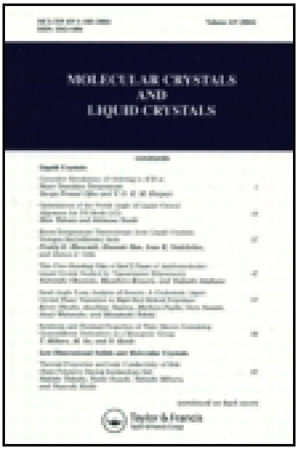

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Field-Induced Liquid Crystal Texture Development of a Side-Chain LCP/7CB Blend

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A blend of side-chain liquid crystal polymer (SCLCP) and 7CB, a low molecular weight liquid crystal (LMWLC), was prepared and used to investigate phase separation behavior induced by applied electric field, and thereby electro-optic property changes. An interesting field-induced LC texture development phenomenon was observed when the film transmittance of a phase-separated sample was measured under crossed-polarizer as function of applied field at a given temperature. That was, when measured at 50°C with applied field for a 20 μm-thick 3/7 SCPMMA/7CB blend film, the light transmittance drastically decreased initially, following unexpected increases from about 10 to 18 V and going down again. This phenomenon could be verified by POM observations and considered as the results of the destruction of LC texture within the blend at initial lower field and re-development at following higher applied field.

Keywords: 7CB; LC texture; PDLC; phase separation; SCLCP

INTRODUCTION

Because of the importance of refractive index matching between a liquid crystal (LC) and a polymer matrix in a polymer-dispersed liquid crystal (PDLC) blend to use as an information display material, phase behavior of LC/polymer mixtures has been intensively studied in recent years [1–4]. When an isotropic polymer is used as matrix of PDLC system, on-state haze phenomenon always occurs because of the material-based refractive index mismatching between LMWLC and polymer matrix. This on-state haze of PDLC film is inevitable because exact matching of refractive index between the phase-separated

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LMWLC and the polymer matrix is possible at only one temperature [5,6].

Several efforts to use a birefringent liquid crystal polymer as the matrix instead of conventional isotropic polymer were made, since it is able to match the on-state refractive indices for all directions, making it possible for a haze-free PDLC film [7–9].

It was shown in our previous investigations that mixing a side-chain liquid crystal polymer (SCLCP) with LMWLC exhibited phase separation at higher than 60 wt% of LMWLC compositions because of good compatibility between SCLCP and LMWLC, which is undesirable from the practical view-point of PDLC film [4]. Non the less, since it may be a better method to prepare an innate haze-free PDLC film, a SCLCP/7CB blend was used in the present study to investigate the phase separation phenomena and the electro-optic properties, which are important factors for the practical PDLC film displays. As the results, an interesting phenomenon in the film transmittance was also observed at the phase transition temperature of SCLCP LC phase and 7CB isotropic phase into the SCLCP LC phase and 7CB LC phase. The phenomenon was considered as the result of micro-phase interfacial interactions between SCLCP and LC phase. Another interesting field-induced destruction and re-development of LC texture will be reported in the followings.

EXPERIMENTAL

Materials

A specially designed side-chain liquid crystal polymer having poly (methyl methacrylate) back bone and 7CB-like side-chain mesogen was synthesized (SCPMMA). Number average molecular weight (Mn) and weight average molecular weight (Mw) of SCPMMA were determined as 1,400 and 10,000 from Gel Permeation Chromatography (GPC), respectively. 4-cyano-*n*-heptyl biphenyl (7CB) was obtained from E. Merck and used without further purification. Detailed chemical structures and physical properties of the used materials were described in our previous paper [4].

