Organic transistor comprising a polymer gate insulator

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Abstract

We report the performance of pentacene-based organic thin film transistors (OTFT) with PMMA (polymethyl methacrylate) as the gate insulator which was spin-coated on the ITO (indium tin oxide) glass substrate which was used as the gate contact. The pentacene thin film was deposited on the PMMA film and then Au source/drain contacts were deposited through shadow mask. The pentacene film shows better molecular ordering on PMMA compared with SiO_2 of Si wafer. The devices exhibited the field effect mobility of ~0.004 cm^2/Vs and on/off current ratio of ~10^3.

1. Introduction

Organic thin-film transistors (OTFTs) are suitable for use in applications requiring large-area, light-weight, flexibility, and low-temperature processing [1-6]. In particular, the OTFTs fabricated on plastic substrates have received increasing interest recently for the application for active-matrix flat-panel displays based on organic electroluminescence devices [1-4]. Most of organic electroluminescence (EL) displays still use rigid silicon-based TFTs and are therefore not suitable for flexible substrates. The organic thin-film transistors are usually fabricated by evaporating or spin-coating organic materials on plastic substrates. They are deposited in the amorphous structure that results in the scattering of carriers, and thereby lowering mobility. Their mobility is not more than the mobility of an amorphous silicon. Therefore, it is important to grow highly ordered organic thin film for improving the carrier mobility.

In this work, we studied the performance of OTFTs fabricated with pentacene and a gate insulator of PMMA. We find that pentacene adheres well to the PMMA surface, resulting in the improved performance compared with the pentacene OTFTs using a SiO_2 gate insulator. The devices exhibited the field effect mobility of ~0.004 cm^2/Vs and on/off current ratio of ~10^3.

2. Experimental

The OTFTs using pentacene reported here use a staggered-inverted structure as shown in Figure 1. The powder of pentacene was purchased from Aldrich with the purity of 99.8%. A PMMA film was spin-coated on top of the prepatterned ITO gate electrode from 4 weight % PMMA in chlorobenzene at the spin-speed of 2000 rpm. A gate insulator thickness is controlled by spin speed [7]. Then, a 60-nm-thick pentacene active layer was deposited by thermal evaporation under the base pressure of 1×10^{-6} Torr. The 50-nm-thick gold (Au) electrodes were deposited on top of pentacene through a shadow mask to form source and drain contacts with a channel length and width of 50 μm and 3 mm, respectively.

