Low Voltage Driven Polymer-Stabilized Blue Phase Liquid Crystal Device with Combined In-Plane and Fringe Field

Jae Ho Lee[1], Kwang-Soo Bae[2], Soo In Jo[1], You-Jin Lee[1], Chang-Jae Yu[1,2], and Jae-Hoon Kim[1,2*]

[1]Department of Electronic Engineering, Hanyang University, Seoul 133-791, Korea
[2]Department of Information Display Engineering, Hanyang University, Seoul 133-791, Korea
Jhoon@Hanyang.ac.kr*

Abstract

We present a low voltage driven polymer-stabilized blue phase liquid crystal (PS-BPLC) device by in-plane and fringe field inner cell. The combined electric field between the slit electrodes can penetrate deeply and induce higher birefringence in LC layer. Thus, high transmittance in our PS-BPLC device was obtained under lower driving voltage.

Keywords: blue phase, liquid crystal, polymer-stabilization, induced birefringence, in-plane field, fringe field

1. Introduction

Polymer-stabilized blue phase liquid crystal (PS-BPLC) device has been an attractive candidate for next generation display owing to good characteristics, such as submillisecond response time, wide and symmetric viewing angle by optically isotropic dark state, and unnecessary surface treatment for LC aligning [1, 2]. However, despite of the several merits, high operating voltage which is still far beyond the acceptable range of mainstream thin film transistor (TFT) can be improved significantly for its widespread applications.

The electro-optic (EO) characteristics of PS-BPLC device are decided by the Kerr effect which can lead to the transition from isotropic to anisotropic phase unlike conventional nematic LCs. In the presence of an electric field (E), the induced birefringence (Δn_i) can be determined by the Kerr effect model [3], $\Delta n_i = \lambda k E^2 = (\Delta n_0)(E/E_s)^2$ 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-BPLC device is corresponded with the induced birefringence (Δn_i) by Kerr effect which is caused by the horizontal electric field induced reorientation of LC molecules [4-6]. By these physical relations, for inducing the maximum birefringence in the condition of lower voltage condition, the strong and deep electric field has to be penetrated into LC layer. Several researches to lower the driving voltage of PS-BPLC device have been introduced, such as the partitioned wall-shaped electrode structure, protrusion electrode structure, and periodic corrugated electrode structure. They have an significant effect on the low driving voltage by the improved electric field characteristic. However, their transmittance is sacrificed and the device fabrication is rather difficult. For realistic PS-BPLC devices, it is satisfied with no decreased transmittance and realistic fabrication as well as low driving characteristic.

In this work, we present the PS-BPLC device with good transmittance and low driving voltage driven by in-pane and fringe field inner cell. The electrode structure has the conventional one for the fringe field switching (FFS) mode, but different electric field distribution by the specified driving method. The strong horizontal electric field penetrates deeply into LC medium and removes dark stripe patterns between patterned electrodes on mainstream FFS type. Finally, our device could be obtained the low driving voltage (~30 V) and improved transmittance corresponding to the existing PS-BPLC device.

2. Cell structure

The schematic diagram of the electrode structure with electric field lines is shown in Fig. 1. Our cell has the conventional FFS electrode structure. The pixel electrodes are patterned with an electrode width w = 4 μm and electrode gap l = 6 μm. The common electrode is separated with the pixel electrodes by a thin passivation layer (g = 0.4 μm). And then, the two substrates were assembled with sustaining a 12 μm cell gap. PS-BPLC material used in this work is consisted of reactive mesogen (RM, RM257, E. Merck), monomer (EHA, Aldrich), chiral dopants (E. Merck), and photo

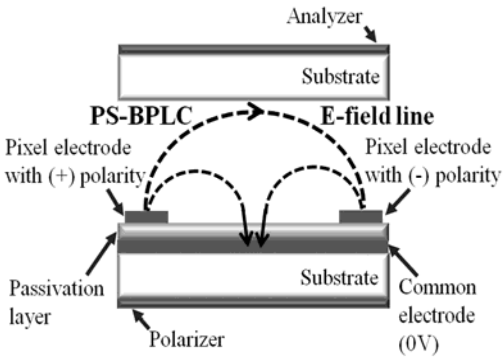

Figure 1. The schematic diagram of PS-BPLC device with an in-plane and fringe fields

initiator (Igracure651, Ciba Chem.) with suitable molar ratio in the particular host nematic LCs. After the LC filling process, the blue phase structure could be stabilized and widen the temperature range through the UV irradiation (intensity ~ 5.4 J/cm^2, λ = 365 nm).

