電気材料技術雑誌　第14巻第2号
J.Soc.Elect.Mat.Eng. Vol.14, No.2, 2005

Characterization and electro-optical properties of the nematic and chiral material mixture systems

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abstract

The phase behavior and optical properties of liquid crystal mixtures consisting of positive nematic/chiral material and negative nematic/chiral material have been studied. These mixtures showed chiral nematic, blue, TGB and smectic A* phase. Blue phase was observed between isotropic and cholesteric phase of iridescence of a peacock's feathers. A unique texture was observed in the chiral nematic-smectic transition. The negative nematic/chiral exhibited fast-bistable and reversible light switching driven by electric fields with high and low frequencies, respectively.

1. Introduction

The ternary composite consisting of two nematic LCs and one cholesteric LC exhibited cholesteric, blue and induced smectic phases, and a novel phase between the cholesteric and smectic phases(1,2). Many homologous series of ferroelectric or cholesteric liquid crystals with high chiality was reported to exhibit the Blue phase(BP) and Twist grain boundary phase(TGB)(3). BP having brilliant platelet texture appears between the isotropic and chiral nematic phase. TGB having filament texture exhibits between the chiral nematic and chiral smectic C phase in a ferroelectric liquid crystal.

In this paper, we report two mixtures of positive nematic/chiral material and negative nematic/chiral material. The aggregation and electro-optical properties of the composite based on light scattering are reported. The reversible opaque (light scattering)-transparent change was observed upon application of electric fields.

2. Experimental

The positive and negative nematic liquid crystals are E7 and ZLI4850. The chiral material is S811. The LC/chiral mixture was first dissolved in acetone and the composite was prepared by solvent casting. The phase transition behavior and the aggregation states of the composites were investigated by DSC and POM. The DSC scanning rate was 0.2°C/min. 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

positive nematic /S811 liquid crystal mixture

Figure 1 shows the phase diagram of the nematic E7 and S811 chiral composite. The composites exhibited chiral nematic, blue , induced smectic A* and TGB phase. Blue I and II phase are modeled asbody-centered cubic and simple-cubic structure, respectively. The phase sequence of the 65/35 exhibited I-BP-SmA*. The optical texture of this blue phase is monodomain with blue color as blue fog (BPIII). BPII, BPI, chiral nematic, TGB phase were observed in 70/30 sample. When cooling the 65/35 mixture, the bluep hase changed directly to the SmA* phase and no TGB phase was observed. It was interesting that the SmA* phase with fan-shaped texture was induced in composite range 60/40-10/90. The S811 content ranges of 0-20% showed the fingerprint and focal-conic textures as chiral nematic phase. When the S811 ratio became higher than 90%, the induced SmA* phase was replaced by needle-like crystalline.

Figure 2 shows XRD profiles during cooling in the 70/30 mixture. The shape and intensity of the peak in the BPII phas was diffuse and weak at low angle (2θ=2.5-3.0°). The BPI phase appeared having a smectic order and might be a smectic blue phase. The orientational ordering changed from a disordered BP phase to the more ordered SmA* phase with decreasing temperature. We propose a possible orientation and stacking is showed in figure 3. The chiral material S811 has rod-like molecules with a molecular length close to that of the E7 molecules. When the chiral material content is low, the weaker helical power of the nematic drives its molecules to orient in a helical fashion, with the axis parallel to the substrate glass, thus developing the chiral nematic phase as (a). On adding more chiral material, the helical power rises and the twist angle of the adjacent molecules becomes higher as (b). Above 40% content of the chiral material, the positional and orientational ordering may increase to give a SmA* phase more ordered than chiral nematic phase as (c).

The binary composite exhibited reversible light switching driven by dc electric fields. Figure 4 shows the transmittance in a chiral nematic state for the 90/10 of E7/S811 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. 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. 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. In the positive nematic composite, the focal conic texture changed to homeotropic state when a high-voltage dc electric field was applied, it transferred to a planar texture after the electric field was removed. The planar texture changed to focal conic texture by applied low-voltage dc electric field. Therefore, the response of positive nematic /S811 liquid crystal mixture is slow.

Transparent and opaque states of the binary composite were remained after ac electric fields with high and low frequencies were removed, respectively. This indicates that the binary composite in a cholesteric state has a bistable and reversible light switching characteristic, or, a memory effect.

negative nematic/S811 liquid crystal mixture

The nematic ZLI4850 was miscible with the chiral S811 over their entire concentration range. The binary composites exhibited cholesteric and blue phase. The chiral pitch, fan-shaped and scale-like texture were observed in the cholesteric phase. The blue phase are often in a narrow temperature range of about 1°C. Figure 5 shows the transmittance in a cholesteric state for the ZLI4850/S811 (96/4 wt%) binary composite. The binary composite exhibited high and low transmittance in the absence and upon application of ac 10 Hz electric field. The chiral pitch texture caused light scattering in the field.