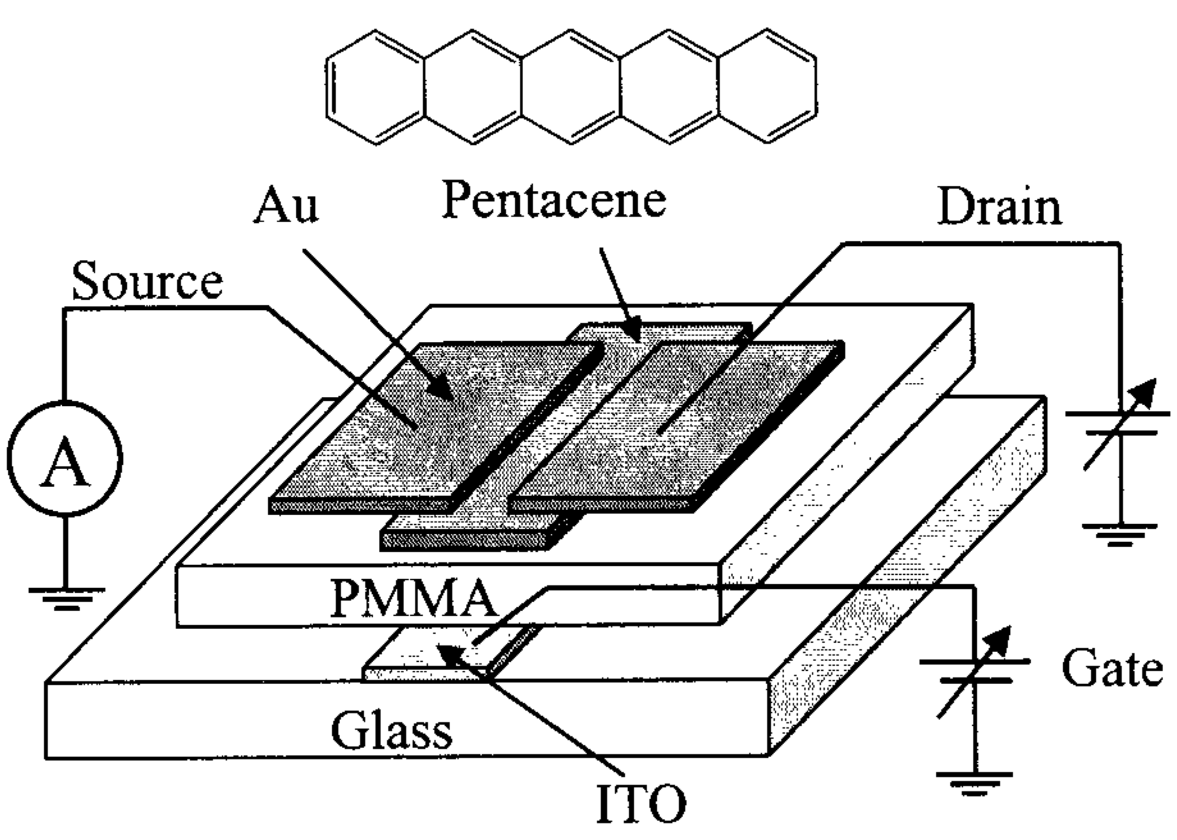

Figure 1. Schematic diagram of a pentacene thin film transistor using PMMA as a gate insulator on an ITO glass substrate.

The surface morphology of pentacene film was examined by atomic force microscopy (AFM). As shown in AFM images in Fig. 2 the grain size of pentacene poly-crystal film deposited on PMMA is larger than that deposited on SiO_2. The result indicates that pentacene adheres well to the PMMA surface compared with the SiO_2 surface, which increases the growth rate in the lateral direction, resulting in larger grain sizes.