Our cell is driven by the dissimilar electric field to the conventional one. When a voltage is applied to the proposed PS-BPLC cell, the common electrode is kept at 0 V and the pixel electrodes is swept from 0V to tens of one with opposite polarities. It was 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 layer.

3. Result and Discussion

First, for comparing the level of electric field strength and penetration into LC layer of three experimental cells, we have analyzed the 2D electric field distribution along the horizontal direction by using the simulation tool (Techwiz LCD, Sanayi system) as shown in Fig. 2. 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. In calculation, the electrode structure was set up with the same to three experimental LC cells of proposed cell, conventional FFS and IPS cell. The applied voltage was 30 V for experimental cells. In all cases, the electric field is decreased as approaching the top substrate. However, the electric field of the proposed electrode structure is stronger than the conventional FFS and IPS's one near the top substrate (compare at z/d = 0.9). Especially, near the region between pixel electrodes, the electric field strength of the proposed structure is much higher than the conventional IPS's one as well as the conventional FFS' one. In conclusion, a FFS cell applied to our driving method could be 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.

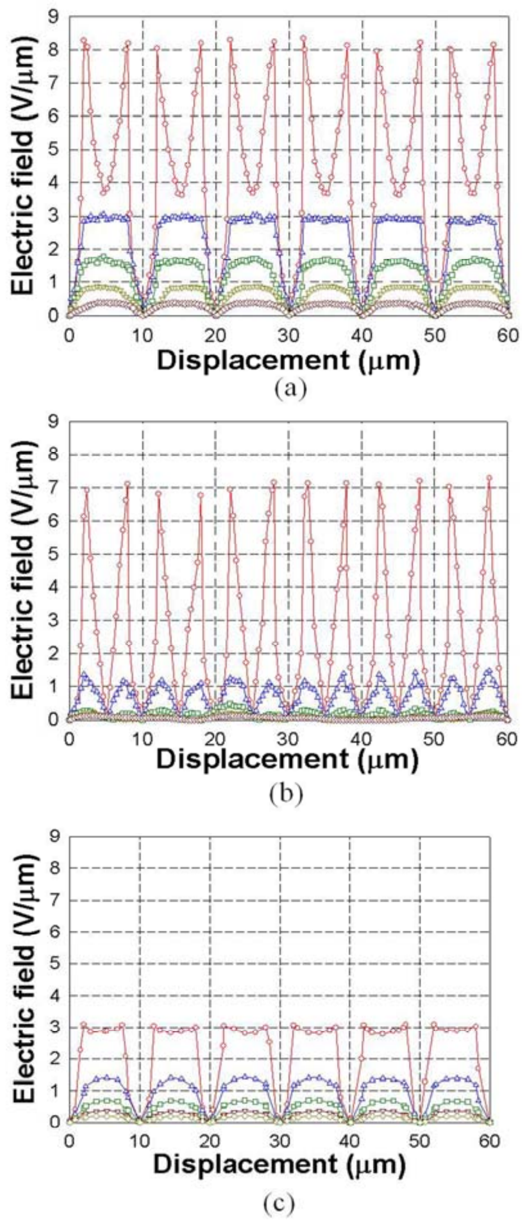

Figure 2. Electric field distributions according to the z/d where z is vertical position from the bottom substrate and d is the cell gap: (a) a proposed FFS cell, (b) conventional FFS and (c) conventional IPS cell

Figure 3 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

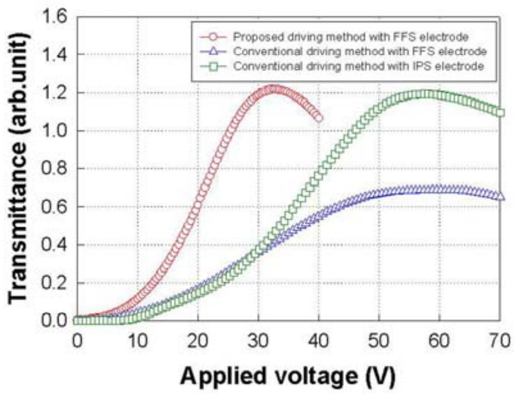

Figure 3. Measured voltage-transmittance curves

increased until the induced retardation ($d_i \Delta n_i$) by electric field is reached to $\lambda/2$. As shown in Fig. 3, the maximum transmittance is gotten at 32 V, 57 V, and 58 V for the proposed cell, conventional FFS and conventional IPS cell, 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 cells with FFS type and IPS type needs 114 and 116 V which are larger than proposed PS-BPLC cell's one [7]. In conclusion, 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, PS-BPLC device driven by in-plane and fringe fields on the conventional FFS electrodes is presented. 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 operate in the lower voltage condition than conventional cells and good transmittance similar to conventional cell with the IPS type due to the removal 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.

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