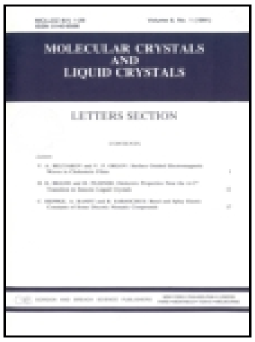

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Investigation of the Electro-optical Dynamics of a Polymer-Dispersed Liquid Crystal Based on a Bisphenol A Diglycidyl Ether

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A polymer-dispersed liquid crystal based on a biphenol A diglycidyl ether (E-44) and 4-pentyl-4′-cyanobiphenyl was prepared by a method of polymerized-induced phase separation. Electro-optical transmissions of the biphenol-A epoxy resin dispersed liquid crystal were measured as a function of applied alternating voltage over a range of 0–90 V for a liquid crystal cell gap of about 20 μm. Influences of heat treating time and content of firming agent on the electro-optical transmissions of the biphenol A diglycidyl ether dispersed liquid crystal were discussed.

Keywords Electro-optical; liquid crystal; phase separation; polymerized-induced

1. Introduction

Recently, the fabrication of polymer-dispersed liquid crystals (PDLCs), for switchable windows without polarizers or alignment films, random lasers, and liquid crystal displays, has become of increasing interest [1–3]. The PDLC is a kind of optical functional material, where liquid crystal phases or droplets are randomly distributed inside polymer matrixes. When the PDLC film is assembled into the gap between two parallel indium tin-oxide (ITO)-coated glasses, the transmittance is sensitive to applied electrical field. It is due to the variation of liquid crystal director, which is changed from randomly distributed orientation to uniformly distributed orientation by applied electrical field. The performance of a PDLC cell depends strongly on the microstructures, chemical and physical properties of polymer matrixes, which manipulate the shape, size, and director configuration of the embedded liquid crystal droplets.

Considerable kinds of polymer matrixes have been used for PDLC films, such as poly(methyl methacrylate-co-butyl acrylate), poly(methyl methacrylate), NOA65, polyacrylonitrile, and E-51 biphenol-A epoxy resin [4–9]. Of all these polymer matrixes, the bisphenol-A epoxy resin with two phenol functional groups, has received attention owing to their excellent chemical and physical properties, such as electric insulation, resistant to corrosion and adhesion to ITO glasses used in the PDLC cells.

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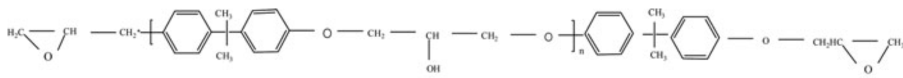
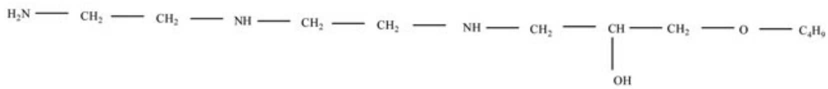


(a)



(b)

Figure 1. Structure formula of regents used. (a) E-44 epoxy resin and (b) 593B firming agent.

Here, we report the preparation of a new kind of bisphenol A diglycidyl ether (E-44) dispersed 4-pentyl-4′-cyanobipheynyl (5CB) nematic liquid crystal. We studied the morphological characteristics and the effect of heat treating time and content of 593B firming agent on the electro-optical dynamics by optical microscopy and measurement of the response for the transmittance. In the system, the PDLC films were fabricated by the method of polymerization induced phase separation.

2. Experimental

2.1 Sample Preparation

The 5CB nematic liquid crystal was purchased from Crown Chemical Reagent Co., Ltd, P. R. China. The biphenol A diglycidyl ether used was E-44 (epoxy values of about 0.44 mol/100g), purchased from Helin Resin Co., Ltd, P.R. China. The firming agent used was 593B, which was a kind of aromatic amine. The structures were shown in Fig. 1. The biphenol A diglycidyl ether was heat treated with differing amounts of 593B firming agent. All the chemical regents were used as received, without any purification.

