Improving performance of organic thin film transistor using an injection layer

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Abstract

The OTFT performance depends strongly on the interfacial properties between an organic semiconductor and a metal electrode. The contact resistance is critical to the current flow in the device. The contact resistance arises mainly from the Schottky barrier formation due to the work function difference between the semiconductor and electrodes. We doped pentacene/source-drain interfaces with F_4TCNQ (2,3,5,6-Tetrafluoro-7,7,8,8-tetracyanoquino-dimethane), resulting in p-doped region at the S-D contacts, in order to solve this problem. We found that the mobility increased and the threshold voltage decreased.

1. Introduction

Organic thin-film transistors (OTFTs) have attracted considerable interest due to the ability to process organic materials at low temperature and on plastic films, which offers the potential to create new applications such as flexible displays[1-6]. The electrical contact between organic semiconductor and source/drain (S/D) electrodes is very crucial in improving the performances of OTFTs[1-3]. Many OTFTs currently developed use pentacene as the semiconductor and gold as the electrode metal. However, gold/pentacene contact shows non-Ohmic behavior due to the existence of an energy barrier between gold and pentacene. Thus, pentacene OTFT exhibits a linearly growing threshold voltage with increased film thickness due to tunnel injection.[7]

We expect that OTFT exhibits low threshold voltages through contact-area-limited doping. In this work, we will show that the mobility increases and the threshold voltage decreases by co-evaporating F_4TCNQ and pentacene near the pentacene/electrode interfaces as shown Fig. 1.

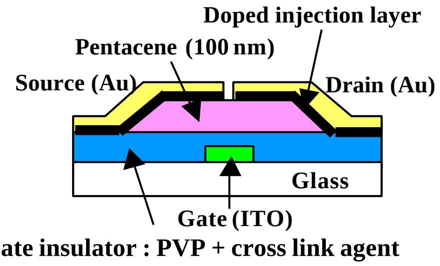

Figure 1. The device structure of OTFT with the p-doped contact.

2. Experimental

The OTFT was fabricated in a top-contact structure with a cross-linked poly-vinylphenol (PVP) film as a gate dielectric layer (Fig. 1). The ITO glass was used as the substrate and gate electrode. The cross-linked PVP was deposited onto the patterned ITO glass by spin coating from a solution of poly-4-vinylphenol (15 wt%) and propylene glycol monomethyl ether acetate (PGMEA) followed by curing at 200 °C for 2 h. The spin speed was 2000 rpm and the thickness of the gate insulator was 945 nm. On top of the polymer gate dielectric layer a 100-nm-thick pentacene active layer was deposited with a deposition rate of 0.5 Å/s under the base pressure of 10^{-6} Torr. The pentacene was purchased from Aldrich and used as received. Then we co-evaporated

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F_4TCNQ and pentacene near the pentacene/electrode interfaces under vacuum through the same shadow mask used for the subsequent gold deposition of source and drain contacts to avoid contamination of channel. The channel length and width are 50 μm and 2 mm, respectively. The transistor characteristics were measured with Keithley 236 source measure units.

3. Results and discussion

We compared the OTFT performance for several devices with different thickness and doping concentrations of the p-doped injection layer. Figure 2 shows OTFT transfer characteristics for different thickness of 20 % F4TCNQ-doped injection layer. As the thickness of the p-doped layer increases, the threshold voltage decreases. However, the mobility of the OTFT with the p-doped layer is almost the same as the undoped device.

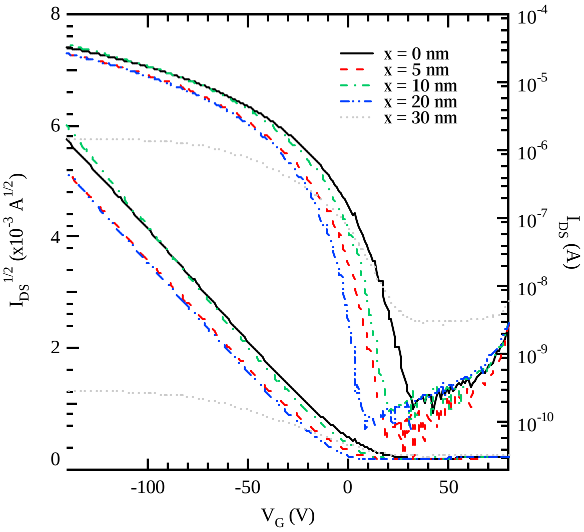

Figure 2. OTFT transfer characteristics for different thickness of 20 % F4TCNQ-doped injection layer.

