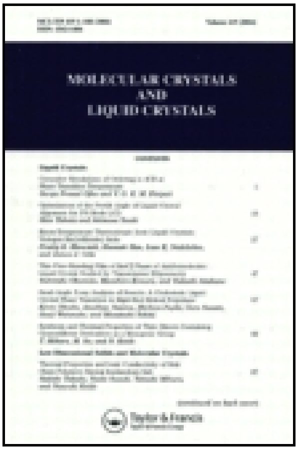

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The Effects of Conditions for Polymerization Induced Phase Separation Processes on the Electro-optic Characteristics of Polymer Dispersed Liquid Crystals

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The Effects of Conditions for Polymerization Induced Phase Separation Processes on the Electro-optic Characteristics of Polymer Dispersed Liquid Crystals

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The electro-optic properties of PDLC films were investigated by process conditions such as PDLC injection temperature, UV curing temperature and UV power. The mixture of liquid crystal (TL205) and the prepolymer substituted 1,6-hexanediol diacrylate (HDDA) for trimethylolpropane triacrylate (TMPTA), and the crosslinker in PN393 was used for PDLC formulation. The contrast ratio and driving voltage of PDLC films were mainly affected by UV curing temperature, rather than by the injection temperature. The film that was prepared at a relatively low UV process temperature revealed a good contrast ratio at a low driving voltage.

Keywords: driving voltage; electro-optic properties; flexible display; microdisplays; PDLC; UV process temperature

INTRODUCTION

Recently great attention has been paid to the fabrication of devices using Polymer Dispersed Liquid Crystals (PDLCs) because of their potential applications. Some of their possible applications include smart windows, microdisplays and flexible displays [1–3]. The optical principle of PDLCs is based on the scattering of light, rather than the polarization of light as is the case of other LC technologies [4,5]. PDLCs consist of a thin film of polymer that contains micro-droplets

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of liquid ctystal [6]. The transparency of PDLCs can be altered by external electric fields, which can control the extent of the mismatch of refractive indices between the liquid crystal and polymer matrix. That is, the birefringent liquid crystal droplets form light scattering centers and their scattering properties, caused by the mismatch of refractive indices, can be switched on and off by applying an electric field across the film. The detailed electro-optical properties of PDLC films mainly depend on the chemical nature of the polymer and LC as well as the preparation conditions, which result in different interface environments between the LC and polymer. LCs inside the droplets will experience different constraints under different interface environments (different droplet sizes and morphology).

In industrial processes of TFT LCD production an alignment layer has to be coated on a glass substrate and rubbed to align the polymer. Also, most of the LCD displays need a polarizer that absorbs much of the transmitted light, thus reducing the brightness. But PDLCs represent the electro-optic composites working in the light scattering mode of the alignment layer, and therefore, the rubbing process and polarizer is not required. In spite of these advantages, PDLC must be applied to a thick film to have the low contrast ratio. Therefore, a high driving voltage is required. The purpose of this research is to

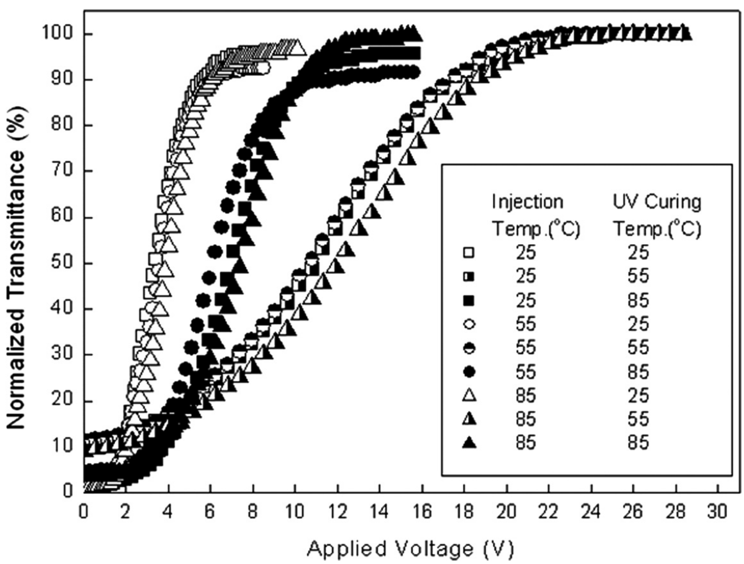


FIGURE 1 The V-T characteristics of PDLC film at the various process temperatures.

