM4Ch surface were achieved. The reduction DC voltage of the photo-aligned TN-LCD decreases with increasing UV exposure time on the PM4Ch surface. Consequently, the reduction DC voltage depends on the alignment layer and cell conditions.

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