# Fabrication of Polymer TFT Arrays on Plastic Substrates Using a Low Temperature Manufacturing Process

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## Abstract

*In this paper, fabrication of a 60x48 polymer TFT array with a top-gate structure on plastic substrates using a low temperature printing process will be presented and the device structure and manufacturing processes will be discussed. The polymer TFT array showed excellent air stability and uniform electrical characteristics over a large area. Finally, a 1.5 inch EPD display with 50 dpi resolution using the polymer TFT array will be demonstrated for e-film device applications.*

## 1. Introduction

Organic Thin Film Transistors (OTFTs) have the advantages of lower-temperature process and light weight for flexible substrate. Now, OTFT technology has been widely reported for driving Twisted Nematic Liquid Crystals Display (CTNLCD), Cholesteric Liquid Crystal Display (ChLCD), Electro Chromic Display (ECD), Electrophoretic Display (EPD) and Organic Light Emission Diode (OLED). [1-6] OTFT based display has higher performance during bending which can use in large area and flexible display application. Some of the study reported TNLCD and ChLCD on flexible substrate which was driven by OTFT successfully. However, there are several issues in the flexible liquid crystal display applications; the first is the flexible back light selection because transparence LCD needed a flexible back light which have higher reliability during bending. The second problem is LC cell gap will be varied when the flexible display bending, which would affect image quality. OTFT drive Electrophoretic Display is one of a candidate in flexible display, which has lower voltage operation, wider viewing angle, and higher image performance during bending. Some of research centers have been reported OTFT drive EPD on flexible substrate and have nice display performance. In this report, we successfully integrated OTFT and electrophoretic process to fabricate 1.5-inch 60 x 48 OTFT-EPD on flexible substrate, and successfully operated at the operated voltage that are used on the gate bias are -30 V during the row data selection and the gate bias are 0 V during the row data hold time. The data voltages that are used on the source bias are -20 V, 0 V, and 20 V during display media operation.

## 2. Experimental

### 2.1 OTFT Fabrication

A 1.5 inch 60 × 48 pixels organic thin film transistors driven electrophoretic used batch type photolithography. The cross section of the pixel structure was indicated in Fig. 1. OTFT devices are top gate bottom contact structure. Source/drain electrode, Au, was patterned by photolithography with thickness about 60 nm. Highly air stable polymer active layer P3HT was used and deposited by ink-jet printing. Gate dielectric PVP (poly-4-vinylphenol), about 500 nm thickness, was deposited by spin coating and cross-linked by UV. The gold metal was used for the gate electrode and patterned by photolithography. Finally, 3000 nm-thick interlayer film was deposited by spin coating. In order to decrease operation voltage, we create via holes through interlayer and dielectric and used induced coupled plasma reactive ion etcher (ICP-RIE) and patterned interlayer hard mask to remove cross-linked PVP on pixel electrode. OTFT electrical characteristics didn't have the degradation after we used ICP-RIE process. Finally, nano-silver pixel electrode patterned by an ink-jet printing and total process completed for a polymer OTFT backplane. The channel length of polymer OTFT devices is 20 μm, and the channel width are 200 μm.

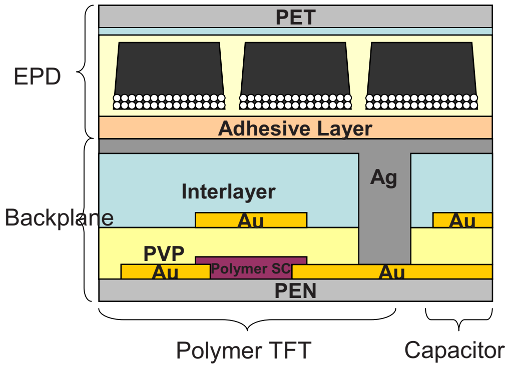



**Fig. 1. The top gate and bottom contact OTFT device which drive electrophoretic structure.**

### 2.2 Pixel Electrode

In order to increase aperture ratio for OTFT-EPD application, we deposited silver pixel electrode on the OTFT by using in jet printing. However, the electrode continuous on via hole and leakage between OTFT and storage capacitor are the most important to determine. We connected electrode pad through via hole beside device and on the top of OTFT device respectively which indicated in Fig. 2 (a). After device measured as shown in Fig. 2 (b), devices also have their transfer characteristics like the initial value which compare with Fig. 3 (b). According above result, we could deposit pixel electrode on the top of OTFT, and increase aperture ratio from 50% to 90%.

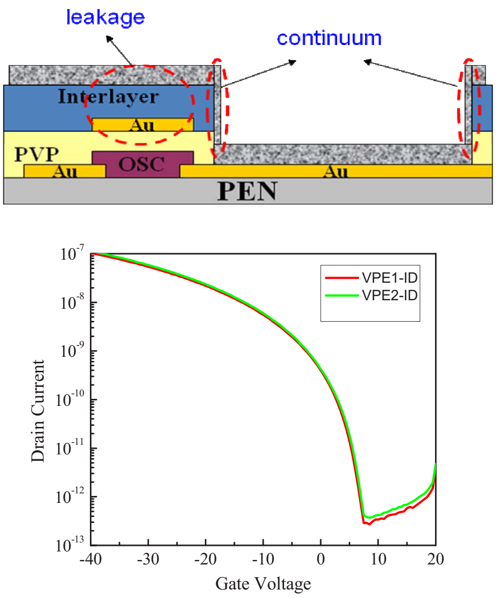



Fig. 2. (a) Structure of pixel electrode patterned on OTFT devices, and (b) Electrical properties of OTFT devices which determined electrode continuous and leakage issue.

