# Integration of 4.5" Active Matrix Organic Light-emitting Display with Organic Transistors

**Sangyun Lee, Bon-Won Koo, Eun-Jeong Jeong, Eunkyung Lee, Sangyeol Kim*, Jungwoo Kim*, Ho-Nyeon Lee*, Ickhwan Ko, Younggu Lee*, Youngtea Chun*, Junyong Park*, SungHoon Lee*, In-Sung Song, OGweon Seo*, Eokchae Hwang, Sungkee Kang*, Lyoungson Pu, and Jong-Min Kim**

**Abstract**

We developed a 4.5" 192x64 active matrix organic light-emitting diode display on a glass using organic thin-film transistor (OTFT) switching-arrays with two transistors and a capacitor in each sub-pixel. The OTFTs has bottom contact structure with a unique gate insulator and pentacene for the active layer. The width and length of the switching OTFT is 800 ㎛ and 10㎛ respectively and the driving OTFT has 1200㎛ channel width with the same channel length. On/off ratio, mobility, on-current of switching OTFT and on-current of driving OTFT were $10^6$,0.3~0.5 $cm^2/V{\cdot}sec$, order of 10 μA and over 100 μA, respectively. AMOLEDs composed of the OTFT switching arrays and OLEDs made using vacuum deposition method were fabricated and driven to make moving images, successfully.

**Keywords** : wet-processible dielectrics, pentacene, organic thin-film transistor, active matrix organic light emitting diode

## 1. Introduction

Since the late 1940s, organic semiconductors (OSCs) have been continuously studied, and organic thin-film transistors (OTFTs) have recently drawn significant interest for several electronic applications such as active-matrix flat panel displays, electronic papers, and chemical sensors, replacing the traditional inorganic semiconductor-based transistors. [1] Among the many developed OSCs, thermally evaporated pentacene exhibited carrier mobility reaching 3 to 5 $cm^2V^{-1}s^{-1}$, which exceeds mobility in thin-film transistors (TFTs) based on amorphous Si.[2] To realize the commercial applications of high performance and low coat OTFT, one of the key issues is to identify solution processible gate dielectric materials.Gate dielectric materials in OTFT should be pinhole free and have ong term stability, good insulation properties and also be compatible with organic semiconductors. There have been a few materials reported to meet these requirements. Recently, it was reported that high performance OTFT (mobility~5 $cm^2/Vs$ and on/off ratio~$10^6$) based on pentacene and $Al_2O_3$/polystyrene double layered gate dielectrics by 3M. However, these approaches still require inorganic layer formed by vacuum process.

In this work, 4.5" OLED based on pentacene TFT array has been demonstrated. Organic thin-film transistor (OTFT) switching-arrays with 64 scan lines and 192 data lines were designed and fabricated to drive organic light-emitting diode (OLED) arrays. Pentacene was used as semiconductor material and an organic insulator was used as gate insulator material. On/off ratio, mobility, on-current of switching OTFT and on-current of driving OTFT were $10^6$, ~0.5 $cm^2/V{\cdot}sec$, which is an order of 10 μA and over 100 μA, respectively. These properties were enough to drive the active-matrix organic light-emitting diode (AMOLED) over 60 Hz frame rate. AMOLEDs composed of the OTFT switching arrays and OLEDs made using vacuum deposition method were fabricated and driven to make moving images, successfully.

## 2. Design and Fabrication

In this work, we synthesized wet-processible gate

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* Member, KIDS
Corresponding Author : Sangyun Lee
Display Lab, Samsung Advanced Institute of Technology(SAIT), Yongin, Korea.
**E-mail** : sangyoon.lee@samsung.com **Tel** : +031 280-6742 **Fax** : +031 280-9349

dielectrics. organic-inorganic hybrid type materials such as mixture of organosilane and low temperature curable polymer are used. The dielectric properties are shown in Fig. 1.[3] After cured at 200°C, Au was deposited by thermal evaporation and patterned using standard photo-lithography process. Prior to Pentacene deposition, Au surface was treated with Self Assemble Monolayer (2-Mercapto 5-nitrogenzimidazole) to reduce the contact resistance.[4] Pentacene was then deposited though shadow mask and passivated using PVA (Polyvinyl Alcohol). Fig. 2 shows the transistor performance. As shown in this Fig. 2, linear mo-bility was ~0.5 $cm^2/Vs$ with $10^6$ on/off ratio.

