5.0 inch WVGA Top Emission AMOLED Display for PDA

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Abstract

Samsung SDI has developed a full color 5.0" WVGA AMOLED display with top emission and a super fine pitch of 0.1365mm(186ppi), the world's highest resolution OLED display ever reported to date. Scan driver circuits and demux circuit were integrated into the display panel, using low temperature poly-Si TFT CMOS technology, and data driver circuit were mounted using COG chips. Peak luminescence was greater than 300cd/ m² with power consumption of 500mW with 30% of the pixels on illuminated.

1. Introduction

Today, display manufacturers are under constant pressure to achieve higher resolution, increased display size, faster refresh rates, more contrast ratio, lighter weight, and lower power consumption. Active matrix organic light emitting diode (AMOLED) using low temperature polysilicon transistors (TFTs) has increasing attention because it is thought to be able to satisfy all the demands described above. Most of the 30+ display manufacturers are targeting mobile phones, PDAs, camcorders and digital cameras as their initial applications.

Samsung SDI have also developed several kinds sized AMOLED displays such as 2.2[1], 3.6, 8.4[2] and 15.1 inch panels since 2000. Especially, 5.0 inch full color WVGA AMOLED was developed targeting for PDA display using LTPS CMOS technologies. This WVGA (800 x 480) resolution recreates a desktop viewing experience, which enables users to see the Internet or other applications without horizontal scrolling.

