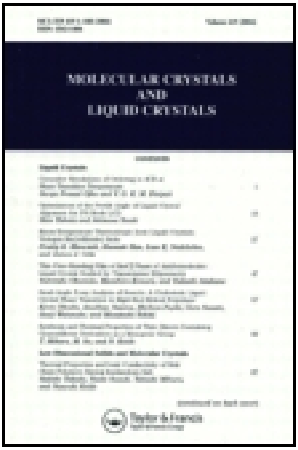

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Thickness Dependence of Blue Phase Transition Behavior of Chiral Nematic Liquid Crystal*

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In this study the thickness dependence of blue phases temperature range was evaluated at chiral nematic LC mixture (LC / chiral dopant) using the wedge cell. The temperature range of blue phase at the 0.5 μm thick part is more than 10 K, while those at the 2 μm and the 4 μm thick part is less than 3 K on cooling process. However, on heating process, the temperature range of blue phase is not nearly changed with changing of thickness of chiral nematic LC.

Keywords: chirality; chiral nematic liquid crystal; temperature range of blue phase; thickness dependence

1. INTRODUCTION

Blue phases (BPs) are types of liquid crystal (LC) phases that appear in a temperature range between a chiral nematic phase and an isotropic liquid phase. Since BPs have three-dimensional cubic structure with lattice periods of several 100 nm [1,2], they exhibit the selective Bragg reflections in the range of visible light. The BPs possess great potential as light modulator because of electrically controllable Bragg diffraction of visible light [3–6]. For practical applications, although BPs are interest for fast light modulators, the narrow temperature

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range, usually less than a few Kelvin, within which BPs exist has always been a problem. Recently, the temperature range of blue phase could be successfully extended to more than 60 K through polymer-stabilized blue phase [7]. However there is not clear at the mechanism for stabilization of BPs, furthermore few reported cases of pure chiral nematic LC without addition of polymer so far [8,9].

It is generally known that the temperature range of BPs in chiral nematic LC is strongly dependent upon the chirality of chiral nematic LC in three dimensional spaces [10]. Therefore the transitional behavior of BPs would be affected by the thickness of chiral nematic LC embedded in some substrates. In particular, the behavior of chiral nematic LC molecules in the very thin region with several hundred nanometer as same as the lattice periods of BPs would be very interesting. However the chiral nematic LC thickness dependence of the temperature range of BPs has not been elucidated so far.

In this study, the thickness dependence of blue phase temperature range was evaluated at chiral nematic LC mixture (LC/chiral dopant) to know the relationship between the blue phase stability and the thickness of LC layer using the wedge cell of which the thickness of chiral nematic LC mixture was continuously changed.

2. EXPERIMENT

JC-1041 (Chisso) and 5CB were used as nematic LC materials and $ISO6OBA_2$ used as a chiral dopant as shown in Figure 1. Chiral nematic LC mixtures containing 7 and 7.5 wt% of $ISO6OBA_2$ were

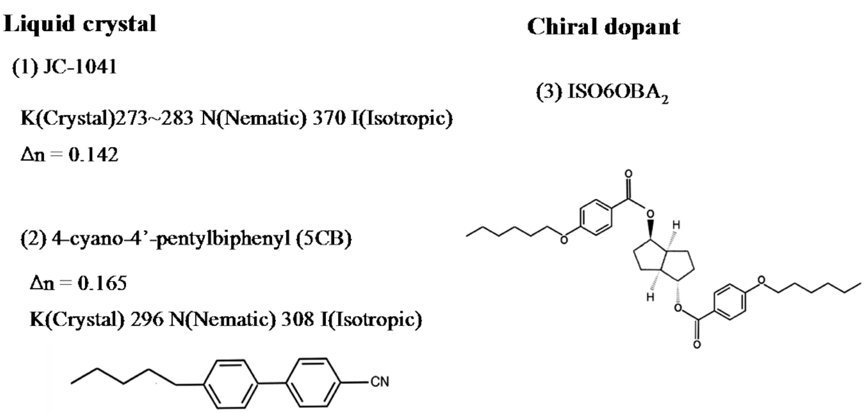


FIGURE 1 Chemical structures and physical properties of the used LCs and chiral dopant.

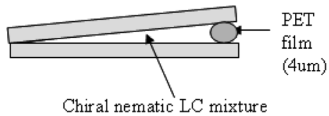


FIGURE 2 Schematic representation of wedge cell which chiral nematic LC is filled between two glasses without surface treatment.

prepared as (JC1041 : 5CB : ISO6OBA$_2$ = 46.5 : 46.5 : 7) wt% and (JC1041 : 5CB : ISO6OBA$_2$ = 46.25 : 46.25 : 7.5) wt%, respectively.