The binary ZLI4850/S811 (85/15wt%) composite exhibited bistable and reversible light switching driven by ac electric fields. The proposed molecular aggregation states for the transparent and opaque states are schematically illustrated in Figure 6.The uniform state is planar structure with the helix axis of helical structure of molecules perpendicular to the cell surface. On the other hand, a focal conic texture appeared in a cholesteric phase when a low frequency ac electric field was applied. Transparent and opaque states of the binary composite were remained after ac electric fields with high and low frequencies were removed, respectively. In nematic/S811 composite, planar and focal conic texture were changed by applied electric fields. This indicates that the binary composite in a cholesteric state has a fast-bistable and reversible light switching characteristic.

Conclusion

Reversible and bistable opaque-transparent change was easily achieved by applied low and high frequencies electric fields. This has the potential for application as a light valve device and storage device utilized for rewriting optical information.

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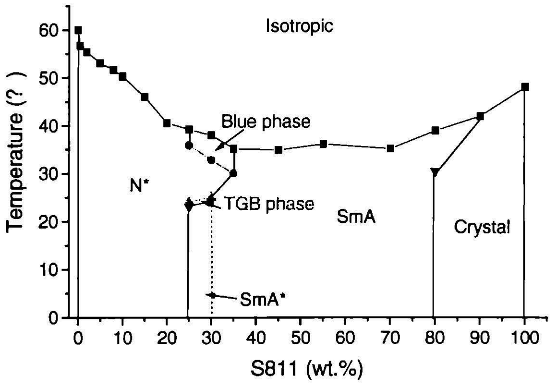

Fig.1 Phase diagramof the E7/S811 composit

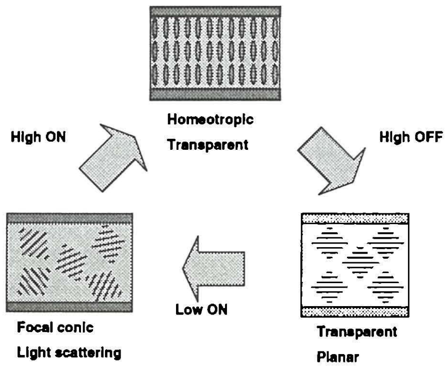

Fig.4 a bistable optical effect in a chiral nematic

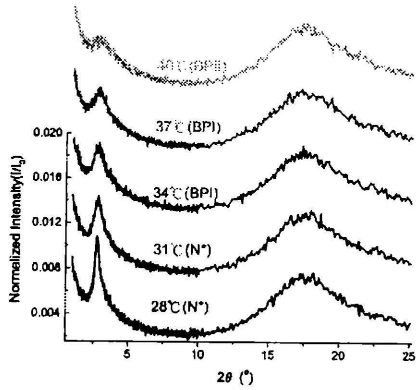

Fig.2 XRD profiles of the 70/30 composite

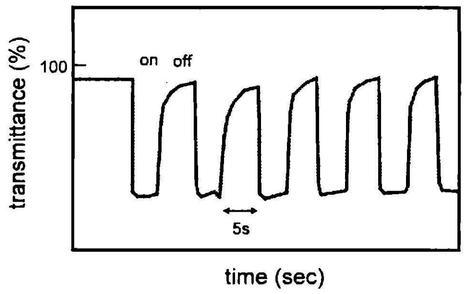

Fig. 5 Reversible transparent and opaque in the 10Hz field.

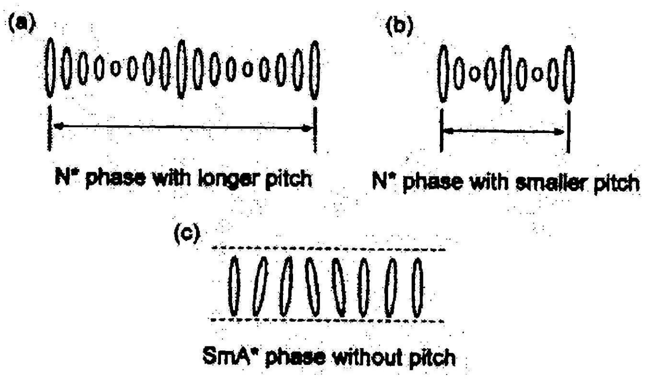

Fig.3 Schematic illustrations of molecular the Orientation of E7/S811

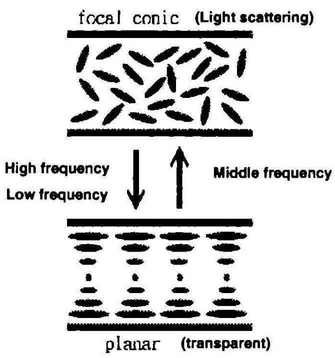

Fig. 6 Schematic illustrations of transparent and opaque states