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Effects of the cinnamoyl group on liquid crystal aligning capabilities on PCEMA surfaces

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Four kinds of poly(4-methacryloyloxychalcone) (PCEMA) photo-alignment materials were synthesized. The effect of the cinnamoyl group on liquid crystal (LC) aligning capabilities and electro-optical characteristics of photo-aligned twisted nematic (TN) liquid crystal displays (LCDs) was investigated by photo-dimerization Uniform NLC alignment by linearly polarized UV exposure at normal incidence on the PCEMA surfaces having a high density of cinnamoyl groups was observed. Also, excellent voltage–transmittance (V–T) curves for the photo-aligned TN-LCDs on the PCEMA surfaces was achieved. We find that the V–T and response time characteristics can be improved by increasing the density of cinnamoyl groups.

1. Introduction

The rubbing process has been widely used to align LC molecules, giving appropriate characteristics such as high transparency, uniform alignment, and good thermal stability. The surface alignment effects in a nematic liquid crystal NLC on various polyimide layers by unidirectional rubbing has been demonstrated and discussed by many investigators [1–7]. However, the rubbing method has some problems, such as the generation of electrostatic charges and dust formation [7]. Thus rubbing-free methods for LC aligning are of interest in LCD technology. Photo-alignment methods using photodimerization have been proposed by many investigators [8–12]. Recently, we reported the synthesis of the photoalignment material poly(cinnamoyl ethylmethacrylate) (PCEMA) and the electro-optical (EO) performance for photo-aligned TN-LCDs on PCEMA surfaces [13]. More recently, we reported the LC aligning capabilities for photo-aligned TN-LCDs on poly(4-methacryloyloxychalcone) (PM4Ch) surfaces [14]. It is important to understand the stability, voltage–transmittance (V–T), and response time characteristics in such photo-aligned LCD devices. In this study, we report the effects of the cinnamoyl group on the LC aligning capabilities and EO performance for photo-aligned TN-LCDs with linearly polarized UV exposure at normal incidence on PCEMA surfaces using the photo-dimerization method.

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2. Experimental

Figure 1 shows the chemical structure of the PCEMA polymers used in this study; the table shows the PCEMA compositions. The molecular structure of the PCEMA used is similar to that previously reported [15]; we used the co-polymer having an OH group in this study. The PCEMA polymer was synthesized by the following method.

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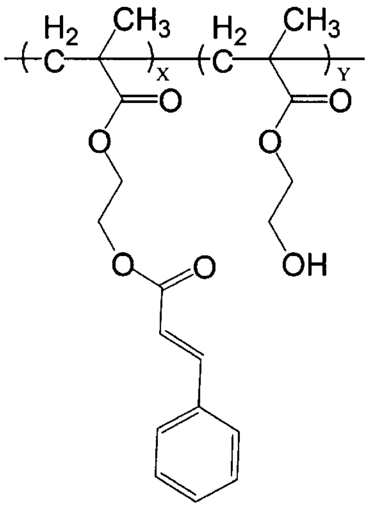

Figure 1. Chemical structure of the PCEMA polymers used in this study.

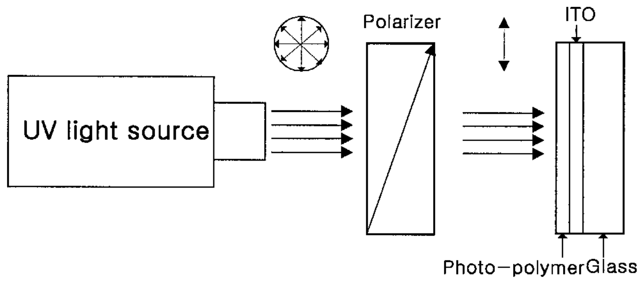

Figure 2. UV exposure system used.

Table. PCEMA compositions.

