Stability of Organic Thin Film Transistors (OTFTs) with Au and ITO S/D(Source/Drain) Electrodes

Hun-Jung Lee, Sung-Jin Kim, Sang-Min Lee, Taek Ahn, Yong-Woo Park, Min Chul Suh, Yeon-Gon Mo, and Ho-Kyoon Chung

Corporate R&D Center, Samsung SDI Co., LTD., 428-5 Gongse-Ri, Giheung-Eup, Yongin-Si, Gyeonggi-Do, 449-902, KOREA.
TEL : +82-31-288-4742, E-mail: leehunjung@samsung.com

Abstract

In this paper, we report on the performance stability of solution processible OTFT devices with Au/Ti and ITO source-drain (S/D) electrodes. It appears that the contact resistance of the S/D electrode strongly affects the stability of OTFT devices. Interestingly, the devices with the Au/Ti electrode showed lower mobility than those with the ITO (S/D) devices. The field effect mobilities of the devices with the Au/Ti and ITO electrodes were 0.06, and 0.44 cm^2/Vs, respectively. However, the mobility of the device with the Au/Ti electrode was increased up to 0.26cm^2/Vs after 2 weeks, while the mobility of the device with ITO electrode was slightly decreased down to 0.41cm^2/Vs. The experimental data show us that ITO could be used as the S/D electrode for low-cost OTFT devices.

1. Objectives and Background

Organic thin-film transistors (OTFT) are gaining attention because it can be applied to a plenty of organic electronics' purpose such as smart card, identification (ID) tags, and flexible display, etc. For this reason, there have been large numbers of efforts the characteristics and performance of OTFT devices over the past decade. As a result, the performance of OTFT have become equals or even exceeds those of amorphous silicon (a-Si:H) thin film transistors. (In most cases, the *ufe* over than 1 cm^2/Vs has often been reported for vapor deposited small molecular OTFTs). In contrast, the most solution-processed, so called, the polymeric OTFTs fabricated by P3HT[1-3] , F8T2[4] , etc. or the precursor pentacene-based OTFTs[5] showed relatively poorer performances. Exceptionally, the precursor pentacene TFTs could give the u_{fe} of 0.2 ~ 0.9 cm^2/Vs. However, most of polymeric OTFTs normally showed much lower u_{fe} (<0.1 cm^2/Vs), than pentacene based OTFT. Nevertheless, the solution process gives very important meaning for OTFT device fabrication because the solution process adopting printing technology such as micro-contact printing, ink-jet printing, wave printing, laser induced thermal imaging (LITI), laser induced forward transfer (LIFT), etc., will contribute a lot toward roll-to-roll process which can reduce a cost ultimately.

To realize the ultimately low-cost display, the next issue may be the selection of inexpensive materials during processing. Unfortunately, the very expensive materials such as Au, Pd, Pt, etc. have been recognized as the best metals for S/D electrode of OTFT devices to solve the contact resistance problems (in between organic semiconductor and the metal electrodes).

In this paper, we have studied the OTFT devices from the two different stand point, that is, solution process and the utilization of cheaper S/D electrodes to realize the ultra low-cost display fabrication in the future.

2. Results

We investigated two types of OTFTs with different S/D electrodes. One has patterned Au/Ti on glass substrate and the other contains patterned ITO electrode on same type substrate. Au/Ti was deposited by e-beam evaporation with 50nm/5 nm thickness and pattered by lift-off method. Ti metal was used as an adhesive layer in between Au and glass. For the patterned ITO sample, a 150 nm ITO was sputtered and wet etched. In case of patterned ITO sample, we treated the electrode surface by using O_2 plasma method to increase the work function higher than ~5.2 eV. Soluble organic semiconductor (OSC) was spincoated on a glass substrate containing pre-patterned S/D electrodes and annealed at 100 °C for 20 min. Soluble organic insulator (OGI) was then over-coated on top of OSC followed by annealing of whole layer at 100 °C for 20 min again. The thickness used for soluble OSC and OGI were optimized as 150 nm and 600 nm, respectively. Finally the gate metal (Al) was evaporated by thermal evaporation method using metal mask (200 nm) as shown in Figure 1.

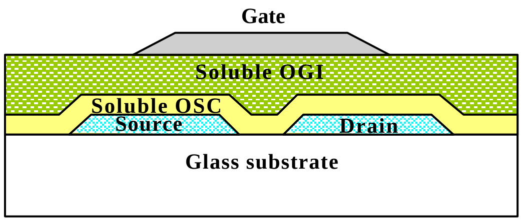


Figure 1. A cross-sectional view of an OTFT device.

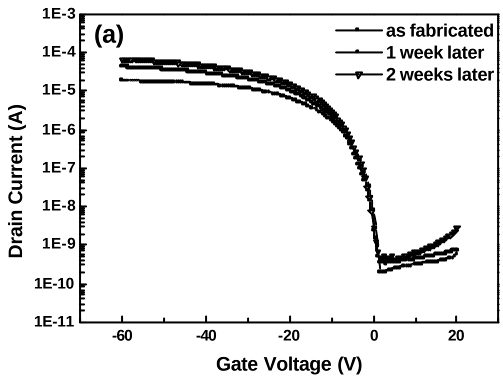
Devices performance was measured by using Keithley 4200. Drain current (I_d) were collected during gate bias (V_g) were swept from +20V to –60V, while drain voltage was fixed to –5V. The W/L ratio was about 370 with finger type layout (W is 37mm). Devices were stored in an ambient condition while we investigated the TFT characteristics for three weeks.

