A Novel Structure with Improved Optical Characteristics in FFS Mode LCD

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Abstract

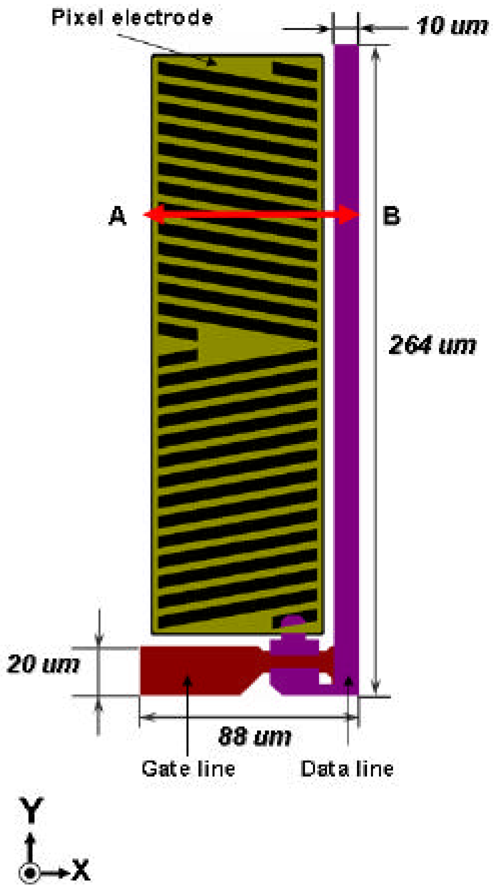
In this paper, we propose a cell structure to improve transmittance and aperture ratio with FFS(Fringe Field Switching) mode. As an exemplary cell, we selected conventional FFS cell with dual domain. Optical transmittance and aperture ratio were calculated with 3D-FEM numerical solver, TechWiz LCD. The simulation results revealed that transmission increases by more than 10% while aperture ratio increases by more than 4% when compared to conventional FFS mode.

1. Introduction

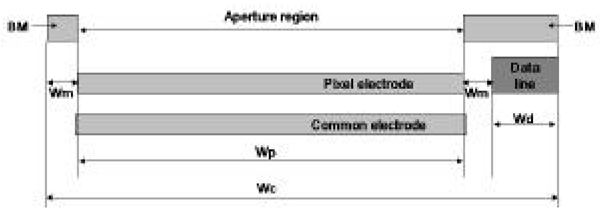
Recently, technologies for quality improvements of display have been studied LCD manufacturing companies around the world. Transmittance, viewing angle and aperture ratio are important characteristics of liquid crystal display. Various display modes have been developed to improve these characteristics for PVA(Patterned Vertical Alignment)[1], MVA(Multi-domain Vertical Alignment)[2], IPS(In-plane Switching)[3] and FFS(Fringe Field Switching)[4,5] modes. However, each mode has its own shortcomings such as low aperture, transmittance, contrast, etc. Recently, electrode of these modes is designed to form two or more domain for wide viewing angle. As electrode structure for multi domain, a symmetrical patterns of ITO shape or chevron shape is used most widely. However, liquid crystal molecules form domain wall in these shape. Because of these domain walls, transmittance and area of aperture are reduced [6]. We have designed a cell structure to improve transmittance and aperture area in FFS mode. FFS mode uses the fringe field to rotate homogeneously aligned liquid crystal molecules almost in a plane above the electrode. Unlike IPS, this mode has a high transmittance area. Although FFS mode has good characteristics such as high transmittance, wide viewing angle, the transmittance of FFS mode is still less than that of TN mode[7]. So, we propose a cell structure which has better transmittance and aperture ratio in comparison with conventional FFS mode. To demonstrate validity of our concept, we use numerical simulator, TechWiz LCD[8].

2. Modeling and Simulation

Figure 1 shows the electrode structure of conventional FFS cell and its cross section. The pixel and common electrode are made of ITO(Indium-Tin Oxide). The data and gate lines are made of opaque metal. The conventional FFS cell(figure 1.(a)) is designed to form dual domain for wide viewing angle. ITO patterns of the pixel are changed those own angle in the center of the pixel. In figure 1(b), Wc is the width of cell and Wp and Wd are the width of pixel electrode and data line, respectively. Wm is the minimum interval between the electrodes to avoid electric field influence by other electrodes. Domain walls are formed between different domains. The conventional FFS cell used dual domain to improve their viewing angle properties. Since domain walls have still remained in dark state, even the cell goes to the on-state. So, domain walls must be removed or minimized to improve brightness. Therefore, we designed a new structure of FFS cell to minimize dark region caused domain wall. Figure 2 shows electrode structure of improved FFS mode. The width of data line, gate line and pixel pattern is equal to those of conventional FFS mode. However, the data line is under each electrode in the center of the cell and the ITO patterns of the improved FFS cell have chevron shape. Because the data line is under each electrode, the cell doesn't need space between data line and pixel electrode. If the cell size of the FFS modes introduced in figure 1 and 2 is equal, the aperture ratio of them will be same.



