Contact resistance extraction between Ink-jet printed PEDOT-PSS and Pentacene in OTFTs

Myung-Kyu Kim*, Rae-Wook Kang and Chung-Kun Song
Dept. of Electronics Engineering, University of Dong-A,
840 Hadan-dong Saha-gu, Busan, 604-714 Korea
TEL:82-51-200-7711, e-mail: cksong@donga.ac.kr
Keywords : OTFTs, contact resistance, PEDOT-PSS, Ink-jet, printing

Abstract

We enhanced the conductivity of PEDOT-PSS by mixing with glycerol and fabricated the low contact resistance of source and drain[S/D] electrodes of OTFT with PEDOT-PSS by ink-jetting printing. The contact resistance was much smaller by seven times than Au with 200kΩ at V_G=-5V. For the bottom contacted OTFTs, the performance was comparable to OTFTs with Au electrodes with the field effect mobility of 0.2 cm^2/V s.

1. Introduction

Contact resistance caused by Schottky energy barrier between organic materials and S/D electrodes [1] drop the performances of organic devices. So many researches are being conducted such as self assembled mono-layers (SAM) treatment [2] or insertion of the buffer layer [3] between organic materials and S/D electrodes.

The most widely used Au as S/D electrodes has high conductivity and work function. But it is not suitable to organic devices because it is expensive and has a high contact energy barrier [1]. PEDOT-PSS is the material researched to alternate Au because of low price, possibility of solution process and low contact resistance. But PEDOT-PSS has poor conductivity, many researches are being conducted to enhance its conductivity [4].

We carried out an experiment on enhancing conductivity of PEDOT-PSS by adding glycerol and fabricated the outstanding pentacene OTFTs with modified PEDOT-PSS as S/D electrodes by using ink-jet printing process. We also extracted and compared the contact resistance of PEDOT-PSS and Au electrodes, confirming the much lower contact resistance of PEDOT-PSS than Au.

2. Experimental

The fabricated bottom contact OTFT is illustrated in Fig. 1.

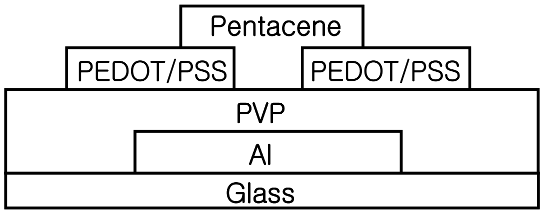

Fig. 1. The structure of bottom contact OTFTs.

For gate electrodes, the 1000Å thickness Al was evaporated on the clean glass in a high vacuum chamber. The PVP layer was spin-coated for 30sec at 1000rpm, and cured in 200℃ oven for 20min after 100℃ oven for 10min. Then, the PEDOT-PSS layer was ink-jet printed on the 70℃ heated substrate with a resolution of 600dpi and dried in 120℃ oven for 30min.

The used PEDOT-PSS solution was modified by glycerol with weight ratio of 10:1. Finally, the 450Å thickness pentacene as active layer was evaporated in a high vacuum chamber. The deposition rates of the Al layer and pentacene layer were 3Å/sec and 0.3Å/sec respectively. A channel width of fabricated devices is 2000 ㎛ and lengths are 80, 120, 160, 200 ㎛ for extracting the contact resistance of devices [5].

To compare the contact resistance values, we also fabricated the device with Au as S/D electrodes under same process conditions. These samples were characterized in atmosphere using Keithley 4200 semiconductor analyzer.

3. Results and discussion

The sheet resistance according to the each condition of PEDOT-PSS is shown in Fig. 2.

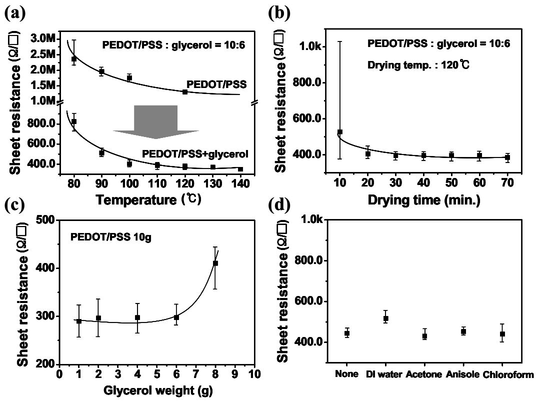

Fig. 2. The sheet resistance of PEDOT-PSS with glycerol electrodes according to (a) the curing temperature, (b) the curing time, (c) the glycerol density, and (d) the solvents.

