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Polarization Analysis of Nanostructured Chiral LC Composites

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The polarization analyses of the isotropic nanostructured LC composites, which is a promising candidate of next-generation LCD material, were performed to investigate the residual birefringence after application of an electric field. The composites showed negative, positive and nearly zero in azimuth angle of optical rotation for the chiral nematic phase, the induced isotropic phase and the isotropic phase, respectively. When the residual birefringence occurred, the optical rotatory of the isotropic nanostructured LC composites exhibited slightly negative. It is suggested that the primary cause of the residual birefringence is the electric field-induced phase transition to the chiral nematic phase.

Keywords: birefringence; blue phase; electro-optical effect; liquid crystal; optical rotation; phase transition

INTRODUCTION

The polymer stabilized blue phase and the nanostructured LC composites with the anomalously large Kerr effect have attracted much attention due to their fast electro-optical response and an application to new materials for liquid crystal display devices. These new generation modes could offer more natural moving images owing to high response.

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Furthermore they don't require LC alignment layer and rubbing process, resulting in considerably savings on production costs. However, the problems such as a non-zero birefringence in an absent of an electric field and relatively high driving voltages remained unsolved.

Pioneering works, the polymer stabilized blue phases with a wide temperature range of more than 60 K including room temperature and high speed response time of the order of 10^{-4} s were demonstrated by Kikuchi *et al.* [1], which have leaded many academic and application researches [2]. Haseba *et al.* reported the optically isotropic-nanostructured liquid crystal composites, which were created by photo polymerizing of the monomers in chiral liquid crystals [3]. Continuously Choi *et al.* investigated the relationship of between the LC parameters and the Kerr effect [4].

Optical rotation is a well-known technique that is widely practiced in chemical sciences, mostly for the purposes of characterizing the chiral molecules. However the research about optical characterization of the nanostructured LC composites and the polymer stabilized blue phases is rare [5–7]. In the present study, in order to elucidate the cause of the residual birefringence after application of an electric field, we investigated the optical rotation of the nanostructured LC composites.

EXPERIMENTAL

The change in rotatory of polarized light passed through the sample was measured before and after application of an electric field with

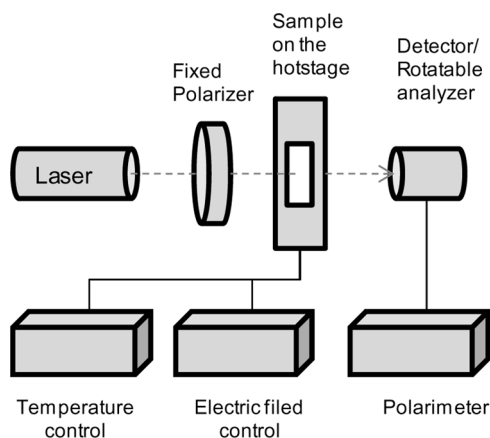


FIGURE 1 Experiment setup for polarization measurement.

TABLE 1 Chemical Composition of the Samples

Sample (Weight %)	LC		Monomer		Initiator	Chiral dopant
	JC-1041XX	5CB	TMPTA	RM257	DMPAP	ISO-60BA2
A10	41.62	41.62	5	5	0.4	6.75
A5	43.94	43.94	2.5	2.5	0.4	7.12
A3.5	44.63	44.63	1.75	1.75	0.4	7.23

the polarimeter consisting of a rotating quarter waveplate, a fixed polarizer in front of and behind the sample and a photodiode. The experimental setup is shown in Figure 1. The He-Ne laser was used as the incident light operating at a wavelength of 632.8 nm and enlarged for elimination of the short area error due to spatial inhomogeneity of the sample. The sample was contained between two pieces of glass with 10 μm cell gap (EHC) mounted in a hot stage equipped with electric connector to apply an electric field.

Table 1 shows the chemical composition of the samples used in this study. To prepare the nanostructured LC composites, at first, the blended liquid crystal material of the nematic mixture (JC1041-XX, Chisso Co. Ltd., $\Delta n = 0.142$, $\Delta \varepsilon = 5.7$ at 298 K) and 4-cyano-4'-pentylbiphenyl (5CB, Aldrich, $\Delta n = 0.19$, $\Delta \varepsilon = 11$ at 298 K) was mixed with 7.5 % of a chiral dopant (ISO-60BA2) [4] which induces a chiral nematic phase and blue phase. To form a polymer network in the chiral nematic liquid crystal, trimethylpropane triacrylate (TMPTA, Tokyo Kasei Kogyo) and RM257 (Merck) were used as monomers, and 2,2-dimethoxy-2-phenylacetophenone (DMPAP) was used as a photoinitiator. The precursors of LC/polymer composites constituted of 10 wt%, 5 wt% and 3.5 wt% of blended monomers, which are shown in Table 1 as A10, A5 and A3.5, respectively. Then, each cell filled with a homogeneous solution was irradiated with UV light (metal halide lamp, Ushio) of intensity 10 mWcm^{-2} (measured at 365 nm) for 3 min at 3 K above the isotropic phase-LC phase temperature for each nematic LC, resulting in the nanostructured LC composites.

