A blue phase liquid crystal for low-voltage Kerr devices

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Abstract

We report here a low-voltage liquid crystal Kerr device with chiral dopants including high helical twisting power (HTP) on blue phase (BP) liquid crystals. 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.

Keywords : BP, HTP, Kerr device, chiral dapant.

Introduction

The advances in liquid crystal (LC) materials and display technologies have led to the development of high performance liquid crystal displays (LCDs) where high brightness, contrast, and ultra-sharp images with vivid color (high color saturation) are commercially available. Many LCD technologies such as super polydomain vertically aligned nematic[1], super in-plane-switching[2], and optically compensated bend nematic[3] have been developed to meet these goals; however, these LC modes still lack the response speed to display video rate images. A device that retains the favorable features of existing displays and is capable of displaying motion picture quality images without blurring is in high demand. To improve the response time of a modern LC device, one may use an ultra-low viscosity LC or reduce the cell gap by using a LC with a large value of optical birefringence. In general, the effort in exploring new fast switching liquid crystal materials is limited to nematics.

Blue phase liquid crystals 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.[5-11] Blue phases exist within a very narrow temperature range between the isotropic and cholesteric phases. A total of three types of blue phases were discovered. Two of the three types of blue phases pack into a cubic lattice on a scale ranging from one to two hundreds of nanometers, while the third type is amorphous. In contrast to conventional nematic and smectic liquid crystals, BPLCs have no linear birefringence, but like cholesteric liquid crystals they selectively Bragg reflect circularly polarized light. The field-induced birefringence, the so-called Kerr effect, in a BPLC has been reported without the alignment layers.[9]

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.[10] 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.[11,12] Expanding the blue phase temperature range was also reported with a mixture of bimesogenic nematic LCs with a chiral dopant.[13] However, the bimesogenic nematic based BPLCs exhibit the electric field induced phase transition from a blue phase to a cholesteric and reversing of this transition requires heating the material to an isotropic state.

Here we report an induced BPLC with low switching voltage characteristics for Kerr devices by using two kinds of chiral dopant which use low and high HTP, respectively.

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 cells 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 BP materials, in-plane switching (IPS) cells were prepared by assembling two glass substrates; one substrate with the patterned indium-tin-oxide (ITO) electrode and the other with no electrode. The substrates with ITO electrode were lithographically prepared with an interdigitated pattern of 4 μm electrode line width (w) and 5 μm electrode line space (l). The IPS cells with either 5 μm cell gap are assembled by spraying glass bead spacers with the corresponding size between substrates. The E-O characteristic properties of the

BP cells were measured with a lab-built electro-optic measurement (EOM) system.

Results and Discussion

Table 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.

TABLE I
The BP temperature range according to the concentration of the chiral dopant with high HTP.

Sample	CD(%)	Temperatureange/°C	T/°C
1	0	39.8–21.4	18.4
2	0.1	47.3–32.4	14.9
3	1	65.8 – 54.5	11.3

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 [14];

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

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 concen-tration of the chiral dopant with high HTP in the BP mix-ture.

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 temper-ature 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 birefringence and dielectric anisotropic dopant.

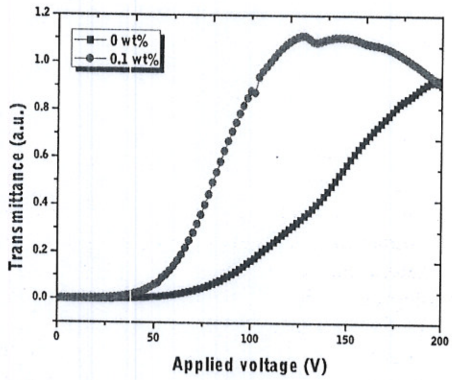

Fig. 2 The plot of VT curves for the cell with 0 wt.% and 0.1 wt.% chiral dopant with high HTP

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