## 3. Results and discussion

The output and transfer characteristics of a polymer TFT array are shown in Fig.3 (a) and Fig.3 (b), respectively. All of electrical characteristic of OTFT is analyzed by HP-4156C. The mobility, ON/OFF ratio, subthreshold swing and threshold voltage of the polymer OTFT array are 0.01 $cm^2$/V-s, $5\times10^5$, 1.3 V/decade and -3.5 V, respectively, which are sufficient to drive an electrophoretic display. In order to determine OTFT device have higher uniformity to drive electrophoretic on flexible substrate, we measured 250 polymer OTFT devices and indicated in Fig. 4. In Fig. 4 (a), the on and off current measured from 250 polymer OTFTs are about $3\times10^{-7}$ and $10^{-12}$, respectively; and the devices on/off ratio for all of are over than $10^5$. We also calculated 250 polymer OTFTs mobility and threshold voltage which indicate in Fig. 4 (b). All of the polymer OTFTs devices which have threshold voltage variation range are $1.03\pm3.89$ V, and mobility variation are $0.01\pm0.002$ $cm^2$/Vs. These results mean that OTFT devices could have higher uniformity .

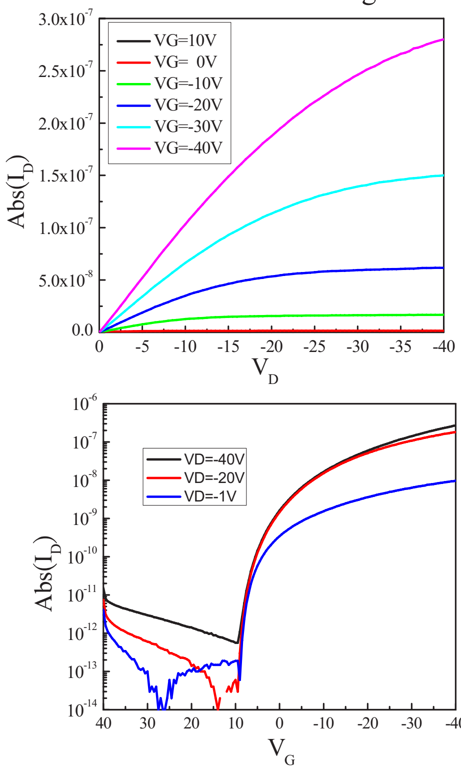
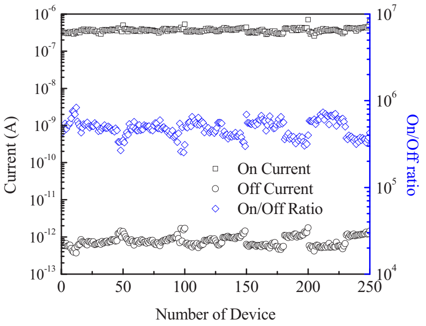
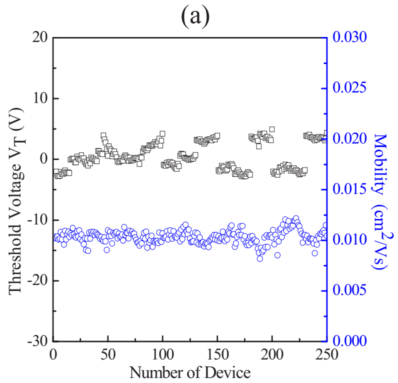



Fig. 3. (a) The output characteristics of a polymer thin film transistor, and (b) The transfer characteristics of a polymer thin film transistor.




(a)




(b)

Fig. 4. (a) The on current, off current, and on/off ratio characteristics measured from 250 polymer OT FTs, and (b) Threshold voltage and mobility va riation measured from 250 polymer OTFTs.

## 4. Summary

In this paper, we successfully fabricated 1.5-inch organic thin film transistors array with 60×48 pixels on flexible substrate. Polymer OTFT devices have higher electrical performance which mobility, ON/OFF ratio, subthreshold swing and threshold voltage are 0.01 $cm^2$/V-s, $5\times10^5$, 1.3 V/decade and -3.5 V, respectively, which are sufficient to drive an electrophoretic display. We also measured 250 OTFT devices which have nice uniformity for OTFT backplane application. In order to increase pixel aperture ratio, we used pixel electrode which deposited on the top of OTFT. After this process, devices also have their transfer characteristics like the initial value and increase aperture ratio from 50% to 90%. Finally, we successfully demonstrate 5 inch QVGA OTFT-EPD on flexible substrate. The high performance OTFTs could drive electrophoretic in 60 ×48 array with operation voltages that are used on the gate bias are -30 V during the row data selection and the gate bias are 0 V during the row data hold time. The data voltages that are used on the source bias are -20 V, 0 V, and 20 V during display media operation.

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