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Organic Static Induction Transistors Based on Pentacene Thin Films with Various Source Electrodes

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1. Introduction

Organic thin film transistors (OTFTs) based on organic semiconductors are very attractive organic electronic devices, which have some advantages in terms of lightweight and mechanical flexibility over the electronic devices based on inorganic semiconductors. Much work has been devoted to achieving the high field effect mobility and to understanding the operational mechanism of the organic field effect transistors (OFETs) for practical device application. However, OTFTs have disadvantage of high operation voltage due to both the low carrier density and the high resistivety of organic semiconductors compared with inorganic semiconductors.

Organic static induction transistors (OSITs) have been studied for an attractive device in respect of the realization of the high-speed and high-power operation at the lower driving voltage[1-3]. The excellent characteristics arise from the vertical structure with very short channel length corresponds to the thickness of the organic semiconductors. In our recently reports, we have fabricated the OSITs using pentacene thin film on the ITO formed on the flexible substrate and have reported their basic electrical property under the bending conditions.[4] However, the OSITs also remain issues of low on/off ratio for use in the electronic devices. In addition, to achieve the high on/off ratio and high current values in the OSITs, we have investigated the influence of inserting ultra-thin CuPc layer between the source electrode and pentacene film on the static characteristics of OSITs.[5] These results provided an important fact indicating that a high on/off ratio and a high current value in OSITs are achieved by controlling the interface energy band condition of an organic semiconductor layer/source electrodes. In this study, the OSITs based on pentacene films were fabricated on various source electrodes to investigate the effect of the interface condition on the static characteristics of the OSITs.

2. Experimental procedure

Figure 1 shows a cross-sectional structure of pentacene OSITs fabricated on various source electrodes. The source electrodes of Au, Pt, ITO were formed on glass substrate using radio frequency sputtering method. On the other hand, the gate electrodes of Al, the drain electrodes of Au drain electrodes and organic semiconductors were deposited using vacuum evaporation method. Further points of the fabricating process are described in detail in Ref. [4, 5]. In addition, OSITs were also fabricated on two type source electrodes. One is the conductive source electrodes such as Au, Pt, and ITO as mentioned above. The other is CuPc/ITO source electrode, which was used to investigate the effect of the thickness (X = 0, 3, 5 nm) dependence of CuPc thin films on the static characteristics of the OSITs. The electrical properties such as the OSITs static characteristics were monitored using a semiconductor parameter analyzer (4156C, Agilent). All electrical measurements were performed in air at room temperature.

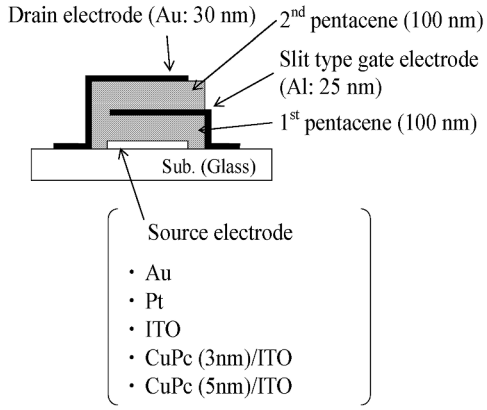
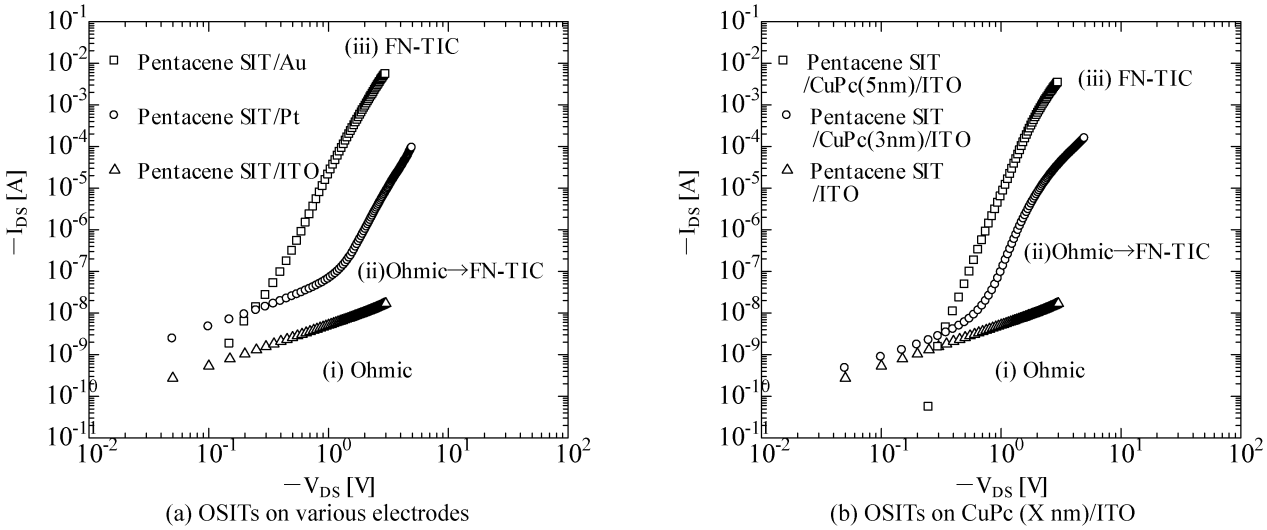


Fig. 1. Cross-sectional structure of OSITs based on pentacene thin films fabricated on various source electrodes.