Figure 3 shows the mobility and threshold voltage as a function of different thickness of injection layer. In the thickness range less than 20 nm of the p-doped, the threshold voltage is lower and the mobility slightly increases. Especially, OTFT with 10 nm thickness of the p-doped layer shows the highest mobility and the lowest threshold voltage. However, the transistor with the thickness of the p-doped layer higher than 20 nm showed deteriorated performance.

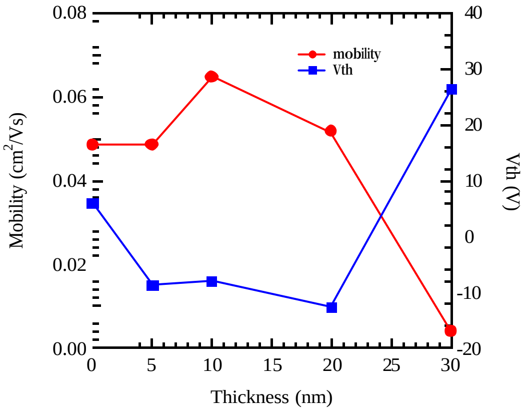

Figure 3. The mobility and threshold voltage as a function of different thickness of p-doped injection layer.

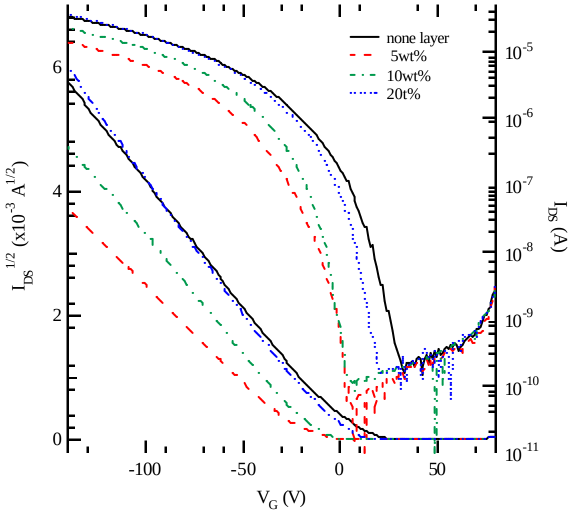

Figure 4. OTFT transfer characteristics for different doping concentrations of p-doped injection layer.

Figure 4 shows the OTFT transfer characteristics for different concentration of p-doped injection layer. The thickness of the p-doped layer is 10 nm. The OTFTs with the p-doped layer show lower threshold voltage. The mobility decreases at low doping concentration but increases at high doping concentration.

Figure 5 shows the mobility and threshold voltage for different doping concentrations of p-doped injection layer. At 20 % doping of F4TCNQ, the mobility increases about 30 % compared with the OTFT without the doping layer.

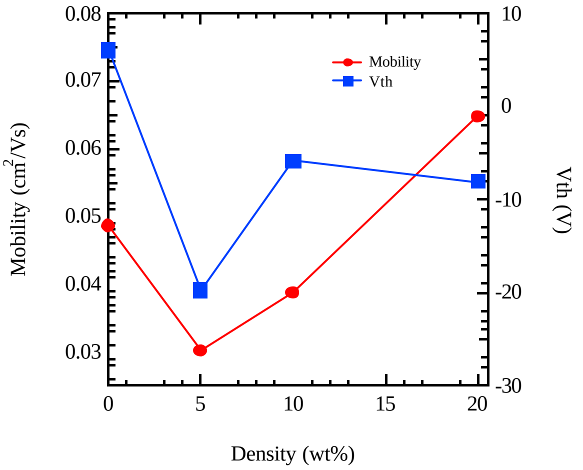

Figure 5. The mobility and threshold voltage for different doping concentrations of injection layer.

From the thickness and doping concentration dependence shown in Figs. 2-5, we found the optimal conditions for doping concentration and thickness are about 20 % and 10 nm, respectively.

4. Conclusion

We found that the OTFT performance can be improved by doping the organic semiconductor/S-D contacts. We also studied the optimal conditions for doping concentration and thickness of the doped layer. The best performance was observed for F_4TCNQ doping concentration of about 20 % and the thickness of about 10 nm.

5. Acknowledgements

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6. References

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