Wedge cell was prepared to evaluate the chiral nematic LC mixture thickness dependence of the temperature range of BPs as shown in Figure 2. The thickness of the wedge cell which the chiral nematic LC mixture is filled between two glasses without surface treatment is nearly zero at the part without spacer and continuously increased with approaching to the space separated with PET film of 4 μm thick. BPs transition behavior of wedge cell was evaluated by observation of texture of polarized optical microscope (POM : Nikon) under crossed Nicols. The cooling and heating ratio of wedge cell was 1 K/min in an accuracy of ±0.1 K (Linkam LK-600PM).

3. RESULTS AND DISCUSSION

Figure 3 shows POM observation photographs at the very thinner part (0.5 μm), the middle part (2 μm) and the thicker part (4 μm) of LC thickness of wedge cell on cooling at 7.5 wt% chiral nematic mixture under crossed Nicols. As shown in Figure 3, the chiral nematic LC mixture was an isotropic phase observed as dark sight around 320 K and further cooling, BP-2 as blue sight around 319 K and then, BP-1 as the green and blue sight due to platelet structure around 318 K at all thickness parts, in spite of changing of LC thickness. However, the transition temperature from BP-1 to chiral nematic phase at the very thinner part (0.5 μm) was about 8 K lower than those of the middle (2 μm) and the thicker (4 μm) parts. Namely, the BPs at the 0.5 μm thick part of chiral LC mixture was observed during more than 10 K, whereas the BPs at the 2 μm and the 4 μm thick part during less than 3 K on the cooling of wedge cell. In particular, the growth speed of chiral nematic nuclear generated from BP-1 at 0.5 μm thick part of LC was the more slowly than those at 2 μm and the 4 μm thick part.

These results indicate that the phase transition from BP-1 to chiral nematic phase is only strongly dependent upon the chiral nematic LC thickness, whereas the transition from BP-2 to BP-1 and the transition from isotropic phase to BP-2 are independent upon the changing

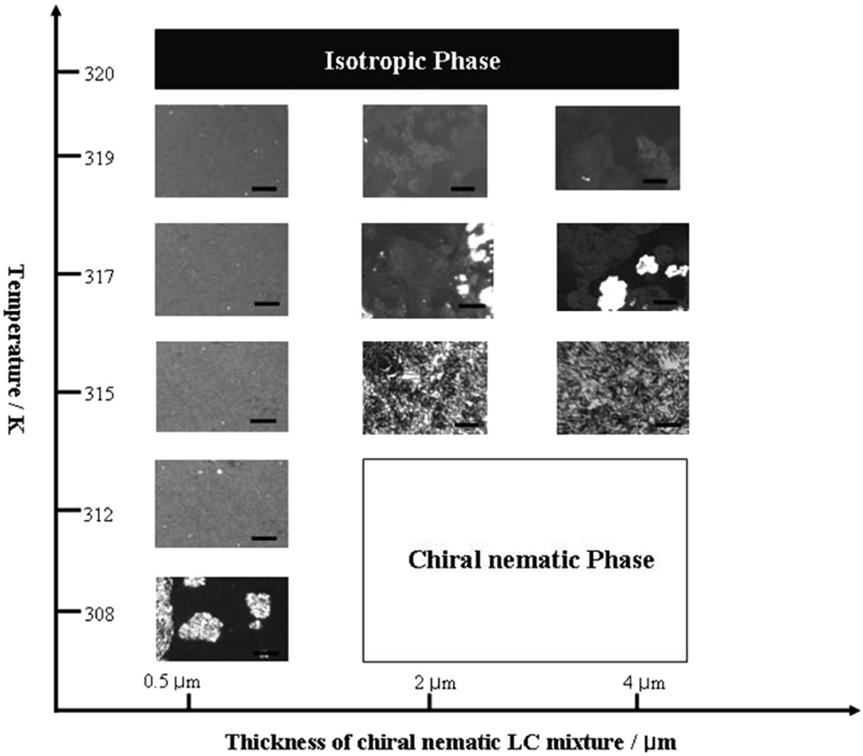
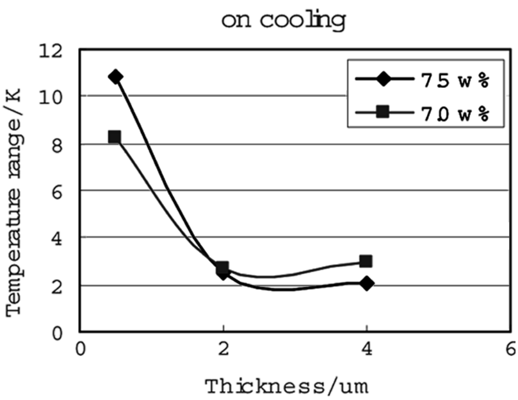


