Array of Pentacene TFTs for AMOLED

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Abstract

In this paper, we studied on the application of Organic Thin Film Transistors (OTFTs) to the active matrix organic light emitting diodes (AMOLED). We designed organic transistor based pixel circuits for AMOLED. The pixel circuit is consisted of two-transistor, one-capacitor and one-OLED. We report the simulation results of the pixel circuits that OLED current varied as the data line and scan line voltage. Also, we will describe the fabrication process of the Pentacene OTFTs arrays and the organic light emitting diodes. The driving results of the fabricated unit pixels and their 4x4 arrays are also presented.

1. Introduction

The development of information technology is growing the display market in these days. Various displays are enthusiastically studied to take the dominant position in the display market. One of these, organic light emitting diodes (OLEDs) have low power consumption, high color purity and wide visual field [1]. Especially, it is easy to apply for the flexible display because of low process temperature.

Recent attention has been paid to addressing mode concerning displays with OLEDs. There are two types of display architecture: passive matrix and active matrix. Nowadays, low temperature poly silicon and amorphous silicon (a-Si) are known as semiconductors of TFTs used in AMOLED [2, 3, 4, 5]. However, it is difficult to fabricate TFTs on the plastic substrates because of the high-temperature process and large-scale facilities required for manufacturing.

In this paper, we proposed Pentacene TFT (OTFT) as an active layer of the TFTs used in AMOLED. Ahead of fabrication of the pixel circuits, we simulated the circuits to expect their electrical characteristics. We fabricated the pixel circuits and their 4x4 arrays on glass substrates and confirm the OLED driven by Pentacene TFTs.

2. Experiments

We developed the fabrication process of OTFT and OLED respectively. And, we designed various pixel circuits for AMOLED and simulated them using Hspice. Finally, we fabricated the pixels and arrays on the glass substrates using the developed unit device fabrication process.

2.1 Design of Pixel Circuit

The pixel circuitry is shown in Fig 1. In an OLED display, in order to continuously supply the current to the OLED pixel while the other rows are addressed, at least two TFTs are needed for one pixel. Two-TFT pixel circuit has high aperture ratio and increases reliability and yield because of low transistor count. However, OLED brightness of this pixel circuit is slightly changed by the threshold voltage variations of the driving TFT due to the manufacturing variations and the circuit aging. And, this pixel circuit requires p-channel TFT for better performance [6].

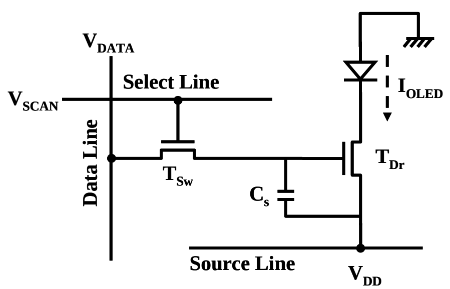
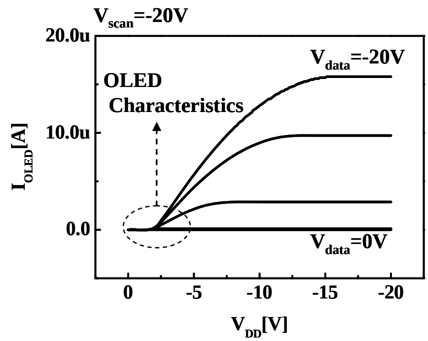
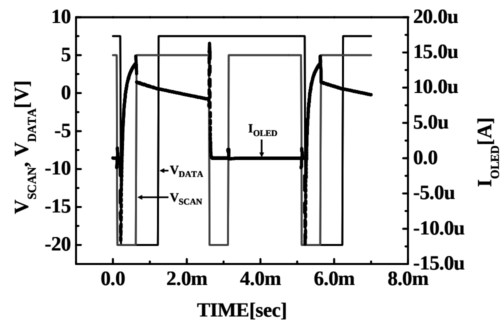


Fig 1. Pixel Circuitry for AMOLED

We designed pixel circuits and simulated to expect the electrical characteristics of them. The simulations are performed with the Hspice. We fit the electric characteristics of OTFT model to our experimental data by adjusting the model parameters of the MOSFET LEVEL 40. OLED modeling for pixel simulation is carried out using the reference [6]. The simulation results of OLED are also fitted to our experimental data. And, we simulate the pixel circuits under the DC and AC bias conditions of the Data and Scan voltages.