Experimental Procedure

Predetermined ratio of SCPMMA and 7CB was dissolved in co-solvent, methylene chloride. The solution was poured into petridish to remove the solvent at room temperature. Remained solvent was thoroughly removed on the hot plate set at *ca.* 120°C. The mixture was sandwiched between two transparent indium-tin-oxide (ITO) conducting glass plates and, then, set in Mettler FP-80 hot stage equipped with temperature controller. Copper-leads using silver paste were attached to each side of ITO glass plates to apply electric field. Zeiss Jenalab Pol-D polarizing optical microscope was used to observe LC texture and measure the transmittance. Phase separation of the sample blend was carried out by the thermally induced phase separation (TIPS) method; cooling the blend from 90°C to room temperature with cooling rate of 2°C/min. To measure the light transmittance, one of the eyepieces of the microscope was replaced with photo-sensor, which was connected to New Port 1830C optical power meter. HP 8904A Function Generator in conjunction with KEPCO BOP 500M Amplifier was used to apply an electric field on the sample. A schematic diagram of the experimental set-up was also shown in our previous paper [4].

RESULTS AND DISCUSSION

As was described our previous works, a low molecular weight liquid crystal (LMWLC) such as 7CB may act as plasticizer in a most amorphous polymer matrix [1]. If a SCPMMA is utilized as matrix instead of a conventional PMMA, much more plasticizing effect of LMWLC is expected because of similar chemical structure of side-chain mesogen of SCPMMA, causing phase separation for the blends having compositions higher than 60 wt% of 7CB [4].

For a 3/7 SCPMMA/7CB blend, when cooled from high temperature over than 90°C to room temperature, micro-phase separation may occur in the blend, which is composed of two different LC phases, i.e., 7CB-rich LC phase and SCPMMA-rich LC phase, respectively. It can be verified from polarized optical microscopy (POM) observation. As we already mentioned in our previous report, because of severe interactions between two LC phases, transmittance of the blend film at room temperature would be lower than that at 50°C, at which temperature 7CB-rich LC phase in the blend transformed into an isotropic state [4].

Figure 1 shows optical transmittance of a 20 μm-thick film of 3/7 SCPMMA/7CB blend as function of applied voltage under crossed-polarizer at 50°C. Initial transmittance at 0 V is due to the phase-separated SCPMMA LC phase. When an electric filed is applied on the film, however, the transmittance decreases drastically up to about 9 V. After then, it goes up unexpectedly with voltage increase, exhibiting a peak transmittance at *ca.* 18 V, and again decreases with higher applied voltages as clearly shown in the ascending cycle of Figure 1.

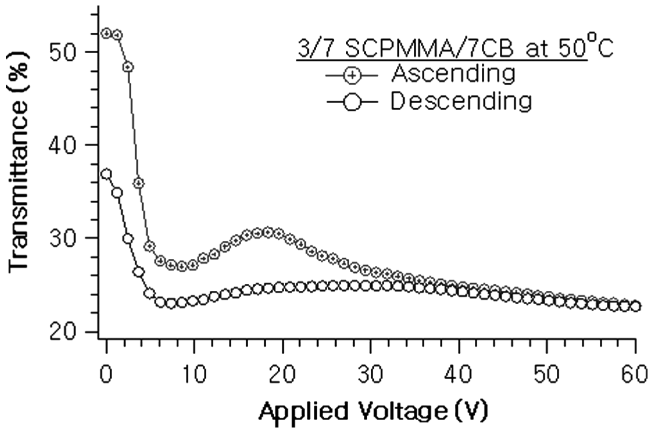

FIGURE 1 Optical transmittance of a 20 μm-thick 3/7 SCPMMA/7CB blend film as function of applied voltage under crossed-polarizer at 50°C.

