A High-Transmittance FFS-LCD with Novel Panel Design

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Abstract

This paper has developed a high-transmittance FFS LCD which adopts novel transistor structure and pixel designs. The transmittance is optimized by enhancing the efficiency of liquid crystal driving and the aperture ratio, thereby increasing the luminance of the LCD without augmenting power consumption and costs. This high-transmittance LCD panel is anticipated to be extensively applied in outdoor displays.

Author Keywords

Liquid crystal display; fringe field switching; thin film transistor (TFT); pixel design; high transmittance; outdoor display; green display;

1. Introduction

LCD (Liquid Crystal Display) is extensively applied in display domains such as mobile phones, computers, and vehicle-mounted displays. FFS (Fringe Field Switching) liquid crystal displays demonstrate significant competitiveness with advantages like wide viewing angle, high contrast ratio, and high transmittance(Tr%)[1]. With the advancement of the communication industry, the application demand for electronic products in outdoor scenarios is expanding increasingly. It is well-known that in strong ambient light like sunlight, if the display luminance is insufficient, its readability and display effect will be compromised significantly, which implies higher luminance requirements for the display [2]. Commonly employed methods to enhance the luminance of LCDs include backlight film materials and liquid crystal materials, as well as increasing the backlight current. Nevertheless, the optimization of materials frequently leads to increased costs. Increasing power consumption goes against energy-saving and green display. For transmissive LCDs, the panel transmittance is another crucial factor influencing luminance. Enhancing the transmittance of LCD panels has become the key to breaking through the luminance bottleneck and fulfilling outdoor requirements.

In this paper, through the novel combination of thin-film transistors and pixel designs, the aperture ratio and the electric field distribution within pixels were optimized, the light utilization efficiency was enhanced, and a remarkable increase in the transmittance of liquid crystal panels was achieved without any Performance deterioration and cost escalation.

2. Design proposal

Figure 1 shows the current distribution of pixel brightness. It can be observed that the major factors influencing its luminance are the aperture ratio and the efficiency of the electric field driving of the liquid crystal. The enhancement of the aperture ratio is mainly accomplished by compressing the area of the black mask (BM).The horizontal BM area is typically highly correlated with the color shift capability, which is not advisable to be modified. It is considered a feasible solution to improve the aperture ratio by compressing the vertical light-blocking area. On the other hand, it should be noted that there are still some dark areas in some positions without BM blocking, especially at the top and bottom of the pixels. This is mainly because the effective electric field driving the liquid crystal at these positions is weaker, which is another direction for design improvement.

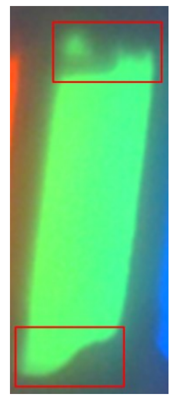

Figure 1. Brightness distribution within pixels

Figure 2 presents the schematic plan view of the pixels. Part of the area of the thin film transistor is exposed outside the BM blocking area in the existing design. The enhancement of the aperture ratio demands that the design optimization of the BM and the Array side. The compression on the Array side encompasses that of the space occupied by the thin-film transistors and the holes of each film layer, and the compression of BM can be accordingly performed.

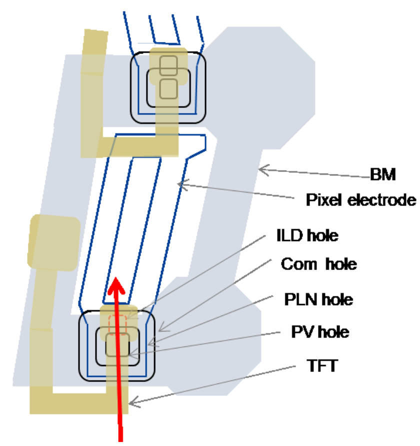

Figure 2. Planar schematic diagram of pixels

As shown in Figure 3, by designing the shape of TFT to change from U-shape to L-shape, it can completely cover the BM area within. Additionally, due to the changes in the position of ILD and PLN holes, the total occupied space is compressed, and the BM area can also be compressed simultaneously. From the cross-sectional diagram in Figure 4, it can be seen that the width of non-transmissive area in the new TFT design has been significantly reduced, which will help to improve the aperture ratio.