improve the contrast ratio and reduce the driving voltage problem by developing and optimizing the process conditions in PDLC formulation.

EXPERIMENTAL

The PDLC systems were prepared by the polymerization-induced phase separation process. The prepolymer consisted of a monomer, a crosslinker, a photo initiator and resin. 2-ethylhexyl acrylate (EHA) was used as the monomer, and Darocur4265 (Ciba, Inc.) was used as a photo initiator. HDDA was substituted for TMPTA, the crosslinker in PN393. The LC was a eutectic mixture of liquid crystals, commercially available as TL205 (Merck, Ltd.). The PDLC formulation was prepared by mixing TL205 (80 wt%) with the prepolymer (20 wt%)

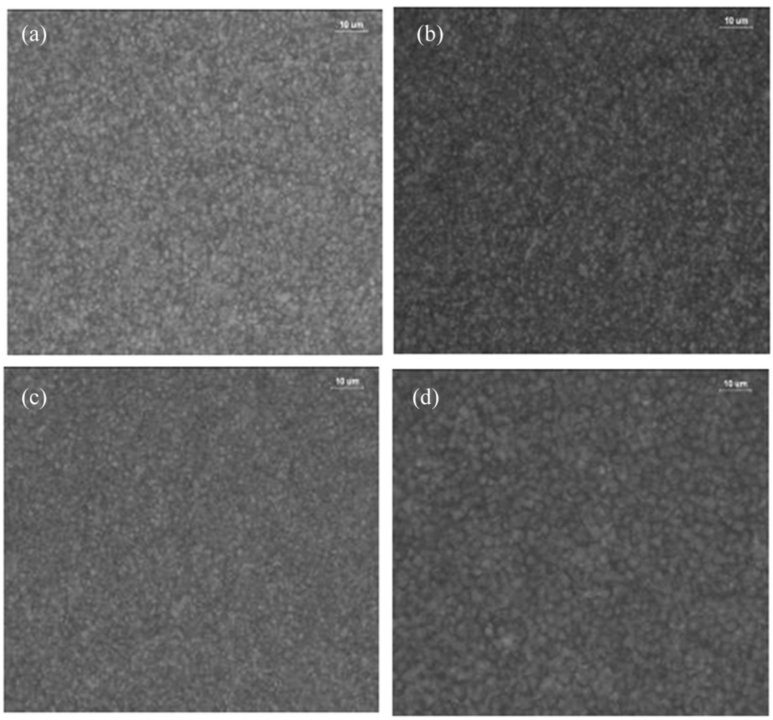


FIGURE 2 The dependence of the PDLC morphology on UV curing temperature. Injection, curing temperature and droplet radii are (a) 25°C, 25°C, 1.05 μm; (b) 85°C, 25°C, 1.15 μm; (c) 25°C, 55°C, 1.20 μm; and (d) 25°C, 85°C, 1.85 μm respectively.

homogeneously. The mixture was injected into two ITO coated glasses spaced at 6 μm and cured by an UV irradiation of 365 nm.

RESULTS AND DISCUSSION

Voltage-transmittance (V-T) characteristics were measured using a He-Ne laser and a photodetector at 25°C. Figure 1 shows the transmittance of PDLC film with various injection and UV curing temperature.

