High Transmittance Polymer-Stabilized Blue Phase Liquid Crystal Display with Fringe Field Switching Electrodes

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Abstract
We propose a polymer-stabilized blue phase liquid crystal (PS-BPLC) device with low operation voltage in fringe-field switching (FFS) electrodes. The in-plane field between the silt electrodes improve the transmittance due to the enhancement of the horizontal field. High transmittance in our PS-BPLC was obtained under low operation voltage.

Author Keywords
Blue phase, polymer stabilized, liquid crystal display, field fringe switching

1. Introduction
Polymer-stabilized blue phase liquid crystal (PS-BPLC) is a promising candidate for next generation display and photonic technology due to their revolutionary characteristics, such as fast response time in sub-millisecond range, excellent dark level by inherently optical isotropic phase, wide and symmetric viewing angle, and no need for any process for initial LC alignment [1, 2]. The electro-optic characteristics of PS-BPLC are governed by the Kerr effect which can lead to the transition from isotropic to anisotropic phase unlike conventional nematic LCs. In other words, when the horizontal electric field is applied into LC layer, birefringence is induced by the electric field distortion of the symmetric cubic structure with the optically isotropic state. In the presence of an electric field (E), the induced birefringence (Δn_i) can be determined by the Kerr effect model [3, 4] $\Delta n_i = \lambda k E^2 = (\Delta n_0)(E/E_s)^2$ where λ is the wavelength, Δn_0 is the maximum birefringence, and E_s is the saturation electric field. As increasing the E, the Δn_i is increased gradually. When the E is reached to E_s, Δn_i could be close to maximum birefringence value (Δn_0). And the transmittance efficiency of the PS-BPLCD is corresponded with the induced birefringence (Δn_i) by Kerr effect which is caused by the horizontal electric field induced reorientation of LC molecules [5-10]. At present, the electrode of in-plane switching (IPS) and fringe field switching (FFS) types are typical methods for the horizontal field-dominant switching of LC modes. It is commonly known that the FFS type applied to nematic LCD can induce lower driving voltage and higher transmittance than those of the IPS electrodes. However, for the PS-BPLCD, the FFS type exhibits worse transmittance efficiency due to dark patterns in two dark areas (between and on the patterned electrodes) as shown in Fig. 1 [11]. It also has higher driving voltage because the electric field cannot deeply and uniformly penetrate into LC bulk. Thus, the IPS type is mostly employed for the PS-BPLCD.

In this work, we propose PS-BPLC device driven by in-plane and fringe fields on the conventional FFS electrodes. The common electrode under the passivation layer is kept on 0 V and the patterned pixel electrodes are swung to the same potential but the opposite polarities. Through this structure and driving method, our PS-BPLC device could obtain the low driving voltage by the strong horizontal electric field which can penetrate deeply into the BPLC layer. Moreover, it had the enhanced transmittance due to the removal of dark stripe pattern at the center between the patterned electrodes. Eventually, we could achieve the low operating voltage (~32 V) to be low 25 V while keeping an optical transmittance similar to it of the IPS type.

2. Cell structure and preparation
Figure 1 is the schematic diagram of device structure with the electrode configurations proposed in this work. The pixel electrodes with 4 μm width and 6 μm intervals are patterned on the bottom substrate and are driven by the applied voltage of the opposite polarity to the neighboring pixel electrodes. The common electrode is separated with the pixel electrodes by a thin passivation layer. PS-BPLC material was injected into cell space of 12 μm at a temperature condition in the isotropic phase (over ~ 50 °C). It is composed with reactive mesogen (RM, RM257, E.

