P-201: Chiral Hybrid In-Plane Switching LC Mode for High Brightness and Contrast Ratio

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Abstract

We propose a new liquid crystal display (LCD) mode, named as chiral hybrid in-plane switching (CHI) mode, which has high brightness and contrast ratio by using a twist effect applied to a conventional hybrid mode on the interdigitated electrode. The mode is optimized to normally white mode without any loss of transmittance on the electrode. The mode has also excellent darkness under field on because LCs are well aligned parallel to the optics axis of polarizer due to lower bulk elastic strength.

1. Introduction

Recently, TFT in-plane switching (IPS) mode of LCDs is widely used due to their wide viewing angle characteristics and uniform gray level and colors since the effective birefringence of LC layer is nearly same even at off-axis [1-6]. In this mode, however, when the voltage is applied to electrode, there is a loss of transmittance on the interdigitated electrode at bright state since the LCs on the electrode rise to the direction of electric field [7]. So in typical IPS mode with 4:6 which means the ratio of electrode width and electrode gap, the transmittance is about 60~65%, comparing to twisted nematic (TN) mode. This mode is also difficult to optimize the fully dark state because of the difference between the rubbing direction and the easy axis of LC and a misalignment between the easy axes of top and bottom LC alignment layers led by the rubbing [8].

To overcome these problems, the normally white IPS mode with initially 90° TN and method of improvement electrode structure for high aperture ratio were presented in interdigitated electrode structure [9-11]. The former shows very high transmittance. However, it shows also bad dark state even under high in-plane field due to difference of rubbing directions by 90° between top and bottom substrates. So it needs very high field which can rotate top surface LCs by 90° to 0°. In The other cases, the transmittance is increased by changing the electrode structure. However, a loss of transmittance on the electrode is remained because the LCs on the electrode still rise to the direction of electric field.

In this paper, we proposed a new LCD mode named as CHI mode, which has high brightness and excellent dark state. The CHI mode set as a normally white LCD mode under crossed polarizer is characterized by adding chiral twist effect to a conventional hybrid nematic liquid crystal mode on the interdigitated electrode structure. In result, this mode shows very high contrast ratio due to high transmittance and good dark state with low light leakage.