The driving voltage is generally chosen as V_{on}, and the threshold voltage is usually defined as V_{th}. Expressions for the V_{on} and V_{th} are given by [7,8]

$$V_{\rm on} = \frac{d}{R}\sqrt{L^2 - 1}\sqrt{\frac{4\pi K}{\Delta\varepsilon}} \tag{1}$$

$$V_{\rm th} = \pi\sqrt{\frac{K_1}{\Delta\varepsilon}} \tag{2}$$

where R is the average droplet radius, $L = R_2/R_1$ is the droplet aspect ratio, d is the cell gap, K is an elastic constant, K_1 is an elastic spray

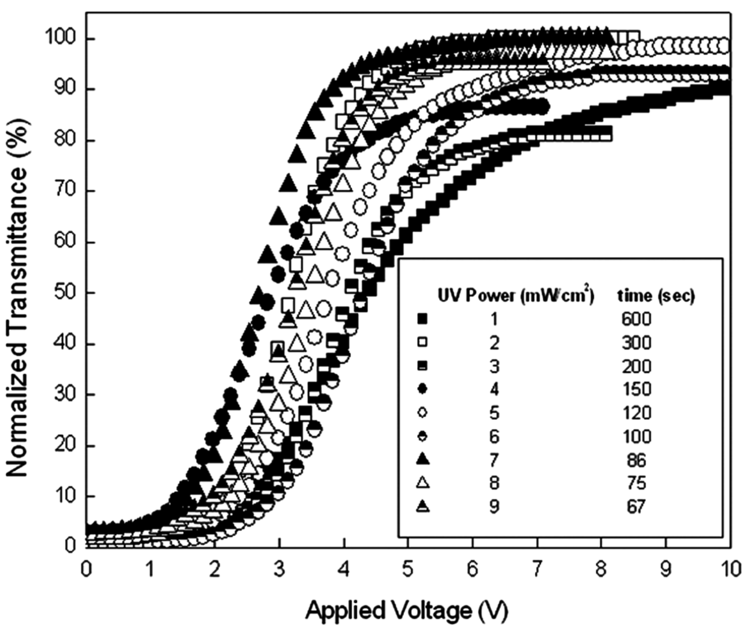
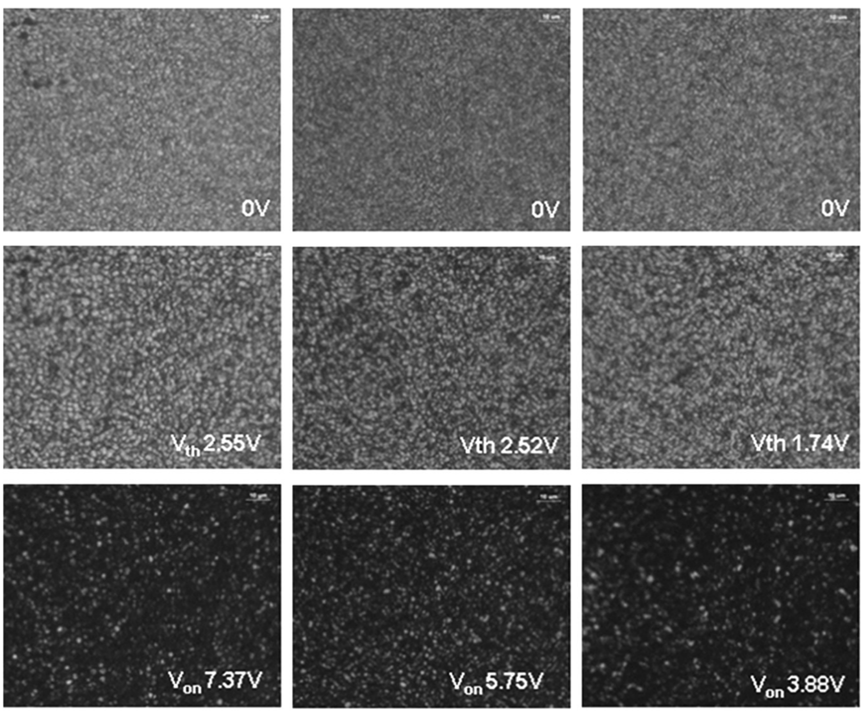