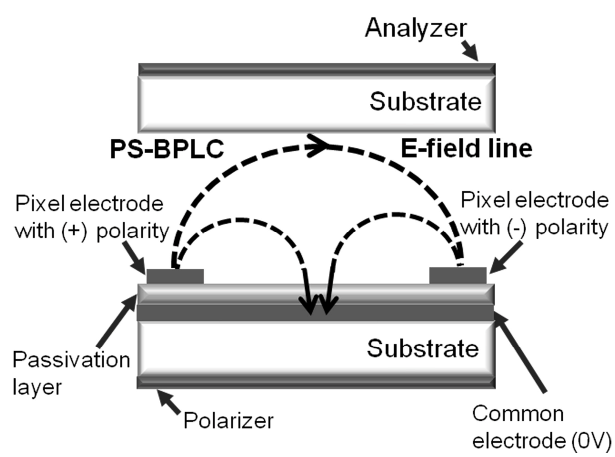
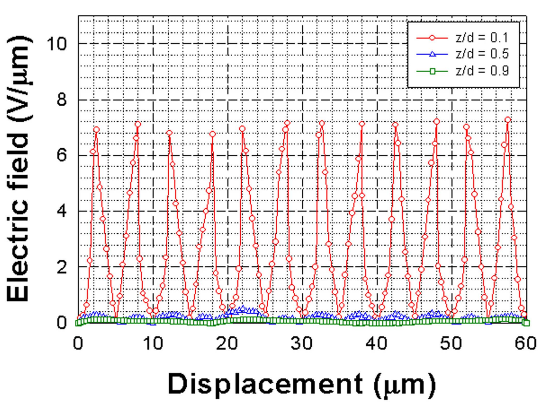


Figure 1. Schematic diagram of PS-BPLC cell with an in-plane and fringe fields

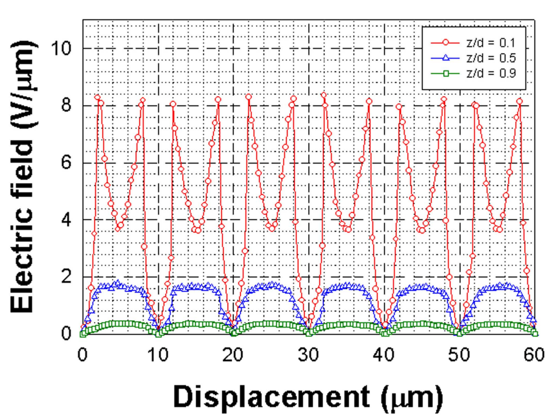
Merck), monomer (EHA, Aldrich), chiral dopants (E. Merck), and photo initiator (Igracure651, Ciba Chem.) with suitable molar ratio in the particular host nematic LCs. After the LC filling process, we exposed the UV light (intensity ~ 5.4 J/cm^2, λ = 365 nm) to polymerization of RMs which could stabilize the blue phase structure and widen the temperature range. Polymer stabilized LC mixture could keep in blue phase until 56 °C. When we applied voltage to the proposed PS-BPLC cell, the common electrode is keeping at 0 V. And voltages with opposite polarities are applied to the pixel electrodes. We expected that the fringe field between common and pixel electrodes and the in-plane electric field between pixel electrodes could make the strong horizontal field and penetrate deeply into the LC bulks. From this configuration, the operating voltage will be reduced and high transmittance will be achieved.

3. Results and Discussion

Figure 2 shows the 2D electric field distribution along the



(a)



(b)

Figure 2. Electric field distributions according to the z/d where z is vertical position from the bottom substrate and d is the cell gap: (a) a conventional FFS cell and (b) a proposed FFS cell

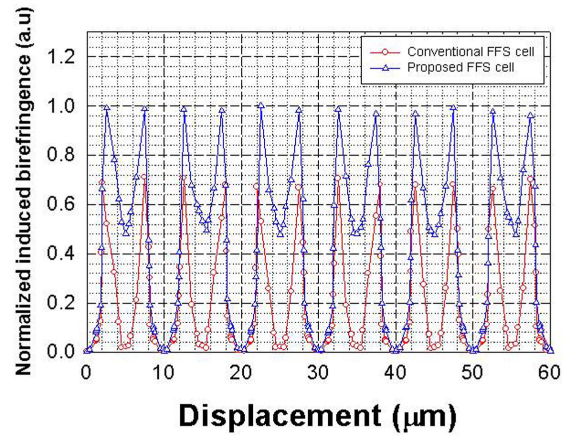


Figure 3. Calculated induced birefringence by the electric field along the horizontal direction at the voltage condition of 30 V

horizontal direction by using the simulation tool (Techwiz LCD, Sanayi system). The electric field distribution is calculated at five different positions between near the bottom substrate (z/d = 0.1) and near the top one (z/d = 0.9), where d is cell gap and z is the position between bottom and top substrate. As shown in Fig. 2(a), the conventional FFS type has the strong horizontal electric fields near the pixel electrodes around the bottom substrate. However, decrease of the electric field was generated between pixel electrodes. The horizontal electric field was also getting weaker as it approached a top substrate. In a FFS cell applied to our driving method, we could confirmed that the considerable E-field of 8 V/μm was generated between pixel electrodes as well as stronger horizontal electric field on the edge of pixel electrodes. It was expected that larger induced birefringence could be induced by enhanced electric field distributions of our cell.