Polymer	X/%	Y/%
PCEMA-1	94	6
PCEMA-2	75	25
PCEMA-3	27	73
PCEMA-4	1	99

First, poly 2-hydroxyethyl methacrylate (P-HEMA) was dissolved in DMF. Cinnamoyl chloride and pyridine, 100, 80, 30 and 1% mol amount of hydroxy group of P-HEMA, was dissolved in DMF dropped using a dropping funnel, respectively. After reacting for 24 h at rt, the polymer was precipitated by adding excess methanol; the crude polymer was purified by reprecipitation with methanol from chloroform solution, and finally dried under vacuum (50°C). We find from NMR analysis that the cinnamoyl group substitutes for 94, 75, 27 and 1% of the P-HEMA hydroxy group.

The polymers were spin-coated onto indium tin oxide (ITO) coated glass substrates and were cured at 150°C for 1 h; the thickness of the polymer layer was 400 Å. To measure the EO characteristics, the photo-aligned TN-LCDs were assembled with linearly polarized UV exposure at normal incidence on the PCEMA surfaces. The UV exposure system is shown in figure 2. The linearly polarized UV source was a 500 W Xe lamp; the substrates were exposed to UV at a wavelength of 365 nm. The LC layer used was 5 μm thick; the NLC used was a fluorinated type mixture (Merck, $T_c = 87°C$). Measurements of the V–T curve and response time for the photo-aligned TN-LCD were made at room temperature.

3. Results and discussion

Photomicrographs for the photo-aligned TN-LCDs with linearly polarized UV exposure at normal incidence on four kinds of the PCEMA surface are shown in figure 3. It is seen that monodomain alignments of the NLC were observed on PCEMA-1 and PCEMA-2 surfaces. But reverse tilt disclinations of the NLC were observed on the PCEMA-3 and PCEMA-4 surfaces. It is considered that the uniform alignments were observed on PCEMA surfaces having a high level of cinnamoyl group. Also, the LC alignment capabilities for the NLC decreased with increasing OH group on the PCEMA surfaces. Consequently, the LC aligning capabilities of the NLC can be attributed to the quantity of cinnamoyl group on the PCEMA surfaces formed by photo-dimerization.

Figure 4 show the V–T characteristics for photo-aligned TN-LCDs on four kinds of PCEMA surface. Good V–T curves for the PCEMA-1 and PCEMA-2 surfaces for all UV exposure times were observed. Also, excellent V–T curves on the PCEMA-1 and PCEMA-2 surfaces for 1 min exposure were obtained. However, poor V–T curves on the PCEMA-3 and PCEMA-4 surfaces were observed for all UV exposure times. From these results, we suggest that the V–T characteristics of photo-aligned TN-LCDs can be improved by a higher level of cinnamoyl group.

The response time characteristics of photo-aligned TN-LCDs with linearly polarized UV exposure at normal incidence on four kinds of PCEMA surface are shown in figure 5. Stabilized response time characteristics on the PCEMA-1 and PCEMA-2 surfaces were observed as shown in figures 5 (*a*) and 5 (*b*), respectively. But poor response time characteristics on the PCEMA-3 and PCEMA-4 surfaces were observed as shown, respectively, in figures 5 (*c*) and 5 (*d*). The backflow bounce effects of

