

ICMCT-2014 [10th – 12th March 2014]
International Conference on Materials and Characterization Techniques

Electro-Optics of Homogeneously Aligned Nematic Liquid Crystals Stabilized by a Polymer Network

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Abstract: We have constructed composite films of homogeneously aligned nematic liquid crystal in a polymer network of photo-curable polymer NOA65. The orientation of liquid crystals was controlled by the polymer networks. The dimensions of the polymer networks and inter-polymer network distance were controlled by varying the monomer concentration in the composites. The effects of applied electric field on the optical transmittance and switching times of the films were measured with a polarized incident light. The experimental results are explained by the formed domain structure of the nematic phase in the polymer network. It was found that the electro-optical characteristics could be optimized by varying the monomer concentration forming micron-sized polymer networks stabilizing the nematic phase.

Keywords: PSLC, Electro-optical, PIPS.

Introduction and Experimental

Thin films of polymer and liquid crystal (LC) are potentially attractive for applications ranging from switchable windows to modern display devices [1-3]. One example is polymer-stabilized liquid crystal (PSLC) which exhibits anisotropic light scattering behaviour and can be used as variable optical attenuators, shutters and polarizers [4,5]. In PSLC, a monomer (generally <10 wt% of the system) is mixed with an LC host and then polymerized *in situ* within the LC phase, producing an anisotropic cross-linked polymer network. In voltage-OFF state, the polymer networks and LC molecules are homogeneously aligned. An applied voltage intends to align the LC material, while the polymer networks resist this orientation. A competition between the applied field and anchoring effects results in formation of multi-domain LC structures, leading to transmission changes through the device. The strength of the polymer-LC interaction is strongly related to the surface area of polymer network [6], which can be controlled by the monomer content. In this work, we fabricate PSLC cells using a nematic LC and a photo-curable polymer. The dimensions of network domains have been controlled by varying the monomer concentration. Electro-optical switching of the samples was studied with transmission changes under crossed polarizers.

To fabricate a PSLC cell, we mixed different concentrations (2%, 4% and 6%) of UV-curable polymer NOA65 (Norland, NJ) in a room temperature nematic liquid crystal E7 (E. Merck, Japan). The LC/polymer mixtures were injected into 6 μm thin empty cell with homogeneous alignment. The samples were then exposed to UV light (intensity $\sim 2\text{mW}/\text{cm}^2$, $\lambda = 354\text{ nm}$) to induce polymerization. The network formed was viewed

through a polarizing optical microscope (POM) (Olympus BX53, Japan). A He-Ne laser ($\lambda = 632.8$ nm) was used as a light source and the cells between crossed polarizers were driven by 50 Hz square waves to record the transmission changes.

Results and Discussion

Figure 1 shows the POM images of developed polymer networks in PSLC cells. The PSLC cells were split open and LC was extracted with methanol as described elsewhere [7]. A homogeneously formed cross-linked bright polymer networks are visible through crossed polarizers due to the residual birefringence of LC.

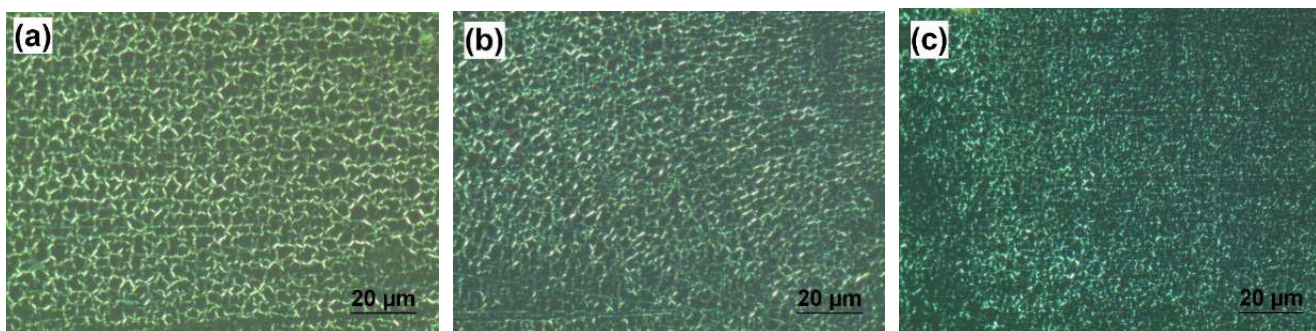


Figure 1. The observed morphologies of polymer networks in PSLC cells with polymer concentration a) 2 wt%, (b) 4 wt%, and (c) 6 wt% viewed at a magnification of 500X.

