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High performance top-contact organic thin-film-transistors using screen printed source and drain electrodes

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1. Introduction

In the past decades organic thin-film transistors (OTFTs) have demonstrated promising potential applications in flexible electronics and large-area flexible electronics such as robotic sensory arrays [1], e-paper [2] and RFID tags [3]. For these applications, it is extremely important to reduce the process cost of OTFTs to compete with the existing mature products. As a simple and environment-friendly way to produce electronic circuitry and make connections, screen printing has drawn special interests recently, especially for patterning source and drain electrodes. The critical challenge for screen printing process is to reduce the feature size, meanwhile not sacrificing too much in the performance of OTFTs. Previously, Sekitani et al. have successfully demonstrated OTFTs with an 18 um channel length using screen printed source and drain electrodes. [4] However, the device was fabricated in bottom contact geometry, which has a higher contact resistance and correspondingly a higher operation voltage. To achieve a better device performance, top contact device geometry is still desirable.

Meanwhile, surface modification of the gate dielectric with a self-assembled monolayer (SAM) [5,6] has been used to reduce the threshold voltage and improve the carrier mobility. However there are two challenge issues to integrate this dielectric layers with screen printed electrodes. One is how to print electrodes on top of SAM layer due to the supper low surface energy of SAM. The other challenge is to minimize the attack of organic solvent in silver (Ag) paste to the underneath organic semiconductor layer.

In this research, a high viscosity Ag paste was used to reduce the concentration of organic solvent, and then successfully solve the above issues. In this study, we demonstrate high performance top contact OTFTs using screen-printed source and drain electrodes. The effect of solvent on the OTFTs performance was also investigated.

2. Fabrication process

Figure 1 shows the cross-sectional illustration and optical microscope photograph of an OTFT using screen printed source and drain electrodes. These transistors are composed of Al gate electrodes, AlO_x and SAM gate dielectric layers, DNTT semicondctor layers, and Ag source and drain electrodes.

First, a 100-nm-thick Al layer is thermally evaporated on a PEN thin film as gate electrodes, patterned via metal shadow mask. Then this Al layer is anodized in a 150 mg/L citric acid electrolyte to form a 25-nm thick AlO_x dielectric layer under a bias of 20 V; and then a following SAM dielectric layer is fabricated via dipping PEN films into 2-propanol solution containing 5 mM of n-octadecylphosphonic acid for 16 hours at room temperature. After dielectric layers formation, purified DNTT is thermally deposited on the gate dielectric layer in vacuum to form a 50-nm-thick organic channel layer. Finally, source and drain electrodes are screen printed by pressing Ag paste through a stencil mask on top of DNTT layer. Before testing, the samples are annealed at 80°C for 5 hours to evaporate the solvent in Ag paste to improve the stability of Ag electrodes and also minimize the attack to DNTT layer of OTFTs. All the tests were carried in the dark using Agilent 4155C semiconductor parameter analyzer.

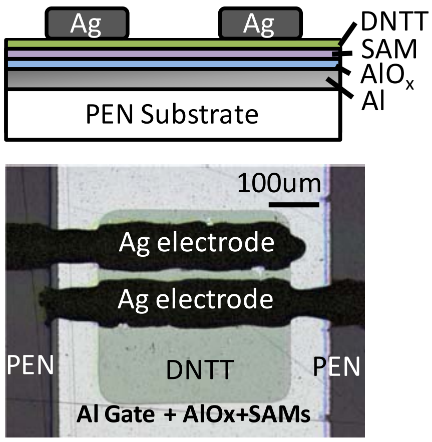

Fig. 1 TOP: The cross-sectional illustration of the organic thin film transistors (OTFTs). Bottom: The optical-microscope photograph of an OTFT using screen printed source and drain electrodes.

3. Results

The current-voltage (I-V) characteristics of OTFTs with screen printed source and drain electrodes are shown in Fig. 2, with channel length and width of 200 µm, 500 µm respectively. For this specific device geometry, the best device achieved by this method has a mobility of 0.43 cm^2/(V·s), leakage current smaller than 10 pA under 4 V gate bias, an on/off ratio of 10^8, and a threshold voltage around 1V.

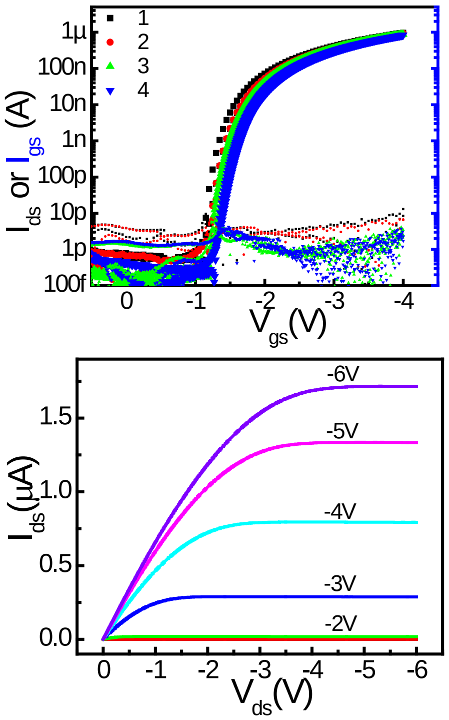

Fig. 2 Transfer (top) and output (bottom) current-voltage (I-V) characteristics of OTFTs with channel length of 200 µm and channel width of 500 µm. In (a), V_{ds} = 3 V. The line-width Of OTFTs is 100 µm.

The effect of organic solvent in Ag paste on the OTFTs performance was also investigated. The threshold voltage of OTFTs is plotted as a function of channel length in Figure 3. As it can be seen in the figure 3, the threshold voltage drops when increasing the channel length. Therefore, it can be concluded that the solvent attacked the underneath DNTT layer during the screen printing process, and thus increased the contact resistance of the OTFTs.

3. Conclusions

In this work, we have demonstrated high performance organic transistors with screen printed source and drain electrodes. The best device achieved by this method has a mobility of 0.43 cm^2/ (V·s), leakage current smaller than 10 pA under 4 V gate bias, an on/off ratio of 10^8, and a threshold voltage around 1V. The effect of solvent on OTFTs performance was also investigated. In the future, this technology will be expected to make a bigger impact towards the full solution processed organic transistors.

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5. References

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