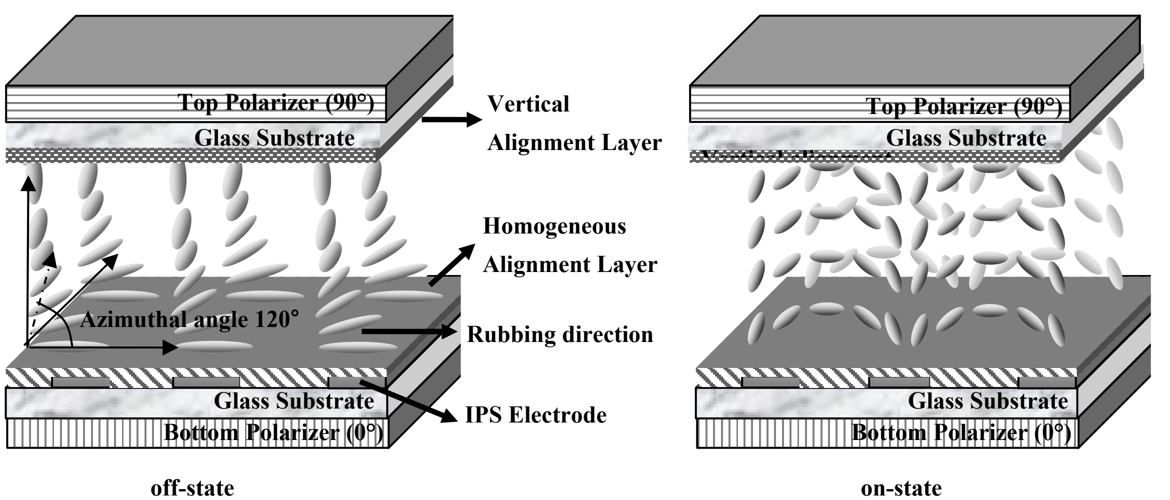


Figure 1. The schematic diagram of proposed LCD mode structure

2. The configuration of the CHI mode

The configuration of CHI mode is shown Fig. 1. The basic structure of CHI mode is same as a conventional hybrid mode which is spin coated by a homeotropic LC alignment layer and homogeneous LC alignment layer on top and bottom substrates, respectively. In our experiment, the bottom substrate was spin coated with JALS 1085 (JSR) for a homogeneous alignment layer. The top substrate was spin coated with AL 60702 (JSR) for a vertical alignment layer. The mode is composed of two crossed polarizers in the direction of 0° and 90° at bottom and top substrates, respectively. Top and bottom substrates are rubbed parallel to the optical axis (0°) of bottom polarizer. Two substrates were assembled with maintaining uniform cell gap by spacer. The indium-tin-oxide (ITO) patterned on the bottom glass substrate was used as an interdigitated electrode to apply horizontal electric field. The width and gap of patterned ITO electrode were 10㎛ and 20㎛. The used LC and chiral dopant were ZKC-5085XX (Δ n=0.15, Chisso) and S-811 (Merck), respectively. The helical twist power of used LC was 10.9 and the S-811, chiral dopant, has a levorotatory. The nematic LC of ZKC-5085XX adopted with the S-811, chiral dopant, was injected into the sandwich cell by capillary phenomenon at a clearing point (108°) of the LC. As shown in Fig. 1, for our structure, the twist effect by adopting the chiral dopant is applied to the conventional hybrid LC mode which is produced typically by homogeneous and vertical alignment layer on bottom and top substrates, respectively. Generally in case of homogeneous LC alignment layers used on both substrates and rubbed to same direction, LC with chiral component is twisted in period by 180° such as 0°, 180°, and 360°. In our proposed case, since they have not azimuthal direction on the vertical alignment layer of the top substrate, LCs are continuously twisted by amount of chiral dopant that determines d/p where d and p are cell gap and chiral pitch, respectively. In our proposed CHI mode, maximum transmittance is obtained numerically under LC cell condition with d/p of 0.4 and Δ n d of 0.62. However, when d/p is 0.4 which means that twisted angle is 144 degree, declination lines can be induced in central area between the interdigitated electrodes, regarded as a singular points of LC behavior resulting from a symmetric electric field area. To guarantee more stable and uniform LC state in really fabricated LC cell, therefore, the d/p was set to 0.33 and the cell thickness was maintained by using glass spacer of 4.5㎛ thick. In this case, the LC was twisted by 120° from bottom to top substrates by the chiral dopant and then, the transmittance is over 90 % even though it is decreased slightly, compared to it in the maximum condition.

3. The characteristic of CHI mode

The CHI mode shows the good darkness as much as IPS mode and removes a loss of transmittance on interdigitated electrode. As referred above, the LC is continuously twisted by adopting chiral dopant and the twisted angle of LC is 120° in our case. Therefore, the CHI mode is optimized to normally white mode without any loss of transmittance on the interdigitated electrode and can get the optically excellent transmittance at initial state by adjusting chiral dopant and cell gap.

In the CHI mode, because the rubbing directions of bottom and top substrates are parallel to the optic axis of bottom polarizer (0°), if only bulk LCs are rotated to field direction, the good dark state will be achieved clearly. Really, it is obtained easily under relatively low voltage since the bulk elastic energy is much lower than surface energy [12]. So we can get also good dark state under lower voltage. In addition, LCs aligned vertically on top substrate which was spin coated with a homeotropic LC alignment layer lead to more excellent dark state in front of an LC panel.

Consequently, we expect that the proposed CHI mode can show more excellent contrast ratio than the conventional IPS mode.

4. The simulated and measured electro-optic characteristic of the CHI mode

The Fig 2. shows the simulated electro-optic (EO) characteristics of the CHI mode and conventional IPS mode. The EO characteristics of the CHI mode and conventional IPS mode were calculated with the commercial simulation program of Tech Wiz LCD (Sanayi System Co., Ltd) based on the 2X2 extended Jones matrix methodes [13]. The simulation condition of the CHI mode and IPS mode were same with experiment. For the simulation of the each mode, ITO was used for electrode and the width and gap of electrode were set to 10㎛ and 20㎛, respectively. The optic axes of polarizers were 0° and 90° at bottom and top substrates, respectively.

For IPS mode, the used LC was ZKC-5085XX (Δ n=0.15, Chisso) that the chiral dopant was not adopted. The cell gap was 3.7㎛ to get maximum transmittance at bright state. The rubbing direction of bottom and top substrates is coincident with the optic axis (0°) of bottom polarizer. The direction of electric field by interdigitated electrode is 83° with respect to LC alignment (0°) to confirm azimuthally one direction rotation of LC.