The lateral size of networks reduces and density increases with higher polymer content. Such a morphology facilitates a greater distortion in the planar ordering of LC and changes the transmission through the device. This is evident from the higher OFF-state transmission recorded for the PSLC cell with higher polymer content, as shown in Figure 2.

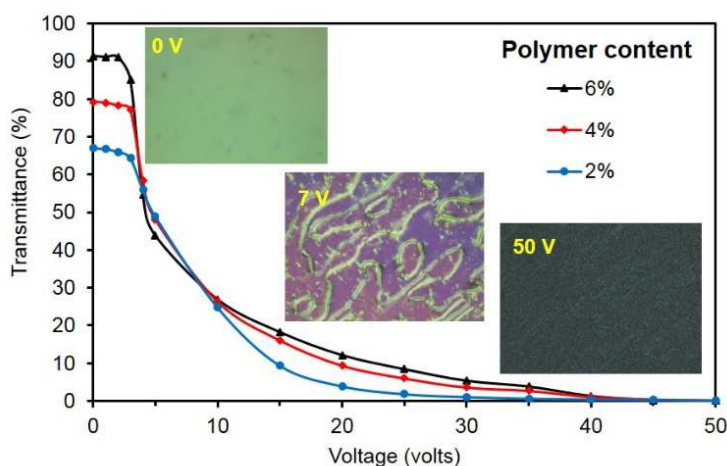


Figure 2. Applied field (Frequency = 50 Hz) dependent transmission of PSLC films under crossed polarizers. **Inset:** the POM textures of PSLC cell (6 wt% polymer) under applied field. The colour observed at 7 Volts is due to change in birefringence of LC.

On application of electric field, the LC orientation changes from planar to homeotropic state and the transmission decreases gradually for all the PSLC cells. It is seen that the decrease in transmittance is much rapid for film with least (2 wt%) polymer content mainly due to the less domain density resulting in a lesser anchoring interaction of LC molecules at the network interface. With higher network density (4 and 6 wt% polymer content), more elastic interactions between polymer networks and LC molecules compete with the strength of applied field. This forces the film to remain in original planar configuration and hence for a given value of applied field, PSLC cell with 6 wt% polymer shows a higher transmission. At higher values of applied field, the cells achieve a dark homeotropic state with the LC directors aligned perpendicular to the substrate surface, as shown in inset of Figure 2. Figures 3(a) and 3(b) shows the measured rise time and decay time of the PSLC cells.

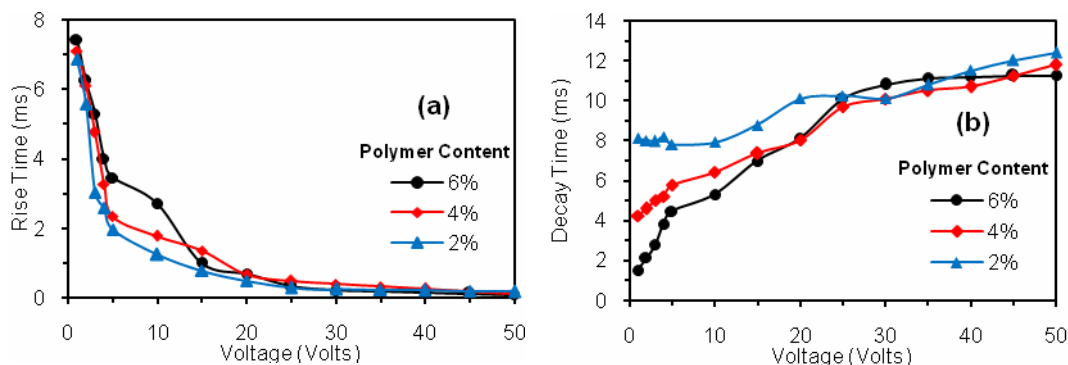


Figure 3. Applied field dependence of (a) Rise time, and (b) Decay time for PSLC cells with varying polymer content.

It is observed that the rise time is higher and decay time is shortened for samples with high polymer content due to the stronger anchoring energy between the LC molecules and polymer domains. The rise time could be shortened further by increasing the applied voltage; however the trade-off is longer decay time.

Conclusions

The morphology and electro-optics of PSLC films have been examined. The dimension of polymer networks was found to be dependent on the monomer concentration. A higher OFF-state transmission was recorded for the film with higher polymer content. Consequently, a strong polymer-LC interaction resulted in a higher threshold field. The rise time increased and decay time decreased with higher polymer content due to strong elastic forces between the two components of PSLC.

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