The detail preparation process for the E-44 based PDLC film was shown schematically in Fig. 2. The reactive mixture was prepared by mixing E-44 epoxy resin and 593B firming agent uniformly with different weight proportions of 3:1, 4:1 and 5:1, respectively. After the reactive mixture was stirred vigorously, 40 wt% content of 5CB nematic liquid crystal was introduced into the above reactive mixture. Then, the reactive mixture was transferred into the ITO glasses for hardening with different heating times and observation with optical microscope.

To create the PDLC cells, the as prepared reactive mixture composed by E-44 resin, 593B, and 5CB was introduced into the gap between two glass substrates covered with ITO. The thickness between the two ITO glass slides was controlled using thermal sealing films with a thickness of about 20 um. Then, the PDLC cell was heat treated at 50°C in an oven for different times.

2.2 Characteristics of the Electro-optical Properties

The electro-optical properties of the prepared PDLC cells were studied in term of transmission changes with an applied alternating current electric filed. A 2 mW He-Ne laser (632.8 nm) without any polarizer was used as a probing beam. The PDLC cell was placed

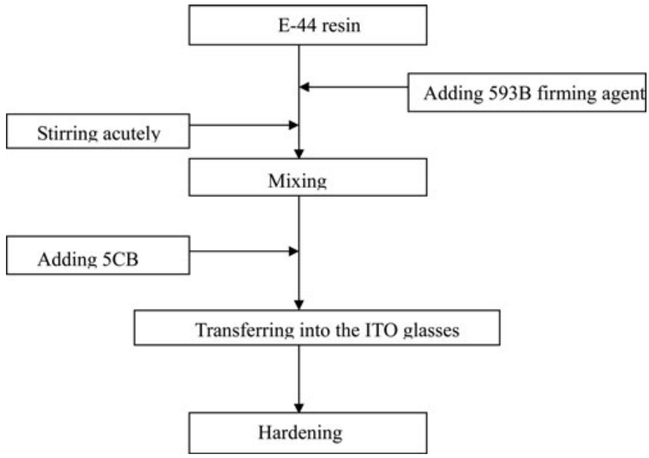


Figure 2. Schematic illustration of the preparation process used for the polymer dispersed 5CB liquid crystal based on E-44 epoxy resin.

between the He-Ne laser and a ready-to-use high-speed photo-detector (Thorlabs DET10A, USA). The transmitted light without any polarizer was measured by the photo-detector. An ac electric field was provided by a homemade power source. The detector was connected to a digital oscilloscope (Tektronix TDS1001B-SC, USA). The PDLC cells were driven by a sinusoidal voltage with a frequency of 1 kHz.

3. Results and Discussion

The electro-optical properties of the polymer dispersed 5CB liquid crystal based on E-44 epoxy resin were greatly dependent on the heat treating time and the content of 593B firming agent. We measured the electro-optical responses of the E-44 epoxy resin based PDLC cell with different heating times and content proportions between E-44 epoxy resin and 593B.

Figure 3 shows the response of the transmittances at various voltages in the E-44 epoxy resin based polymer dispersed 5CB liquid crystal with different heating times, which were tested by applying alternate voltage to the ITO glasses. These PDLC cells, in which 40 weight percent of 5CB liquid crystal was embedded, were hardened at 50°C for 0.5, 3, and 10 hr, respectively. The proportion between E-44 epoxy resin and 593B was 5:1. As can be seen from Fig. 3, all the transmittance curves increased slowly with applied electrical field, then increased rapidly, after which they reached a maximum transmittances. For the PDLC cells hardened for 0.5, 3, and 10 hr, they had maximum saturation transmittances of about 80%, 70%, and 60%, respectively. The results also indicated that the operating voltages for the three PDLC cells hardened for 0.5, 3, and 10 hr were about 10 V, 12 V, and 30 V, respectively. These results showed that there were different responses of the transmittance for different heating times. Regarding the operating voltage and transmittance, the optimal heating time was about 0.5 hr.