It is notable in the figure that transmittance shows a peak around *ca*. 18 V during ascending cycle. This interesting phenomenon, when considering that the blend may exist in the state of phase-separated LC-SCPMMA/isotropic-7CB at 50°C, may be explained by describing that the initial LC texture in the blend should be broken at first into an isotropic texture at lower applied field and, after then, a new LC texture be re-developed at higher voltages, following re-destruction with more increasing voltages over 18 V. Somewhat strong hysteresis

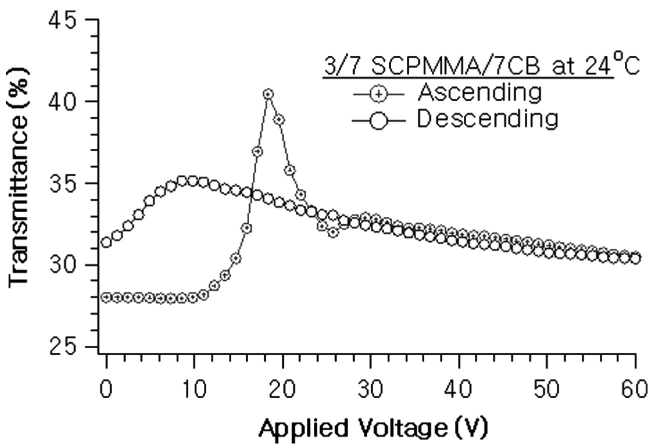

FIGURE 2 Optical transmittance of a 20 μm-thick 3/7 SCPMMA/7CB blend film as function of applied voltage under crossed-polarizer at 24°C.

during descending cycle, exhibiting a broad peak around 30 V and lower value than that for ascending cycle at 0 V, can be explained as the effect of molecular interactions between phases within the blend [4].

When the same measurement was performed at 24°C as seen in Figure 2, at which temperature the blend may exist in the state of phase-separated SCPMMA LC phase and 7CB LC phase, peak transmittance was shown at slightly higher voltage, *ca.* 20 V during ascending cycle, and around 8 V during descending cycle. Lower initial transmittance than that at 50°C can be explained by the more severe interfacial molecular interactions between SCPMMA and 7CB phase [4]. These phenomena can be easily understood from the fact that the more difficult molecular mobility will be induced in the lower temperature, resulting a stronger hysteresis. Reversed and lower transmittance at 0 V compared with that at 50°C can be also explained by this effect.

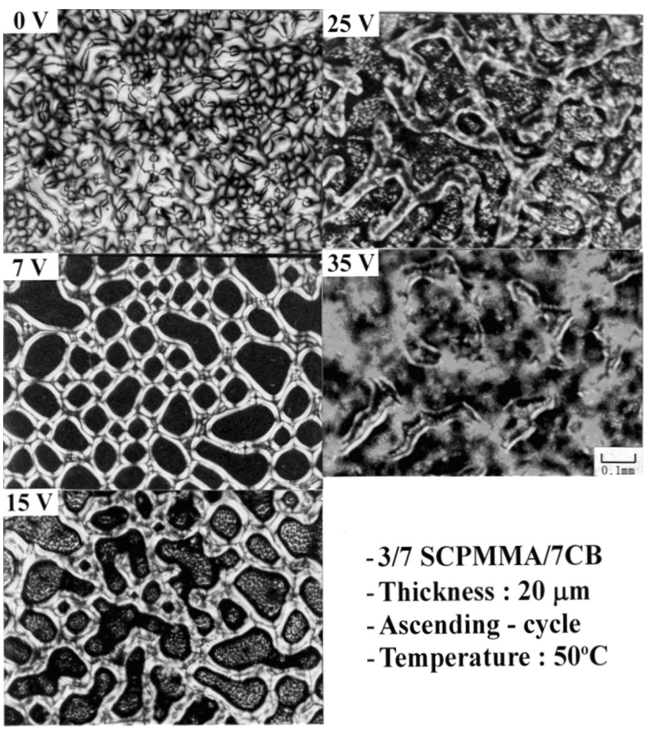

FIGURE 3 POM micrographs of 3/7 SCPMMA/7CB blend film at several different applied voltages at 50°C.

