Development of a 14.1 inch Full Color AMOLED Display with Top Emission Structure

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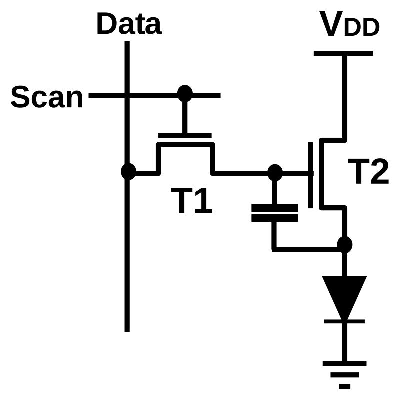
Abstract

A structure and a design of device were developed to fabricate large-scale active matrix organic light-emitting diode (AMOLED) display with good color purity and high aperture ratio. With these technologies, we developed a full color 14.1 inch WXGA AMOLED display. For the integration of OLED on an active matrix a-Si TFT backplane, an efficient top emission OLED is essential since the TFT circuitry covers a large position of the pixel aperture. These technologies will enable up the OLED applications to larger size displays such as desktop monitors and TVs.

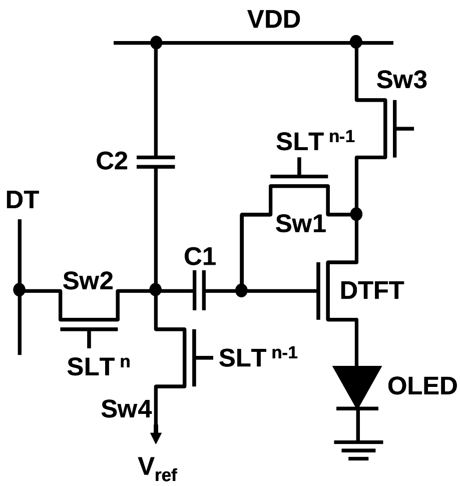
1. Introduction

Organic light emitting diode (OLED) displays have been attracting more attention because of their various advantages including simple structure, fast response time and wide viewing angle. Recently, active matrix OLED (AMOLED) displays using amorphous silicon thin film transistors (TFTs) demonstrated their potential for low cost and high uniformity [1-3]. However, the stability of a-SI TFT is still the fundamental problem. Solving this problem enables large size applications such as desktop monitors and TVs, which require high quality image. In addition, low aperture ratio is a problem for high-resolution active matrix displays. The solution for these problems is needed for future evolution of AMOLED. We have developed top emission a-Si TFT backplane technology, which is applicable for larger size displays and demonstrated a 14.1 inch full color WXGA display prototype.

2. Development of pixel circuit



(a)



(b)

Figure 1. (a) Conventional circuit
(b) Newly developed 5 Transistor pixel driver circuit

Although a-Si TFT active matrix is considered as the new technology for full-color OLED display, pixel-driving scheme is still one of the most critical issues. The simple 2 transistor circuit (Figure 1 (a)) suffers from pixel to pixel luminance non-uniformity due to characteristics variation of the driver TFT (T2 in Figure 1). The problem would become serious especially when display size becomes large. To overcome these non-uniformity and stability issues, several technologies have been proposed. The driver circuit by Dawson et al. can compensate threshold voltage (Vth) variation [4], but mobility variation still remains [5]. Digital modulation schemes are effective in improving uniformity [5,6], but it is difficult to increase pixel count and the number of gray levels. Field sequential methods often cause moving picture break-up.

Current mode data programming schemes can compensate both Vth and mobility variation [7,8]. They are free from cross talk caused by voltage drop in the power supply line, while most of voltage programming schemes suffers from this problem especially for larger panels or higher brightness [9]. Finally, current programming schemes have to manage very small current at low brightness, which may lead to unrealistically long programming time [7]. Figure 1 shows the equivalent pixel circuit for this panel. The pixel circuit consists of four switching TFTs (Sw1-Sw4), one driving TFT (DTFT), two capacitors (C1 and C2) and one OLED. Control signal lines are two row lines (SLT and TNO) and two column lines (Data line and V_{DD}). SLT^{n} and SLT^{n-1} are at present and from previous row, respectively. DT is a voltage-data signal line and V_{DD} is a common constant voltage source line. The operation of the pixel circuit is described as follows in three stages shown in Figure 2. In the first stage, the gate of DTFT is charged up to a potential, by current supplied from V_{DD}, high enough not to interfere with compensation operation at the next stage. In the second stage, a reference voltage V_{ref} is applied to DT and the gate of DTFT is discharged through Sw1, DTFT and OLED until both of DTFT and OLED are turned off. Then, the gate voltage is self-biasing to the sum of the turn-on voltage (V_{TO}) of OLED and the threshold voltage (V_{TH}) of DTFT. This voltage is stored in C1. In the last stage, an input-data voltage V_{input} at DT is transferred to C1. Then, the gate voltage of DTFT is bootstrapped by C1. If V_{CC} and V_{ref} are ground, then the gate voltage V_G becomes

$$V_G = V_{TH} + V_{TO} + V_{input} .$$

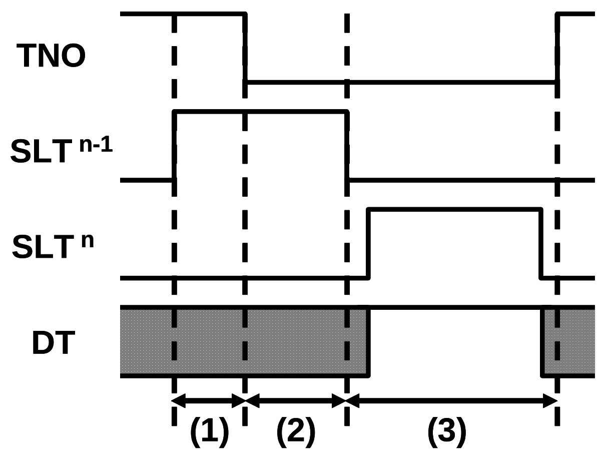


Figure 2. Driving scheme of 5 Transistor pixel driver circuit.