Figure 4 shows the response of the transmittance at various voltages in the E-44 epoxy resin-based polymer-dispersed 5CB liquid crystal with different weight proportions between E-44 epoxy resin and 593B firming agent. These PDLC cells, in which 40 wt% of 5CB was embedded, were heat treated at 50°C for 10 hr. All the three PDLC cells showed

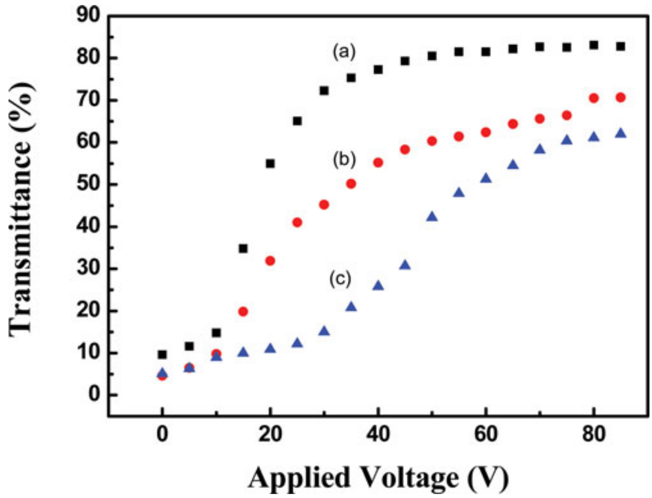


Figure 3. Transmittance at various voltages in E-44 epoxy resin-based polymer-dispersed 5CB liquid crystal with 5:1 proportion between E-44 epoxy resin and 593B for different heating times. (a) 0.5, (b) 3, and (c) 10 hr.

higher transmittance than those in their initial states. The transmittance of the PDLC cell with 5:1 proportion between E-44 epoxy resin and 593B showed a lower operating voltage of about 30 V. However, the operating voltages of the transmittance for the PDLC cells with 4:1 and 3:1 proportions were 40 and 50 V, respectively. Under the operating voltage, the transmittance of the PDLC cells increased slowly, after which the transmittance increased sharply. The PDLC cell with 5:1 proportion exhibited the best electro-optical performance than that with 4:1 and 3:1 proportions. The reason for this was that when increasing the

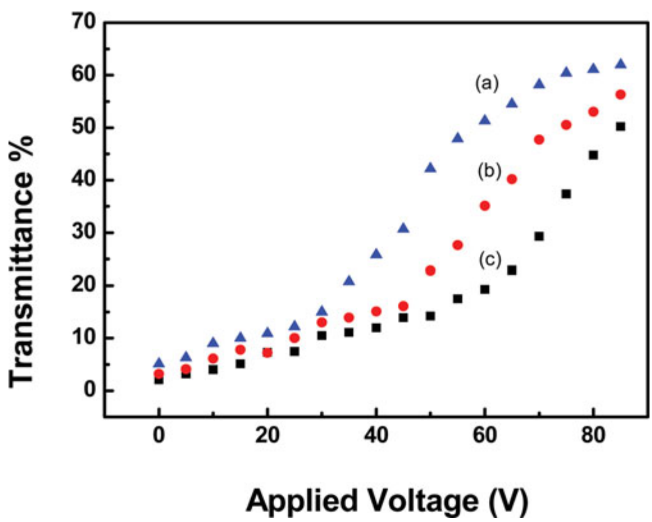


Figure 4. Transmittance at various voltages in E-44 epoxy resin-based polymer-dispersed 5CB liquid crystal with different contents of 593 B firming agent. (a) 5:1, (b) 4:1, and (c) 3:1.