In Fig. 2(a-c), the sheet resistance was the most stable under the conditions of glycerol weight 6g per PEDOT-PSS 10g, drying temperature 120℃ for 30min. The PEDOT-PSS layer was not affected adversely against each solvent in Fig. 2(d).

The Fig. 3 shows the PEDOT-PSS solution dropped by ink-jetting on the PVP layer. One drop size of PEDOT-PSS is 83.58 ㎛ in Fig. 3(a). The Fig. 3(b-d) shows that the PEDOT-PSS drops were lumped because of hydrophobic PVP surface and the drops viscosity although the resolution and substrate temperatures were changed. In order to reduce the viscosity, we decreased glycerol density to 10:1 in weight without changing the conductivity as shown in Fig. 2(c).

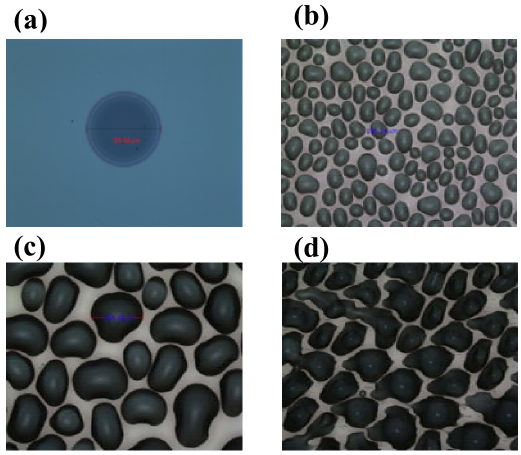

Fig. 3. The picture of PEDOT-PSS dropped on PVP layer by using a ink jet printing; (a) single drop, (b) drops of pad patterned by resolution of 400dpi, (c) 600dpi, (d) 600dpi with substrate temperature of 70℃.

The patterned PEDOT-PSS pad is shown in Fig. 4, and its sheet resistance was 38Ω/□.

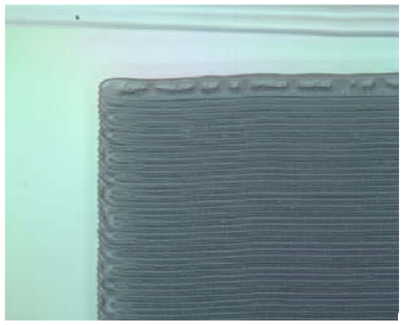

Fig. 4. The pad electrode of PEDOT-PSS on PVP layer optimized by PEDOT:glycerol=10:1 and resolution of 600dpi and substrate temperature of 70℃.