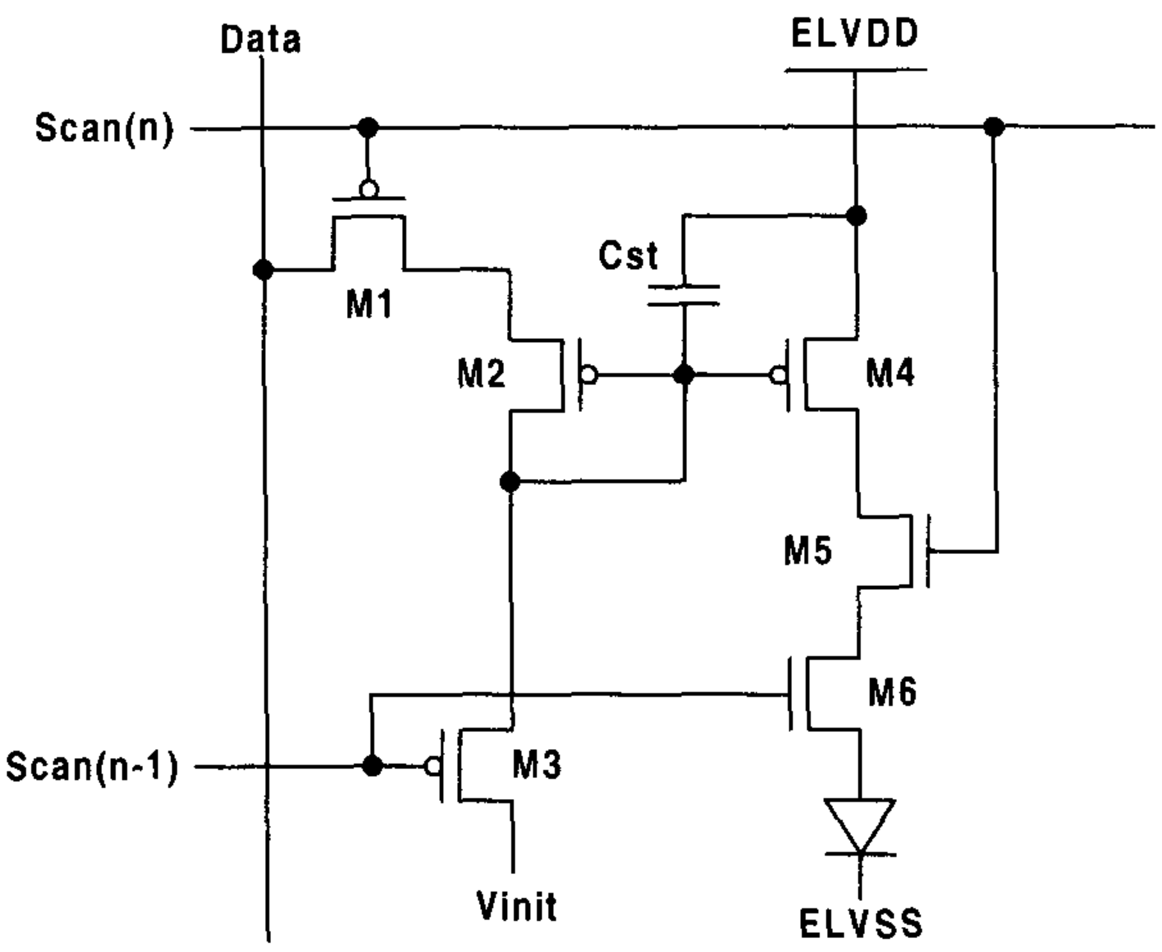

Figure 1. Pixel circuits for 5.0" WVGA AMOLED display

2. Results

1) Pixel Circuit

Figure 1 shows the pixel structure for our 5-inch AMOLED display. The pixel circuit is composed of 6-TFTs and 1-capacitor, which can effectively eliminate the TFTs threshold voltage variation. M1 is switching TFT and M4 is driving TFT of OLED. Diode connected M2 is used for compensation of threshold voltage of the driving TFT. M3 is used for initializing the stored voltage at the capacitor. Additional M5 and M6 that are composed of n-channel TFTs, prevent current from flowing at the OLED during programming and precharging period respectively. These n-channel TFTs can effectively improve the dark gray level, increase the contrast ratio and decrease power consumption of the panel.

2) Top Emission Structure

The conventional bottom emission with multiple transistors and high resolution has inevitably very small aperture ratio because of the metal line of the TFTs and small pixel pitch, the display with the low aperture ratio requires the higher brightness. The higher current density in EL could deteriorate OLED devices rapidly. Figure 2 shows the relationship for the optical efficiency (aperture ratio) in the function of the resolution by simulation.

