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The effect of the resultant microphase-separated structures of polymer matrices on the electro-optical properties of polymer dispersed liquid crystal films by Iniferter polymerization

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ABSTRACT

Iniferter polymerization was employed to prepare polymer dispersed liquid crystal (PDLC) films and an additional photoinitiator was introduced to induce the phase separation of polymer matrices themselves on the process of preparing the PDLC. The effect of the polymerization kinetics and the resultant microphase-separated structures of polymer matrices on the electro-optical properties of PDLC films were studied. It was found that the bigger length scale of phase separation of polymer matrices induced strong light-scattering resulting in low ON-state transmittance. And faster polymerization kinetic induced higher threshold and saturation voltages.

Polymer dispersed liquid crystals (PDLCs) have been extensively studied as promising candidate new materials for application in the field of electro-optical devices, such as optic shutters, smart windows, optical sensors, memories and flexible display devices [1–9]. They can be optically switched from a highly light scattering opaque state (OFF-state) to a transparent one (ON-state) under voltage regulation due to the mismatching and matching of the refractive indices of the polymer and the voltage-depending oriented liquid crystals [9].

Since the original report of these materials, researchers have focused on correlating PDLC morphology to seek optimized performance such as high ON-state transmission, low OFF-state transmission, and low switching voltage [8,9]. PDLCs are often formed through polymerization induced phase separation (PIPS), in which a polymerization initially occurs in an isotropic homogeneous mixture of liquid crystals and prepolymer [9]. In general, the morphology is controlled by relative rates of phase separation, which depends on a number of factors such as liquid crystal concentration, polymerization kinetics, and polymer composition [3,4,9]. Especially, polymerization kinetics has the paramount effect on the morphology of PDLC. Usually, under a higher polymerization rate, smaller droplets are formed. On the other hand, polymer matrix as an important component of PDLC films has great influence on the electro-optical properties. Wu et al. reported that the electro-optical response was greatly dependent on the ratio of the refractive index of polymer and the ordinary refractive index of liquid crystal, and the high ON-state transmittance could be obtained by matching the refractive index of the matrix with that of liquid crystal [10]. Cupelli et al. showed that the electro-optical properties of PDLC films could be improved by fine adjustment of conductivity in polymer matrices. A large reduction in the reorientation fields was observed when a low percentage of conductive polymers were doped into the matrix [11]. Kim et al. showed the composition of polymer had a great effect on the properties of PDLC films; they and Senyurt showed the low glass transient temperature resulted in low switching voltage [12–14]. Ono, Jeong et al. and our

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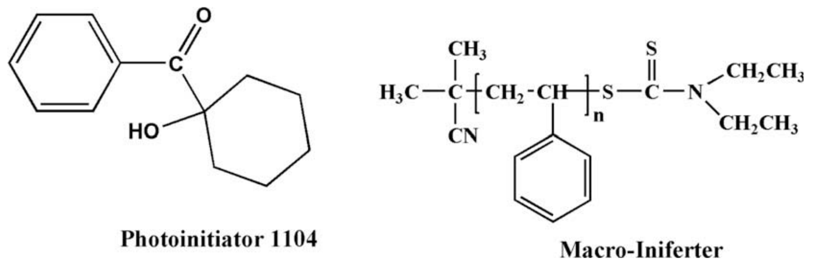

Fig. 1. Chemical structures of the photoinitiator 1104 and macro-Iniferter.

Table 1
The composition and polymerization result of samples.[a]

No.	MI type[b]	RI[c]	1104[d] (wt%)	T_{OFF} (%)	T_{ON} (%)
1	MI2	1.5339	0.05	14.3	75
2	MI2	1.5355	0.1	13.4	71.1
3	MI2	1.5358	0.5	7.1	53.2
4	MI2	1.5379	1	5.3	46.2

[a] All prepolymer mixtures consist of MI and MA (15:85 in weight); liquid crystal: prepolymer = 50:50 (in weight).
[b] All the samples could be marked by MI used, i.e. 1-MI1, 1-MI2, 1-MI3 etc. For MI1: M_n = 7100; PDI = 1.16. For MI2: M_n = 10,200; PDI = 1.18. For MI3: M_n = 20,200; PDI = 1.14.
[c] The refractive indices of the resultant polymer matrix were measured using an Abbe refractometer at room temperature.
[d] The photoinitiator, 1104, was added additionally in wt% of MA.