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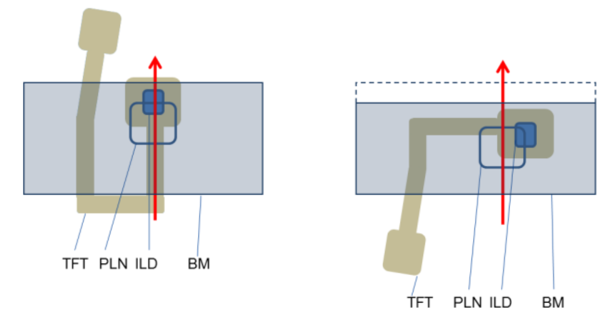


a. U-TFT of previous design b. L-TFT of new design

Figure 3. Comparison of TFT designs

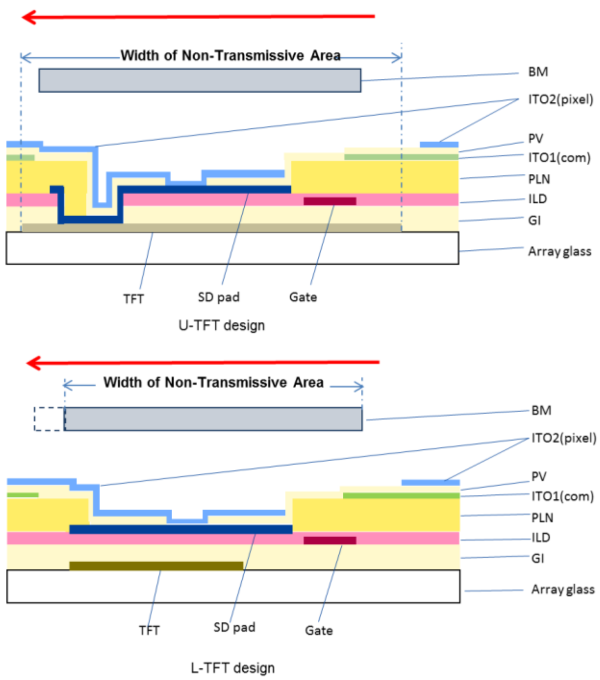
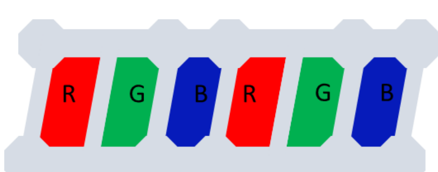
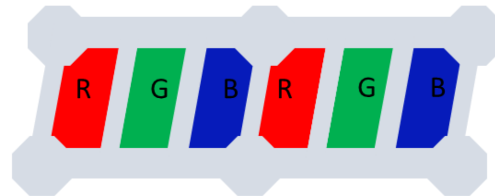


Figure 4. Cross-sectional diagram of the non-transmissive area

Another approach to enhance the aperture ratio is by reducing the density of photo spacer（PS）.As depicted in Figure 6, two sub PS are distributed within each main pixel in the current design . The new design reduces the BM occupied area around sub PS by eliminating one sub PS. Certainly, as the support of the LCD cell, PS still requires ensuring a certain area density to guarantee the mechanical properties of the panel. Through the shape and area density design of the main PS and sub PS, the enhancement of transmittance and the mechanical properties are balanced. The reliability of the single sub PS solution in terms of mechanical capacity has been verified in this experiment.



