P-197: Improved Patterned VA Mode for Fast Response Time by using Strong Fringe-field Effect

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Abstract

We propose an improved pattern structure that can reduce the response time by using strong fringe field in the pattern vertical alignment LCD. We applied an additional buried electrode in the PVA LCD so that we could increase the fringe field on the edge of the electrode. The strong fringe field on the edge of the electrode helps the liquid crystal director in the bulk area to have an appropriate orientation quickly when the voltage is applied. As a result, we could improve the response time effectively. We used the software TechWiz LCD in order to calculate the director configuration and the response time. From the simulation results, we have found that the proposed structure exhibited 74.2% improvement in response time compared to the conventional structure in calculation.

1. Introduction

Liquid Crystal Displays take the main position in the display industry. Due to the falling prices and high quality, LCD’s market has been expanded in the field of cell phone, notebook computer, desktop monitor, and LCD TV. Various kinds of advanced Liquid Crystal modes such as in-plane switching (IPS) mode [1], patterned vertical alignment (PVA) mode [2-4], multi-domain vertical alignment (MVA) mode [5], fringe field switching (FFS) mode [6-7] were developed to exhibit a high image quality with high contrast ratio, wide viewing angle and fast response time. In particular, the PVA mode, developed by Samsung Electronics, provides an excellent electro-optical performance.

Especially the vertical alignment modes including PVA and MVA LC cell allow the non-rubbing process so that they are suitable for large-sized LCD module like TV applications. On the contrary, it has some disadvantages that the non-rubbing process in the VA LC cell makes the lying speed of the LC director slower when the voltage is applied because the initial orientation of the LC director on the surface is aligned with an arbitrary pretilt angle. This phenomenon can deteriorate the rising time of the VA LC cell and cause the motion blur on fast moving images.

In this paper we will discuss some problems, which have to be solved, regarding the large-sized PVA LC mode. We propose an improved pattern structure that can reduce the response time, especially rising time, by using strong fringe field near the slit of the pixel electrode on the bottom glass. We apply an additional buried electrode in the PVA LC cell to increase the fringe field on the edge of the electrode. We expect that the increased strong fringe field have a function of helping the LC director in the bulk area to have an appropriate orientation quickly when the voltage is applied to the PVA LC cell.

2. Characteristics of the PVA mode

2.1 Conventional structure

In a typical PVA panel, the pixel and common electrodes are patterned creatively. Figure 1 represents the optical transmittance of a pixel of PVA mode and the transmittance depends on the extent of applying the voltage. LC director in the PVA LC cell is vertically aligned in the absence of electric field and PVA mode shows the dark state. The applied electric field gives LC director a tilt downward because of their negative dielectric anisotropy. It shows the bright state as shown in figure 1. The tilting direction of LC director is determined by the fringe field generated by the patterned structure of the common and pixel electrode.

Figure 1. Optical transmittance of a pixel of PVA mode

(a) Dark state
(b) Bright state

Figure 2 shows the cross section of a pixel of the conventional PVA LC cell with the crossed slits on the common and pixel electrode; Part (a) shows the dark state in the off-state voltage and part (b) shows the bright state in the on-state voltage. The dashed circle represents the slits on the edge of the common and pixel electrode, which generates the fringe field effect.

(a) LC configuration in the Dark state
The structure of the PVA LC cell leads to an oblique field between the common and pixel electrode. Since the LC director is vertically aligned at an initial state without rubbing the substrate, they reorient with a slight tilt angle from the vertical alignment in response to the intensity of electric field between the common and pixel electrode.

2.2 Proposed structure for fast response time

In the PVA LCD, it is necessary for LC director to tilt downward uniformly with the same direction, that is to say, the tilting direction angle between the LC optic axis and the transmission axes of the crossed polarizer should be 45 degrees to obtain the maximum transmittance. The transmittance versus time should reach to an equilibrium state across all electrodes as quickly as possible in the existence of an electric field.

The improved electrode structure of the proposed PVA LC cell is shown in Figure 3. The cell gap is 3.8 um. The slit width is 10 um and the width of the fringe field electrode is 6 um. The purpose of designing this structure is to reduce the rising time of the LC director field in the ON state. The proposed structure includes an additional electrode in the dielectric layer. Its function is to increase the fringe field on the edge of the electrode for the fast response time.

3. Results and Discussion

Figure 4 shows the comparison of the iso-potential line and LC director field between the conventional and the proposed PVA LC cell. In order to calculate the outputs, we assumed that the surface pretilt angle is arbitrary in the range of 89°~91°, voltage on the common electrode $V_{\text{com}}$ is 10 V from 0 to 400 msec, voltage on the pixel electrode $V_{\text{pixel}}$ is 0 V from 0 to 450 msec and voltage on the fringe field electrode $V_f$ is just 10 V from 0 to 2 msec. We used the commercially available software Techwiz LCD for the optical characteristics in which the motion of the LC director is calculated based on the Ericksen-Leslie theory and the 2x2 Jones matrix [8-10]. In the software, the pretilt angle on the surface of vertical alignment layer could be controlled as the parameter value. As for the proposed PVA LC cell as shown Figure 4 (b), we can observe the strong fringe field which occurs near the slits by the fringe field electrode than the case of the conventional PVA LC cell. The dashed line represents the fringe field on the edge of the pixel electrode and the dashed circle represents the fringe field electrode. We can see the strong fringe field on the edge of the electrode helps the liquid crystal directors in the bulk area to tilt faster downward from the vertical aligned state when we applied voltage.

Figure 5 represents the comparison of the calculated response time between the conventional cell with the black solid line and the proposed cell with the red solid line. In the conventional structure, we can observe the slow increase in the rising time because the initial arbitrary homeotropic state of the LC director makes it difficult to be a uniform reorientation of the LC director field in the bulk area. It may cause the motion blur on fast moving images, which has been one of the big issues to solve in LCD TV. On the contrary, we can see the improved response time, especially rising time, by using the proposed structure. The strong
fringe field by the voltage on the fringe field electrode helps the reorientation of the LC director field in the bulk area from the edge faster so that we can get the faster rising time. In calculation and simulation using the software, we could achieve faster rising time (3.98 msec) of the proposed cell than the rising time (15.43 msec) of the conventional cell. We have found that the response time of the proposed PVA LC cell was excellent as expected.

Figure 5. Comparison of the calculated response time between the conventional and proposed PVA LC cell.

4. Conclusion

We proposed an improved PVA LC cell which can reduce the rising time by applying the additional buried electrode. The software made it possible to define the arbitrary pretilt angle from vertical aligned LC director across the entire electrodes as the internal condition of the real PVA LC cell. From the simulation results, the proposed structure exhibited 74.2% improvement in rising time compared to the conventional structure in calculation.

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6. Reference