Invited paper: Blue Phase Liquid Crystal Mediums by Doing Chiral Dopant with High Helical Twisting Power

Jeoung-Yeon Hwang[1], Young-Eun Kang[2], Kwang-Soo Bae[1], Chang-Jae Yu[1,2], and Jae-Hoon Kim[1,2*]

[1]Department of Information Display Engineering, Hanyang University, Seoul 133-791, Korea

[2]Department of Electronic Engineering, Hanyang University, Seoul 133-791, Korea

*Tel.:+82-2-2220-0343, *E-mail: jhoon@hanyang.ac.kr*

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Abstract

We report a study of the effect of the chiral dopant with high helical twisting power (HTP) on blue phase (BP) liquid crystal medium. The BP temperature range decrease with increasing the concentration of chiral dopant with high HTP as keeping same chiral pitch approximately, while the isotropic temperature of the BP mixture was increased. The threshold voltage of the cell with high HTP was lower than that of the cell without high HTP.

1. Introduction

Blue phase (BP) liquid crystals (LCs) are highly chiral materials that self-organize into an arrangement characterized by strong helical twisting along any radial direction around a central director that is perpendicular to all twist axes, which are the so-called double twisted cylinders [1]. BPs exist within a very narrow temperature range between the isotropic and cholesteric phases. Three types of BPs, BP I, BP II, and BP III, were discovered. Two (BP I and BP II) of the three types of BPs pack into a cubic lattice on a scale ranging from one to two hundreds of nanometers, while the third type (BP III) is amorphous. The field-induced birefringence, the so-called Kerr effect, in a BPLC has been reported without the alignment layers. Recently, the polymerization of a small amount of reactive monomer in a BPLC has been another breakthrough. The phase-separated polymer tends to nucleate at the defect regions and is capable of stabilizing the cubic lattice against the temperature variation [2]. With the discovery of new blue phase liquid crystal mixtures and polymer composites, fast switching displays have been explored; however, the issues of high switching voltage, hysteresis, light scattering and long-term stability are still challenges for practical applications.

One of important is to study about the relationship between the electrooptic response properties and the chiral pitch of a BP [3]. The variation of BP temperature range according to the concentration of chiral dopant was approximately small. The effect of the chiral pitch on the response time was dependent on type of electric field-induced birefringence of the BP, while the effect of the chiral pitch on the response was insignificant due to few millisecond response times. Recently, the temperature range of BP I in a sample mixture of bent-core molecules having a nematic (N) phase and some percentage of a chiral additive with high helical twisting power (HTP) was reported [4]. They experimentally confirmed the existence of BP over a wide temperature range (~15 °C) in a bent-core molecular system, which was already predicted by theoretical studies.

Here, we report a study of the effect of the chiral dopant with high HTP on blue phase liquid crystal medium. The BP temperature range decrease with increasing the concentration of chiral dopant with high HTP to keep approximately same chiral pitch, while the isotropic temperature of the BP mixture was increased. We will report the about the relationship between the electrooptic properties and the chiral dopant with high HTP.

2. Experimental

The BPLC (E. Merck) consists of a nematic mixture whose optical birefringence is Δn (~0.27), and dielectric anisotropy $\Delta\varepsilon$ (~11) and two chiral dopants with low and high HTPs. The helical pitch of the mixture estimated in the cholesteric phase is about 0.25 μm. The BP mixtures were prepared by mixing chiral dopant with high HTP such as 0, 0.1, and 1 wt.%, respectively. The cel ls were heated to the isotropic state temperatures of the BP materials and cooled to the BP at 0.2 °C/min on a polarizing optical microscope (POM) equipped with a hot stage and computer program-assisted controller. To determine the electro-optical (E-O) properties of the B P materials, in-plane switching (IPS) cells were prepare d by assembling two glass substrates; one substrate wit h the patterned indium-tin-oxide (ITO) electrode and th e other with no electrode. The substrates with ITO ele ctrode were lithographically prepared with an interdigita ted pattern of 4 μm electrode line width (w) and 5 μm e lectrode line space (l). The IPS cells with either 5 μm c ell gap are assembled by spraying glass bead spacers with the corresponding size between substrates. The E-O characteristic properties of the BP cells were measur ed with a lab-built electro-optic measurement (EOM) system.