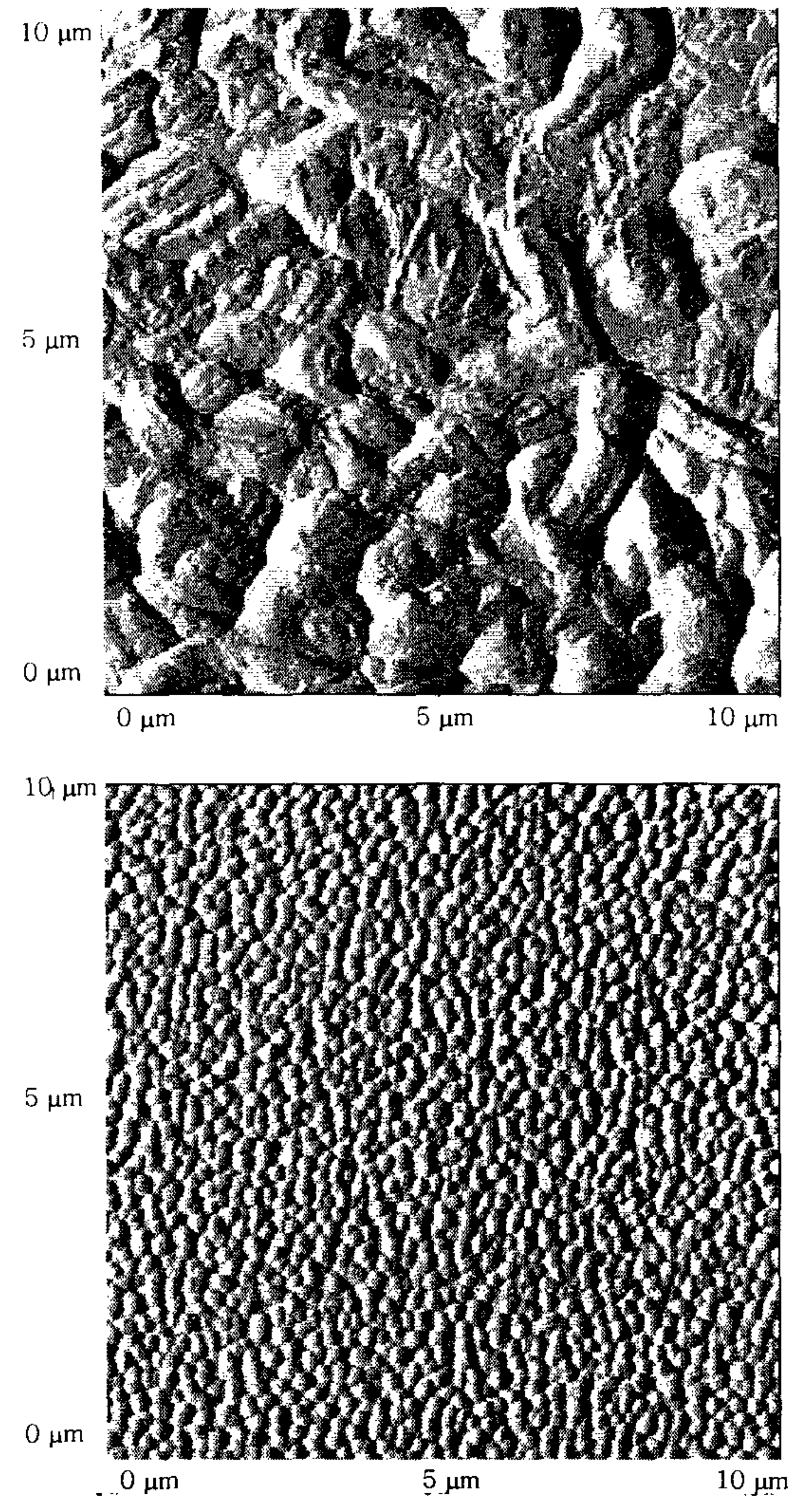

Figure 2: AFM images of pentacene thin film on PMMA gate insulator (top) and on SiO_2 gate insulator (bottom).

3. Results and discussion

Figure 3 shows the drain current (I_{DS}) versus drain-to-source voltage (V_{DS}) characteristics for several values of gate voltage (V_G) for a pentacene TFT using PMMA as a gate insulator. A gate insulator thickness is about 1 μm. The data shows an $I_{DS} - V_{DS}$ characteristics of a p-channel FET. The field effect mobility μ and the threshold voltage V_T can be extracted from the transfer characteristics. Figure 4 shows the square root drain-source current ($I_{DS}^{1/2}$) versus gate voltage (V_G) (left axis) and $\log_{10}I_{DS}$ versus gate voltage (V_G) characteristics (right axis), respectively. The mobility was calculated from the slope of $(I_D)^{1/2}$ vs V_G relationship. The threshold voltage V_T was estimated by the linear extrapolation. The TFT on/off current ratio and carrier mobility at V_{DS} = -11 V are greater than 10^3 and 0.004 cm^2/Vs, respectively. The threshold voltage is about -0.035 V, and an off-state leakage current is about $3x10^{-10}A$.

