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Space-charge induced by traps and its effect on threshold voltage and contact resistance evolution.
トラップ空間電荷と閾値電圧及び接触抵抗の変化の関係

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1. Introduction

Organic field-effect transistors (OFETs) are widely used as logic devices in organic electronics applications, because of their low-cost fabrication and reliable performance. Electrical properties of pentacene field-effect transistor with different thicknesses were studied. A silver nanoparticles self-assembled monolayer (Ag NPs SAM) was incorporated in pentacene field-effect transistor to act as a trapping center to see how the space charge induced by traps can influence the carrier injection and transport by using the current-voltage (*I-V*) measurements under different pentacene thicknesses.

2. Experiment

Heavily-doped Si wafers with a 100 nm thick thermally prepared silicon dioxide (SiO_2) insulating layer were used as the base substrates. Pentacene (100, 200 and 300 nm) served as an organic active layer was vacuum evaporated at the pressure of less than 10^{-4} Pa and the deposition rate was fixed at 0.5 Å/sec using shadow mask and patterned with gold electrode. On the other hand, device with traps is fabricated by introducing the self-assembled monolayer (SAM) of Ag nanoparticles (Ag NPs) on the pentacene-gate insulator interface. Note that no change in pentacene morphology was observed when introducing NPs SAM [1]. The surface morphology study was done with the atomic force microscope (AFM) system (Veeco, Woodbury, USA) operating in the tapping mode, with silicon tips (TESPA, NanoWorld, Switzerland) of curvature radius ~ 8 nm.

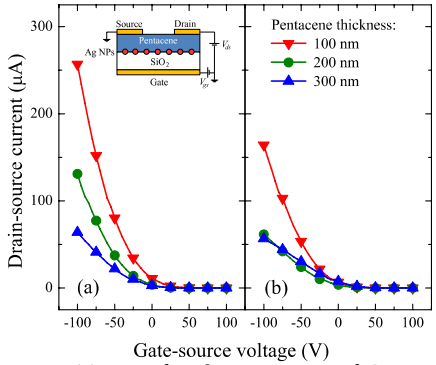

Figure 1: (a) Transfer characteristics of OFETs (a) without and (b) with NPs for channel length L=50 μm and V_{ds}=-100 V for different pentacene thicknesses. The inset illustrates the sketch of top contact structure of organic field-effect transistor.

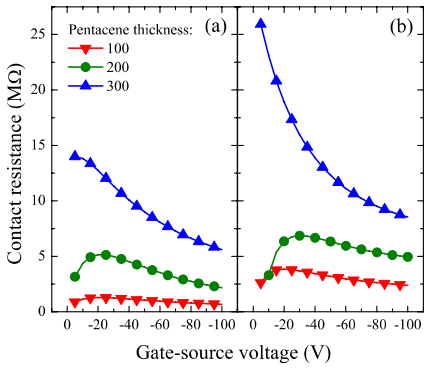

Figure 2: (a) Contact resistance as a function of applied voltage for device (a) without and (b) with NPs for different pentacene film thicknesses.

3. Results and discussion

Figure 1 shows the transfer characteristics of OFETs without and with NPs. There is an obvious positive shift of the threshold voltages as the thickness increases. Interestingly, the shift for NP device is more significant which might be attributed to the flat potential requirements due to traps. Figure 2 plots the contact resistance for both samples under different thicknesses. The device without NPs is more sensitive to thickness change because the charge accumulation is already suppressed at the beginning for NP device. As a result, the field is weak even for the thin films and the contact resistance is already high in comparison with reference device.

4. Conclusions

We have demonstrated the effect of pentacene thickness to the carrier injection and transport. The positive shift of threshold voltage is attributed to the flat potential requirements when the thickness increases, where more significant for NP device due to additional space charge induced by traps. Contact resistance study reveals the device without NPs is more sensitive to the thickness change due to the presence of suppression charge accumulated under the electrode for NP device at the beginning.

References

[1] K. Lee, M. Weis, J. Lin, D. Taguchi, E. Majkova, T. Manaka, M. Iwamoto, *J. Appl. Phys.*, **109**, 064512 (2011).

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