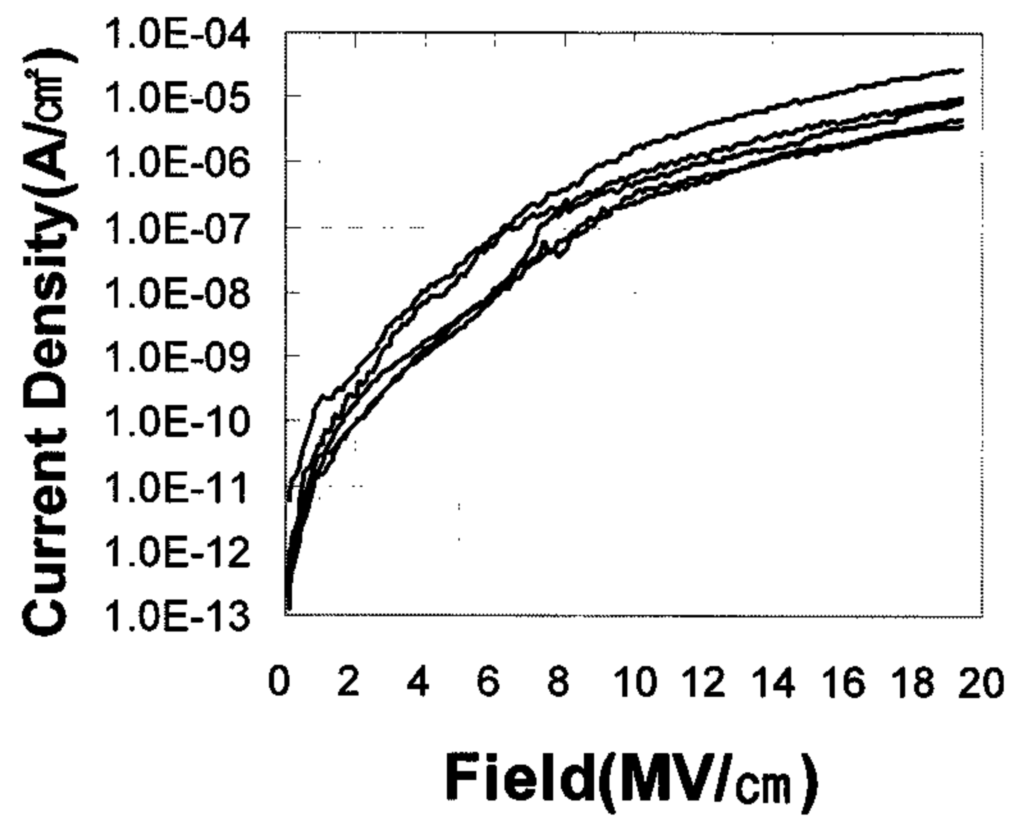


**Fig. 1.** Current-Voltage characteristics of gate insulator measured using Metal-insulator-metal structure

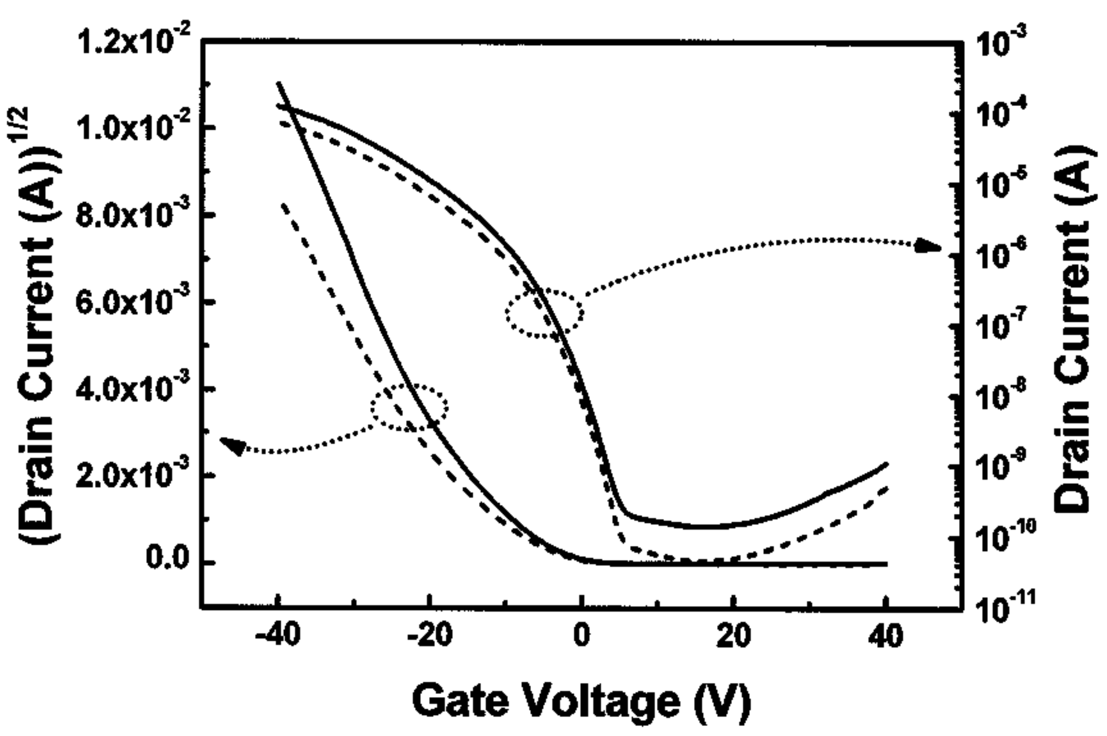


**Fig. 2.** Drain current versus gate voltage at a drain voltage of -20 V; dashed line and solid line show the drain currents of switching transistor and driving transistor, respetively.

Active-matrix array of 4.4 inch square shape was designed to drive OLED array. 192×64 pixels were integrated in the array. Each sub-pixel had a pixel-circuit to drive the OLED.

Pixel-circuit had a storage capacitor and two transistors; one was a switching transistor and the other was a driving transistor. Fig. 3 shows the schematic diagram of pixel-circuit and Fig. 4 shows the photograph of a sub-pixel. Switching TFT stored the data signal (Data in Fig. 4) into the storage capacitor (Cst in Fig. 4) during on-stage of the scan signal (Vgate in Fig. 4) and kept the stored data during off-stage of the scan signal. Driving TFT controlled the current of OLED according to the data stored in the storage capacitor.