(a) Output Current



(b) Transient Response

Fig 2. Electrical Characteristics of the Pixel Circuit

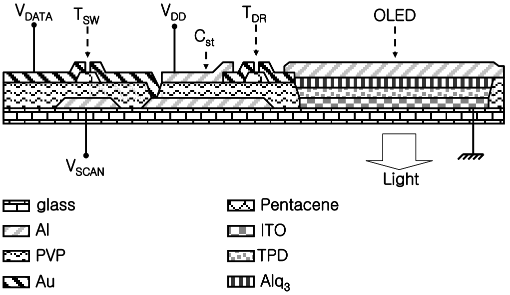
Fig 2(a) is DC characteristic of the pixel. Diode characteristics are shown in figure, due to the OLED. OLED current in the pixel circuit are very small at low supply voltage region because OLED restricts the current, while saturated current flow at high supply voltage region due to the driving transistor. We investigated the transient response by applying pulse voltage to the select line and data line. Fig 2(b) is the transient response of the pixel circuit in storage mode. Storage mode means that data line is set to zero after the select line voltage decreases to 0V. As shown in Fig 2(b), OLED current reduction is observed because of the large leakage current of the switching transistor (approximately 10^{-9}). As shown in Fig 2(b), there is a Kickback Drop in OLED current. This current reduction is caused by the overlap capacitances of the driving transistor. In the simulation, the overlap capacitance is very large (approximately 10pF) because of alignment limitation of our fabrication equipment. The spike current is also caused by the overlap capacitance. If we prepare the more delicate alignment, the Kickback Drop and spike current will be dramatically reduced.

2.1 Fabrication of pixel circuit

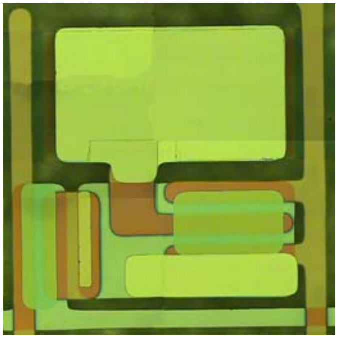
We designed the Pixel Test Mask including four different pixel circuits. The Table 1 is the specification of mask. The mask includes a 4X4 array of each pixel.

	Pixel circuits			
Size	1560µ X 1560µ			
Active layer	Pentacene			
Gate insulator	PVP			
	Pixel 1	Pixel 2	Pixel 3	Pixel 4
Switching Tr(W/L)	500µ/ 50µ	500µ/ 50µ	1700µ/ 50µ	500µ/ 50µ
Driving Tr(W/L)	750µ/ 50µ	750µ/ 50µ	2200µ/ 50µ	1000µ/ 50µ
Storage Capacitor	21pF	17pF	19pF	17pF
Aperture Ratio	31%	31%	27%	25%

Table 1. Specification of Pixel Test Mask



(a) Cross Section of thePixel



(b) Micrograph of the Pixel

Fig 3. Fabricated Pixel circuit

Fig 3 shows the fabricated pixel circuit. We used the glass substrates. First of all, we patterned ITO as an anode electrode of OLED and deposited Al as a gate electrode of the switching and driving transistors. The gate insulator that is made by the solution with poly 4 – vinylphenol (PVP) and melamine-co-formalde hyde (poly) in propylene glycol monomethyl ether acetate (PGMEA) is spin coated. After lithography process, we patterned gate insulator using O2 plasma. Pentacene as active layer is deposited by organic molecular beam deposition (OMBD). Au is used by contact metal. OLEDs are double layer structure with HTL and EML. Al is thermally evaporated as a cathode of the OLED, a storage capacitor electrode. And Al also is the connection between driving transistor and OLED.

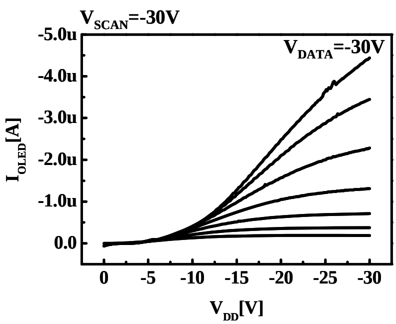


Fig 4. Output Current versus Supply Voltage at various Data Voltage

Fig 4 shows the output characteristic of the fabricated pixel circuit with two OTFTs under DC operation. This is expected by simulation. The data line voltage was varied from 0V to -30V, and the scan line voltage is -30V. At the data line voltage of 0V, the current was under 10nA. On the other hand, when data line voltage was nonzero, the output current of the pixel was observed and found to be saturated. The function of the data line voltage is confirmed by this result.

3. Conclusion

We have studied on the application of OTFTs to AMOLED. We designed the pixel circuits and their fabrication process for AMOLED and the electrical characteristics of each pixel circuits are confirmed by simulations. And we fabricated the pixel circuit and observed the AMOLED driven by Pentacene TFTs.

Acknowledgement

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