# Simplified Process for Passive Matrix OLEDs

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## Abstract

*We have developed simplified processes for the formation of insulators, cathode separators and bus electrodes in PMOLEDs. The insulators and cathode separators are patterned simultaneously by a single layer of image reversal photoresist. And, the bus electrodes of low resistance are formed by the cathode separator and cathode metal. Using these simplified processes, we fabricated 1.17" 96xRGBx96 panels and analyzed their performance and reliability.*

## Introduction

In general, small molecule PMOLEDs are fabricated by the following processes; bus electrode patterning, transparent anode patterning, insulator patterning, cathode separator patterning, evaporation of organic multi-layers such as HIL, HTL, EML, ETL, evaporation of LiF and a metal cathode, etc.(1)

In the meantime, PMOLEDs are driven by a one-line-at-a-time driving method, that is, each scan line is selected in regular sequence.(2) When a scan line is selected, an electric current flows to each pixel from a drive IC through each data line. And, each pixel current merges and flows to the selected scan line consisting of a cathode electrode and a bus electrode. As a result, while a voltage drop along the data line is small, a voltage drop along the scan line arises to a relatively large degree. This voltage drop increases operation voltage and power consumption, and causes cross talk. Moreover, the voltage drop increases as the resolution, brightness and display size increase.

We have developed a so-called single isolation structure for insulators and cathode separators, and a simplified process for bus electrodes of low resistance.(3 - 7) These simplified processes are compared to the conventional ones in Fig. 1. In the single isolation structure, the insulators and cathode separators are formed simultaneously by a single layer of image reversal photoresist as shown in Fig. 2. In the simplified process for bus electrodes of low resistance, the cathode separators are defined both in the peripheral area and in the active area as shown in Fig. 3 (a). And, the cathode metal of aluminum is deposited in both areas so that the cathode and bus electrodes are formed by the deposited aluminum as shown in Fig. 3 (b).

Using the simplified processes, we fabricated 1.17" 96xRGBx96 panels to analyze their reliability and performance. In addition, the bus electrodes and cathode electrodes were formed by a single and bi-layer of aluminum and copper to lower the line resistance.

## Experiment and Results

Using the simplified processes, 1.17" 96xRGBx96 PMOLEDs were fabricated on 200x200mm2 ITO coated glass substrates. A single and bi-layer of aluminum and copper were deposited to form the bus electrodes and cathode electrodes. Using glass lids, the encapsulation was performed under an ambience of nitrogen and oxygen mixed gas. To cure and prevent pixel short circuits, we carried out the so-called oxygen aging where the data lines were floating and an alternate current voltage was applied to the even and odd scan lines.

As expected, the sheet resistance, line resistance and voltage drop were lowered to a considerable degree. And, the power consumption was reduced significantly compared to that of the conventional ones. To investigate the dependence of device reliability on the simplified processes and aluminum thickness, reliability tests were carried out varying the thickness of aluminum from 1000Å to 2500Å The test results were equivalent to those of the conventional ones when the aluminum was 1000Å to 2000Å in thickness. But, when it was 2500Å thick, the occurrence rate of pixel short circuits was increased in spite of the oxygen aging. We analyzed it and found a clue to the cause from the microscopic images of pixels after the oxygen aging. Most of the pixel short circuits are caused by sub-micro particles located between the anode and cathode electrodes and some of them arise during operation. When the oxygen aging is applied, the aluminum gets holed at the spots where the sub-micro particles are located so that the oxygen in the encapsulation lid is supplied through the hole and the sub-micro particles are burned away or oxidized. This is the reason why the pixel short circuits are cured by the oxygen aging. When the aluminum was 1000Å to 2000Å in thickness, it was holed and the pixel short circuits were cured. On the other hand, it was deformed, but not holed at 2500Å It was too thick to be holed so that the pixel short circuits could not be cured by the oxygen aging. Consequently, there is a limitation on increasing the aluminum thickness and lowering the line resistance with a single layer of aluminum.

