Advanced Pixel Structure for Higher Aperture Ratio in TFT-LCD

Jong Hoon Kim*, Sang Yong Noh, Shin Tack Kang, Jong Hwan Lee, and Kwang-Soo Choi

Product Engineering Part 1, LCD Business, SAMSUNG ELECTRONICS CO., LTD
Seongseong-Dong, Cheonan-City, Chungcheongnam-Do, Korea (ROK)
Phone: +82-41-529-5233, E-mail : jonghoon1.kim@samsung.com

Abstract

An advanced TFT-LCD structure was proposed to increase aperture ratio (AR). In this structure, metal layers formed below the data lines are used as light-blocking layers, achieving higher AR ratio than that of a conventional structure. Since average misalignment between the metal light-blocking layers and pixel electrodes is smaller than that of black matrixes on color filter glass, substantially less light-blocking areas are needed to achieve misalignment margin. The AR of the LCD panel fabricated by using proposed structure was enhanced by 18.7 % over that of the conventionally structured panel.

1. Introduction

TFT-LCD technology has been used in a wide range of applications such as cellular phones, PDAs, notebook PCs, monitors, and TVs. For these LCD applications, one of the common requirements is high aperture ratio (AR). Since AR enlargement enables reduction of backlight cost and power consumption, various attempts have been made to increase AR [1,2].

Figure 1 shows the cross section of the data line for a conventional pixel structure. The conventional pixel structure implements electrically floating metal layers, indicated as the light-blocking layers in Fig. 1, in the plane of the gate layers to block the light leakage. These layers were fabricated during the same process step as gate metal layers themselves.

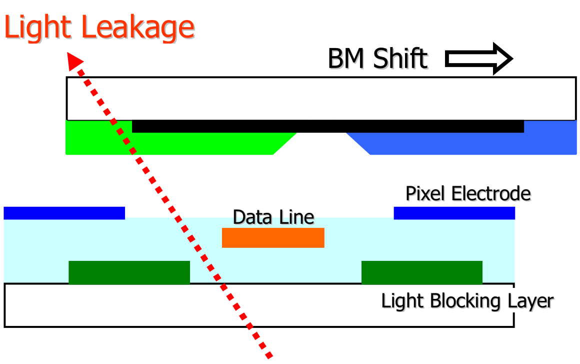

Figure 1. Data line cross section of conventional pixel structure

In this structure, AR depends greatly on the black matrix's (BM's) width which depends on spacing between pixel electrodes. To obtain higher AR, it is necessary to reduce BM width while decreasing the space between pixel electrodes. The BM width must be designed to block light leakage from edges of the floating metal layers as shown in Fig. 1, and there must also be adequate margin for misalignment with the pixel electrodes.

The pixel electrodes' space should be determined taking into account the coupling effect between the pixel electrode and data lines [3,4]. Figure 2 explains the capacitive coupling between a pixel electrode and the adjacent data lines.

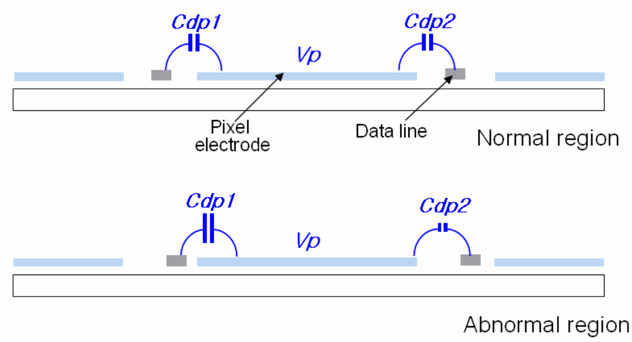

Figure 2. Coupling capacitors between a pixel electrode and adjacent data lines according to the aligned state

Data line misalignment generates undesired pixel voltage fluctuation due to capacitive coupling between the pixel electrode and the adjacent data lines. This voltage fluctuation causes an artifact on the display. The amount of pixel voltage fluctuation ΔV_p can be described by

$$\Delta Vp = \frac{(Cdp1 - Cdp2)}{Cp} \cdot \Delta Vd$$

where Cp, Cdp1,2 and ΔVd are pixel capacitance, capacitances between a pixel electrode and data lines, and amount of data line voltage swing, respectively.

