Phase Behavior and Electro-optical Effects in a (Cholesteric and Induced Smectic) Liquid Crystal Mixture System

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1. Introduction

A binary mixture of a nematic liquid crystal with a weak polar end group and a nematic with a strong polar end group may yield an induced smectic phase(1,2). The reversible opaque (light scattering)-transparent change was observed upon application of ac electric fields with low and high frequencies, respectively. In this paper, we add a cholesteric LC to the induced smectic phase formed by mixing two nematic LCs. The aggregation and electro-optical properties of the resultant ternary composite based on light scattering are reported.

2. Experimental

The chemical structures of the liquid crystals used in this study are shown in Fig. 1. The LC/LC mixture was first dissolved in acetone and the composite was prepared by solvent casting. The phase transition behavior and the aggregation states of the HPPB/E7/CB15 composites were investigated by DSC and POM. The heating/cooling rates for DSC and POM studies were 3 K/min and 0.1K/min, respectively. In this study, the glass surface was not treated by rubbing, so that the alignment of the composite molecules was random. A change in transmission intensity of the He-Ne laser light (632.8 nm) through the cell without any optical polarizers was detected with a photodiode and recorded by a digital storage oscilloscope.

3. Results and discussion

Figure 2 shows the phase diagram of the HPPB/E7/CB15 composite, which was obtained on the basis of DSC and POM. A smectic phase was induced over the entire composition range and a wide range of temperature below the temperature of smectic-cholesteric phase transition. The ternary composites exhibited isotropic phase, cholesteric phase, blue phase, induced smectic phase and a mesophase denoted as "M phase". The M phase was observed within a narrow temperature range at cholesteric-smectic phase transition.

The electro-optical effects based on light scattering was also investigated under various conditions with application of DC electric fields. Fig. 3 shows the transmittance in a cholesteric state for the HPPB/E7/CB15 (45/55/25 wt%) ternary composite. The ternary composite exhibited bistable and reversible light switching driven by DC electric fields. The transmittance increased to 100% when high voltage DC electric field was applied. In this stage, the helical structure was unwinding and homeotropic state was formed. A large scale of homeotropic alignment of molecules is easily created due to a positive dielectric anisotropy of the ternary composite. Uniform state of cholesteric was observed when an applied electric field was removed. The uniform state is planar structure with the helix axis of helical structure of molecules perpendicular to the cell surface. Transparent state having 96 % transmittance was maintained after electric field was turned off. On the other hand, a focal conic texture appeared in a cholesteric phase when a low DC electric field was applied. Since the application of low voltage may induce helical structure which collapses a fairly well organized uniform alignment into small fan-shaped textures. This would induce an increase in light scattering due to the effective formation of an optically heterogeneous structure. Transparent and opaque states of the ternary composite were remained after DC electric fields with high and low voltages were removed, respectively. This indicates that the ternary composite in a cholesteric state has a bistable and reversible light switching characteristic, or, a memory effect.

The temperature dependence of the transmitted light intensity for the HPPB/E7/CB15 (45/55/35 wt%) composite is shown in Fig. 4. A dip of transmission intensity was observed at the cholesteric-smectic phase transition range. This dip is due to the light scattering caused by the spiral texture of the M phase. The ternary composite system exhibits transparent state in an induced smectic phase and light scattering state in a cholesteric phase. Strong light scattering state was observed because many focal conic textures may induce deflection of light. It is interesting that the 100% transmittance was observed when cholesteric phase (focal conic) was cooled to smectic phase. This is due to that a large scale of homeotropic alignment of smectic layers was easily formed, which resulted in highly transparent state. Reversible and bistable opaque-transparent change was easily achieved by heating and cooling treatment.

Conclusion

Thermal-sensitivity light switching is performed in a cholesteric and induced smectic states for the ternary composite system. This has the potential for application as a light valve device and storage device utilized for rewriting optical information.

References

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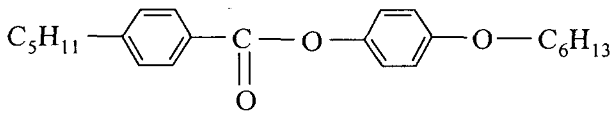
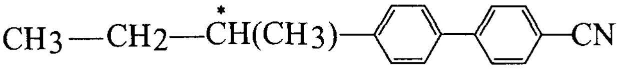
2) J. C. Hwang and Y. C. Tsai: Jpn. J. Appl. Phys. **36** (1997) 2214.

(1)HPPB



(2) CB15



(3) E7

Figure 1. The chemical structures of the HPPB,CB15 and E7 liquid crystals field.

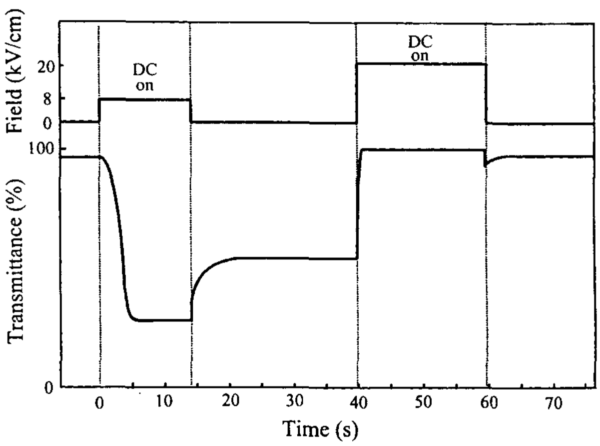


Figure 3. The electro-optical properties of ternary composite in the cholesteric phase under conditions of high and low DC electric.

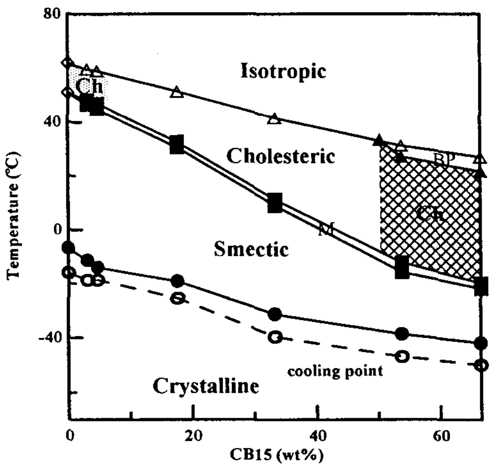


Figure 2. Phase diagram of the HPPB /E7/CB15 composite system

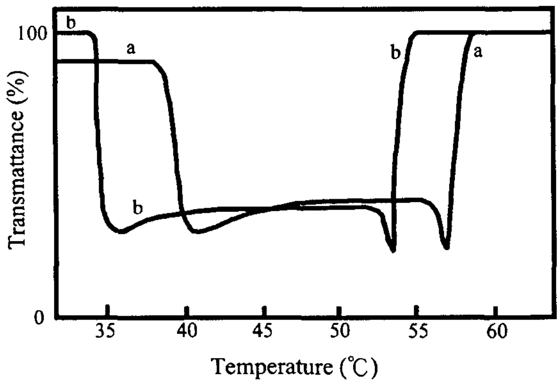


Figure 4. Temperature dependence of the transmittance for ternary composite without applied field