Through the electric field distribution by using the simulation tool, we could calculate the induced birefringence and transmittance at each position of the PS-BPLC cells of two types (a conventional FFS cell and a proposed one), as shown in Fig. 3. At the same voltage condition of 30 V, a conventional FFS type has the decreased transmittance due to the dark pattern between electrodes upper the insulating layer. This weak transmittance is the reason that FFS electrode structure cannot be applied to PS-BPLCD. Contrarily, our cell had higher induced birefringence and could solve the optical demerit of the conventional FFS type. The conventional cell should get the higher electric field to have the same birefringence of our cell. From these results, we could expect that our PS-BPLC cell gets the good display characteristics such as low driving voltage and high transmittance.

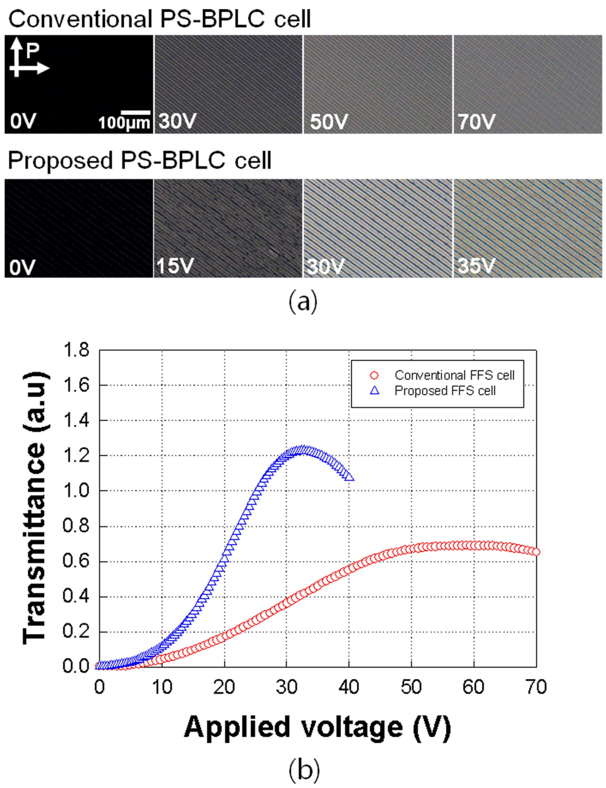


Figure 4. (a) Microscopic textures of experimental cells under the crossed polarizers as a function of applied voltages and (b) normalized voltage-transmittance (V-T) characteristics

Figure 4 shows the voltage-transmittance (V-T) characteristics of our PS-BPLC cell and other. In the field off-state, there is no light leakage even though the cells are rotated between crossed polarizers. When the applied electric field is increased gradually, the transmittance is also increased until the induced retardation ($d_i\Delta n_i$) by electric field is reached to $\lambda/2$. As shown in Fig. 4(b), the maximum transmittance is gotten at 32 V and 58 V for the proposed cell and other, respectively. In real LCD driving, our PS-BPLC cell needs the swing voltage difference of 64 V at frame by frame. On the other hand, the conventional PS-BPLC cell with FFS type needs the 116 V which are larger than proposed PS-BPLC cell's one [12]. From these results, we could confirm that our PS-BPLC cell with the designed electrode structure get the good display characteristics such as low driving voltage and high transmittance.

4. Conclusion

In this work, we propose PS-BPLC device driven by in-plane and fringe fields on the conventional FFS electrodes. The common electrode is kept on 0 V and the patterned pixel electrodes are swung to the same potential but the opposite polarities. Our cell could be got the lower operating voltage than conventional cell's one and good transmittance similar to conventional cell with the IPS type due to the elimination of dark stripe pattern between pixel electrodes. Besides, it is expected that our PS-BPLCD is to be applicable to the next generation display for high display performance and simple the driving properties.

5. Acknowledgements

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6. References

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