Organic Thin-Film Transistors with Screen Printed Silver Source/Drain Electrodes

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Abstract

We show that the electrical properties of organic thin-film transistors(OTFTs) can be enhanced by controlling the morphology of interface between screen printed electrodes and gate dielectrics. Modified surface of the insulator layer(SiO_2) affect on the interface energy of electrode on SiO_2 layer. Contact angle measurement and FT-IR spectrum shows that the interface is properly modified. OTFTs device with high efficiency has been realized through modification of interface layer.

1. Introduction

Organic thin-film transistors(OTFTs) have attracted great interest as low-cost alternatives to there silicon counterparts for large area, flexibility, and ultralow-cost electronics. However, most research have been focused on the organic materials which is applied on OTFTs and the study on electrode materials is insufficient despite on its importance.

Recently, the gold nanoparticle dispersion has been utilized in printing to get the good electrical conductivity[1]. But the high cost of gold act as an obstacle in appling on electrode materials. Moreover, the conjugated polymer as an alternative of metal has been used for electrode materials[2], its application on OTFTs is not suitable due to the low electrical conductivity and the poor electrical/thermal stability. Therefore, screen printing using silver nanoparticle has been paid much attention because of its low-cost and high stability. But for OTFTs using SiO_2 gate dielectric layer, silver electrodes cause mismatch on interfaces. (1)Mismatch between active layer and electrode can be enhanced by using stabilizer when synthesize silver nanoparticles. On the other hand, (2)mismatch between electrode and gate dielectric layer affecting on dimension and leakage current of devices is necessary to be solved.

In this study, we focused on modification of SiO_2 surface as a gate dielectric layer to enhance uniformity and accuracy of electrodes pattern as an highly efficient OTFTs device.

2. Experimental

Highly doped n-type Si wafer(100) was used as a substrate for a gate electrode and 1500 Å thick SiO_2 layer was used as a gate dielectrics as shown in Fig. 1.

Substrate was cleaned by ultrasonic treatment in acetone, ethanol and distilled water, respectively. Octyltrichlorosilane self assembly monolayers(OTS SAMs) were deposited to enhance the adhesion between gate dielectrics and source/drain electrodes by immersing the substrate in a 4 mmol/L solution (solute in toluene) for 30min. To enhance the uniformity of OTS SAMs, we used shaking system during deposition.

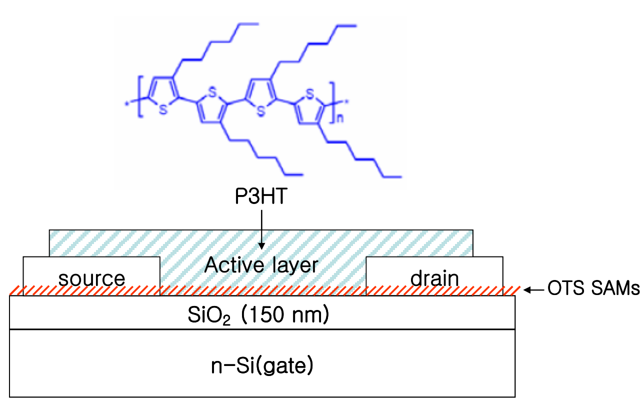


Fig. 1. Bottom-contact structure of OTFT in our study.

After removal from solution, the samples were cleaned immediately to remove any OTS SAMs overlayers by rinsing with toluene. Mechanism of OTS SAMs process well described in Fig. 2.

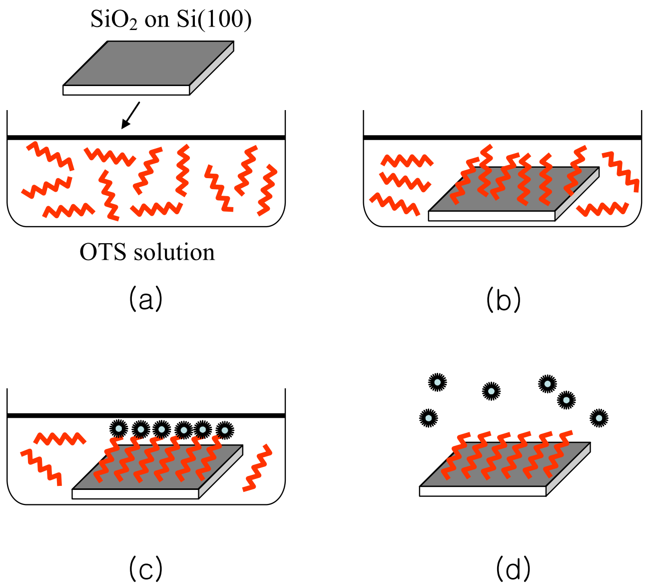


Fig. 2. Mechanism of OTS SAMs process. (a)immersion in OTS solution, (b)absoption of OTS, (c)organization of OTS SAMs and (d)rinsing for remove SAMs overlayers.

On the monolayer, silver paste was printed by screen printing system to form patterning of the source/drain electrodes. Silver paste was prepared by mixing Silver nano-particles and organic binder.

Patterned source/drain electrodes were sintered at 150℃ for 20min to develop the conductive path. For organic semiconductor as an active material, regioregular poly-3-hexylthiophene(P3HT) dissolved in a chloroform was dispersed between the silver screen printed source and drain electrodes by using spin coating method.

