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In this paper, we present electro-optic characteristics in cholesteric phase of the bimesogenic material with the helical twist power [HTP] agent BDH1218. The cholesteric phase of such mixture is more stable than blue phase and frequency-dependent in its alternative-current electric field response. It shows multi-stable-like domain structure characterized by the frequency and voltage applied. There are two driving methods for operation as a display. One is changing voltage under each of high and low frequency. The other is changing frequencies under a high voltage. We consider that the electro-optic characteristics of this cholecteric phase could be applied to electro-optic storage devices since all obtained gray levels are realized as memory states.

Keywords: bimesogen; cholesteric liquid crystal; LC bistability

PACS Numbers: Codes 42.70.Df and 64.70.M

INTRODUCTION

Recently, the blue phases of cholesteric liquid crystal have been investigated extensively with many potential applications. Blue phases can scatter light by Bragg condition in the visible wave length range because the blue phases have 3-dimensional structures in wavelength scale light. Blue phases contain also many domains which are aligned

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differently, so the color of the reflected light is different for each domain, inducing a mosaic color patterns [1]. In general, however, the blue phases are observed in a narrow temperature range between the isotropic and cholesteric phase in highly chiral doped liquid crystals. As a reason about this, Meiboom *et al*. described that the free energy of a blue phase double twist structure could be reduced only when the liquid crystal approaches the isotropic transition [2]. In contrast, Coles et al. recently found blue phase materials with a wide temperature range due to their very high flexoelectric properties. The materials are mixtures of bimesogenic molecules with 3.9% of the high twisted power [HTP] agent BDH1218 (Merck Chemicals) [3]. However, such blue phases still have many problems in electro-optic characteristics as a LC display due to irreversible director behavior caused from unstable blue phase state.

In this paper, we investigate electro-optic characteristics of the bimesogenic material with the helical twist power [HTP] agent BDH1218 used by H. J. Coles and examine stability in blue phase and cholesteric phase of the material for an LCD application. From experimental result, we find that the cholesteric phase of such mixture is more stable than blue phase and has frequency-dependent in its alternative-current electric field response. The cholesteric phase of the material shows various stable domain structure modulated by the frequency and voltage applied.

EXPERIMENT AND RESULT

We used the blue phase material mixing both symmetric and non-symmetric bimesogens presented by H. J. Coles [3] as shown in Figure 1. In this experiment, we used mixtures of the ratio 30% for $n = 7$, 35.5% for $n = 9$, 30% for $n = 11$ with 4.5% of HTP agent BDH1281. The ratios are determined by weight percent and n means the number of methylene spacers in the alkyl chain linking the two mesogenic structures. The material was injected in 60°C into

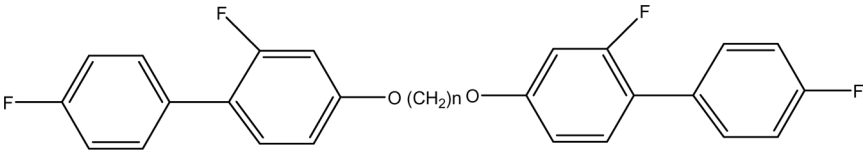

FIGURE 1 Chemical structure of bimesogenic material used in this experiment.

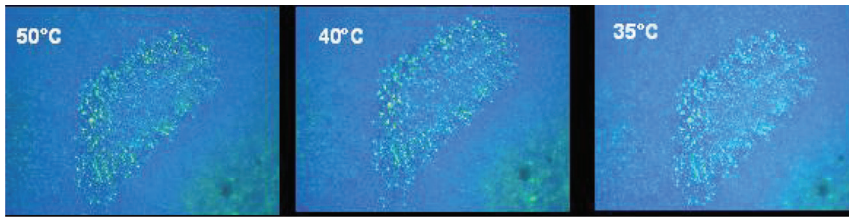

FIGURE 2 Typical text of blue phase 1 observed reflective microscope.

20-μm-thick sandwich cell in which there is no alignment layer on electrode.

Figure 2 shows blue color with two specific platelets (green and blue) observed in reflective spectrum of typical blue phase I. The cooling rate was 0.05°C/min at near isotropic-nematic phase transition temperature and 0.5°C/min at under 55°C. There is little difference of image between 35°C and 50°C. The material exhibited blue phase I with a wide temperature range as reported by H. J. Coles. However, we observed that the blue phase induced by bimesogen is unstable especially with defects. Figure 3 shows that the blue phase collapses gradually by non-wetting air defect and is changed into cholesteric phase. The blue phase was collapsed more rapidly at lower temperature. This may mean that the blue phase by the bimesogenic mixture is unstable even though it has a wider temperature range.

We examine also whether the blue phase by the bimesogenic mixture has the potential capability as a display or not. Figure 4 are the transmissive microscopic images showing the change of the text of the blue phase when in-plane electric field with 1 KHz is applied. In this case, the blue phase was changed abruptly into cholesteric phase, having frequency-dependency and was irreversible from the cholesteric phase even in any driving skill. From this result, we estimate that the blue phase by the bimesogenic mixture may be difficult in LCD applications due to its unstable state.

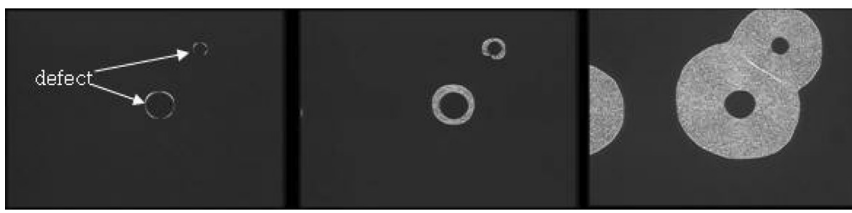

FIGURE 3 Collapse of blue phase by defect observed transmissive microscope.