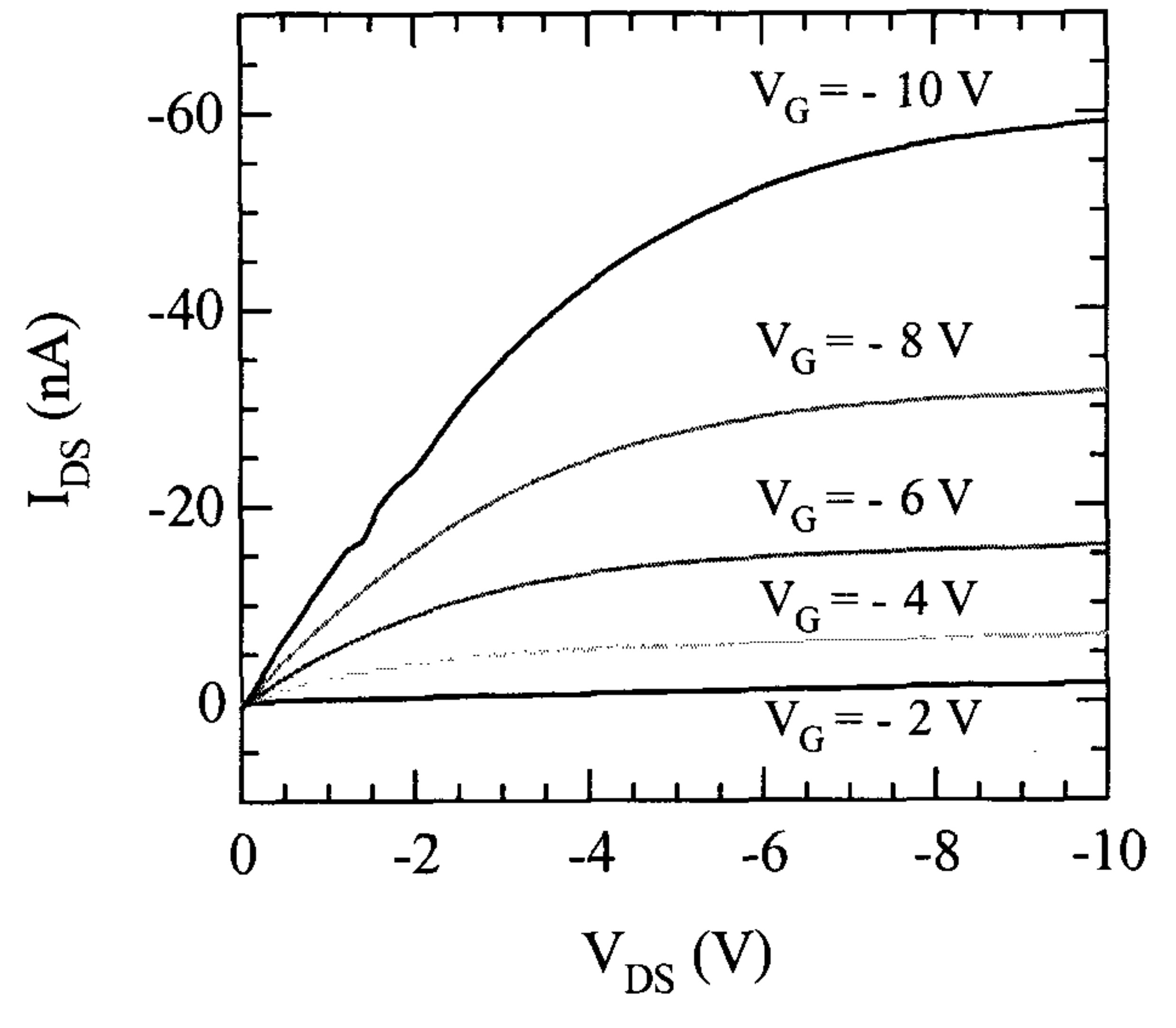

Figure 3. I_D – V_D characteristics for a pentacene OTFT having a PMMA gate insulator.