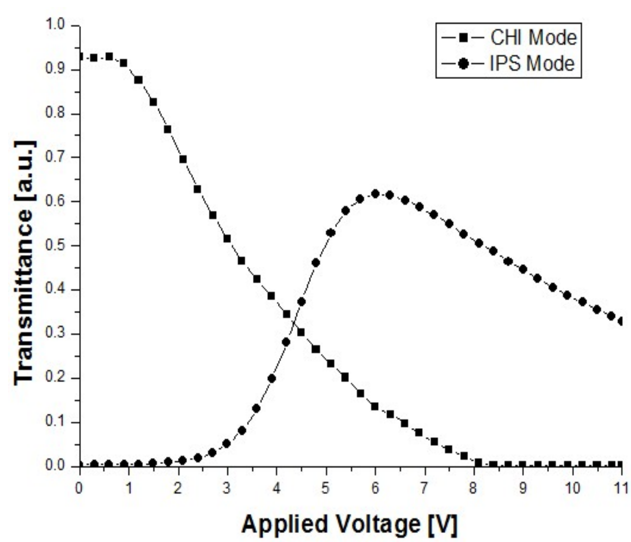


Figure 2. The simulated EO characteristics of the CHI mode and IPS mode

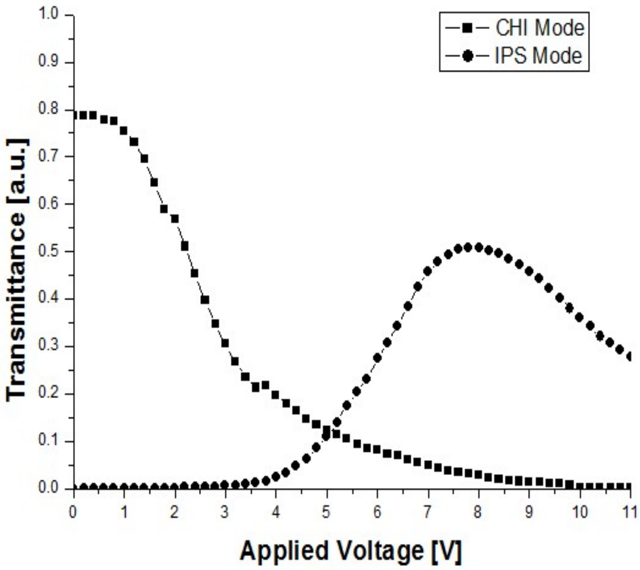
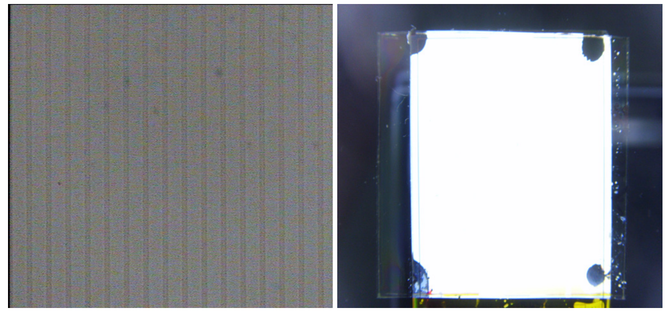


Figure 3. The measured EO characteristics of the CHI mode and IPS mode

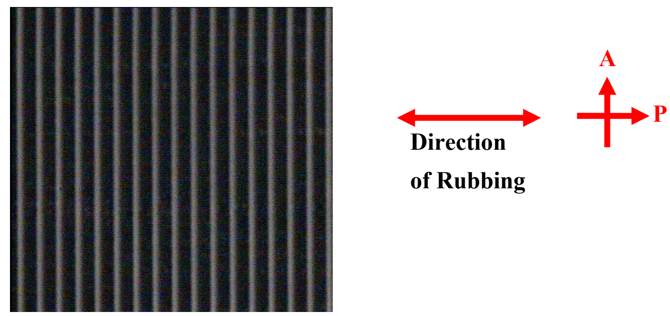
As shown in the figure 2, the transmittance of the CHI mode is much higher than IPS mode at the bright state and the light leakage at the dark state is as small as IPS mode. In the simulation result, we can check that the CHI mode get much higher contrast ratio than the IPS mode.

Figure 3. shows the result of measured EO characteristics of the CHI mode and IPS mode for the same structure condition with the simulation. The measured EO characteristics have good agreement with our expectation and the simulated results. The CHI mode exhibits high contrast ratio (1000:1) with a high transmittance at bright state and good dark state.

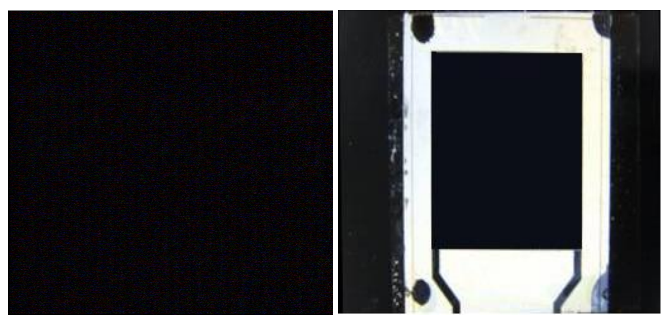
Figure 4. shows the microscope images and photo images of the CHI mode sample corresponding to applied voltage at same cell. Contrary to the IPS mode, we can know that there is no any loss of transmittance on the interdigitated electrode at bright state (0V) as shown in Fig. 4 (a) and the good dark state is achieved as small as the IPS mode as shown in Fig. 4 (c), when the 10 voltage is applied.



(a) 0V



(b) 3V



(a) 10V

Figure 4. The microscope images and photo images of the CHI mode sample.

5. Conclusion

In summary, we proposed a new LCD mode, namely CHI mode applying the chiral effect to the conventional hybrid LC mode in IPS electrode structure. As shown in the simulated and measured EO characteristics results, we could get the dark state as good as the IPS mode since the bulk LCs are well responded to the direction of applied electric field. Contrary to the IPS mode that has a loss of transmittance on interdigitated electrode, the CHI mode doesn't have any loss of transmittance on the electrode at bright state because this mode is optically optimized to normally white mode by chiral effect. As a result, our CHI mode exhibits excellent isocontrast (1000:1) with a high transmittance and good darkness at dark state. We expect that this mode will be used in LCD applications.

6. Acknowledgments

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7. Reference

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