Table 1. shows the summarized properties of each sample. The initial mobility of sample having patterned Au/Ti S/D electrodes was smaller than that obtained from a device containing the plasma treated ITO electrodes. However, the former showed slightly bigger sub-threshold slope and On/Off ratio. The surface of Au/Ti was not modified by self-assembled monolayer (SAM) such as mercapto nitro benzimidazole (MNB). Thus, the smaller initial mobility of Au/Ti sample might resulted from the higher contact resistance which could be improved from the further surface treatment.

Table. 1. Device parameters of OTFTs with S/D Au/Ti and ITO S/D electrodes with time.

	m_{fe} (cm^2/Vs)	m_{sat} (cm^2/Vs)	V_{th} (V)	I_{on}/I_{off}	SS (V/dec.)
As fab. Au	0.06	0.37	-13.1	4.4E+4	1.26
1 week later Au	0.21	0.42	-11.6	6.3E+4	1.23
2 weeks later Au	0.26	0.49	-10.9	6.3E+4	1.25
As fab. ITO	0.44	0.51	-8.0	1.2E+4	2.10
1 week later ITO	0.50	0.53	-9.5	1.0E+4	2.49
2 weeks later ITO	0.41	0.48	-8.3	2.0E+4	2.24

Figure 2 shows all the electrical transfer characteristics of OTFTs in this study. The most important difference of the OTFTs fabricated by using Au/Ti or ITO S/D electrodes is the transfer behavior at a lower V_g region. Au/Ti device showed very sharp transfer characteristics at a lower V_g region while the device with the ITO electrode showed additional gentle slope at low voltage region. This is also the reason why the V_{th} of Device with the ITO electrode is lower than that that of Au/Ti device. Nevertheless, device with the ITO electrode showed more stable behavior in terms of shelf lifetime, and also showed good initial characteristics such as the mobility [Figure 2(b)]. We are investigating the reason of this gradual slope for the devices with ITO electrodes.



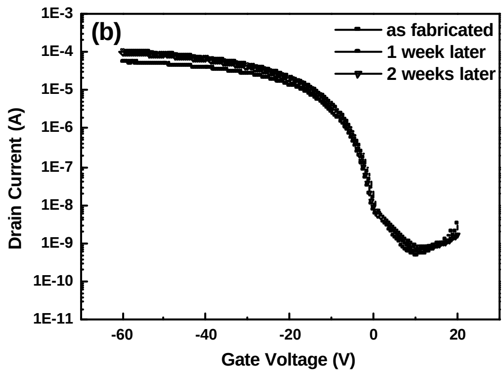
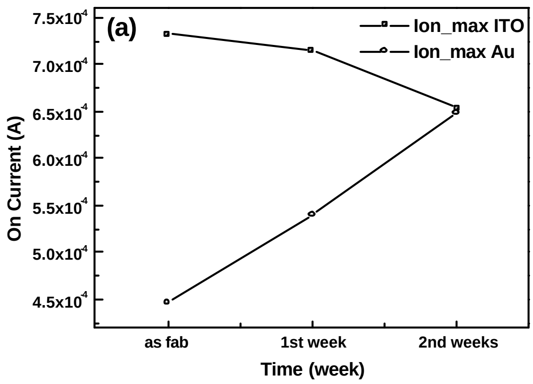


Figure 2. Drain current changes of the OTFT devices with (a) Au/Ti and (b) ITO S/D electrodes with time. The W/L ratio of the OTFT was 370 (W is 37mm). V_g range was +20 V to –60 V, at –5 V of V_d.

Figure 3 showed the change of maximum I_{on} and minimum I_{off} upon time duration respectively. Au/Ti device showed greater I_{on} as well as I_{off} levels while device with the ITO electrode demonstrated smaller I_{on} as well as I_{off} level after 2 weeks.



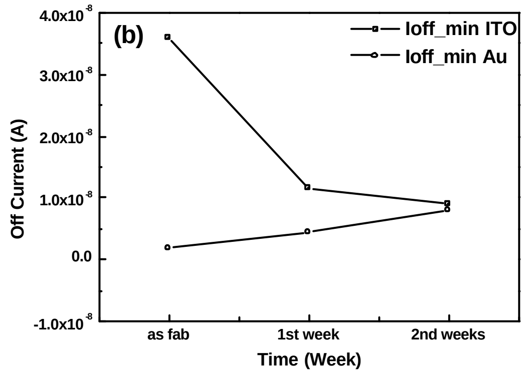


Figure 3. On (a) and off (b) current change of OTFT devices with Au/Ti and ITO S/D electrodes.

3. Conclusions

We have studied two different OTFT devices with the Au/Ti and O_2 plasma treated ITO S/D electrodes. The OTFT device with Au/Ti electrode showed smaller sub-threshold swing but worse long term stability. In contrast, the device with O_2 plasma treated ITO electrode gave higher mobility, and more stable in on-current behavior than that with Au/Ti electrode. This means that the surface O_2 plasma treatment can improve the performance stability of the OTFT devices. We believe that ITO could be applied as the S/D electrode materials for low-cost OTFT devices in the future.

4. References

[1] Z. Bao, A. Dodabalapur, A. J. Loviner. *Appl. Phys . Lett.*, **69**, 4108, 1996.

[2] Z. Bao, A. J. Lovinger. *Chem. Mater.*, **11**, 2607, 1999.

[3] H. Sirringhaus, N. Tessler, R. H. Friend. *Science*, **280**, 1741, 1998.

[4] H. Sirringhaus, *et al.*, Appl. Phys. Lett., **77**, 406, 2000.

[5] A. Afzali, C. D. Dimitrakopoulos, T. L. Bree. *J. Am. Chem. Soc.*, **124**, 8812, 2002.