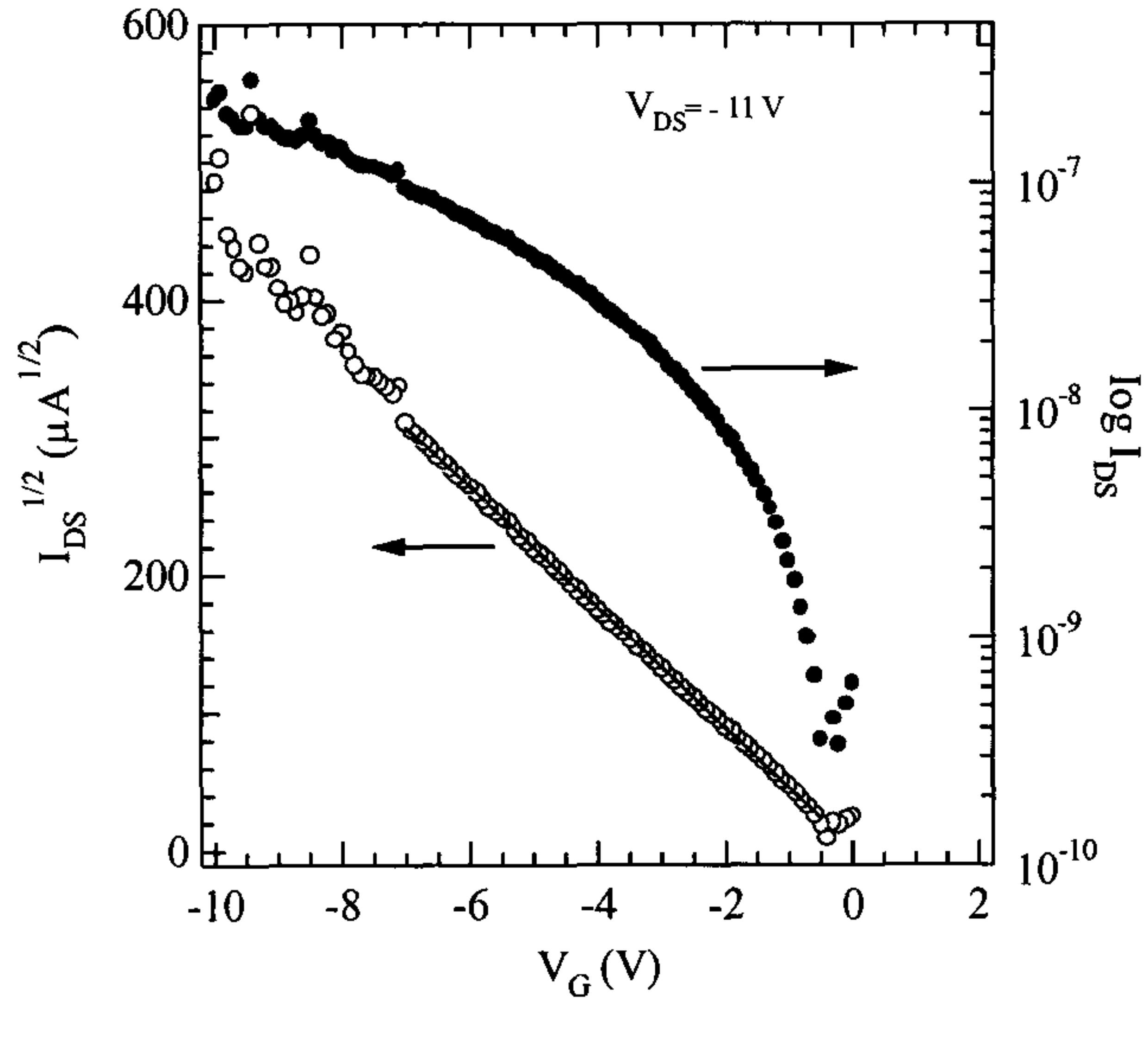

Figure 3. $I_{DS}^{1/2}$-V_G (left) and I_{DS}-V_G (right) characteristics for a pentacene OTFT having a PMMA gate insulator.

4. Conclusion

We have reported the enhancement of the FET characteristics of pentacene OTFTs by using PMMA gate insulator to which pentacene adheres well. Since PMMA gate insulator is easily deposited on any substrates including various plastics, the result is important for the development of flexible displays. Mobility values of 0.004 cm^2/Vs were measured from devices with a W/L ratio of 60 (W = 3000 μm, L = 50 μm). The TFT on/off current ratio is about 10^3.

5. Acknowledgements

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6. References

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