RESULTS AND DISCUSSION

The solution of the liquid crystals and the chiral dopant without polymers shows a chiral nematic phase at the room temperature, 298 K. After polymerization at the temperature where the each sample shows an isotropic state and subsequently cooling to 298 K, the samples A10 and A5 were optically isotropic, while the sample A3.5 showed birefringent and light scattering, indicating that the optically isotropic

state was successfully stabilized for the samples A10 and A5 by polymerization, while it was not enough stabilized for the sample A3.5. The birefringent state of the sample A3.5 should be due to a phase transition to a chiral nematic phase which is the stable phase at the measuring temperature if the polymer does not exist. When an electric voltage, 100 V, was applied to the cells filled with the samples A10 and A5, they show slight birefringence after removing the electric field. We call this phenomenon the residual (non-zero) birefringence, which is an origin of decreasing constant in the electro-optical effects. We have investigated the optical rotation properties for the isotropic-nanostructured composites before and after application of electric fields by detecting the change in the azimuth angle of the polarization of incident light. Figure 2 shows the applied voltage dependence of the azimuth angle of the composites. The azimuth angle was measured after removing the electric voltage which was applied for 2 second at each step. For the fresh samples, before application of an electric field, A10 and A5 exhibited positive 0.5 and 0.8 degree at 298 K. However A3.5 showed negative 1.4 degree at 298 K. This result clearly shows that the polymer-stabilized isotropic state has a positive optical rotation while the segregated chiral nematic phase by the incomplete polymer-stabilization has a negative one. With increasing voltage the azimuth angle decreased to nearly zero, negative 1 and negative 3.5 for A10, A5 and A3.5, respectively. It is clear that the composite

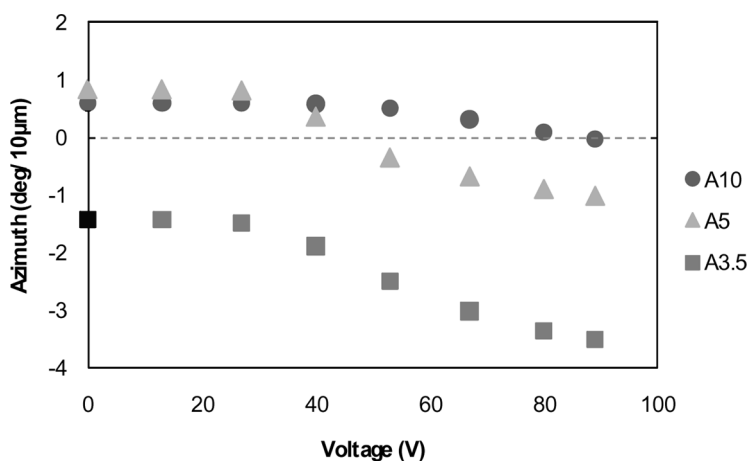


FIGURE 2 Voltages dependence of rotatory of azimuth angle for the samples. After application of an electric field azimuth angles fall down to negative (AC, 1 kHz, 298 K).

including a small amount of polymers showed the larger decreasing of the azimuth angle. Namely the polymer network in the composite including a small amount of polymers was easily destroyed by application of electric fields.

Figure 3 shows the temperature dependence of the azimuth angle for A3.5 during the heating and the cooling processes. As we mentioned above, A3.5 showed the chiral nematic phase, the azimuth angle was negative 1 degree at the room temperature (298 K), owing to incomplete polymer-stabilization. On heating process the azimuth angle increased slightly and a drastic change in the sign from negative to positive was observed near 316.8 K. In the vicinity of 317 K, it reached the maximum (positive 0.5 degree) and then decreased to zero at near 319 K. When the temperature decreased (cooling process) the azimuth angle increased to positive 1 degree and drastic decreasing from positive to negative degree in the vicinity of room temperature at 297 K. These transit temperatures of the sign of the azimuth angle can be assigned to the phase transition temperatures of the chiral nematic phase, the blue phase and the isotropic phase of A3.5 based on the observation of the LC mixture without polymers. It is clearly demonstrated that negative, positive and nearly zero in azimuth angle at 632.8 nm were responsible for chiral nematic phase, induced isotropic phase and isotropic phase of the composite, respectively. In addition, Figure 3(b) showed the detail of azimuth angle in the vicinity of the isotropic phase as a function of the temperature. The slopes of the azimuth angle change had slight inflections at 317.7 K and

