An improved electrode structure of the Patterned Vertical Alignment Liquid Crystal Cell for high optical property

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Abstract

In this paper we propose a novel electrode structure for high transmittance in the Patterned Vertical Alignment (PVA) LC cell. Normally, the transmittance of PVA LC cell is depended on the shape of the electrode and cell gap. We studied the area decreasing the transmittance through the electrode structure for wide viewing angle and proposed new electrode design to change LC director configuration in the area. We use the 'TechWiz LCD' for calculation of the director configuration and optical characteristics. We show the comparison of the calculated optical transmittance between the conventional PVA mode and the proposed PVA mode. From the results, we confirm that the optical transmittance of the proposed structure of the PVA cell becomes higher.

1. Introduction

Demand on Large-area FPD-TVs has been sharply increased by expansion of the digital TV market. Liquid Crystal Displays (LCDs) is considered as a leading candidate for next generation display devices. LCDs have many advantages over other display technologies and have been used widely for applications such as monitors, TVs, and mobile phone display. For this reason various types of LCDs have been proposed, such as twisted nematic (TN) [1], in-plane switching (IPS) [2], and the patterned vertical alignment (PVA) [3] mode, each with their advantages and disadvantages. Of these, a PVA mode using a liquid crystal of negative dielectric anisotropy has a high contrast ratio because of no residual retardation. And manufacturing does not require rubbing process. In the absence of an electric field, the liquid crystal molecule is aligned homeotropically under the crossed polarizers, and thus the cell appears to be black. When an electric field induced by electrodes is applied, liquid crystal molecules rotate even with the electrodes and thus the cell transmits light. For high optical performance LC cell with wide viewing angle and high contrast ratio, a PVA mode uses multi-domain effect by electrode structure. The resulting multifold symmetry of the director field gives an excellent viewing angle performance. However, the structure for multi-domain reduces optical transmittance because they have non-uniform electric fields in the active area of the cell [4] , so that defects can occur in the active area. Therefore, the defect [5] on the slit decreases the optical transmittance and on/off response time. When applying the voltage, in the PVA mode, we have found 3 positions where defects occurred in the active area generated by non-uniform electric fields. In this paper we studied one of them and proposed new electrode structure which can improve the transmittance at the middle gray operation voltage. The improved high performance of the proposed structure can obtain as decreasing dark area.

2. Conventional Structure of PVA mode

The PVA mode is constructed from two patterned electrodes as shown figure 1. In figure 1, blue (upper) and red (lower) patterns represent the common and pixel electrodes, respectively. When the electrodes are applied voltage, the chevron-shaped patterned electrodes like fig.1 produce a fringe electric field with the in-plane component that directs the molecular tilt in the ON state.

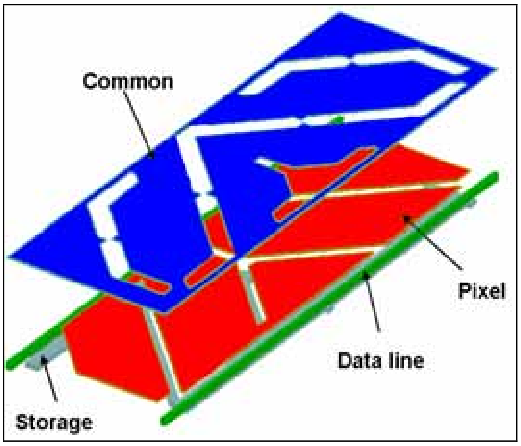
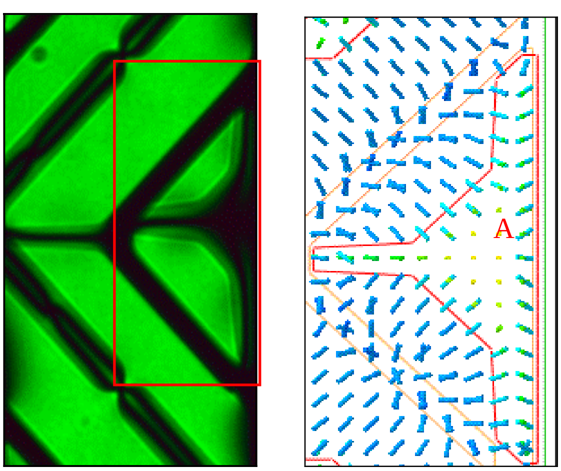


Fig.1. The conventional structure of the PVA mode

The light transmittance in the crossed polarizers can be obtained as below [5].

$$T = \frac{1}{2}\sin^2(2\alpha)\sin^2\left(\frac{\pi\Delta nd}{\lambda}\right) \quad (1)$$

α and λ are azimuth angle and wave length of the incident light for the LC cell layer, respectively. And Δnd is the phase difference of LC cell between the long and short wavelength. The transmittance T has the maximum value where α is at a 45 degrees. Therefore the slit are patterned at an angle of 45 degrees. Figure 2.(a) shows the light transmission passing through a pair of crossed polarizers.