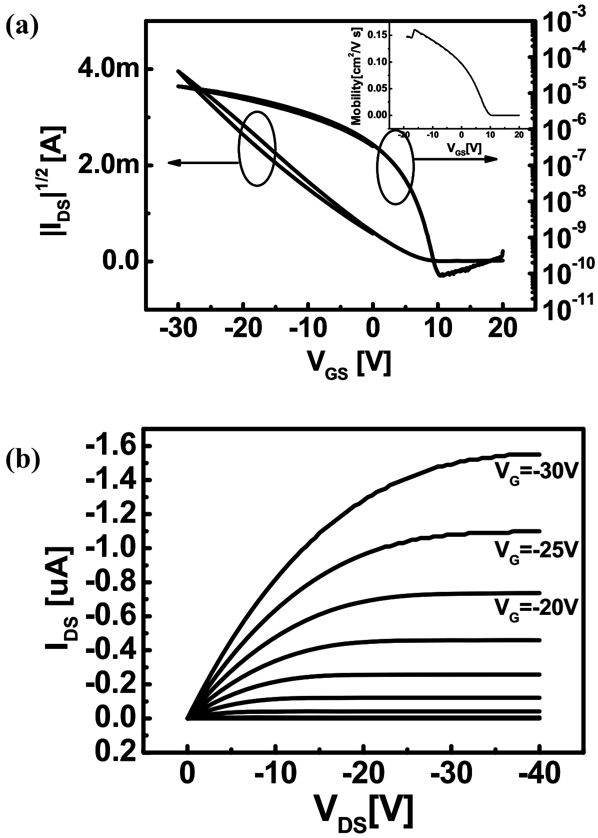

Fig. 5. The characteristics of OTFT with PEDOT-PSS S/D electrodes; (a) transfer characteristics with the inserted graph of the field effect mobility vs. gate voltage, (b) output characteristics; μ_{FET}=0.2cm^2/V.s, on/off current ratio=10^5, V_{th}=4.1V, and SS=1.4V/dec.

Fig. 5 shows the transfer curve and output curve of OTFTs with PEDOT-PSS as S/D electrodes. The graph inserted in Fig. 5(a) is the mobility characteristics versus gate voltages. The field effect mobility is 0.2 cm^2/V s, on/off current ratio is 10^5, threshold voltage is 4.1 V and sub threshold swing is 1.4 V/decade.

The extracted contact resistance of PEDOT-PSS is about 200k Ω/□ at V_G=-5V, which is much smaller than that of Au, 1.4M Ω/□.

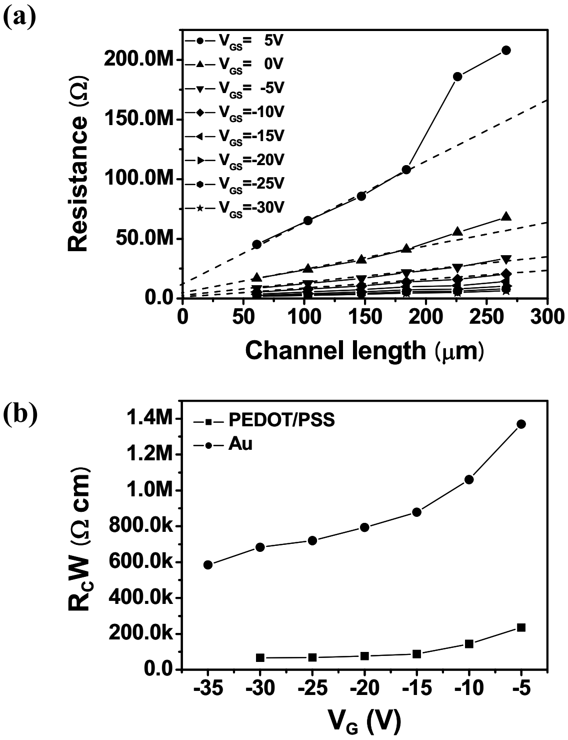

Fig. 6. (a) The total resistance of OTFT with PEDOT-PSS S/D electrodes according to the channel length, (b) the normalized contact resistance of PEDOT-PSS and Au electrodes vs. gate voltages.

4. Summary

We enhanced the conductivity of PEDOT-PSS by mixing with glycerol and fabricated the low contact resistance of S/D electrodes of OTFTs with PEDOT-PSS by ink-jetting printing. The contact resistance was much smaller by seven times than Au with 200k Ω/□ at V_G=-5V. For the bottom contacted OTFTs, the performance was comparable to OTFTs with Au electrodes with the field effect mobility of 0.2 cm^2/V s.

5. Acknowledgements

This research was supported by a grant(F004061) from Information Display R&D Program funded by the Ministry of Knowledge Economy of Korean government.

6. References

1. A. Kahn, N. Koch, W. Gao, *Journal of Polymer Science: Part B: Polymer Physics*, 41 (2003) 2529-2548
2. F. Nüesch, F. Rotzinger, L. Si-Ahmed, L. Zuppiroli, *Chem. Phys. Lett.* 288 (1998) 861-867
3. J.Y. Lee, *Appl. Phys. Lett.* 88 (2006) 073512
4. J. Ouyang, Q. Xu, C.W. Chu, Y. Yang, G. Li, J. Shinar, *Polymer* 45 (2004) 8443-8450
5. H. Klauk, G. Schmid, W. Radlik, W. Weber, L. Zhou, CD. Sheraw, JA. Nichols, TN. Jackson, *Solid-State Electronics* 47 (2003) 297-301