15” XGA Dual-plate OLED Display (DOD) based on Amorphous Silicon (a-Si) TFT Backplane

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Abstract

We report the improved AMOLED with a-Si TFT backplane based on our unique structure. Our new structure is called Dual-plate OLED Display (DOD). It can also achieve not only higher uniformity of luminance in large-sized display due to low electrical resistance of common electrode but also wider viewing angle.

1. Introduction

For AMOLEDs, a-Si TFT backplane is a suitable candidate because it has low manufacturing cost and it is easy to make large-area devices compared to its competitors like LTPS [1]. But it also has the weak point which requires large TFT area to operate OLEDs, so the top-emitting OLED (TOLED) structure is recommended.

Since the conventional TOLED has an anode at bottom and a cathode on top, it is electrically connected to the driving TFT through the anode which is called a cathode common structure. In this structure, the current of the driving TFT is not independent of the operating voltage of the OLED (V_{OLED}) [2]. The situation can get even worse during the degradation of the display since the V_{OLED} increases affecting the gate-source voltage of the driving TFT.

Some groups have proposed an anode common structure to solve the problems generated from the anode common structure [3],[4]. They employed an inverted-TOLED, i.e. making TOLED that has a cathode at bottom and an anode on top. However, one major challenge in the inverted-TOLED has been to prepare a reflective cathode providing an effective electron injection. Based on such considerations, low work-function metals, such as Mg [4] and Li [5] were introduced to reduce the turn-on voltage. But there remained issues in employing highly reactive metals particularly their handling and operational stability. Another group has demonstrated a more complicated structure using an ultra thin Alq_3-LiF-Al tri-layer as the electron-injection layer [6].

As an alternative anode common structure, we developed a new structure called a dual-plate OLED display (DOD) which uses the encapsulation glass as a plate for OLED and connect to TFT backplane via the contact spacer. For the usual top-emitting type AMOLED, the encapsulation glass is just for the encapsulation or that with the functioning layer for the moisture resistance. We also utilize this as an OLED substrate. This enables us to achieve the high aperture ratio, sufficiently large TFT area and another advantage of this structure is highly uniform emission from panel due to low anode resistance.

2. Fabrication of DOD

The DOD structure consists of 2 plates which are TFT on bottom plate and OLEDs on top plate connected by the contact spacer as illustrated in Figure 1 and 2. Both plates are separately made and encapsulated afterwards. This way provides the higher yield than the conventional method by screening bad plates separately. The conventional manufacturing flow is that TFT components are made first on the glass and then OLED component are made on top of the TFT. Therefore if just one part of two components fails, it will directly affect the total yield. By separating plates, we can use only good plates from both plates and it results in more yields.

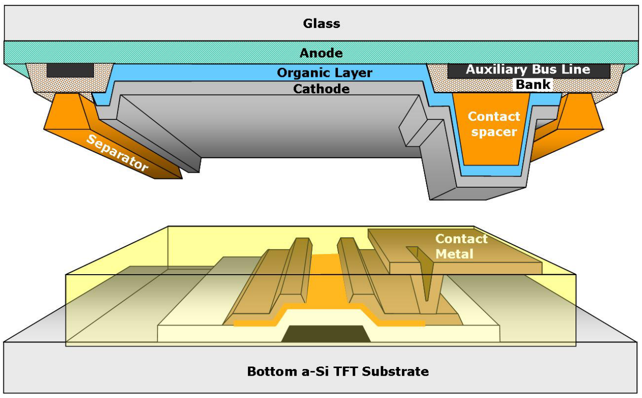

Figure 1. DOD (Dual-plate OLED Display) structure after encapsulation

Figure 2 shows the process flow DOD combined a bottom plate that carries TFT array and a top plate that carries OLED.

In Figure 3, it shows the separator and the contact spacer from the actual panel. These SEM images are taken after detaching the top plate, and showing the sufficient separation in organic layer and cathode.