recent work showed that the size of liquid crystal droplet in PDLC films was strongly dependent on the molecular weight of polymer matrix; the high molecular weight resulted in small droplets, which induced the high driving voltage [15–19]. Additionally, the role of the initiator on the properties of PDLC prepared by conventional radical polymerization is well known. However, the influence of the initiator on the performance of PDLC prepared by not conventional radical polymerization but Iniferter polymerization (one of living radical polymerization) has rarely been investigated. On the other hand, to the best knowledge of the authors, the effect of the microphase-separated structures of polymer matrices themselves on the electro-optical properties of PDLC film has not been involved so far. In this letter, Iniferter polymerization was employed to prepare PDLC films and an additional photoinitiator was introduced to induce the phase separation of polymer matrices themselves on the process of preparing the PDLC. The effect of the polymerization kinetics and the resultant microphase-separated structures of polymer matrices on the electro-optical properties of PDLC films were studied.

The nematic liquid crystal E7 (n_o = 1.521, Δn = 0.22, $T_{N\text{-}I}$ = 60 °C) was obtained from Shi Jia Zhuang Crown Display Material Co., Ltd. Styrene (St) and methyl acrylate (MA) (98%) were passed through a column of silica to remove inhibitors. A set of macro-Iniferters (MIs) shown in Fig. 1 was synthesized according to the procedures reported [20]. For MI1: M_n = 7100; PDI = 1.16, yield: 75%. For MI2: M_n = 10,200; PDI = 1.18; yield: 85%. For MI3: M_n = 20,200; PDI = 1.14, yield: 80%. The prepolymer was obtained by dissolving the MI in MA with a constant weight ratio (15:85) and amounts of the photoinitiator (1104, Changzhou LanDing Sci-Tech. Co., Ltd.) were varied (the detail shown in Table 1). PDLC films were prepared by

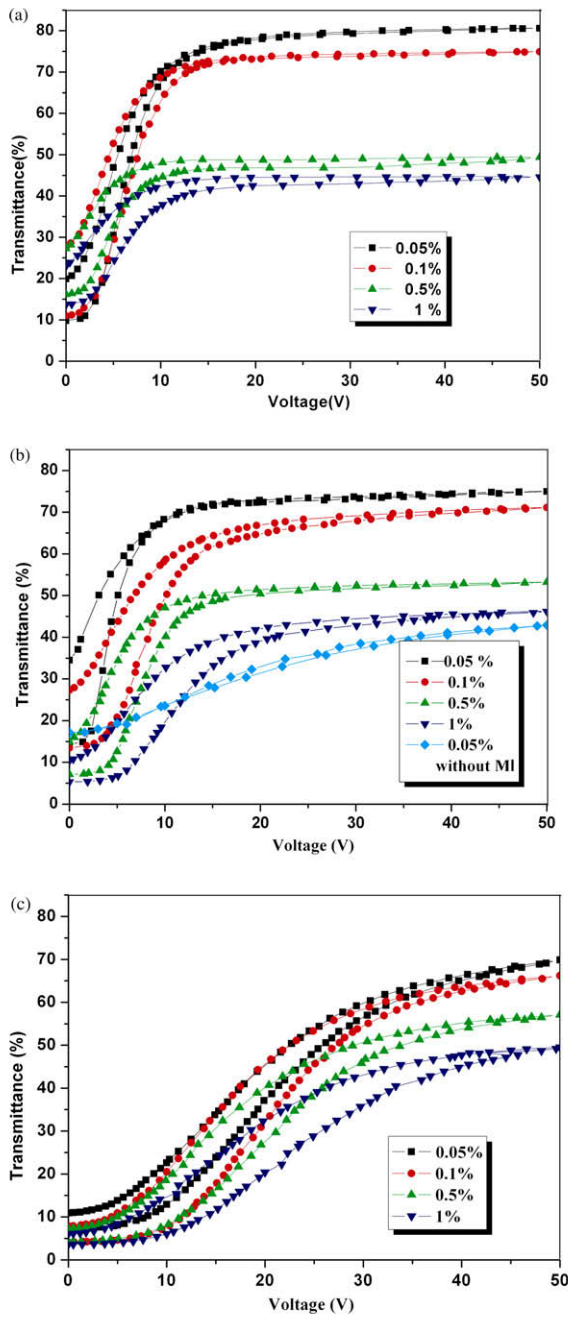

Fig. 2. The electro-optical response in of PDLC film with as a function of different amounts of the initiator 1104: (a) MI1, (b) MI2, and (c) MI3.