3. Results and discussion

Synthesized silver nanoparticles as shown in Fig.3 (inset) are uniformly dispersed with average diameter 10±5nm. And XRD pattern shows that the crystal structure of the synthesized silver nanoparticles was identified Fm-3m(225) point group and has good crystallinity(Fig. 3). This result makes the sintering temperature lower to form conductive path as well as patterning uniform at screen printing.

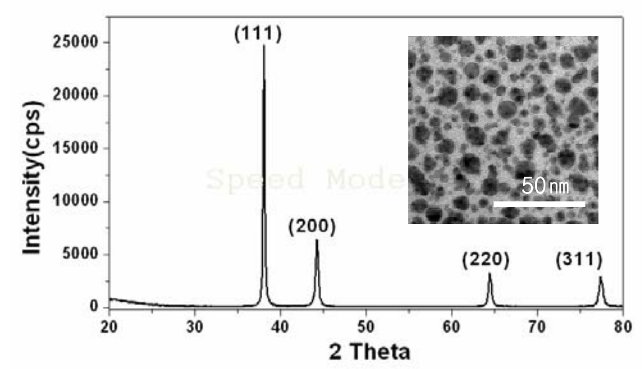
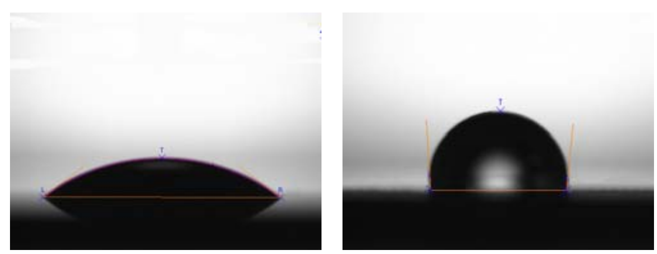


Fig. 3. XRD pattern of monodispersed silver nano-particles and TEM image(inset).

To characterize the property of the OTS SAMs dispersed substrate, we used contact angle measurement instrument, FT-IR.

Contact angle measurement shows that the substrate has hydrophobic characteristics as 94° compared to 37° for untreated(Fig. 4). We can assume from this result that the dispersed OTS monolayer makes interface energy against water larger with having strong surface energy at SiO_2 surface. FT-IR spectrum in Fig. 5 also shows typical OTS SAMs spectrum and supports contact angle measurement result[3~6].



(a) (b)

Fig. 4. Image of contact angle of water. (a)Untreated, (b) after formation of OTS SAMs at Si substrate.

Electrical properties of the device characterized by using Agilent Technologies E5270B Precision measurement system. Fig. 6 shows that the I-V characteristics of the source/drain electrodes. The current through P3HT increases proportionally with the applied voltage. We confirmed the formation of ohmic contact between screen printed silver electrode and spin coated P3HT without any notable contact resistance.

OTS SAMs were dispersed to modify the surface characteristics of the substrate and we can get not only uniform electrode pattern but also stable electrical characteristics. But the problems like a deterioration of electrical properties by high leakage current should be improved.

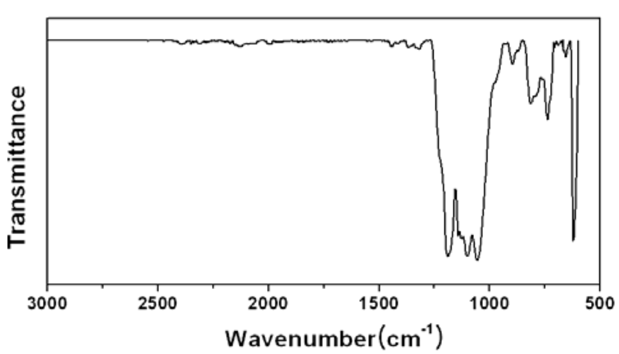


Fig. 5. FT-IR spectrum of OTS SAM on SiO_2.

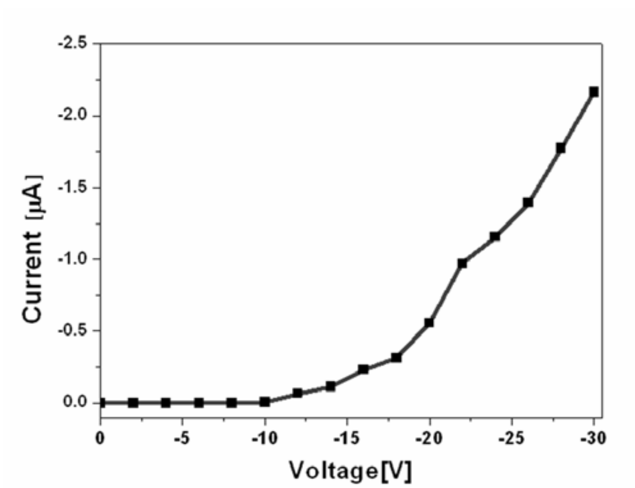


Fig. 6. I-V characteristics of the source/drain electrodes.

4. Summary

We made OTFT device using P3HT as an organic semiconductor. By using screen printing method, silver nanoparticle was imprinted as source/drain electrodes on a highly doped n-type Si wafer (100) with 1500Å thick SiO_2 which surface is modified by OTS SAMs. Screen printing method makes it possible to print pattern with minimum line width 30µm and to sinter at 150℃ which is comparably low temperature. This result is applicable to the polymer substrate which requires low processing temperature.

P3HT which used as organic semiconductor shows good electrical properties. And it is expected that P3HT can be a candidate which shows good transistor characteristics.

5. Acknowledgements

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6. References

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