3. Results and Discussion

Figure 1 shows the relationship of BP temperature range and the concentration of the chiral dopant with high HTP in the BP mixtures. The istropic temperature of BP increases with increasing the concentration of the chiral dopant with high HTP while the range of BP temperature decreased with increasing the concentration of the chiral dopant with high HTP. This result indicates the chiral dopant with high HTP can be due to increase istropic temperature of BP, and an elongation of the cubic lattice or enlargement of Kerr constant of the BP mixture by the strong permanent dipole interactions of the the chiral dopant with high HTP.

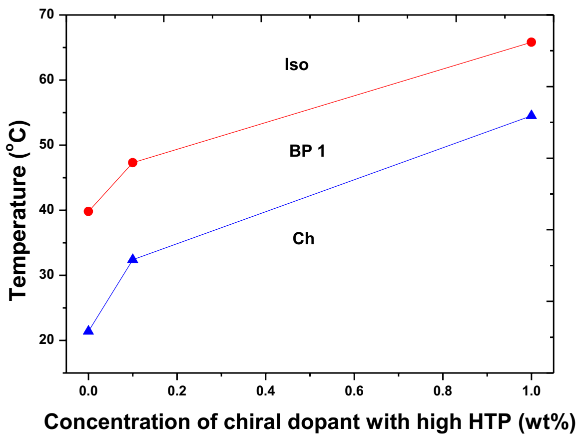

Fig. 1 The plot of BP temperature range according to the concentration of the chiral dopant with high HTP

Figure 2 shows the curves of transmittance versus applied voltage with the chiral dopants with high HTP (0 wt.% and 0.1 wt.%). The transmttance of 0.1 wt.% BP mixture increases than that of 0 wt.% BP mixture, while the threshold volage (V_{th}) of 0.1 wt.% BP mixture decreases than that of 0 wt.% BP mixture (Fig. 2). The reduced operating voltage and increased transmittance is thought to be caused by an increase in Kerr constant because the enhanced Kerr constant is related to the saturated induced birefrignece Δn_s, and the stauration electric field E_s as follow [5];

$$K \approx \Delta n_s/(\lambda E_s^2). \quad (1)$$

As shown in Eq. (1), the Kerr constant increase as the concentration of the chiral dopant with high HTP increase. This is corroborated with the extended Kerr constant Δn, which is due to the increase of the trasnmittance as increase in the concentration of the chiral dopant with high HTP as shown in Eq. (2) as follow;

$$I/I_0 = \sin^2(\pi d \Delta n / \lambda), \quad (2)$$

where I_o is the intensity of the initial incident light.

Conspicuously, compared to the cell with 0 wt.% the chiral dopant with high HTP, the the cells with the same configuration but with 0.1 wt.% the chiral dopant with high HTP show significant improvements in operating and turn-on voltages due to the increase in concentration of the chiral dopant with high HTP in the BP mix -ture.

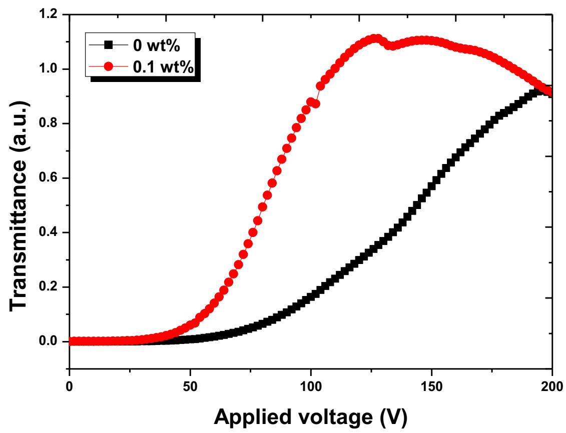

Fig. 2 The plot of VT curves for the cell with 0 wt.% and 0.1 wt.% chiral dopant with high HTP

4. Summary

A low voltage and high transmittance blue phase liquid crystal mixture has been demonstrated with the chaial dopant with high HTP in BPLC. The range of BP temperature decreased with incresing the concentration of the chiral dopant with high HTP. Electro-optical behavior of the blue phase material with chiral dopant with high HTP led to reduction in operating and turn-on operational voltages. The reduction in applied voltage is believed to be achieved by the addition of a high bire-fringence and dielectric anisotropic dopant.

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