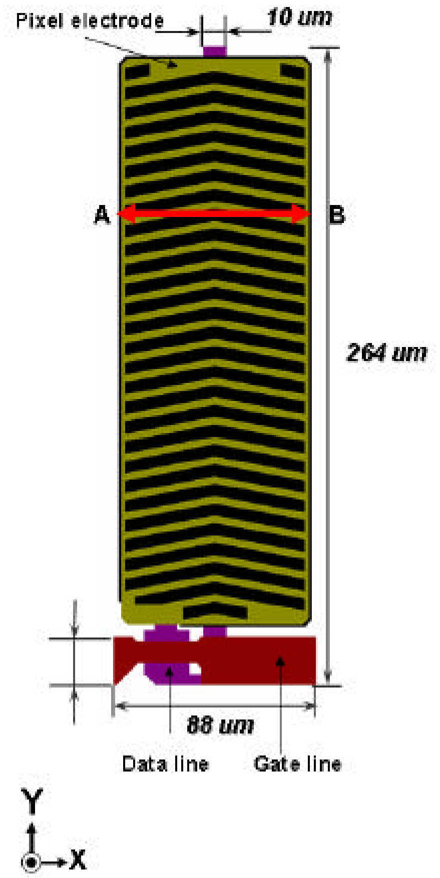
(a)



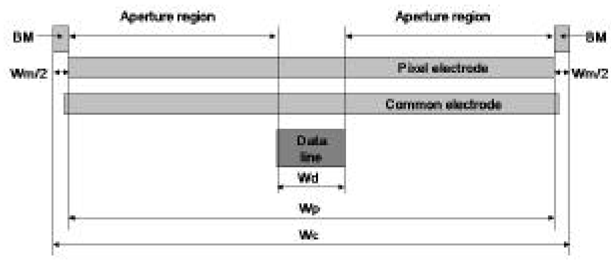
(b)

Figure 1. (a) Electrode structure of conventional FFS cell (b) Cross-section of the cell from A to B

However, if a BM(Black Matrix) is added for two cells, the aperture region will be different. In order to block a light leakage by disclination between electrodes, BM can form as shown in figure 1(b) and figure 2(b), respectably.



(a)



(b)

Figure 2. (a) Electrode structure of improved FFS cell (b) Cross-section of the cell from A to B

In case of the conventional FFS mode, the aperture region from cross-section is

$$W_C - (2 \cdot W_m + W_d)$$

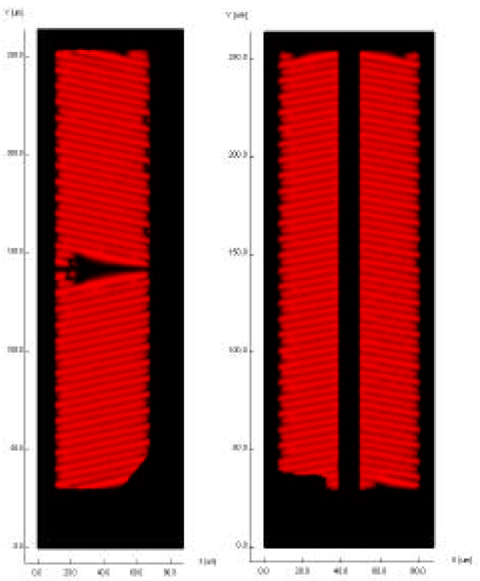
In case of improved FFS mode, the aperture region from cross-section is

$$W_C - (2 \cdot \frac{W_m}{2} + W_d)$$

The aperture region of improved FFS cell is wide in comparison with conventional FFS. The aperture ratio of conventional FFS is 56% and that of improved FFS is about 60%. Therefore, the aperture ratio of improved cell is improved about 4% in comparison with conventional cell. We simulated two cells in figure 1(a) and (b) with numerical FEM simulator, TechWiz LCD[8]. All simulation conditions are same except for the electrode structure and the position of the data line.

4. Simulation Results and Discussion

Figure 3 shows the simulation results for transmittance of the conventional and improved FFS cell when 6V applied at the pixel electrode. As shown in figure 3, the transmittance tendency by ITO patterns is similar each other.