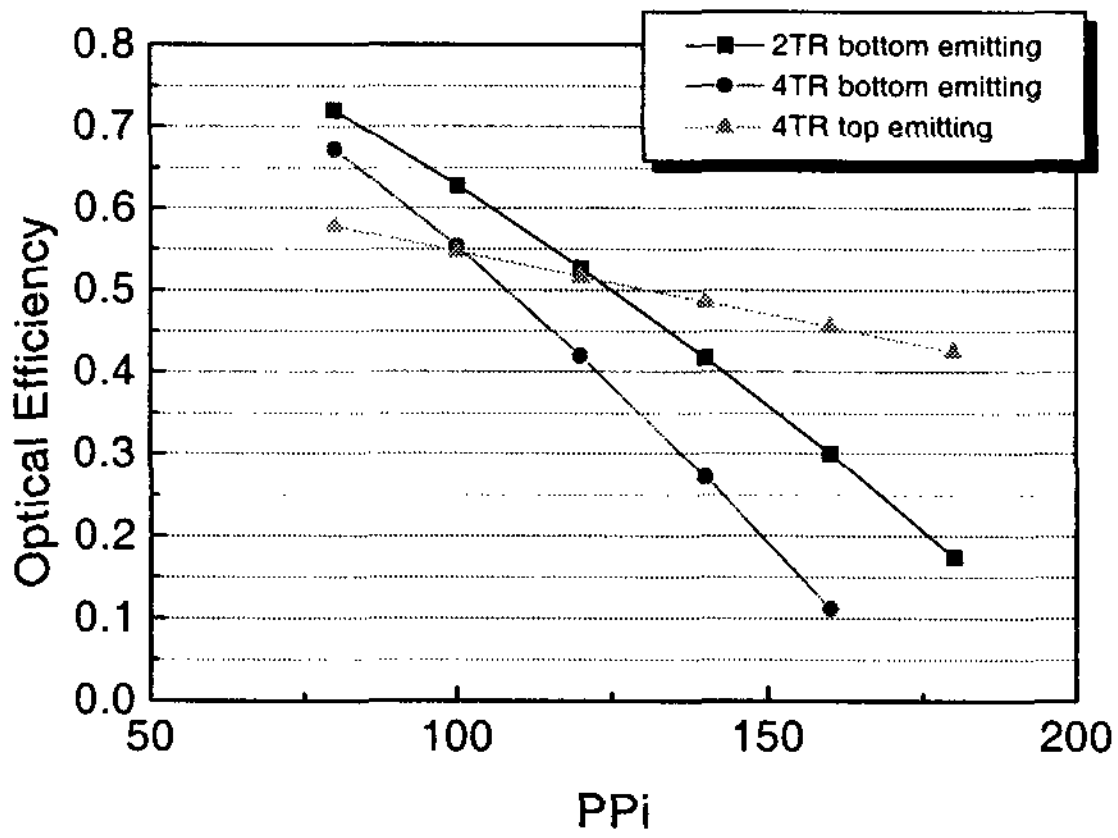

Figure 2. The relationship between optical efficiency and resolution.

In the other viewpoint, the color reproducibility in the bottom emission was mainly determined by the color coordinate of the emitting materials for red, green and blue, but the top emission structure can regulate the color coordinate by using the light interference. After considering the OLED structure in the several points, We have used the top emission in order to overcome the low aperture ratio due to fine pixel pitch in this full color WVGA 5-inch AMOLED.

Figure 3 shows the cross section of the top emission device developed in this work. The top emission structure has reflective anode layer and organic layer and semitransparent cathode on the thin film transistor substrate. Poly-Si TFTs were fabricated under low temperature (<500°C) on glass substrate by CMOS process. Planarization layer below reflective anode was introduced to eliminate the roughness of the pixel electrode.