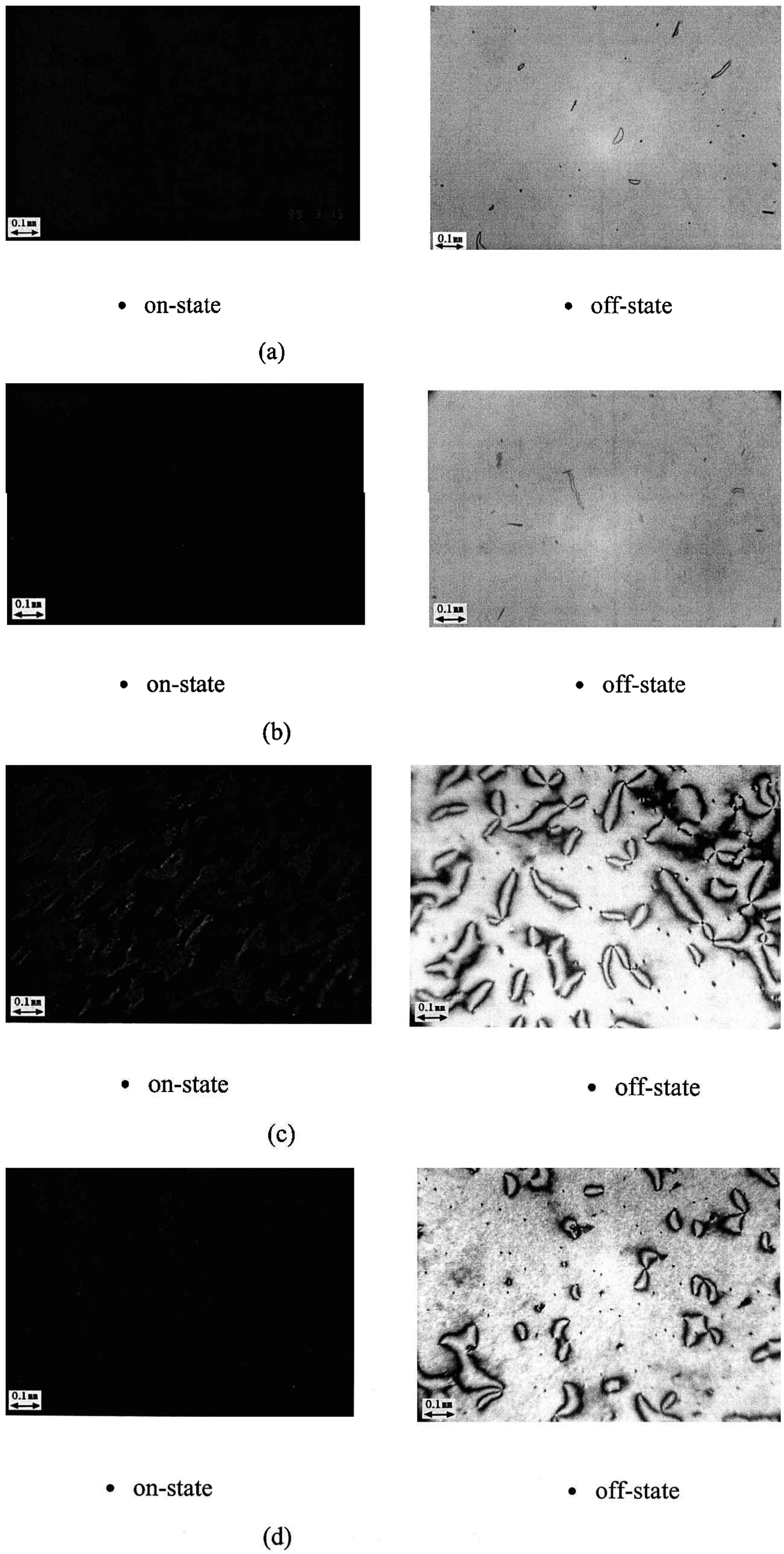

Figure 3. Photomicrographs for photo-aligned TN-LCDs with linearly polarized UV exposure at normal incidence on four kinds of PCEMA surface (crossed Nicols). (*a*) PCEMA-1, (*b*) PCEMA-2, (*c*) PCEMA-3, (*d*) PCEMA-4; all 1 min exposure.

