Extended Abstracts of the 2007 International Conference on Solid State Devices and Materials, Tsukuba, 2007, pp. 1088-1089

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Study of Pentacene-Based Organic Thin Film Transistor with PMMA as Insulator

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1. Introduction

Organic materials are generally used in many electrical devices like as light emitting diodes [1], thin film transistors [2-3], and photo-detectors [4]. Due to variety of materials, fabrication methods, and amazing characteristics, the organic electrical devices attract many researchers to jump into this field. For organic thin film transistors, many different materials, structures, and special modification methods were used to improve the characteristics of devices. Nowadays, the characteristics of OTFT were almost the same as amorphous silicon (A-Si) which was commonly adapted in the modern liquid crystal display (LCD). Pentacene-based OTFT with a field-effect mobility greater than 1 $cm^2/(V \cdot s)$ and an on/off current ratio over 10^8 have been demonstrated by several groups[5-7].

In this study, we used Poly(methyl methacrylate) PMMA as insulator to substitute SiO_2 and conferred the transfer characteristics of PMMA-insulator OTFT. We also compared the transfer characteristics of PMMA-insulator OTFT with the characteristics of SiO_2-insulator OTFT.

2. Experiments

The PMMA-insulator OTFTs structure was shown in Fig. 1. The OTFTs were fabricated on a high doping n-type silicon substrate. PMMA was dissolved in Toluene with a concentration of 8 wt% and then spin-coated on high doping n-type silicon substrate to form a 300 nm thin film to serve as organic insulator. SiO_2 is thermally grown on high doping n-type silicon substrate and the thickness of SiO_2 is also 300 nm. The molecular structures of PMMA and Pentacene were shown in Fig. 1. Pentacene thin films are grown on SiO_2 and PMMA by vacuum evaporation under a base pressure of approximately $5*10^{-6}$ torr, respectively. The thickness of Pentacene is 60 nm. After depositing Pentacene thin film, for the drain source and gate electrodes, 200-nm-thick Au layer, are deposited through a shadow mask by a thermal evaporator. The channel length and width of these devices are 50 μm and 1000 μm, respectively. The characteristics of these devices are measured with Keithley 4200 system.

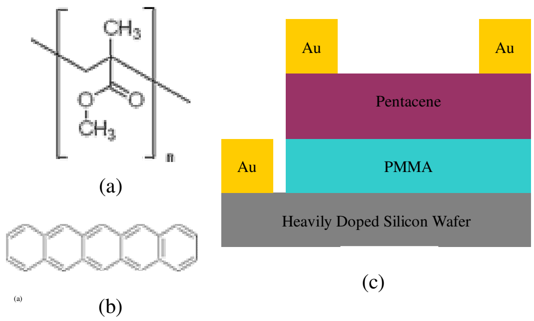


Fig.1 (a) PMMA molecular structure, (b) Pentacene strcture, (c) OTFT structure

3. Results and discussion

Fig. 2 shows the transfer characteristics of the PMMA-insulator Pentacene OTFT and SiO_2-insulator Pentacene OTFT. From this figure, it can be found the drain current I_{DS} of PMMA-insulator OTFT is higher than the drain current I_{DS} of SiO_2-insulator OTFT on the same gate voltage V_G.

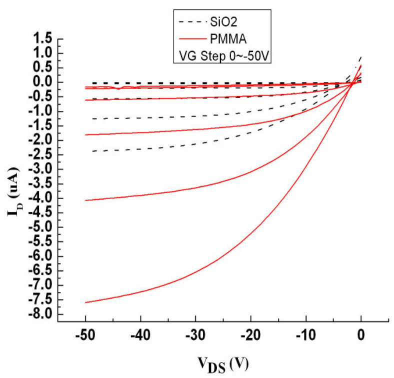
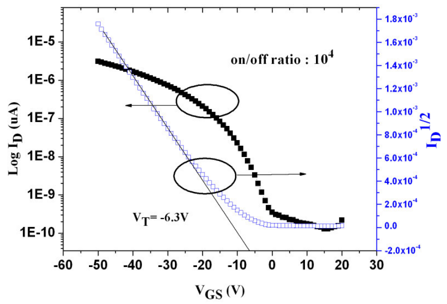
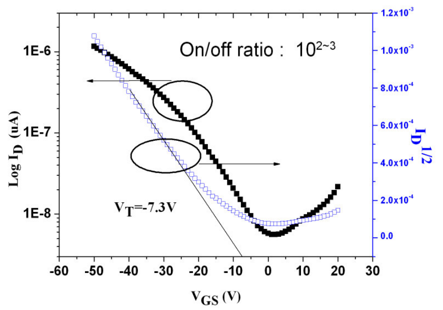


Fig.2 Transfer characteristics of OTFTs with PMMA and OTFTs with SiO2 in the same Pentacene-deposited process

Fig. 3a and Fig. 3b present the transfer characteristics of PMMA-insulator OTFT and SiO2-insulator OTFT when V_{DS} (the voltage between drain and source) is -50 V, respectively. It can be found that the on/off current of PMMA-insulator OTFT and SiO2-insulator OTFT are $10^{2\sim3}$ and 10^4, respectively. It also can be found that the threshold voltage V_T of PMMA-insulator OTFT and SiO2-insulator OTFT are -6.3V and -7.3V, respectively. The mobility of PMMA-insulator OTFT and SiO2-insulator are 0.215 $cm^2/V \cdot s$ and 0.0372 $cm^2/V \cdot S$, respectively.



(a)



(b)

Fig.3 (a)transfer characterisitcs of OTFT with PMMA, (b)transfer characteristics of OTFT with SiO2 in the same Pentacene-deposited process.

For the same Pentacene-deposited process of OTFT, we found that the all transfer characteristics of PMMA-insulator OTFT are greater than transfer characteristics of SiO2-insulator OTFT. Fig. 4 shows the X-ray diffraction spectra of pentacene thin films deposited on PMMA and SiO_2. From this figure, it can be found that the peak intensity of Bragg reflection of pentacene thin film on PMMA is stronger than pentacene thin film on SiO2 very much. It means that the quality of Pentacene thin film on PMMA is greater than Pentacene thin film on SiO_2. The intensity of X-ray diffraction influences on the mobility of OTFT and it is why the mobility of PMMA-insulator OTFT is higher than the mobility of SiO_2-insulator OTFT.

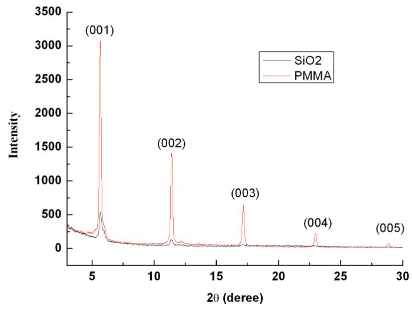


Fig.4 XRD spectra of Pentacene thin film on PMMA and on SiO_2

4. Conclusion

In this experiment, it was found that the all transfer characteristics of Pentacene-based OTFT with PMMA are greater than Pentacene-based OTFT with SiO_2. Threshold voltage V_T of OTFT with PMMA as insulator is smaller than OTFT with SiO_2 and the mobility of OTFT with PMMA is higher than OTFT with SiO_2. We also used XRD to measure the diffraction intensity to study the crystalline quality of Pentacene thin film on PMMA and Pentacene thin film on SiO_2. For the flexible substrate, PMMA will be a good material for insulator.

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