The gate voltage of DTFT controls OLED currents during a frame time. Therefore, in this pixel circuit, the OLED current has high immunity to threshold voltage of TFT and turn-on voltage of OLED.

3. Development of top emission structure

A conventional bottom emitting OLED emits light through an aperture on a glass substrate, in which pixel circuitry is integrated. The open aperture ratio in such an OLED architecture is severely limited because the pixel circuitry occupies a large area of the substrate. On the other hand, the pixel count required for PC monitors and TVs is constantly increasing, which results in an even smaller aperture ratio. This is a critical issue because the smaller aperture leads to higher current density and it could deteriorate OLED devices. However, the top emission structure makes it possible to design larger aperture without being bothered by the TFT circuitry. Therefore, we have chosen top emission structure and optimized the device. The cross section of the developed top emission device is shown in figure 3.

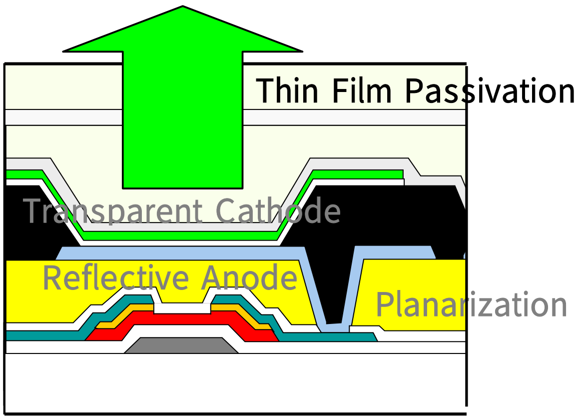


Figure 3. Cross section of top emission device.

The OLED consists of reflective anode, hole-transport layer, emissive layer, electron-transport layer and semitransparent cathode. Light generated in emissive layer emits through the semitransparent cathode. In developing the top emission structure, we defined multiple interference effect to purify R, G and B color. This effect in top emission device is generally greater than in bottom emission device because of the slight reflectance from the semitransparent cathode. We have also developed a unique technology for panel sealing. As shown in Figure 4, a capping layer is placed on the semitransparent cathode, followed by a glass faceplate. The all-solid-state panel has been realized as a result. In contrast to that, conventional capping structure using canister and inert gas is mechanically weak and requires getter material.

4. Display performance of 14.1 inch AMOLED

The 14.1 inch display has 1280X768 pixels, each of which has individual R, G, and B pixels. We applied a conventional shadow mask method to fabricate the pixel arrangement in the 14.1 inch display. The pixel alignment is well controlled with a pixel-pitch of 0.24mm. The developed display produces the large color gamut by optimizing the top emission structure. The R, G and B luminescence yield CIE coordinates of (0.66, 0.35), (0.27, 0.67) and (0.15, 0.12). Another feature of our display is high luminance. The white peak luminance is more than 400cd/m2 since the top-emitting structure also makes the aperture larger and so reduces the driving voltage and the current density of OLED devices. This is very favorable for the reliability of the panel.

Figure 4. Image of 14.1 inch WXGA AMOLED Display.

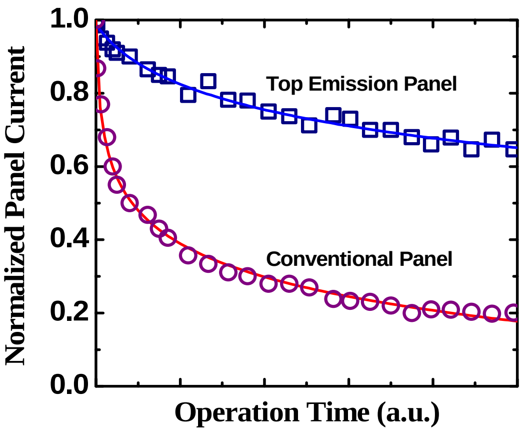


Figure 5. Extension of a-Si TFT backplane

Figure 4 shows a typical image of the AMOLED display. Pixel to pixel luminance variation is almost invisible. This fact shows that the proprietary pixel drive circuit compensates the variation of driving TFT characteristics over the entire display area of 14.1 inch. The data shown in Figure 5 demonstrate the effectiveness of the compensation circuit. In our top emission panel, longer life time is expected by adopting this newly developed compensation circuit.

5. Summary

We have developed the a-Si TFT AMOLED technology, which is effective for designing large OLED display panels with high image quality. As a result, a 14.1 inch WXGA AMOLED display has been realized. The developed display demonstrates attractive progress such as long life time, large color gamut and all solid-state panel structure.

6. References

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