Usually, data line to pixel electrodes spacing fluctuates within a panel according to alignment accuracy. Thus, a panel has both normal and abnormal regions as shown in Fig. 2. Since the (Cdp1-Cdp2)/Cp changes according to alignment accuracy, the pixel electrodes in the normal and abnormal regions have different Δ Vp's. This difference in Δ Vp causes uneven luminance across the panel.

To reduce these Δ Vp differences between normal and abnormal regions, small capacitance difference (Cdp1-Cdp2), large pixel capacitance, and small data line voltage swing are necessary. Because small (Cdp1-Cdp2) requires large spacing between pixel electrodes, there is a limit to how much the pixel electrodes' space can be reduced. The limit of electrode spacing should be decreased to obtain higher AR

Additionally, Fig. 1 shows a disadvantage of the conventional structure in that AR loss occurs when a BM edge shifts passing the edge of the light-blocking layer. By comparison, there is no AR loss due to misalignment in the structure which is proposed below.

This paper proposes a new high AR pixel structure to enable further reduction of pixel electrodes spacing and BM width.

2. Results

2.1. Proposed pixel structure

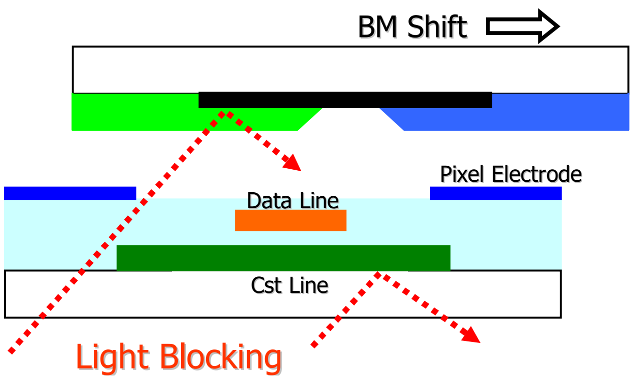

Figure 3. Cross section of proposed high AR pixel structure

Figure 3 shows the data line cross sections of proposed pixel structure. In the advanced pixel structure, only one wide metal line is implemented below the data line, and it is biased with a constant voltage. Thus, most of the light leakage paths are blocked by the light-blocking metal layer.

The role of BM is restricted only to blocking the residual path through the edge of metal layer as indicated in Fig. 3. Therefore, the BM width can be shrunk to far less than that of the metal blocking layer, so that the BM edges are always located within the metal light blocking area even in the case of severe misalignment. This means that the advanced structure does not lose AR according to misalignment, which is quite different from the conventional structure.

Furthermore, an additional width of light-blocking layer for misalignment margin can be decreased to far smaller than that of the conventional structure since the alignment accuracy between the pixel electrode and the light-blocking layer is superior to BM to pixel electrode accuracy, thereby further improving AR.

The space between pixel electrodes can be further reduced in proposed structure since the coupling capacitances of Cdp1 and Cdp2, compared at the same dimension, are smaller than those of the conventional structure due to the DC field caused by the light-blocking metal layer. A portion of the capacitive coupling between the pixel and data lines is shielded by the DC field. This breaks the limit of pixel electrodes' spacing caused by the coupling capacitances. The closer spacing between the pixel electrodes enables the width of light-blocking layer to be shrunk, achieving higher AR.

Moreover, since a constant voltage is biased into the light-blocking metal layer, the overlapped area of a pixel electrode and a light-blocking layer works as a storage capacitor, enabling reduction of each pixel's storage capacitor area, which further contributes to AR enlargement.

However, there is a weak point in that the overlapped area of the data line and the light-blocking layer increases capacitive load on the data line. Figure 4 shows the effect of the additional line load by means of RC delay simulations at the top and bottom positions of the conventional and proposed structures. For the same data

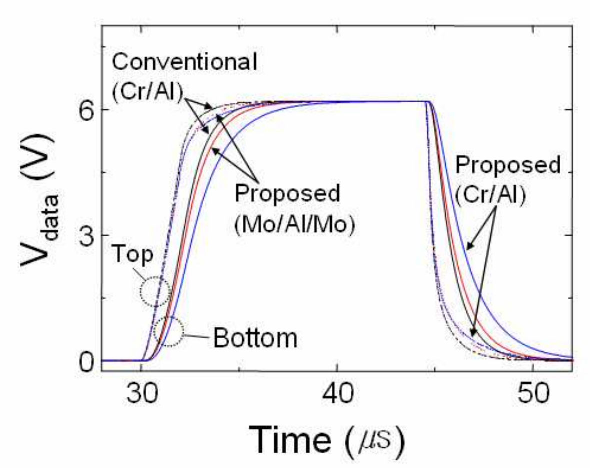

Figure 4. Waveforms of data line voltages for the conventional and proposed structures