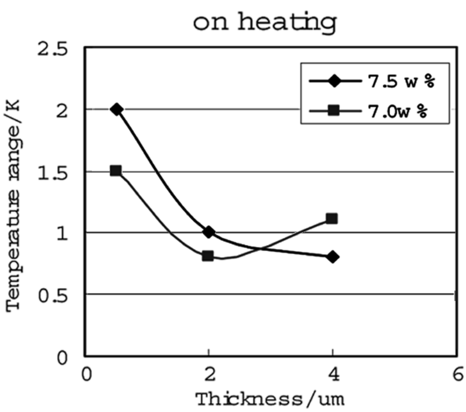
FIGURE 3 Photographs of POM observation for chiral nematic LC mixture of 7.5 wt% from isotropic phase to chiral nematic phase on cooling at various thicknesses such as 0.5, 2, 4 μm. Length of line in each photographs is same to 100 μm.

of LC thickness. In general, those are experimentally observed that BP-1 has the body-centered cubic symmetrical structure to arrange the double twist cylinders of LC director and BP-2 has the simple cubic symmetrical structure to arrange the double twist cylinders of LC director, whereas chiral nematic phase does not have any cubic symmetrical structures, only has the single twist structure of LC director [10]. Therefore, these results indicate that the phase transition from the body-centered cubic symmetrical structure with periodic lattice of several hundred nanometer composed of double twist structure of LC director to the single twist structure of LC director is strongly dependent upon the thickness of chiral nematic LC, where as the transition among cubic symmetrical structures and the transition from isotropic structure to cubic symmetrical structure are independent upon the changing of LC thickness. In other words, chiral nematic LC molecules confined in the very small space such as several hundred nanometers would be more hard to change from the body-centered cubic symmetrical structure to single twist structure of LC director.

Figure 4 shows chiral nematic LC mixtures thickness dependence of temperature range from isotropic phase to BPs on cooling (a), and from chiral nematic phase to BPs on heating (b) at two concentrations of chiral nematic LC mixture such as 7.0 and 7.5 wt%. In the case of 7.5 wt% chiral nematic mixture, the temperature range of BPs at the 0.5 μm thick part of LC layer was the more than 10 K, and also, in



(a)



(b)

FIGURE 4 Thickness dependence of the temperature range of BPs on cooling (a) and heating (b) of wedge cell at the concentration of 7.0 and 7.5 wt% chiral nematic LC mixtures.

the case of 7.0 wt% chiral nematic mixture at the 0.5 μm thick part of LC layer, the temperature range of BPs was the more than 8 K as shown in Figure 4a). These results indicate that the magnitude of BPs temperature range at the very thinner part such as 0.5 μm is dependent upon the chirality of chiral nematic LC mixture. Namely, the temperature range of BPs at 0.5 μm thick part is increased with increasing chiral dopant. In general, the chirality due to twist power of LC director of BPs is the larger than the one of chiral nematic phase LC [11]. Therefore, it could be reasonable that the increase of chirality of chiral nematic LC involves the enlargement of BPs stability at the very thinner LC molecules surrounded by solid material from the result of Figure 4a).

However, on heating process of the cell, in the case of 7.5 wt% chiral nematic LC, the temperature range of BPs at 0.5 μm thick part is the more than about 1 K, in comparison with the thicker part such as 2 and 4 μm and also, in the case of the lower concentration of 7.0 wt% chiral nematic LC, the temperature range of BPs at 0.5 μm thick part was almost same to those of the thicker part of 2 and 4 μm as shown in Figure 4b). These results indicate that the transition from chiral nematic phase to BPs and from BPs to isotropic phase on the heating process are not almost affected by the changing of the thickness and the chirality of chiral LC mixture.

And also, it was reported that BP-1 is easily supercooled with respect to the chiral nematic phase by several degrees [12–14]. Therefore, the enlargement of BP-1 temperature range on cooling at the 0.5 μm thick part could be connected to the larger supercooling effect in comparison with those of the thicker parts. However, there is not only supercooling effect, but another effect could be existed because of the abrupt enlargement of BP-1 temperature range at the thickness less than the 0.5 μm and the chiral dopant amounts dependence of BP-1 temperature range. We need further study to discuss more perfectly about the chiral nematic thickness dependence of BP-1 temperature range.

4. CONCLUSIONS

It is confirmed that the temperature range of BPs was strongly dependent upon the thickness of chiral nematic LC and the temperature range of BP-1 was more strongly affected by changing of their thickness in comparison with the one of BP-2 on cooling process. And also the temperature range of BPs at the very thinner part of LC molecules surrounded by solid material was dependent upon the chirality of chiral nematic LC.

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