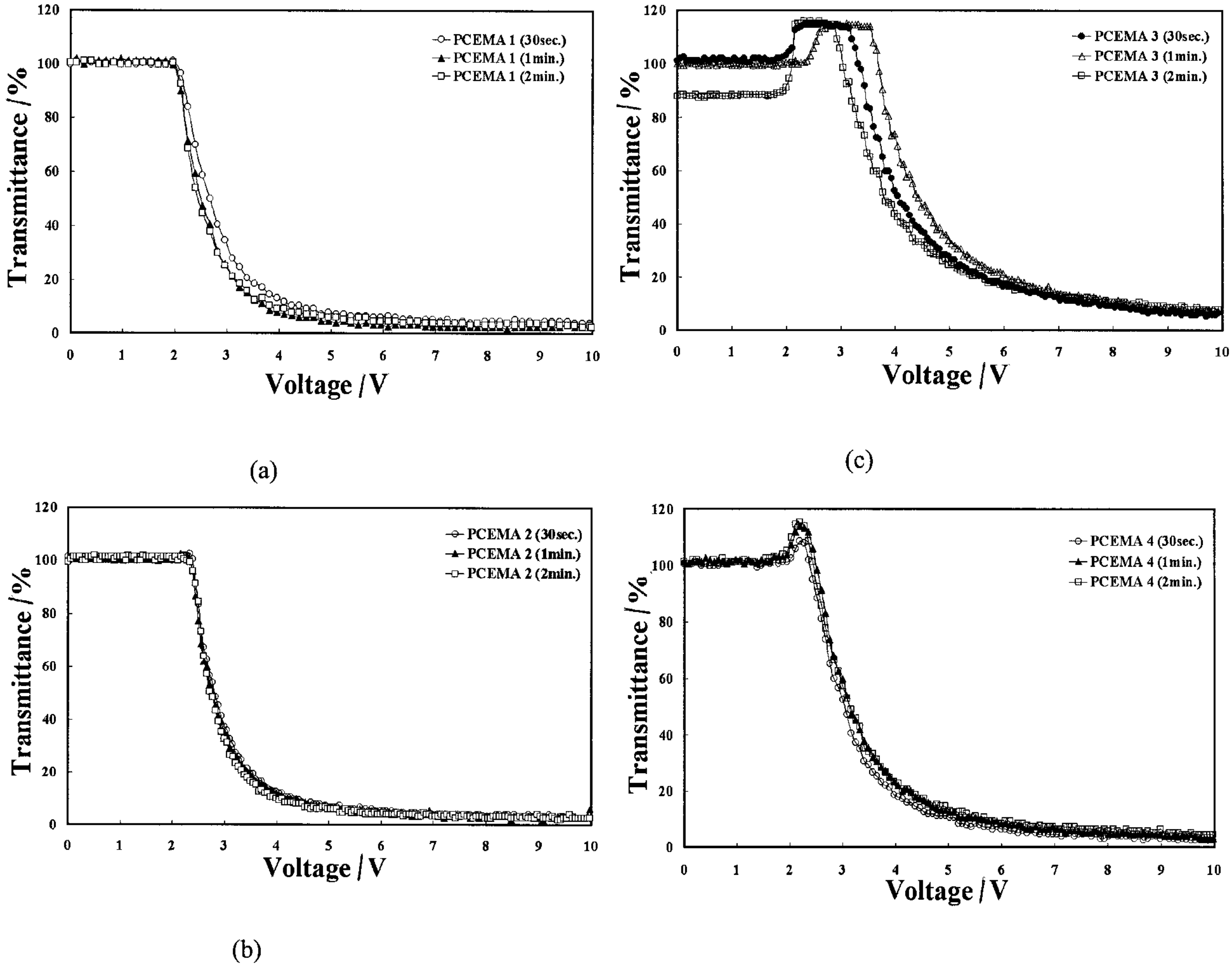

Figure 4. *V–T* characteristics for photo-aligned TN-LCDs with linearly polarized UV exposure at normal incidence on four kinds of PCEMA surface. (*a*) PCEMA-1, (*b*) PCEMA-2, (*c*) PCEMA-3, (*d*) PCEMA-4.

the response time are clearly observed. It is likely that low LC aligning capability influences the backflow bounce behaviour of the response times. Therefore, stable response times for photo-aligned TN-LCDs with UV exposure on PCEMA surfaces can be attributed to uniform alignment of the NLC by high levels of cinnamoyl group.

4. Conclusions

The effect of the cinnamoyl group on LC aligning capabilities and EO characteristics for photo-aligned TN-LCDs on four kinds of PCEMA surface were investigated by photo-dimerization. Monodomain alignments of the NLC for photo-aligned TN-LCDs with linearly polarized UV exposure at normal incidence on PCEMA surfaces having large amounts of cinnamoyl group were observed; these surfaces also gave excellent *V–T* characteristics. Reverse tilt disclinations for photo-aligned TN-LCDs on the PCEMA surfaces having much OH group were observed, and gave poor *V–T* curves. It is considered that the *V–T* characteristics for the photo-aligned TN-LCD with polarized UV exposure on PCEMA surfaces can be improved by increasing the amount of cinnamoyl group.