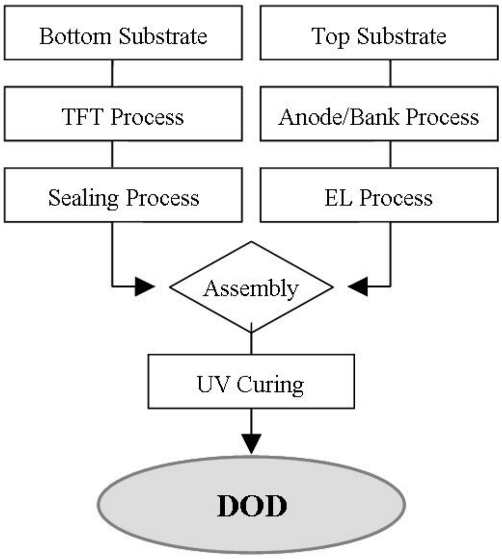

Figure 2. Process flow to fabricate a DOD

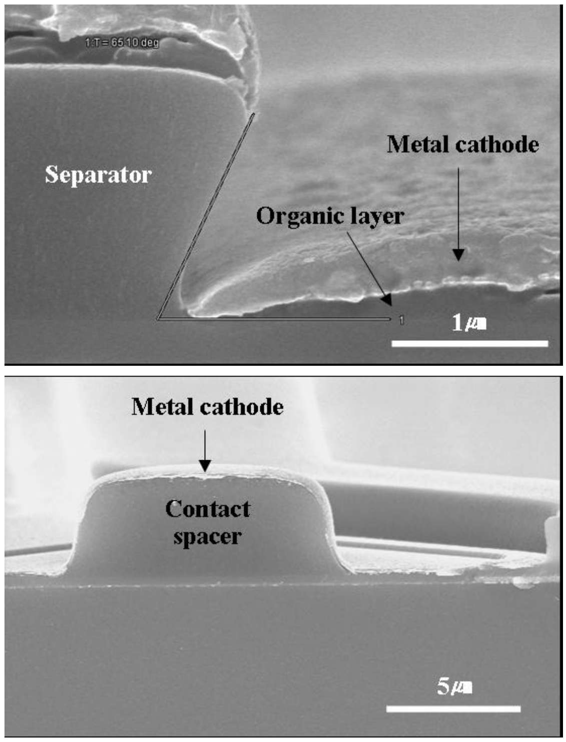

Figure 3. SEM images Separator and contact spacer after detaching the top plate from panel

3. Characteristics of DOD

Advantages of the DOD structure are versatility and a uniform luminescence from a whole panel. Due to the separate manufacturing process, the making sequence of the DOD top-plate is the network of auxiliary electrodes, ITO as anode, OLED, cathode and other structures like the separator and the contact spacer. So the top plate is almost same as a conventional OLED devices and that gives us a flexibility to modify and improve the OLED components.

When the OLED components directly connect with TFT in the conventional structure as, there is always a problem of a large electrode resistance, which results in a non-uniform luminescence across the center and edge of the panel. Because of the unique DOD structure, we can put auxiliary electrodes of good conducting metal like Mo in all connected mesh network as shown in Figure 1. These networks give us the low anode resistance and finally uniform luminescence. Figure 4 shows the voltage drop at the center of display due to the resistance of

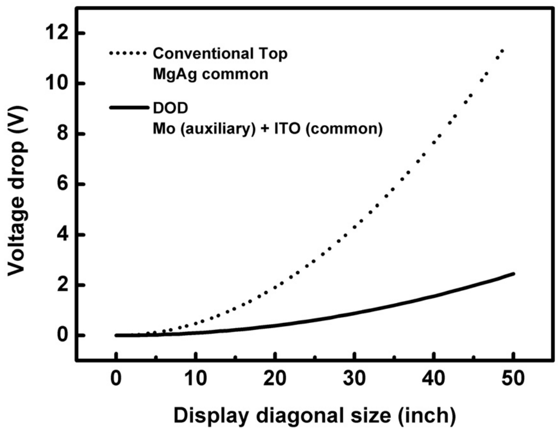

Figure 4. The voltage drop at the center of display due to the resistance of common electrode as display size

common electrode. To compare the voltage drop between conventional top emission and DOD, we assumed the sheet resistance as 10 Ω /sq. of MgAg electrode in conventional top emission and 2 Ω /sq. of mesh-patterned Mo and ITO electrode in DOD. As display size increases, the voltage drop is a most critical issue in conventional top emission structure.

