P08

Phase observation of liquid crystal blue phases in ultraviolet region by using UV polarizing optical microscope

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Abstract

Temperature range and phase transition behavior of blue phases (BPs) are related with chirality. However, it is difficult to observe the phase transition behavior of BPs with high chirality by using conventional polarized optical microscope (POM), because they show Bragg's reflection only in ultraviolet region. In this study, we observed textures and phase behavior of BPs with high chirality by using our unique ultra-violet (UV) POM with measuring changes of the dielectric constant in in-plane switching cell, and made their phase diagrams.

1. Introduction

The liquid crystal blue phases (BPs) are intermediate phases which appear in a narrow temperature range of 1~2 K between isotropic and chiral nematic phases with high chirality. BP I and II show structural color based on their giant cubic lattice structure. While, BP III was observed as an amorphous structure in a temperature range higher than those of other BPs. Owing to their optical isotropy and electro-optical Kerr effect with response time less than millisecond, they have a great potential as a next generation liquid crystal (LC) material for displays with wide viewing angle without alignment layer in the cell. However, their narrow temperature range had been obstacle to their industrial application. Kikuchi et al. reported that the temperature range of BP was extended to over 60 K through polymer-stabilization [1]. These polymer-stabilized blue phases (PSBPs) have been researched intensively as a candidate of next generation LC material for a decade. However, there were still remained some issues to be solved.

Owing to their structural color in visible wavelength, usual BPs used in academic study are not applicable for LC display with high contrast. Because the lattice constant is inversely proportional to the concentration of chiral dopant, highly chiral BPs show structural color only in ultra-violet (UV) light region and is expected as LC material for display with high contrast ratio. However, therefore their textures couldn't be observed with polarized optical microscope (POM) using visible light. In this study, phase transition of LC mixtures was observed by using ultra-violet (UV) POM for the first time, and their phase diagram in highly chiral region was obtained. Furthermore, an electric capacitance change during the transition in in-plane switching (IPS) cell was measured.

2. Experiment

LC mixtures for BPs were prepared by adding chiral dopant, ISO-$(6OBA)_2$ (5~15 wt%) to 1:1 (wt. ratio) nematic LC mixture of JC-1041XX (JNC Co. Ltd.) and 4-cyano-4′-pentylbiphenyl (5CB). The LC mixtures were filled into in-plane switching (IPS) cells with a quartz cover glass, and then their phase behaviors were observed by using UV POM with ultraviolet and visible light. Simultaneously, changes of the electrical capacitance in the phase transitions were also measured by an impedance analyzer. (4192A LF, HP). UV-Vis spectrometer (JASCO, MSV-350) were used to observe reflection spectra of BP cells mounted on a temperature controlled stage (LTS-E350, LINKAM).

3. Results and Discussion

Phase behaviors of BPs with various concentration of chiral dopant were observed on heating process at 0.1 K/min that is hard to show the metastable state by using UV-POM. As increasing the concentration of chiral dopant, BP I began to appear from 5 wt% of chiral dopant and BP II was observed from 8 wt% of chiral dopant. Until LC mixture with 9 wt% of chiral dopant, phase behavior of BP could be observed by POM with visible light source. From LC mixture with 10 wt% of chiral dopant, phase behavior was observed by UV-POM.

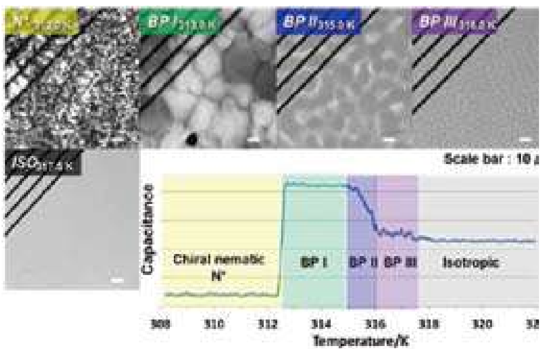

Figure 1. Phase behavior and temperature dependence of electric capacitance of BPLC sample with 10 wt% of chiral dopant on heating process. Background color indicates the phases by UV polarized light microscope