(a) (b)

Fig. 2. Conventional PVA mode
(a) Optical transmittance (b) LC directors

Figure 2(b) shows the electrode structure and LC director configuration at the red square of figure 1(a). In order to compare to experimental result, we set geometric parameters to same values with the real panel as shown in fig. 2(a). The distance between the slits is 20 µm, the width of the slit is 10 µm and cell gap was set to 3.8 µm. The parameters of used LC are as follows; k11 = 12.7, k22 = 6, k33 = 15.3, γ= 0.133, $\varepsilon_{/\!/}$: 3.6, $\varepsilon_{\perp}$: 7.4. As shown figure 2(b), the region 'A' remains dark state although applying voltages till middle gray level. We can explain the reason from the liquid crystal molecular director configuration. The LC directors around region 'A' patterned widely have various directions. They don't fall down easily thus the phase retardation of the cell is still almost zero. To solve this problem, we designed new electrode structure.

3. New slit design for PVA mode

As mentioned above, to turn white state, azimuth angle of liquid crystal molecule director is at a 45 degrees angle with transmittance axis of polarizer.

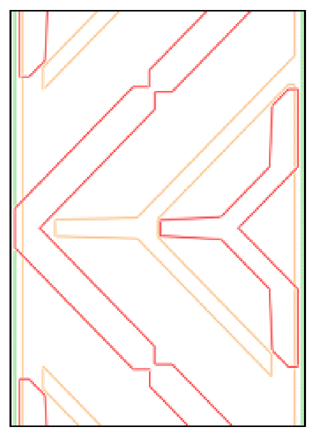


Fig. 3. The electrode structure of a proposed PVA mode cell

For that, we proposed new design of slit pattern as shown in fig. 3. The width of pixel and common structure of the proposed PVA mode is equal to that of the conventional PVA mode. However, we apply chevron-shaped pattern to deciding tilt angle of molecule directors as other chevron-shaped patterned electrode on the slit of common electrode.

4. Experiments

A simulator is a good tool for calculating the movement of molecule directors and optical characteristics. We used the commercially available software "TechWiz LCD" (Sannayi-system, Korea), where the motion of the LC director is calculated based on the Ericksen-Leslie theory and a 2x2 Jones matrix is applied for optical transmittance calculation. Using the above electrode structure, we can obtain improved optical transmittance.

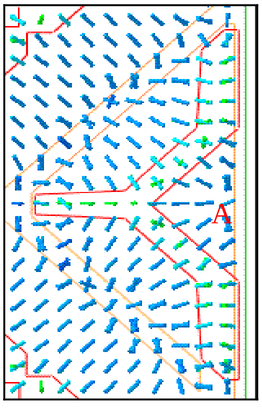


Fig. 4. LC director configuration of proposed PVA mode cell

Fig. 4 shows the liquid crystal molecule director configuration of proposed PVA mode cell using simulator. As shown in fig.4, the directors of molecule around region 'A' lean at an azimuth angle of 45 degrees applying new electrode structure. Through molecular tilt angle has at a 45 degrees angle, the dark area around region 'A' become white state. Fig. 5 shows the calculated optical transmittance of the proposed PVA mode. From this simulation result, we can obtain higher optical transmittance.

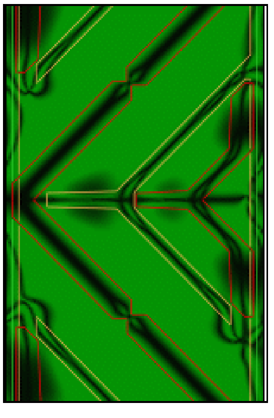


Fig. 5. The calculated optical transmittance of proposed PVA mode cell

And the calculated transmittance value can prove it. Moreover, we change the slit width of the proposed design. As shown in fig. 6, the optical transmittance has the highest value when the slit width is 6.5um. Therefore, the loss of transmittance by electrode structure on conventional PVA mode can decrease using the proposed design.

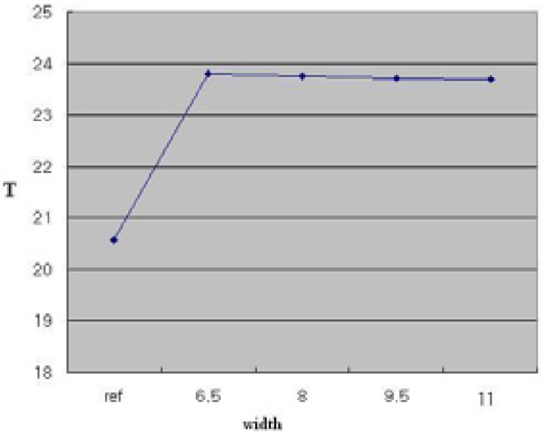


Fig. 6. Transmittance as changing the slit width

5. Summary

In this paper we studied about the transmittance improvement with respect to the slit pattern in the PVA mode. We proposed an improved design of electrode which does not lose the superior viewing angle property by maintaining chevron-shape of conventional PVA mode while it has higher transmittance. And we analyzed and compared the optical transmittance of the proposed cell by changing the slit width. From the novel electrode structure, we can obtain superior electro-optic characteristics.

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