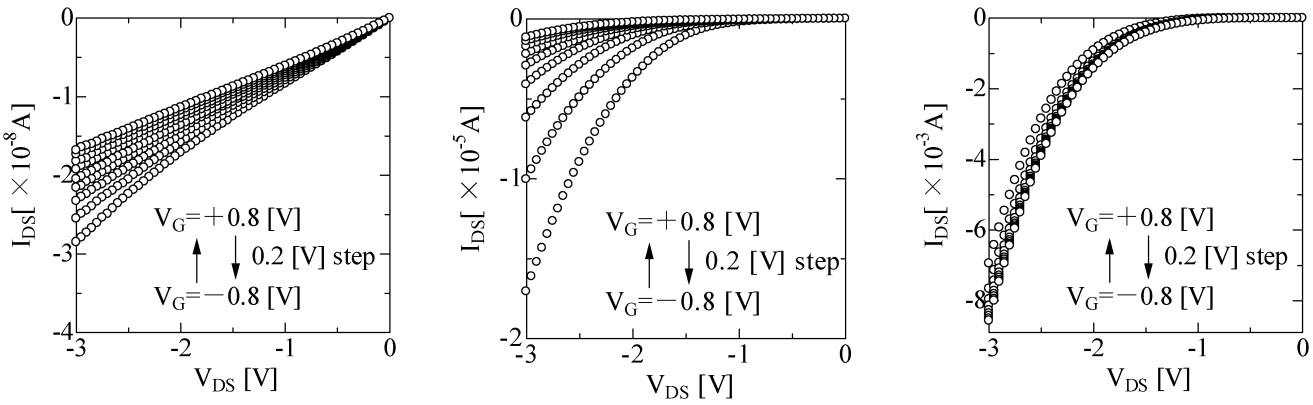
3. Results and discussion

To investigate the hole injection mechanism at the interface between various source electrodes and pentacene thin films, the current-voltage characteristics between the source electrode and drain electrode under floating gate condition for OSITs fabricated on various source electrode were measured as shown in Fig. 2. The observed I_{DS}-V_{DS} curves was classified with three characteristics: (i) Ohmic current at the interface of pentacene/ITO, (ii) shift from Ohmic to Fowler Nordheim tunneling injection current (FN-TIC)[6] at the interface of pentacene/Pt and pentacene/CuPc (1 nm)/ITO, (iii) FN-TIC at the interface of pentacene/Au and pentacene/CuPc(5 nm)/ITO. Figure 3 show the static characteristics of OSITs based on pentacene film with various source electrodes. Note that high on/off ratio of OSITs based on pentacene thin film was achieved when the observed I_{DS}-V_{DS} characteristics have the charac-



(a) OSITs on various electrodes (b) OSITs on CuPc (X nm)/ITO

Fig. 2. Current-voltage characteristics between the source electrode and drain electrodes under floating gate condition for OSITs based on pentacene thin films fabricated on (a)various source electrodes and (b) CuPc (X = 0 nm, 3 nm, 5 nm) / ITO.



(a) OSITs on ITO electrode (b) OSITs on Pt electrode (c) OSITs on Au electrode

Fig. 3. Static characteristics of OSITs based on pentacene thin films fabricated on various source electrodes, (a) ITO, (b) Pt, (c) Au.

teristics with (ii) shift from Ohmic to FN-TIC. These phenomena were also observed in the case of the OSITs based on pentacene thin film with CuPc/ITO. These results demonstrate that the formation of the hole injection barrier with moderate height at the interface of pentacene/source electrodes is effective to fabricate the high performance OSITs with high on/off ratio. The moderate hole injection barrier effectively controls the current injected from the source electrode by applying a gate voltage in addition to the effect of the restriction by spreading the depletion layer around Al Schottky gate electrode.

4. Summary

We found that the on/off ratio of OSITs static characteristics have strong relevance to the interface state of organic semiconductor layer/source electrode. In addition, the formation of the moderate hole injection barrier at the interface of organic semiconductor layer/source electrode was needed to fabricate the OSITs with high on/off ratio. Therefore, it is important to carry out the further investigation of the energy band condition of the interface of organic semiconductors/source electrodes for the realization of high performance OSITs.

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