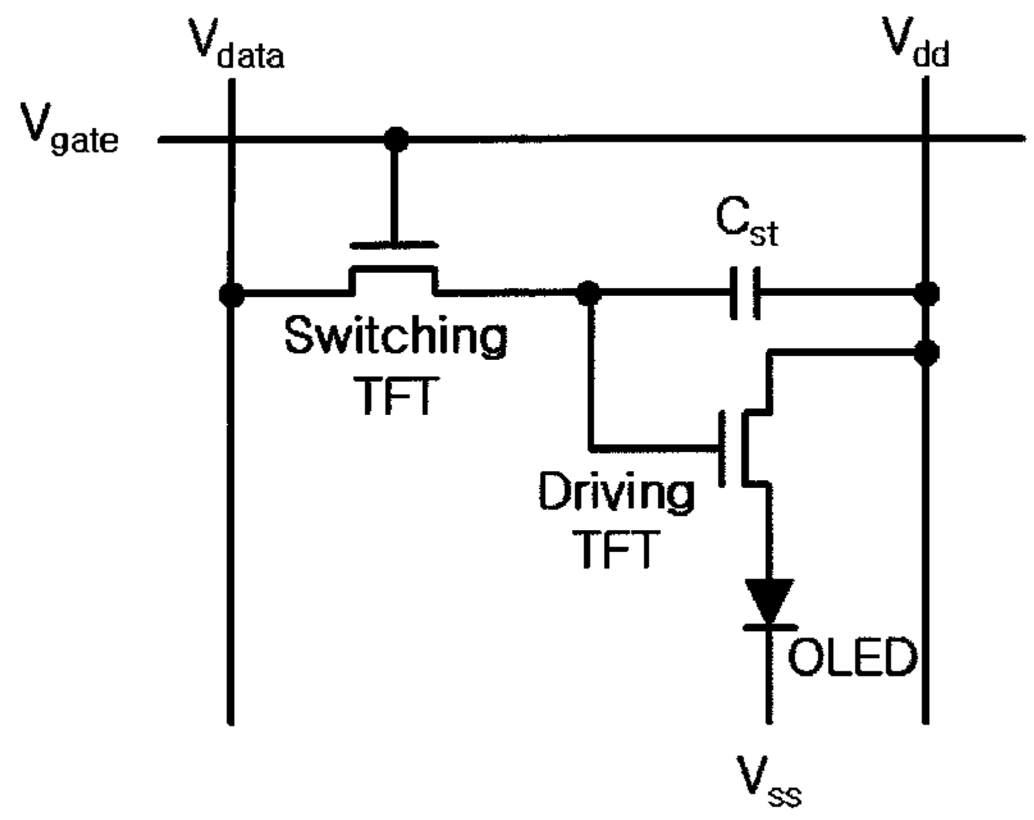


**Fig. 3.** Schematic diagram of pixel-circuit of voltage writing scheme; Vgate is a scan signal, Vdata is a voltage writing data, Vdd is a power line for OLED and Vss is a cathode voltage for OLED.

The channel length was 10 μm for both transistors. The channel widths of switching TFT and driving TFT were 800 μm and 1200 μm, respectively. The capacitance of storage capacitor was 1 pF. The ratio of channel width over length (W/L) of driving TFT was chosen to guarantee on-state drain current large enough to lighten the OLED. Storage capacitor was designed to have enough capacitance to reduce the cross-talk owing to the parasitic capacitance of circuit. W/L of switching TFT was designed considering the charging time of the storage capacitor. As shown in Fig. 2, we used finger-shaped TFTs to increase channel widths. The width of finger was 30 μm. The widths of gate line, data line and power line were 50 μm, 40 μm and 50 μm, respectively. Storage capacitor was designed to use the same layer of the gate insulator as its dielectric layer.

OLED array was fabricated on the active-matrix switching-array after the characteristics of OTFTs were measured. AMOLED was fabricated using low molecular weight materials and thermal deposition process with shadow mask. After the OLED process, devices were encapsulated using glass can and getter. Next, we made tap bonding on the devices, which were driven by external electronics.