FIGURE 3 The V-T characteristics of PDLC film at various UV power levels.

constant, ε_0 is the LC dielectric permittivity and $\Delta\varepsilon$ is the LC dielectric anisotropy. It is known that the elastic constant K_i ($i = 1, 2, 3$) associated with the splay, twist, and bend elastic deformations has the same temperature dependences.

The electro-optic characteristics showed a relatively low V_{on} ($5.11 \sim 5.64$ V) and V_{th} ($1.93 \sim 2.09$ V) at a 25°C UV curing temperature, and a relatively high V_{on} ($17.75 \sim 18.88$ V) and V_{th} ($4.87 \sim 5.28$ V) at a 55°C UV curing temperature. On the other hand, the effect of the injection temperature was less. While the injection temperature had fewer electro-optic characteristics, the UV curing temperature greatly influenced the results. Even if there was a change to the injection temperature in equal UV curing temperature conditions, the LC droplet radii had similar size. However, in equal injection temperatures, the LC droplet radii increased according to the UV curing



(a) (b) (c)

FIGURE 4 The dependence of the PDLC morphology on UV power. UV power conditions and droplet radii are (a) 1 mW/cm^2, 1.22 µm; (b) 5 mW/cm^2, 1.20 µm; and (c) 7 mW/cm^2, 1.09 µm at a 25°C UV curing temperature.

temperature (Fig. 2). Accordingly, as the LC droplet radius increases, V_{on} must decrease, as shown in Eq. (1). But this experiment actually showed opposite results. This behavior could be due to the larger fraction of droplets that are in contact with the electrodes and are consequently deformed. Also, the degree of polymerization and polymer properties changed according to the UV curing temperatures, and therefore, anchoring energy changes in the interface between the LC and the polymer, and V_{on} changes by elastic constant change.

Figure 3 shows the transmittance of PDLC film with the various UV power levels. UV power changed from 1 to 9 mW/cm^2, and the energy became 600 mJ by controlling time. The electro-optic characteristics changed according to the UV power, but the LC droplet radii had similar sizes (Fig. 4). These results were anchoring energy change, caused by the polymerization change.

CONCLUSIONS

PDLC film was prepared with TL205 and the prepolymer substituted HDDA for TMPTA, the crosslinker in PN393. From this investigation, the UV curing temperature affected the electro-optic characteristics among the polymerization process parameter. Optimum PDLC process conditions were a 25°C UV curing temperature and a 7 mW/cm^2 UV power. In these conditions, the PDLC films showed a good contrast ratio (34:1) and a relatively low driving voltage (3.88 V).

REFERENCES

[1] Crawford, G. P. & Zumer, S. (1996). *Liquid Crystals in Complex Geometries*, Taylor & Francis: London.

[2] Armitage, D., Underwood, I., & Wu, S.-T. (2006). *Introduction to Microdispalys*, Wiley: Chichester, UK.

[3] Crawford, G. P. (2005). *Flexible Flat Panel Displays*, Wiley: Chichester, UK.

[4] Yang, D.-K. & Wu, S.-T. (2006). *Fundamentals of Liquid Crystal Devices*, Wiley: Chichester, UK.

[5] Lueder, E. (2001). *Liquid Crystal Displays*, Wiley: Chichester, UK.

[6] Drzaic, P. S. (1995). *Liquid Crystal Dispersions*, World Scientific Publishing: Singapore.

[7] Amundson, K. (1996). *Phys. Rev.*, *E53*, 2412.

[8] de Gennes, P. G. & Prost, J. (1993). *The Physics of Liquid Crystals*, Oxford University Press: New York.