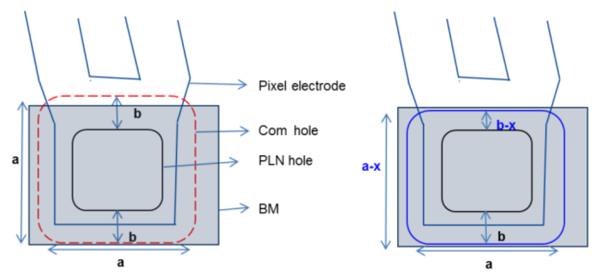
a. dual sub-PS per main pixel



b. single sub-PS per main pixel

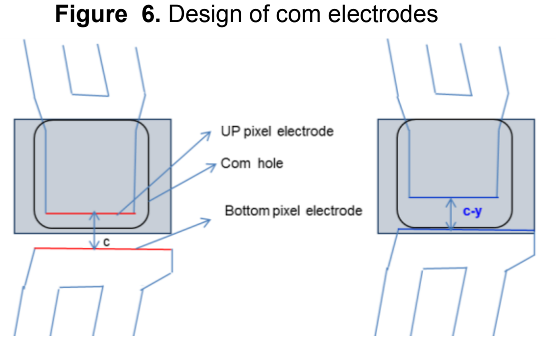
Figure 5. Comparison of PS designs

In the previous section, the design of increasing the aperture ratio was described. However, if the electric field driving force of the increased aperture area is insufficient, the deflection of the liquid crystal will be limited, and the upper and lower black areas of the pixel will still exist. An improved liquid crystal driving efficiency design is shown in Figure 6: The upper edge of com hole is compressed, making it cover a greater extent below the BM, which helps enhance the liquid crystal driving in the aperture area. It is worth noting that this new design is within the process capability range. As shown in Figure 7，another design is to raise the upper part of the pixel as a whole and compress the distance between the upper and lower pixels, which also increases the liquid crystal driving at the edge of the aperture area. As shown in the cross-sectional diagram of Figure 8, the compression of the non-transmissive area and the improvement of the liquid crystal driving are matched, which maximizes the transmittance.



a. previous design b. new design

Figure 6. Design of com electrodes



a. previous design b. new design

Figure 7. Design of pixel electrodes

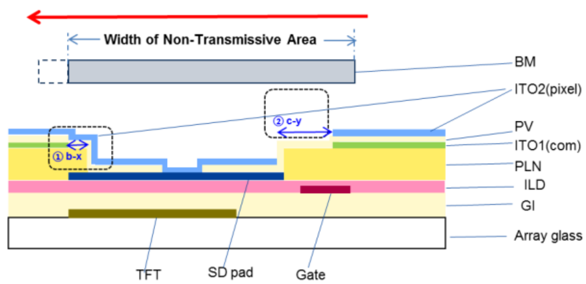


Figure 8. Cross-sectional diagram of the non-transmissive area with improved electric field drive

3. Result &Discussion

By combining the above design solutions, the transmittance of the panel was significantly improved and reached its maximum value. As shown in Figure 9, the actual test results of the transmittance show an increase of 7.0%.

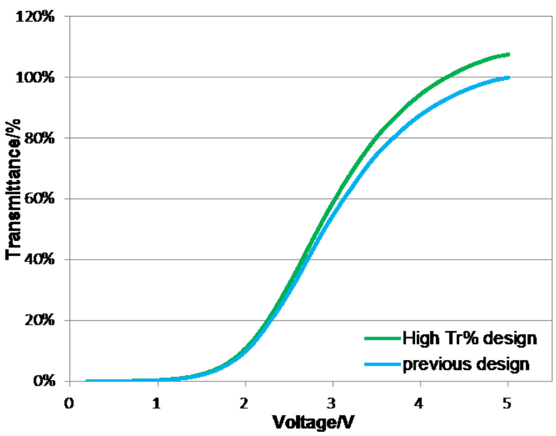


Figure 9. Comparison of V-T curve

As depicted in Figure 10, the actual brightness distribution of the pixels reveals that the increase in the effective light-transmitting area is remarkable. In our experiment, the new design was applied to a 6.7' LCD with a resolution of 1080*2388. The extent of increase on other resolutions may fluctuate, but its beneficial effects are definite.

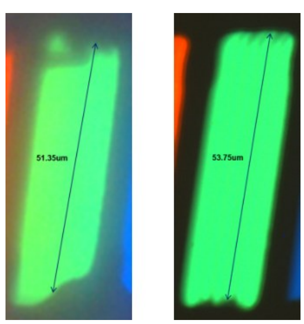


Figure 10. Comparison of brightness distribution within pixels

Table 1 presents the other key performances of the panel with the new design. It can be observed that there is no deterioration in other performance manifestations, including electrical and mechanical properties.

Item	Previous design	High-Tr% design
Transmittance	Ref	↑7.0%
Luminance	930nits	1000nits
Contrast Ratio	1500	1500
Response Time	27ms	27ms
Crosstalk	0.7%	0.7%
Flicker@60hz	-45dB	-45dB
Mechanical Test	Ref	Consistent level

Table 1. Key performance comparison

4. Conclusion

In conclusion, a FFS liquid crystal display encompassing pixel structure design and TFT design has been reported. This design has been proven to enhance transmittance without the requirement for additional manufacturing and process masks. Moreover, the comprehensive performance can satisfy the demands of the display screen. This can assist LCD displays in attaining 1000 nits, which is a luminance milestone for LCD displays. For the high brightness requirements of outdoor displays, the new FFS LCD provides an option with better readability and visual experience.

5. Reference

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