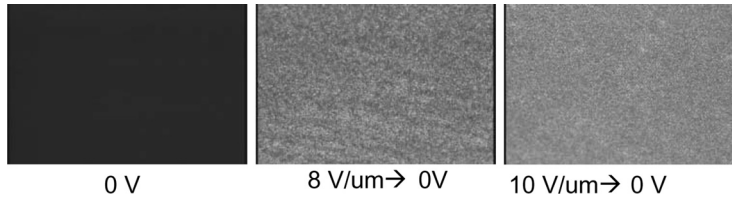

FIGURE 4 The blue phase collapsed by in-plane field of 1 KHz. It is not reversible.

So, as one of actual approaches for LCD application of this material, we investigate electro-optic characteristics in the cholesteric phase of the bimesogenic material. The cholesteric phase is generated from rapid cooling. Figure 5 shows the transmissive microscopic images of two stable states in the cholesteric phase. It has been well known that the A state, a scattering mode, is driven by eletrohydrodynamic instabilities induced from the motion of doped charged impurities at low frequency power and the B state, the optically clear state, is led by dielectric reorientation at high frequency power [4]. As shown in Figure 4, it is possible to produce various gray levels by applying an appropriate voltage and frequency between A state and B state. All states including gray states have almost permanent stability with no degradation. After all, it shows multi-stable-like domain structure characterized by the frequency and voltage applied. The reduced threshold voltages are within $4 \sim 10\,V/\mu m$ and the response time depending on applied voltage is within $100 \sim 20\,s$. Therefore, from these electro-optical operating results of the cholesteric phase, we suggest that the material can be used in a long time memory display with low power consumption and slow update.

Here, we also propose the switching method between two states. There are two driving methods for operation as a display as shown in Figure 6. One is changing voltage under each of high and low

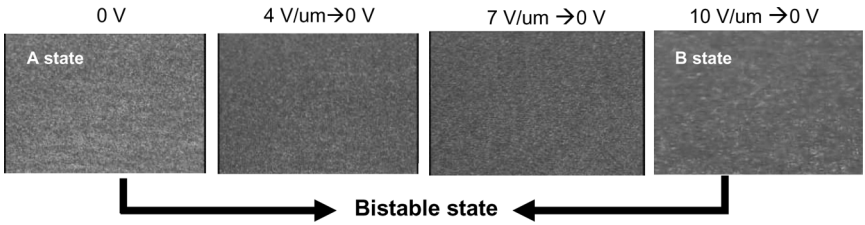

FIGURE 5 Two stable states in cholesteric phase shown by vertical field.

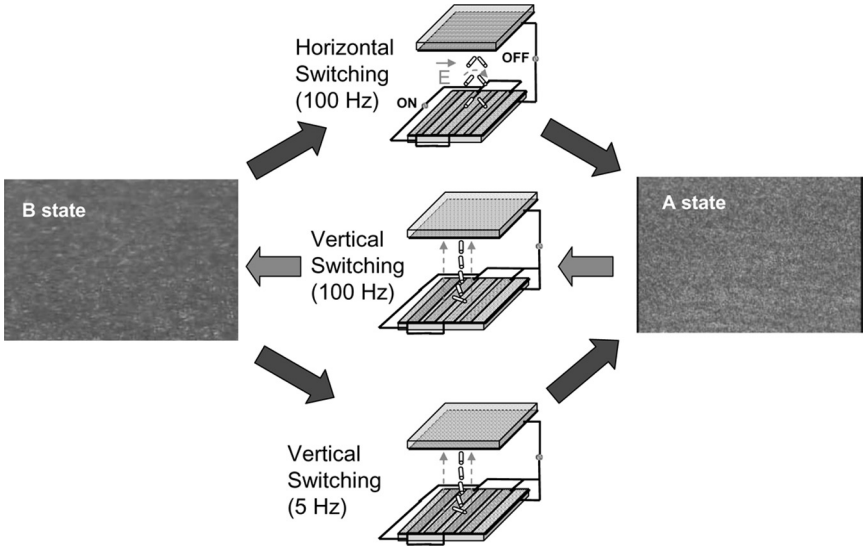

FIGURE 6 Schematic of switching methods between two stable states in cholesteric phase.

frequency. The other is changing frequencies under a high voltage. In the case of vertical switching of this experiment, to change the B state into the A state, we have to apply higher frequency field to the LC and to change the A state into the B state, lower frequency field must be applied. On the other hand, in the case of horizontal switching, we could change easily the B state into the A state by using electric field about 100 Hz, but it was difficult to change the A state into the B state even in both higher and lower frequencies. It may be due to intrinsic property related to strong flexo-electric effect of the bimesogenic molecule with the chiral impurity.

CONCLUSION

We investigate electro-optic characteristics in cholesteric phase of the bimesogenic material with the helical twist power [HTP] agent BDH1218. The cholesteric phase of such mixture is more stable than blue phase and frequency-dependent. The cholesteric phase of the material shows various stable domain structure modulated by the frequency and voltage applied. We consider that the electro-optic characteristics of this cholecteric phase could be applied to electro-optic storage devices with low power consumption since all obtained gray levels are realized as memory states.

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