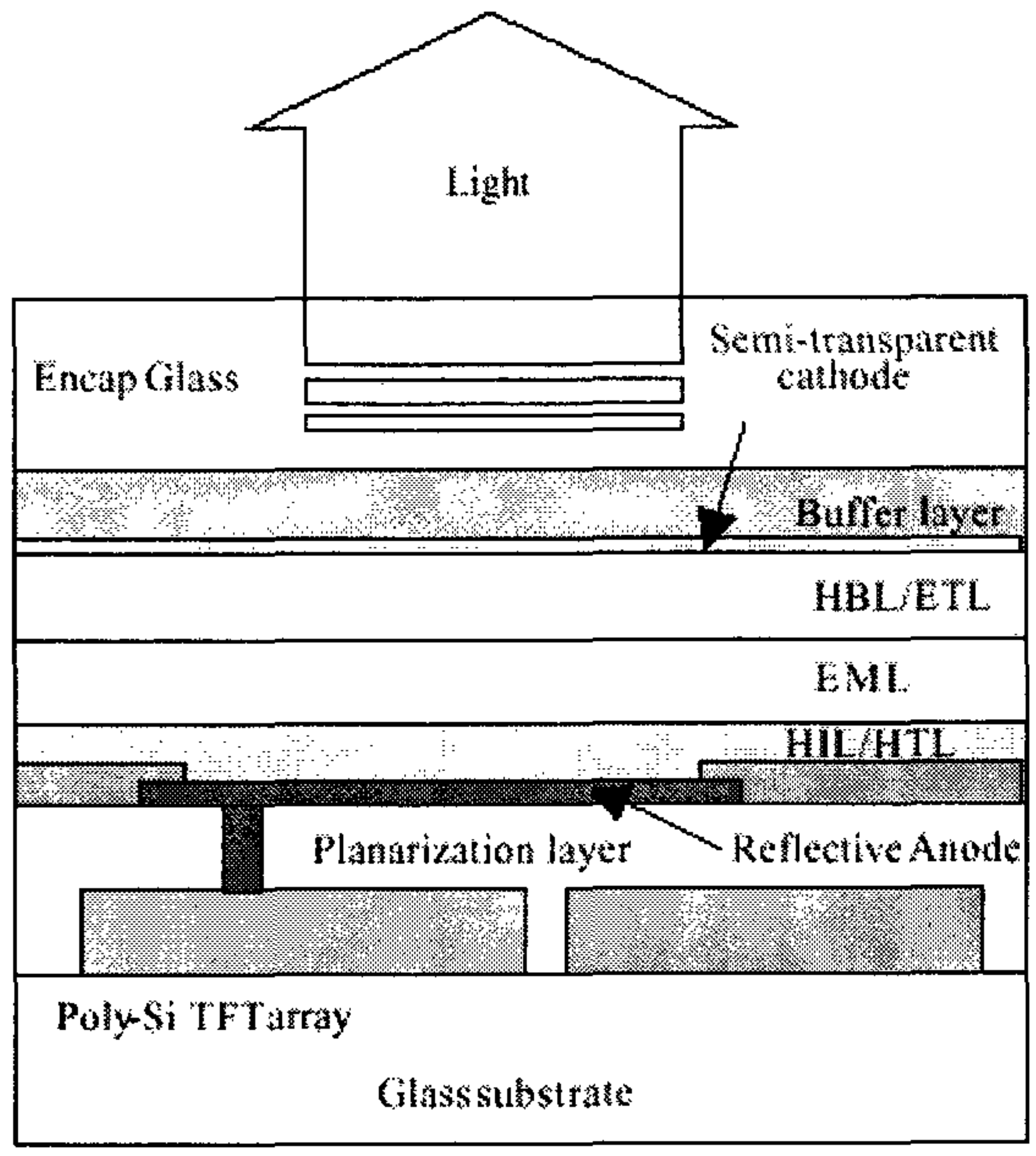

Figure 3. Cross sectional View of the top emission structure

The reflective anode has high reflectivity in order to maximize the light efficiency using multiple interference effect of lights between reflective anode and semitransparent cathode. The organic layers have the conventional structure with HIL, HTL, EML, HBL and HTL using the phosphorescent materials as an emitting material supplied by UDC for green and red color. In case of blue color, conventional structure with fluorescent material was used.

Color	Red (@300cd/m^2)	Green (@600cd/m^2)	Blue (@200cd/m^2)
Efficiency (cd/A)	12	23	4.2
C.I.E. (x,y)	0.64, 0.35	0.23, 0.65	0.13, 0.13

Table 1. The characteristics of the 3 colors in a display using common layer thickness

In order to optimize the white balance from RGB components, the EL thickness and the doping concentration were optimized by simulation based on the extensive experimental results[4], especially we carefully optimized the thickness of the semitransparent cathode, even though the color coordinate in the device could be maximized in the separate three colors. The thickness of the organic layers was determined in consideration of both efficiency and color coordinates of the full color device.

The characteristics of EL for the top emission structure were shown in Table 1 and figure 4.

