P-147: Novel Electrode Structure in the Super-IPS LC Cell for High-Aperture Ratio

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Abstract

In this paper, we propose a novel electrode structure, which exhibits high-aperture ratio, in the super in-plane switching (S-IPS) liquid crystal (LC) cell for high transmittance. Generally, the transmittance of the S-IPS LC cell is not superior to other LC mode using the multi domain effect because of the low aperture ratio. To improve the aperture ratio of the S-IPS cell, we found the method to minimize the black matrix (BM) area by applying the novel electrode structure which can move the disclination from the active area. As a result, we found that the proposed electrode structure could provide higher aperture ratio than that of the conventional type by reducing the BM area, so that we could achieve the high transmittance compared to the conventional structure. We used the commercial software ‘TechWiz LCD’ for calculation of the director configuration, which applies Q-tensor method.

1. Introduction

Liquid crystal displays (LCDs) have been used widely for applications such as monitors, TVs, and mobile phone display. In particular, recent display devices have been required to have better electro-optical characteristics such as the wide viewing angle and fast response time. The most common LCDs mode is the Twisted Nematic (TN) Mode. It uses an optically uniaxial medium which shows a birefringence effect when light passes through the medium in an oblique direction to the optical axis. The birefringence effect is the cause of limited viewing angles in various liquid crystal modes. For that reason, new technologies to obtain wide viewing angle characteristics have been developed the In Plane Switching (IPS) Mode which has a promising possibility to improve the viewing angle characteristics drastically [1]. Furthermore, the Super In-Plane Switching (S-IPS) technology with two-domains has super wide viewing angle and small color shift performances [2]. In spite of their superior optical properties, optical transmittance of the S-IPS mode is generally lower than the TN mode because of their mechanical electrode structures and non-uniform retardation of liquid crystal cell due to different director profiles around the electrode. In the early days, main issue of the S-IPS mode is how to increase transmittance.

In order to increase the transmittance, Lin has proposed an electrode structure which can decrease the crosstalk over the each line [3]-[5], so that it can increase the optical transmittance. In addition to the crosstalk, we can find out disclination [6] at around the edge of the electrode. Generally, the disclination exhibits unstable dynamical behavior and non-uniform optical transmittance, so that BM area is needed to block the disclination. In this presentation we propose the novel zigzag pattern of the electrode which can reduce the BM area by moving the disclination to out of the active area. This can induce the high optical transmittance compared to the conventional structure. We calculated the director configuration of the S-IPS cell using Q-tensor method [7]. As a result, we found that optical transmittance increases in compared to the conventional structure.

2. Experimental

Figure 1 The crosstalk effects by the structure in dark state. (a) The conventional structure of the electrode. (b) Optical transmittance of the conventional

Figure 2 The crosstalk effects by the structure in dark state. (a) The novel structure of the electrode. (b) Optical transmittance of the novel structure.
and the shielding pattern in the dark state. The conventional structure of the electrode occur the light leakage between data line and common line. So we use the Black Matrix (BM) to prevent light leakage. The width of BM is 36um. Then the light leakage is also occurs between data line and pixel by capacitance. So we use Lin’s structure for solving them. Figure 2 (a) represents the novel structure of the electrode to decrease the crosstalk between the lines in cross-sectional view. Lin optimized electrode structure by controlling the thickness of the organic layer. However, it is not sufficient to prevent the crosstalk from each line. In order to complete the optimization, we experimented as to know changing the width of the common line for decreasing BM area and the shielding pattern for decreasing light leakage between the data line and the pixel.

![Figure 3 The reference structure](image3.png)

![Figure 4 The simulation condition (unit: um)](image4.png)

**Figure 3** The reference structure

**Figure 4** The simulation condition (unit: um)

3. Result

We simulated to verify the improved optical characteristics of the proposed structure using the TechWiz LCD. Fig.6 and Fig.7 show a result of experiment. As a result, optimized values for width of the common line is calculated as 30 um, the width of the shielding pattern is calculated as 4 um and the distance between data line and shielding pattern is calculated as 2 um, respectively. Decreasing the crosstalk prevents the distortion of the applied signal from the original signal of the each line, so that we can block the light leakage as shown in Fig. 2 (b).

![Figure 6 The comparison of luminance at dark state](image6.png)

![Figure 5 The structure of the electrode in the edge and the calculated optical transmittance.](image5.png)

(a) Conventional structure
(b) Optical transmittance of conventional structure.
(c) Proposed structure.
(d) Optical transmittance of proposed structure.
Generally, the optical transmittance calculated by a 2 x 2 Jones matrix. The normalized transmission of the liquid crystal layer placed between the polarizer and analyzer for the configuration with the polarization axes crisscrossed could be given by

\[ T / T_0 = \sin^2(2\alpha)\sin^2\left(\frac{\delta}{2}\right) = \sin^2(2\alpha)\sin^2\left(\frac{\pi d \Delta n}{\lambda}\right) \] (1)

Where \( \alpha \) is the angle between the effective optical axis of the liquid crystals and the transmission axis of the polarizer. [11] At \( \alpha = 45^\circ \), the equation was simplified to

\[ T / T_0 = \sin^2\left(\frac{\delta}{2}\right) = \sin^2\left(\frac{\pi d \Delta n}{\lambda}\right) \] (2)

The calculated optical transmittance presents Figure.8 by a numerical formula (1) and (2). As a result, the novel structure of electrode decreased in BM area from 36um to 30um and optical transmittance increased in 4.3%.

4. Conclusion

For high performance, LCD mode has been evolved into multi-domain structure as S-IPS mode. S-IPS mode has super wide viewing angle and small color shift performances. But optical transmittance of the S-IPS mode is generally lower than the TN mode. So we studied the novel electrode for high optical transmittance. We calculated the director configuration of the S-IPS cell using Q-tensor method. As a result, we found that BM area decreased and optical transmittance increases in compared to the conventional structure.

5. Acknowledgements

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6. Reference


Figure 7 The comparison of capacitance at dark state

Figure 8 Comparison of the calculated optical transmittance
(a) The conventional structure of the electrode. (b) The novel structure of the electrode

Figure 9 The comparison of transmittance