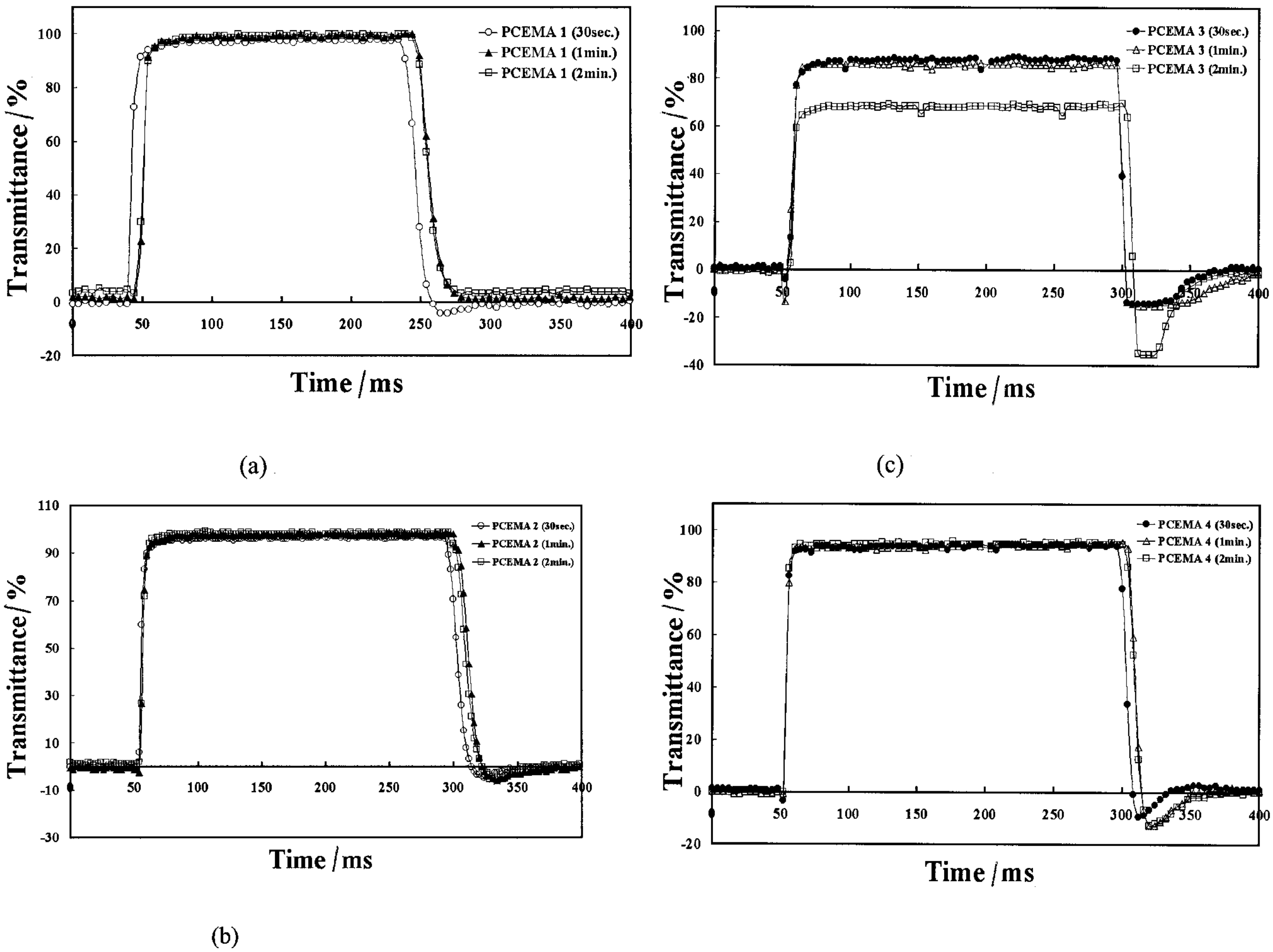

Figure 5. Response time characteristics of photo-aligned TN-LCDs with linearly polarized UV exposure at normal incidence on four kinds of PCEMA surface. (*a*) PCEMA-1, (*b*) PCEMA-2, (*c*) PCEMA-3, (*d*) PCEMA-4.

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