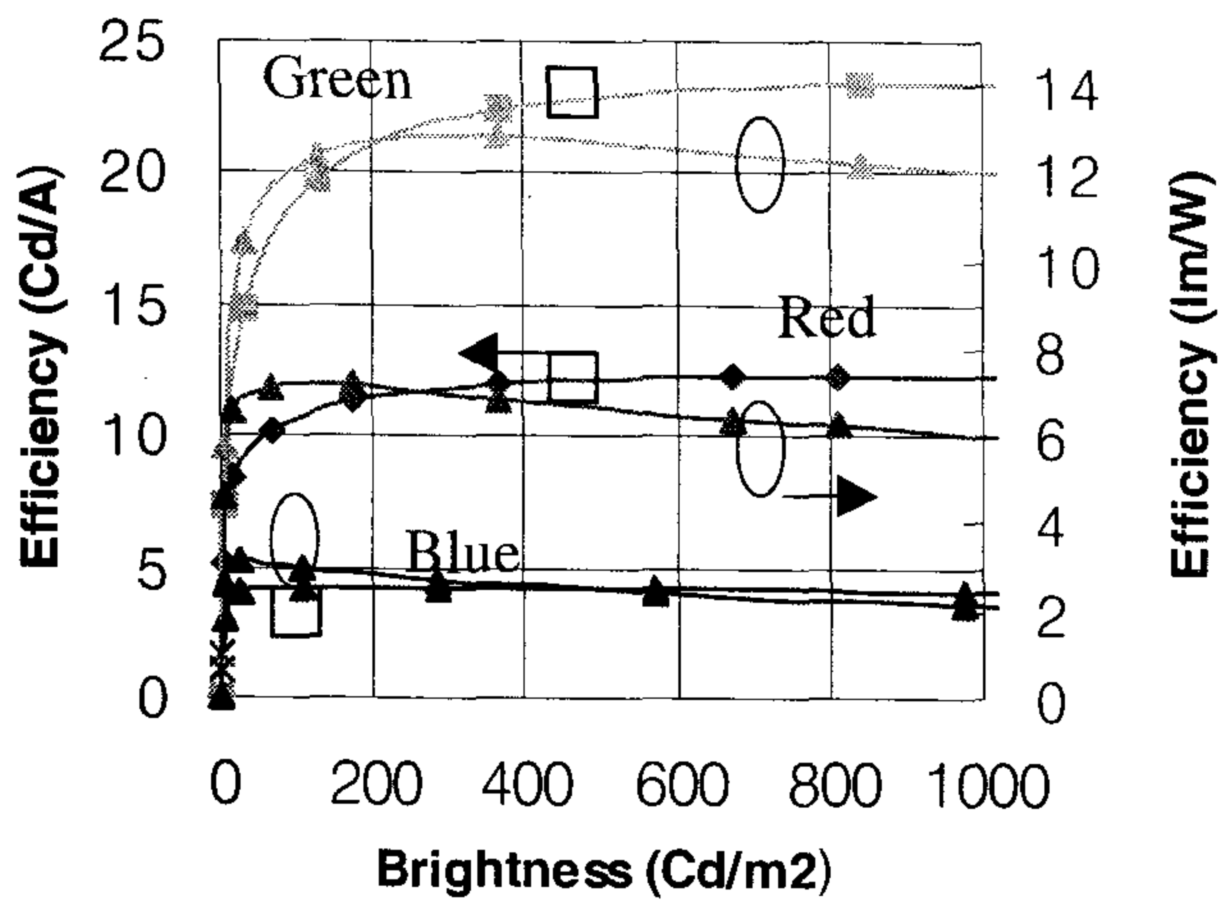

Figure 4. EL efficiencies curves for R, G, B colors.

It gave the luminescence efficiency of 11cd/A in white color (0.31,0.32) and high color reproducibility (>74%) compared to NTSC. Even though top emission structure had the low transmittance and the low reflectivity compared to conventional OLED (bottom emission), it gave the similar efficiency for the conventional emission.

3) Display performance

The developed display has 5.0-inch diagonal size with WVGA (800 x 480) resolution. Its pixel pitch is 0.1365 mm (186ppi), the world's highest density OLED display ever reported to date. The specifications of the 5.0-inch WVGA AMOLED prototype are indicated in Table 2 and the display image is shown in Fig. 6. The white CIE coordinates are x=0.31 and y=0.32. The white color AMOLED has a luminance efficiency of 11 cd/A and peak brightness of over 300 cd/m^2. The contrast ratio is 200:1 under the light of 500 Lx

Parameter	Specification
Display size	5.0 inch diagonal
Resolution	800(H) x RGB X 480(V)
Pixel pitch (mm)	0.1365
Pixels per inch (ppi)	186
Aspect ratio	5:3
Peak luminance	> 300 cd/m^2
Driving frequency	50 Hz
Gray level	64
Contrast ratio	>200:1
Aperture ratio	33

Table 2. Specification of 5.0-inch AMOLED display

3. Conclusion

Samsung SDI has developed 5.0 inch AMOLED panel with CMOS LTPS and high efficiency EL materials. Top emission structure can maximize the pixel aperture ratio and can accommodate 6-TFTs + 1 capacitance in a pixel even in small pixel pitch (186ppi) display. As the wireless era unfolds, customers demand smaller and lighter batteries for their devices. By using phosphorescence-based technology, increased external luminance efficiency and the drastic reduction in the power consumption makes the AMOLED quite suitable for mobile display such as PDA and hand-held PC.

4. References

[1] S. H. Ju et al, SID'02 Digest, 37-1 (2002)

[2] H. K. Chung, IMID, 325 (2001)

[3] Y. W. Kim et al, Euro-Display'02 Digest, P-60 (2002)

[4] J. S. Oh et al, SID'02 Digest 47-4(2002)

Figure 5. Display image of 5" WVGA AMOLED