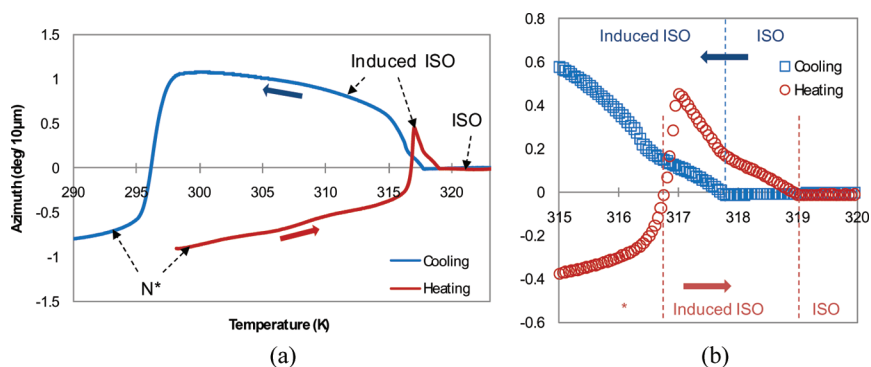


FIGURE 3 (a) Azimuth angle for A3.5 as a function of the temperature during the heating and the cooling process (1 K/min). (b) Enlarged figure in the vicinity of the phase transition for A3.5. It represented negative, positive and nearly zero in azimuth angle for chiral nematic phase, induced isotropic phase and isotropic phase, respectively.

316.4 K on heating and cooling process, respectively, in the induced isotropic phase range. Those temperatures, about 1 K lower than each T_c , could correspond to the phase transition between BP I and BP II because the LC mixture without polymers shows phase transition of BP I and BP II at 1 K lower than the T_c .

The sign of optical rotation depends on the pitch of helical alignment of liquid crystal molecules, its orientation and wavelength of incident light. In the experimental condition of our study, it becomes clear that the signs of the optical rotation were positive for the polymer-stabilized isotropic state of the nanostructured chiral LC composites and blue phases, negative for the chiral nematic phase and the nanostructured chiral LC composites showing residual birefringence after application of an electric voltage, and nearly zero for the genuine isotropic phase. Therefore it is strongly suggested that the optically isotropic nanostructured chiral LC composites have a similar molecular alignment to blue phases, that is double twist alignment, and the nanostructured chiral LC composites showing residual birefringence have a similar molecular alignment to a chiral nematic phase, that is simple twist alignment.

CONCLUSION

We investigated in detail the optical rotation of isotropic-nanostructured LC composites by electro-optical and thermo-optical measurements. Consequently, the sign of the azimuth angle shifted from positive to negative after application of an electric field, indicating that the phase transition from the stabilized isotropic phase, of which local structure might be similar to the blue phase, to the chiral nematic one occurred by the application of an electric field.

REFERENCES

- [1] Kikuchi, H., Yokota, M., Hisakado, Y., Yang, H., & Kajiyama, T. (2002). *Nat. Mater.*, *1*, 64.
- [2] Hisakado, Y., Kikuchi, H., Nagamura, T., & Kajiyama, T. (2005). *Adv. Mater.*, *17*, 96.
- [3] Haseba, Y., Kikuchi, H., Nagamura, T., & Kajiyama, T. (2005). *Adv. Mater.*, *17*, 2311.
- [4] Choi, S.-W., Yamamoto, S.-I., Haseba, Y., & Kikuchi, H. (2008). *App. Phys. Lett.*, *92*, 043119.
- [5] Vanweert, F., Demol, W., & Dael, W. V.. (1989). *Liquid Crystals*, *5*(3), 853–859.
- [6] Grelet, E., Collings, P. J., Li, M.H., & Nguyen, H. T. (2001). *Eur. Phys. J. E*, *6*, 157–161.
- [7] Zhang, B. Y., Meng, F. B., & Cong, Y. H. (2007). *Optics Express*, *15*(16), 10175.