(a) Conventional cell (b) Improved cell

Figure 3. Simulation results for transmittance distribution without BM(Black Matrix), when 6V is applied at pixel electrode

In the case of the conventional cell(figure 3.(a)), the dark region appears along the data line, gate line and domain wall which has formed along the horizontal line of center. However, in the case of the improved cell(figure 3.(b)), the dark region appears only along the data line and gate line. The dark region caused domain wall has overlapped with the region of the data line. Therefore, the domain wall caused dark region is decreased and transmittance will be increased. In figure 4, we can confirm improved transmittance. Figure 4 shows the transmittance as a function of time for each cell. The transmittance of improved FFS is about 10% compare with the conventional FFS cell.

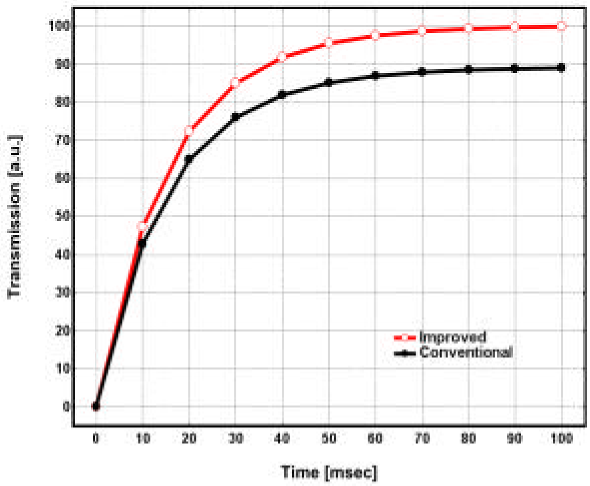
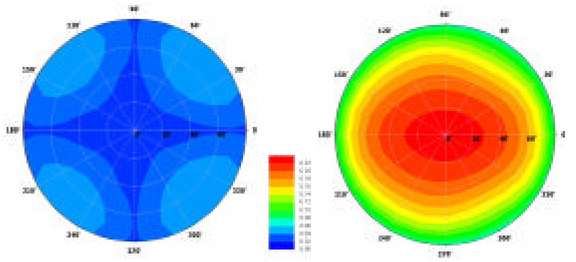
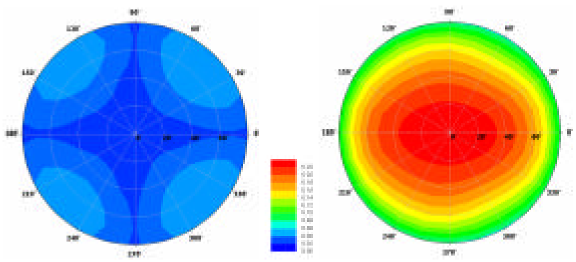


Figure 4. Transmittance of the conventional and improved FFS cell

Figure 5 shows transmittance distribution for viewing angle in polar coordinate. This figure shows similar result of the conventional and improved FFS mode cell. In the off state, the tendency of the transmittance is the same. In the on state, brightness of the improved FFS mode cell is improved but the improved quantity is little bit small in comparison with the conventional FFS mode cell.



(a) Off-state (b) On-state



(c) Off-state (d) On-state

Figure 5. Transmittance distributions for viewing angle in polar coordinate; conventional FFS cell((a),(b)) and improved FFS cell ((c),(d))

5. Conclusion

In order to improve aperture ratio and transmittance, we revised the cell structure of the conventional FFS mode. The improved FFS cell has particular ITO patterns in comparison with the conventional FFS cell. Moreover, the data line is under pixel and common electrode and in the center of the cell. We analyzed optical characteristics of each cell by 3-D numerical simulator. We obtained two improved results. First, the space which should leave between electrodes due to influence by electric field is reduced. Therefore, we obtained high aperture ratio. Finally, we obtained high transmittance due to extension of aperture region.

6. Acknowledgements

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7. Reference

[1] A. Takeda, S. Kataoka, T. Sasaki, H. Tsuda, K. Ohmuro, T. Sasabayashi and K. Okamoto, SID, p. 1077, (1998).

[2] A. Takeda et al., SID, p. 1077 (1998).

[3] J. O. Kwang, K. C. Shin, and s. S. Kim, SID, p. 256, (2000).

[4] S.H. Lee, S. L. Lee and H. Y. Kim, Appl Phys. Lett, 73, p.2881, (1998)

[5] S. H. Hong, I. C. Park, H. Y. Kim and S. H. Lee, Jpn. J. Appl. Phys. 39, p. 527, (2000).

[6] C. S. Lee et al., SID, p. 982, (2005)

[7] Y. Toko, T. Sugiyama, K. Katoh, Y. Limura, and S. Kobayasi, Jpn. J. Appl. Phys. 34, p.2396, (1995)

[8] User's Guide of TechWiz LCD 2005.