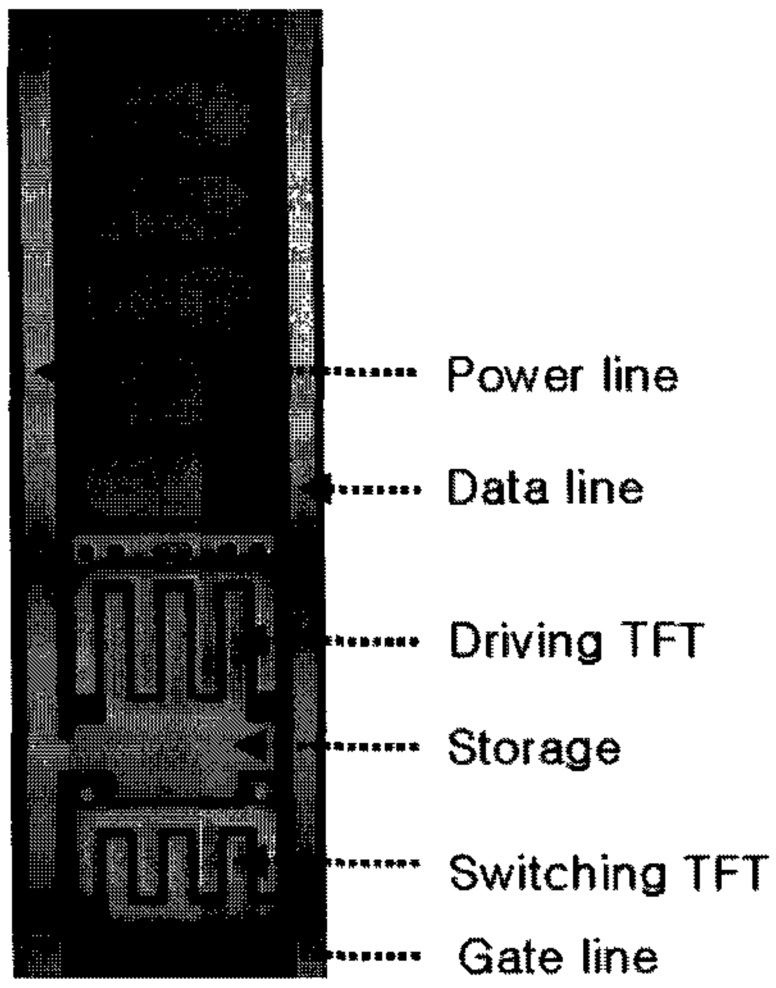


**Fig. 4.** The photograph of sub-pixel.

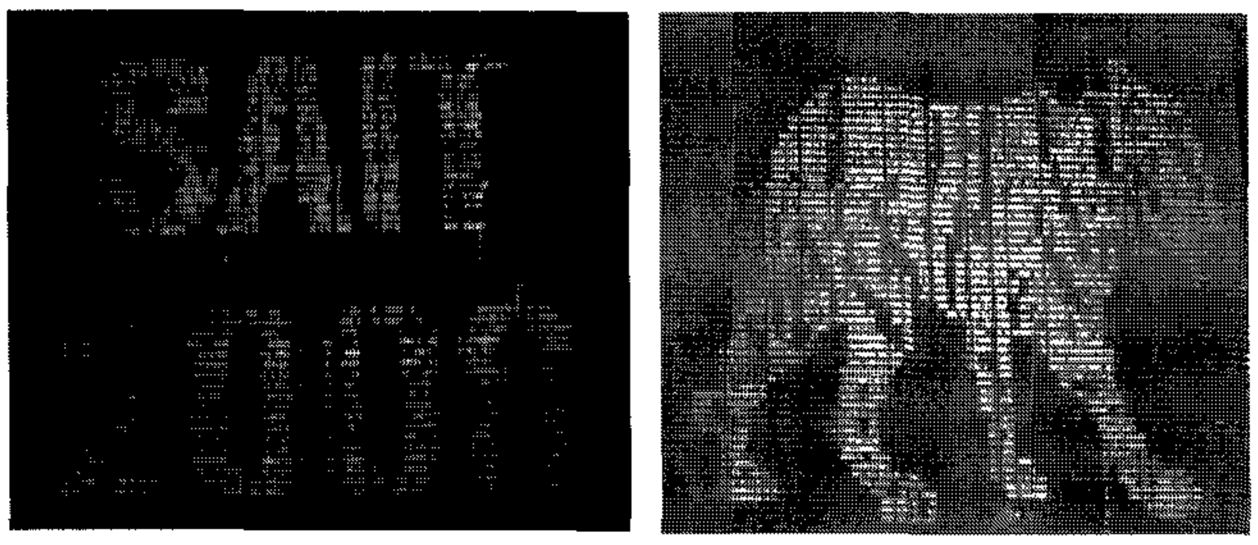

**Fig. 5.** A still cut of moving image displayed on an AMOLED.

## 3. Summary

We designed and fabricated 192×64 active-matrix switching-array using OTFTs for driving of OLED array. In each sub-pixel, a pixel-circuit with two transistors and one capacitor was integrated. OTFTs gave on/off ratio of $10^6$ and mobility of 0.5 $cm^2/V{\cdot}sec$. On-currents were over 100 μA in case of driving TFT and order of 10 μA in case of switching TFT. Using this switching array, AMOLEDs with deposition process were fabricated and driven successfully. From these results, it was confirmed that AMOLED driven by organic TFTs can be fabricated; this is a dramatic develop-ment in terms of in making the all-organic display device at low-cost.

## 4. References

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