Performance improvement in bottom-contact pentacene organic thin-film transistors by the PMMA layer insertion

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Abstract

For the bottom-contact pentacene organic thin-film transistors (OTFTs), the insertion of a thin PMMA layer (20 Å) between the pentacene and the electrode improves the electrical performances, such as carrier mobility and on-current magnitude, about 4 times larger than those of the devices without the PMMA. The performance enhancement is presumably due to the decreased contact resistance between metal and pentacene by inserting the thin PMMA layer.

1. Introduction

In recent years, the OTFTs have attracted much attention for e-paper, flexible display, RFID, and etc, but the performance of the OTFTs has to be improved for those applications. Various methods to improve the performance are studied: The self-assembled monolayer (SAM) surface treatment is one of those methods. The process of SAM, however, has some problems: such as complicated steps, strict conditions, and critical damages to metal [1].

For the top-contact type OTFTs, the dilute PMMA coating process was proposed to overcome the problems, (Fig. 1(a)) and it improves the electrical characteristics [2]. However, the top-contact type OTFT has some disadvantages in fabricating circuits. In this paper, the bottom-contact type OTFT with thin PMMA layer is fabricated, (Fig. 1(b)) and the improvement of the electrical characteristics is reported.

2. Results & Discussion

The transfer curves of the fabricated devices with the various thicknesses of the PMMA layer are shown in Fig. 2, these are measured from 4 devices for each PMMA thickness. The devices with the PMMA layer show different electrical

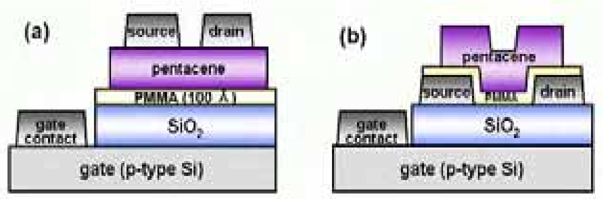

Figure 1. The schematics of (a) top-contact and (b) bottom-contact OTFT with a PMMA layer

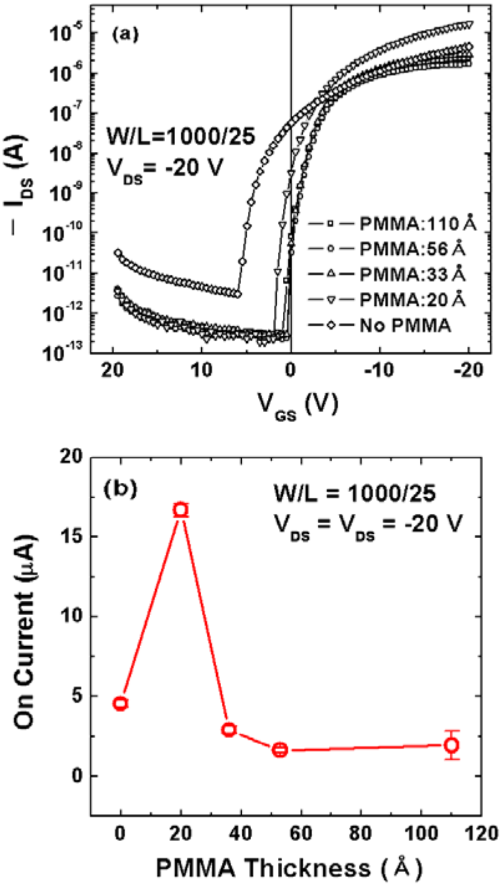

Figure 2. Transfer curves with various PMMA thicknesses. (a) I_{DS}-V_{GS} curves (b) on-current with various PMMA thicknesses