In order to lower the line resistance further, a bi-layer of aluminum and copper was deposited. The aluminum layer is required because of its work function and also as a barrier layer to prevent the copper from diffusing into the underlying organic layers. In addition, since copper has low reflectance and its own color, the aluminum layer has to be used. When a single layer of copper was deposited, the current level, efficiency and brightness were decreased and a color shift occurred slightly to red. In order to determine the thickness of the aluminum layer, the reflectance was measured against the thickness. When the aluminum layer was above 300Å the reflectance was over 90% and appeared to be saturated. We fabricated 1.17" 96xRGBx96 PMOLEDs using a bi-layer of aluminum and copper where the aluminum layer was 500Å thick and the copper layer was 1500Å thick. The sheet resistance was 0.07Ω ㄱ and much smaller than that of the conventional bus electrodes of low resistance consisting of Mo/Al/Mo (500Å 000Å 00Å 0.15Ω ㄱ

## Conclusions

Using the simplified processes, we fabricated 1.17" 96xRGBx96 PMOLEDs and analyzed the device characteristics and reliability. The simplified processes improved their performances such as operation voltage, power consumption, crosstalk, etc., and reduced the fabrication processes.

In case of a single layer of aluminum for the cathode and bus electrodes, there was a limitation on increasing the aluminum thickness and lowering the line resistance because of pixel short circuits. Using a bi-layer of aluminum and copper, we obtained 0.07Ω□ in sheet resistance much smaller than that of the conventional bus electrode of low resistance.

## References


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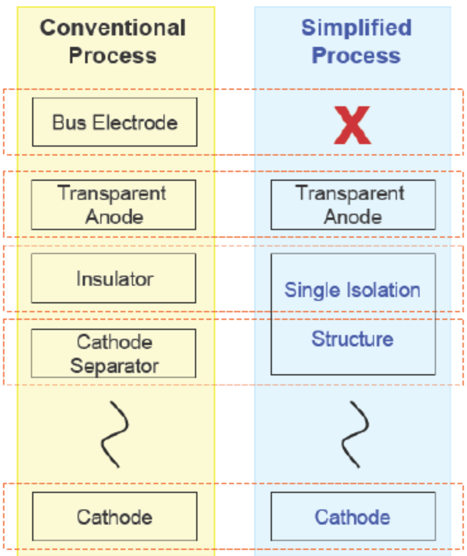



FIGURE 1. Process simplification for PMOLEDs

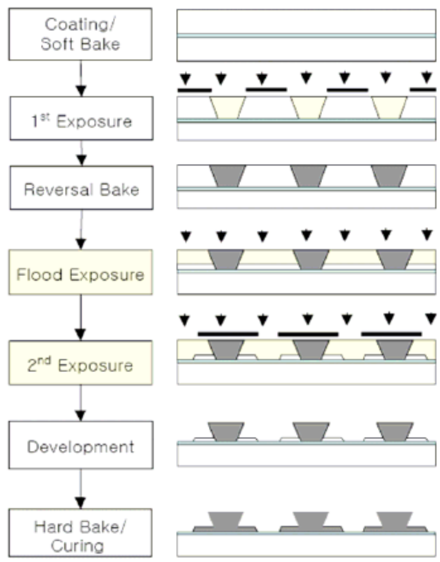
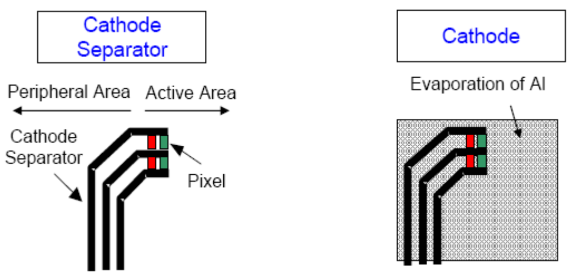



FIGURE 2. Single isolation structure




(a) (b)

FIGURE 3. Simplified process for bus electrodes of low resistance