For usable TFT area we can utilize whole area as a TFT area. The increased TFT area has a room for a further enhancement of TFT panel by adding more TFT like the compensation circuit. Also no need for planar layer also gives us advantages in manufacturing cost and process time.

The DOD structure also can avoid the damage of the organic layer during the making process of the transparent cathode or the anode deposition on organic layer and the additional investment for the low temperature sputtering equipments which is expensive and requires additional longer process time. Depending on TFT and circuit structure, the conventional top-emitting type may need the semi-transparent cathode or need to be made by inverted sequence of cathode, ETL, EML, HTL, HIL and anode. These final electrode making processes need the low temperature process to avoid damages to the organic layer. By making OLEDs on top-plate, we can avoid these disadvantages and high processing cost.

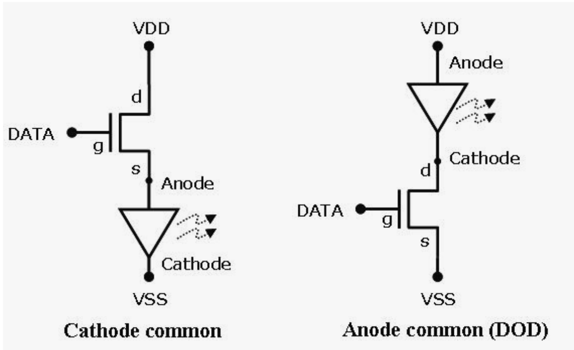

Figure 5. Comparison of the structure and circuit diagram between the conventional bottom emission and the proposed DOD top emission structure

Also, the drain of TFT can be directly connected to the cathode of OLED and it results that the performance of TFT is not affected by the operation of OLED. As illustrated in Figure 5, in the conventional type, the effective driving voltage for a target current level depends on the OLED voltage as well as the data voltage.

The OLED current increases as the data voltage increases, but the OLED voltage (i.e. anode voltage) also increases so that the current increment may be suppressed. It is noted that this uneasy control causes poor display performance. On the other hand, the OLED current of the proposed one is independent of the anode voltage of OLED, this meant that the effective driving voltage is always equal to the data. Therefore the DOD is suitable for better image performances having high luminance and contrast ratio at the same driving conditions as reported [7].

4. 15-inch AMOLED employing DOD structure

By introducing the top OLED glass we can achieve the high aperture ratio of 52% for the 15 inch XGA panel configuration.

These values are obtained after considering the process margin of making separators and insulating layer and using the shadow mask for the separated red, green and blue (RGB) emitting layer. This increased aperture ratio allow us operate OLEDs at lower current level to get the same brightness which

Figure 6. Photograph of fabricated 15-inch XGA (1024RGBx768) DOD panel

results in the increased lifetime of devices. The specifications of the fabricated AMOLED panel are summarized in Table 1.

Table 1. Panel specification

Feature	Specification
Panel dimension	304.13(H) x 228.10 (V)
Diagonal	15.0 inch
Pixel pitch	96㎛ x 297 ㎛ (85.5 ppi)
Resolution	Conventional
Pixel arrangement	Semi Transparent
Emission type	Top emission
Aperture ratio	52%

This panel shows 300 cd/m^2 of peak luminescence and 80 % NTSC*xy* color-gamut ratio.

5. Conclusion

A-Si is a very good candidate for the large area AMOLED due to its virtue, but some intrinsic problems has become a barrier. We think we can overcome this by introducing the DOD structure. Preserving the existing infrastructure and minimized new investment of the DOD structure provide very cost effective manufacturing with the enhanced performance.

The reliable large area AMOLED at the lower cost is one of the most important goal in the display business. To achieve this, many efforts is going on at the industrial and academic sector and their efforts are ripe to show outcomes. We also can provide one of many steps to reach that by the DOD structure by fabricating 15-inch panel.

6. References

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