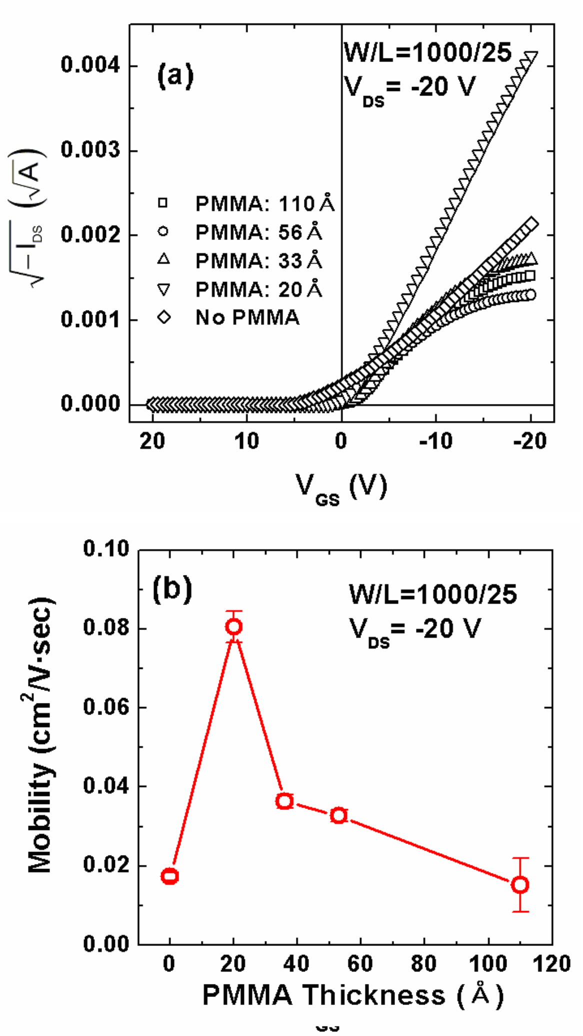

Figure 3. (a) $\sqrt{-I_{DS}} - V_{GS}$ curves (b) saturation mobility

characteristics, such as effective mobility, on-current and off-current, from the device without it. The on-current of the device with 20 Å PMMA layer is 1.7~3.7 times larger than that of the other devices with the thicker PMMA layer, and when the thickness of the PMMA layer is increased, the on-current is as small as that of no PMMA device. The off-current of the devices with PMMA layer is improved by ten times than that of the device without it. Fig. 3 shows the effective mobility which is calculated from Fig. 3(a) at V_{gs} = -20V. The device with 20 Å PMMA layer showed the 2~3.5 times larger mobility than the other devices. To find out the causes of these results, the morphology of the pentacene layer is observed by the AFM. The AFM image of the pentacene grain on the gold and SiO_2 is shown in Fig. 4. As the PMMA thickness is increased, the pentacene grain size becomes larger which is expected from the result of the top contact OTFTs [3]. The size of the pentacene grain on the 20 Å PMMA layer is as small as that of no PMMA device (Fig. 4 (c) and Fig. 4 (d)). Although the size of the pentacene grain on the 20 Å PMMA layer is smallest among the PMMA processed devices, it showed the best performance. The result means that the size of the pentacene grain is not a dominant factor in the electrical performance improvement.

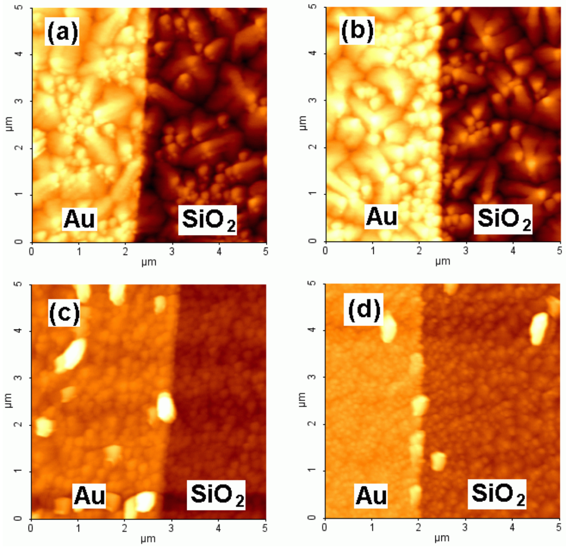

Figure 4. AFM images, when the thickness of PMMA (a) 110 Å, (b) 36 Å, (c) 20 Å, and (d) 0 Å

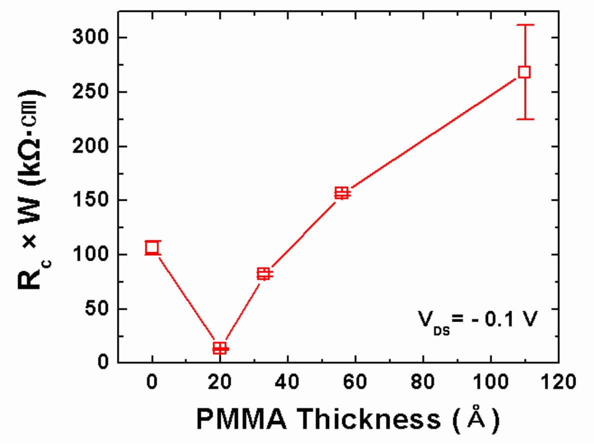

Figure 5. Contact resistance with various PMMA thicknesses

The contact resistance is expected to be increased by the insertion PMMA between pentacene and electrode. Fig. 5 shows the contact resistance of these devices. It is extracted using the channel resistance method from the devices of which the channel length is 5, 10, 30μm. When the PMMA thickness is 20 Å, the contact resistance is the minimum. The result is different from what we expected, because the PMMA is originally expected to interrupt the carrier injection like an insulator. One cause might be that the PMMA layer reduces the interface dipole effect. Interface dipole effect occurs when the pentacene is directly contacted with the gold [4] [5]. It results in the creation of the energy barrier. If the PMMA is coated on the gold, the PMMA layer reduces the barrier height because it interrupts the direct contact between the gold and the pentacene. However, as the PMMA thickness is increased, the mobility and the maximum on-current are decreased, because the width of the tunneling distance is also increased. This might be one of the reasons for the improved performance of the device with 20 Å PMMA layer.

3. Conclusion

For the bottom contact OTFTs, the insertion of a thin PMMA layer improves the saturation mobility and the maximum on-current, because it might reduce the interface dipole effect. Therefore, the insertion of thin dielectric material between electrode and semiconductor is a useful method for improvement in the performance of the bottom contact type OTFTs.

4. Acknowledgements

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5. References

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