Electrical Applications of OTFTs

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Introduction

π-conjugated organic and polymeric semiconductors are receiving considerable attention because of their suitability as an active layer for electronic devices[1-3]. An organic inverter with a full swing and a high gain can be obtained through the good qualities of the transfer characteristics of organic thin-film transistors (OTFTs); for example, a low leakage current, a threshold voltage (V_{th}) close to 0 V, and a low sub-threshold swing.[4] One of the most critical problems with traditional organic inverters is the high operating voltage, which is often greater than 20 V. The high operating voltage may result in not only high power consumption but also device instabilities such as hysteresis and a shift of V_{th} during operation.

In this paper, low-voltage and little-hysteresis pentacene OTFTs and inverters in conjunction with PEALD Al_2O_3 and ZrO_2 as the gate dielectrics are demonstrated and the relationships between the transfer characteristics of OTFT and the voltage transfer characteristics (VTCs) of inverter are investigated.

Experimental

Si wafers with thermally grown 300 nm SiO_2 were used as substrates for these experiments. 50 nm Ti was deposited by e-beam evaporation through a shadow mask. 150 nm Al_2O_3 and 120 nm ZrO_2 dielectric films were deposited at 150 °C on top of the Ti gate metal. The capacitances of the devices were C_o= 41 nF/cm^2 for Al_2O_3 (ε=8) and C_o= 150 nF/cm^2 for ZrO_2 (ε=24). For the source (S) and drain (D) electrodes, an Au (80 nm)/Ti (3 nm) double layer was used. After spin coating of hexamethyldisilazane (HMDS) on the dielectric films, pentacene thin films were deposited at 70 °C on the Si substrate by the thermal evaporation method. The deposition rate was 0.1 nm/sec, and the total deposited thickness was 100 nm.

Results and discussion

Hysteresis is frequently observed in OTFTs[5] and organic inverters.[6] The hysteresis may be larger for high capacitance devices with ZrO_2 gate dielectrics. Figure 1 shows the threshold voltage(V_{th}) shift behavior of an OTFT according to the repetition of gate voltage sweep. As the scan number increase at a fixed V_d, the V_{th} shifted to the negative voltage side. In fig. 2, hysteresis behavior of OTFT is shown. When sweep down the gate voltage, a turn-on voltage is about 5 V, while when sweep up the gate voltage, it is around -20 V. This hysteresis phenomenon is known as due to the trap charge between organic semiconductor and gate dielectrics.

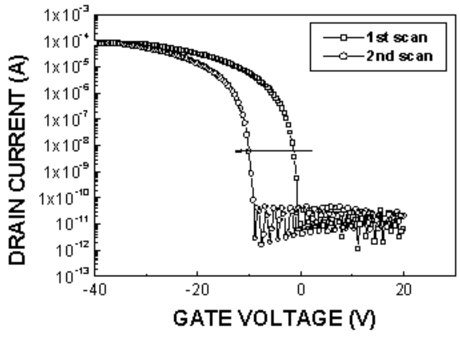

Figure 1. V_{th} shift according to the repetition of gate voltage sweep.

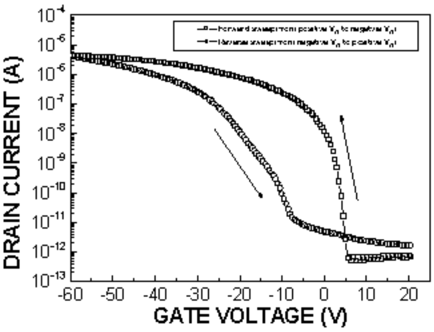

Figure 2. Hysteresis of OTFT.

Figure 3 shows the hysteresis behavior of OTFT according to the maximum gate voltage. As shown in these figures, the value of V_{th} shift increased as increase of the gate voltages. This indicates that there are injection barrier between organic semiconductor and gate dielectrics to inject charge from organic semiconductor to traps located in the gate dielectrics near the interface. This is why the hysteresis increases according to the gate voltage increases.

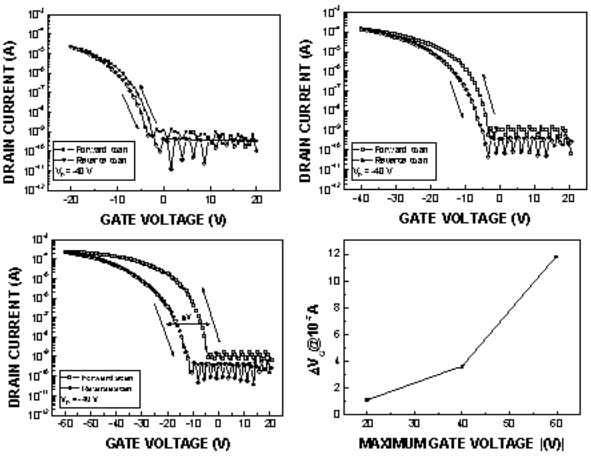

Figure 3. Hysteresis of OTFT according to the various maximum gate voltage.

Conclusions

In summary, the present work suggests that PEALD Al_2O_3 and ZrO_2 are promising candidates for the gate dielectrics of low-voltage OTFT and inverter. The hysteresis observed in transfer characteristics of OTFTs fabricated by inorganic gate dielectric such as Al_2O_3 and ZrO_2 were mainly determined by the scan range of gate voltage. Consequently, low-voltage OTFT would be helpful for the reduction of both power consumption and hysteresis effect. In addition, in the case of organic gate dielectric such as PVP, the amount of hysteresis was closely related to polarity of gate dielectric.

References

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