Fig. 1 shows texture of BPLC mixture with 10 wt% of chiral dopant and change of its electric capacitance. Shape and size of BP I texture were almost same as those of BP I with low chirality observed in visible region. In case of BP II, the shape of texture, which was usually not observed by conventional POM, was clearly observed. The rounded texture was similar to that of BP II observed by confocal laser scanning microscope, and the texture kept growing during BP II state. In BP III, mottled pattern with a period of about 3 μm has been found. This pattern may be important to understand BP III structure that is believed to be amorphous. Its capacitance started to decrease when the phase transition occurred from BP I to BP II, and became constant in BP III. It is considered that the decreasing of the capacitance in BP II sate corresponds to the growing of the rounded texture observed by UV-POM. In phase transition from BP III to the isotropic phase, capacitance has decreased slightly.

Bragg's reflection of BP I with various concentration of the chiral dopant in LC mixtures was measured (Fig. 2).

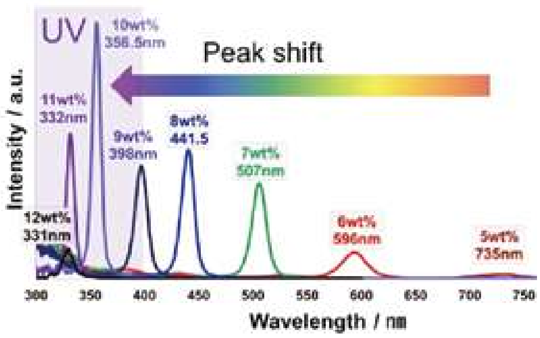

Figure 2. Bragg reflection of BPs with various concentrations of chiral dopant in LC mixtures.

As increasing the chiral dopant, Bragg's reflection peaks shifted to UV wavelength region in practice. Especially from 10 wt% of chiral dopant, Bragg's reflection peak appeared in UV region. And then, from 12 wt% of chiral dopant, Bragg's reflection peak couldn't be confirmed. It because of Bragg's reflection peak appeared in less than 300 nm, that is the shortest wavelength observable using our spectrometer.

The phase diagram of BPs with various concentration of chiral dopant was established finally as shown in Fig. 3. BP I began to appear at 5 wt% of the chiral dopant BPLC mixture. BP II and III were observed the sample with from 8 wt% to 10 wt% of the chiral dopant BPLC mixture. More than 9 wt% of the chiral dopant BPLC mixture, the phase behavior was observed only by UV light. Samples with chiral dopant more than 12 wt% did not show BP II. However critical point between BP III and isotropic phase was not

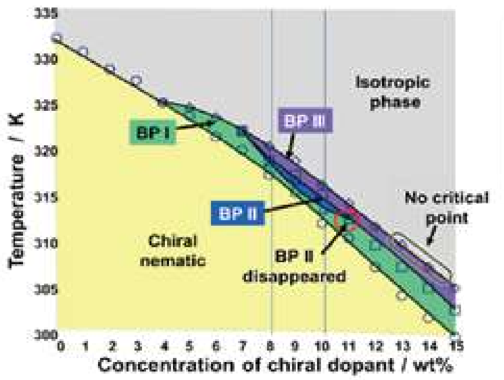

Figure 3. Phase diagram for BPs with various concentrations of chiral dopant in LC mixtures.

observed in the measured concentration range of chiral dopant (0~15 wt%).

4. Conclusion

Blue phases started to appear from 5 wt% of chiral dopant BPLC mixture. BP II and BP III appeared from 8 wt% of chiral dopant BPLC mixture. However BP II disappeared at high chiral region from 11 wt% of chiral dopant BPLC mixture. BP III appeared until 15 wt% of chiral dopant BPLC mixture, thus the critical point was not observed in measured concentration range of the chiral dopant (0~15 wt%). Electrical capacitance of BPs filled in in-plane switching cells changed depending on the phase transition.

Reference

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