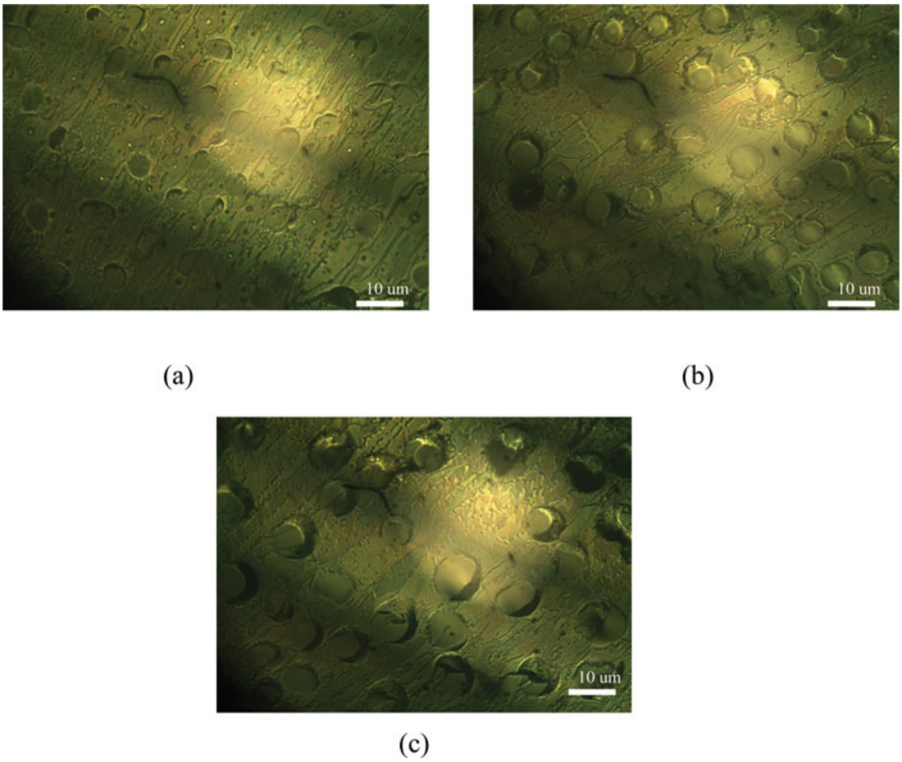


Figure 5. Optical microscope photographs of the E-44-based polymer-dispersed 5CB liquid crystal with different contents of 593 B firming agent (100X). (a) 3:1, (b) 4:1, and (c) 5:1.

proportion of the 593B firming agent, the reaction speed of the E-44 epoxy resin was speeded. This would decrease the droplet size of the 5CB liquid crystal embedded inside the E-44 polymer matrix.

It is well known that when there is no other impressed field to the PDLC films embedded with spherical liquid crystal droplets, the required reorientation electrical field (E) dependence of the radius of spherical liquid crystal droplet (R) can be described by [10]:

$$E_{th} \propto \frac{1}{R}\sqrt{\frac{k}{\Delta\varepsilon}},$$

where R is the radius of spherical liquid crystal droplet, k is the liquid crystal elastic constant, and $\Delta\varepsilon$is the liquid crystal dielectric anisotropy. The different operating voltages for the three PDLC cells hardened for 0.5, 3, and 10 hr were resulted from different radius of spherical 5CB liquid crystal droplets. These could be demonstrated with observation results of optical microscopy, which was shown in Fig. 5. The 5CB liquid crystal content of the PDLC cells with 10 hr heat treating time were 40 wt%, in which different contents of 593B firming agent (3:1, 4:1, and 5:1) were used. The microcopy observation showed that the size of the 5CB liquid crystal droplets embedded in the E-44 epoxy resin based PDLC film decreased by increasing the proportion of 593B firming agent. The largest size of the 5CB liquid crystal droplets embedded in the PDLC film was found in the PDLC cell with 5:1 proportion. According to relation between the reorientation electrical filed with the radius of spherical liquid crystal droplets, we concluded that the operating voltage for the PDLC cell with 5:1 proportion was lower than that for the PDLC cell with 4:1 and 3:1 proportions. These were demonstrated in the response of the transmittance at various voltages in E-44 epoxy resin based polymer dispersed 5CB liquid crystal with different weight proportions between E-44 epoxy resin and 593B firming agent.

4. Conclusions

In conclusion, we have prepared a biphenol A diglycidyl ether (E-44) dispersed 4-pentyl-4′-cyanobiphenyl liquid crystal. We confirmed that the operating voltage for the transmittance of the PDLC becomes increased, when extending the heat treating time. By varying the proportion between E-44 epoxy resin and 593B firming agent in the reactive mixture, we can improve the response of the transmittance at various voltages.

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