To investigate above described electro-optical phenomena, polarized optical microscope (POM) studies were performed to observe phase changes at the several given voltages as shown in Figure 3. Temperature was fixed at 50°C. As expected, smaller and complex phases consisting SCPMMA LC phase and 7CB isotropic phase could be found at 0 V. On applying 7 V, however, the phases divided into a clear isotropic phase and LC phase, which was exhibited by drastic transmittance decrease as shown in Figure 1. And then, a new LC phase interestingly started to develop in the isotropic-7CB phase when voltage increased above 10 V. The texture could be clearly seen in the case of 15 V in the figure. By developing this field-induced LC texture, the film transmittance increases continuously up to *ca.* 18 V. Applying higher voltages over 18 V induces the gradual re-destruction of LC textures, finally leading into two isotropic phases. Reversed texture changing processes with descending voltages, though not shown in the figure, could also be observed because they would undergo through the similar processes as in the case of ascending cycle.

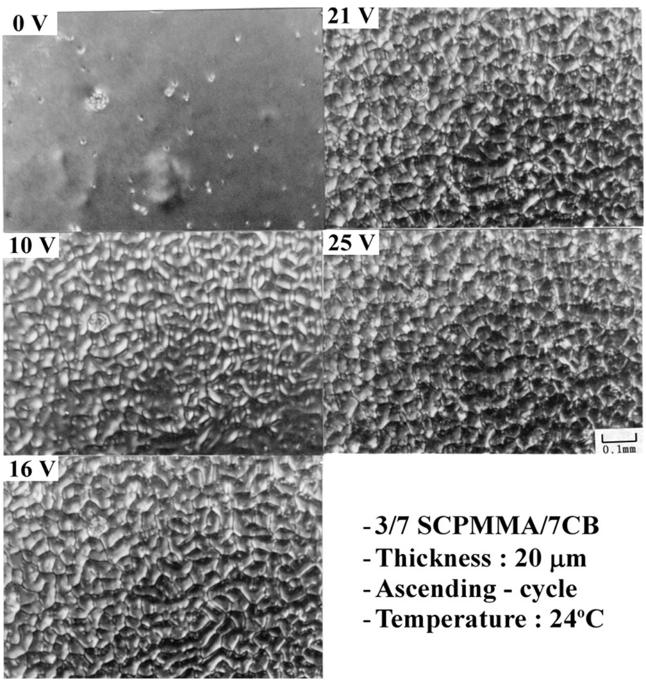

FIGURE 4 POM micrographs of 3/7 SCPMMA/7CB blend film at several different applied voltages at 24°C.

Observations under POM for the same sample at 24°C were shown in Figure 4. Similar morphology change processes at different applied voltages as in Figure 3 could also be observed for the both ascending and descending cycles, though the textures were not clear as in Figure 3. This comparatively less clear textures were also considered as due to the above described molecular interactions at lower temperature. However, considering in conjunction with observations in Figures 2 and 3, it was expected that the same phase change would occur even at 24°C.

CONCLUSIONS

A blend of side-chain liquid crystal polymer with PMMA back bone (SCPMMA) and 7CB was prepared and used to investigate phase separation behavior induced by applied electric field, and thereby electro-optic properties. Interesting field-induced LC texture destruction and re-development phenomena were found with applied voltages when observed under POM. The film transmittance, when measured at 50°C, at which temperature the blend exists in the state of phase-separated SCPMMA LC phase and 7CB isotropic phase, decreased drastically up to about 9 V. After then, it increased unexpectedly and showed a peak transmittance at *ca*. 18 V, following decreases again with higher voltages. These interesting field-induced electro-optic phenomena could be explained effectively by POM observations of the LC textures at several voltages. That was, 7CB-rich LC phase was broken into an isotropic phase at lower field, following a new field-induced LC phase re-development at higher voltages. After then with higher voltages, re-destruction of LC-phase would occur in the blend.

From the practical point of view, even though the SCPMMA/7CB system showed an interesting phase-separation and electro-optic properties induced by electric field, a comparatively low molecular weight SCLCP seems to be improper as a matrix material of PDLC systems. As the final comment, however, it is expected that a new kind of an innate haze-free PDLC material can be developed with deeper investigations of SCLCP/LMWLC blend systems as in the present study.

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