line material, Cr/Al, the waveform of the advanced structure has a seriously delayed shape compared with the conventional structure. Thus, Cr/Al cannot be applied as the data line material for the advanced structure. When the data line material is changed to Mo/Al/Mo with lower resistivity, the RC delay shape approaches that of the conventional structure. Thus, data lines of the proposed structure were fabricated using Mo/Al/Mo metal.

2.2 Prototype panel

A prototype panel was built based on the proposed pixel structure. There was no loss of image quality, light leakage, and unevenness of luminance from the differences in Δ Vp's by comparison to the conventional structure.

Figure 5 shows photographs of the conventional and proposed structures, showing the higher AR was achieved using the new method. The data line images show that the space between pixel electrodes is decreased in the proposed structure due to the reduction of coupling capacitances between the pixel and adjacent data lines. With the closer spacing, the light-blocking layer in the plane of the gate layer can shrink the BM width effectively. Savings in storage capacitor area enlarge the open area in the vertical direction.

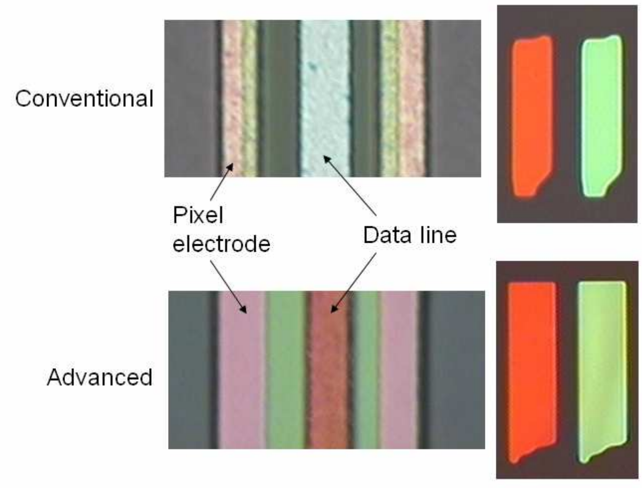

Figure 5. Photographs of conventional and proposed structures

Table 1 summarizes the panel characteristics of the conventional and proposed structures. The AR of new structure increases from 55.1 % to 65.4 %.

Table 1. Panel characteristics

Structure	Conventional	Proposed
Data line metal	Cr/Al	Mo/Al/Mo
Aperture ratio	55.1 %	65.4 %

A prototype panel was made using a proposed structure. In the case of the 15.4" WXGA, the AR of the LCD panel fabricated by using proposed structure was enhanced by 18.7 % over that of the conventionally structured panel.

This significant increase of AR enables a brighter panel for higher luminance applications, reduced power consumption in the backlight, or cost savings via the removal of brightness enhancing film. Considering these advantages, it is expected that this structure will be adopted rapidly and broadly in the LCD industry.

3. Summary

We have proposed an advanced TFT-LCD structure for high aperture ratio. In this structure, a metal layer formed below the data line is used as a light-blocking layer, achieving higher aperture ratio than that of a conventional structure.

4. References

[1] H. Todeda, Y. Tsuji, M. Murooka, A. Sugahara, M. Ideka, and K. Suzuki, "A high aperture and high density a-Si TFT-LCD with a new pixel structure", IEDM, pp. 401, 1993.

[2] W.-S. Hong, K.-W. Jung, J.-H. Choi, B.-K. Hwang, and K. Chung, "High Transmittance TFT-LCD Panels Using Low-k CVD Films", IEEE Electron. Dev. Lett., **25**(6), pp. 381, 2004.

[3] Y.-C. Jeong, C.-C. Park, and L.-S. Kim, "A New Crosstalk Compensation Method in Line Inversion TFT-LCD's", IEEE Trans. Circ. Syst., **44**(6), pp. 552, 1997.

[4] T. H. Kim, S. S. Jung, J. W. Park, and J. S. Choi, "Simulation of Crosstalk and Flicker in TFT-LCDs", J. Kor. Phys. Soc., **39**(1), pp. 67, 2001.