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Study on the Carrier Transport of Pentacene Thin Film Transistor at High Temperatures

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1. Introduction

Organic thin film transistors (OTFTs) based on Pentacene have received increased attention in the last several years as a material of low cost devices for flexible electronics [1-3]. The properties of Pentacene OTFT such as carrier transport [4-5] and the contact resistance [6] are well studied by many groups in the certain controlled environment. Applications of OTFT such as radio-frequency identification (RFID), OLED display, smart card and smart sensor should integrate varieties of devices and processes; the OTFT should therefore pass through higher temperatures and severed environments. However, the carrier transport properties at higher temperature in the air are rarely reported. In this study, the mobility, oxidation of Pentacene and improvement of interface at the high temperatures and in the ambient environment are reported.

2. Experiment and results

The OTFT was made in the top contact structure which reported has a lower contact resistance by shadow masks as shown schematically in Fig. 1. The OTFTs with different Pentacene thickness (30 and 100nm) and dielectric treatment (treated and non-treated) conditions were evaluated. The output (I_d-V_d) and transfer (I_d-V_g) characteristics are shown in Fig. 2 and Fig. 3. The threshold voltage was determined by the linear plot, and the mobility was calculated according to the square law of drain current, which is around 0.7 cm^2/V-S for non-treated and 0.57 cm^2/V-S for PMS (poly-α-methyl styrene) treated Pentacene OTFTs.

The temperature for devices measurement is raised from room temperature up to 200^{o}C. The mobilities increase from room temperature to around 80^{o}C for all devices then decrease rapidly toward to zero at 200^{o}C as shown in Fig 4. The PMS-treated OTFT was increased more obviously from 0.57 to 0.78 cm^2/V-S at 30 nm thickness device than other devices. The mobility of Pentacene OTFT is dominated by two factors, the hopping transport of carriers in the Pentacene between grains and the scattering by the interface states between dielectric and semiconductor. The higher activation energy (77 meV) for PMS-treated OTFT (9 meV for non-treated OTFT) indicate the PMS-treated OTFT might have lower mobility because of higher barrier for carrier hopping. However, PMS-treated OTFT exhibit higher mobility at temperature between room temperature and 80^{o}C. This indicates the higher mobility of PMS-treated OTFT might owe the surface modifications at higher temperatures. The threshold voltage for PMS treated OTFT show large deviation between RT and 80^{o}C, while the non-treated sample is rarely changed as shown in Fig. 5, supporting the merits of surface modification. As to the thick Pentacene device has lower mobility, which may encounter the contact resistance. The degradation of mobility at temperature beyond 100^{o}C is due to the oxidation of Pentacene, which break the π-bonding and limit the hopping mechanism inside Pentacene. This can be proved by the appearance of C=O and the disappearance of C=C in the FTIR spectra after 100^{o}C as shown in Fig.6.

3. Conclusions

In summary, we found the non-treated Pentacene OTFT is relatively stable than the treated OTFT at higher temperature. The mobilities of Pentacene OTFT degrade after 100^{o}C is owing to the surface oxidation, which suggest the suitable conditions for OTFT fabrication.

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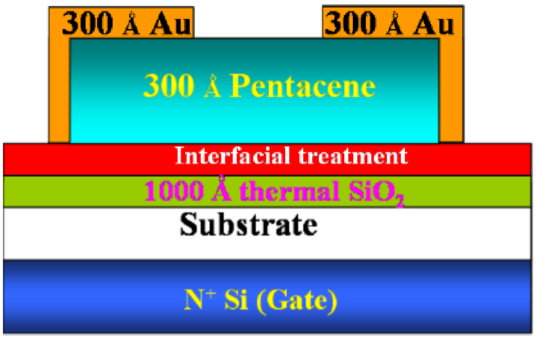

Fig. 1 The cross-section of Top contact Pentacene OTFT

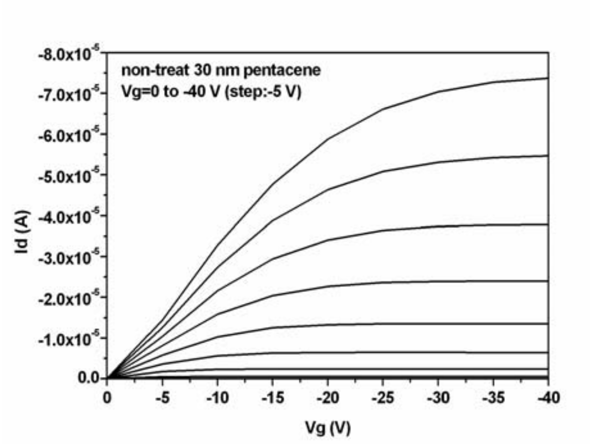

Fig. 2 The output characteristics (I_d-V_d) of top contact Pentacene OTFT

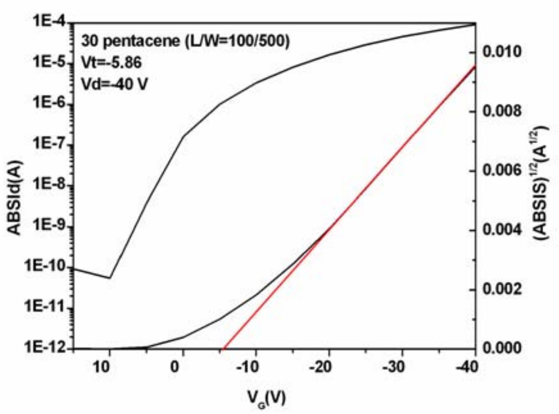

Fig. 3 The transfer characteristic (Id-Vg) of top contact Pentacene OTFT

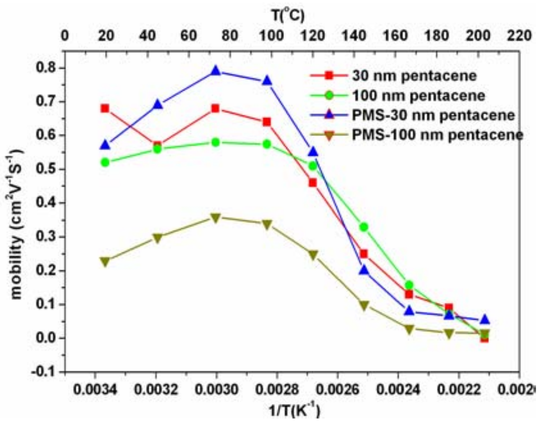

Fig. 4 Temperature dependent mobilities of the OTFT

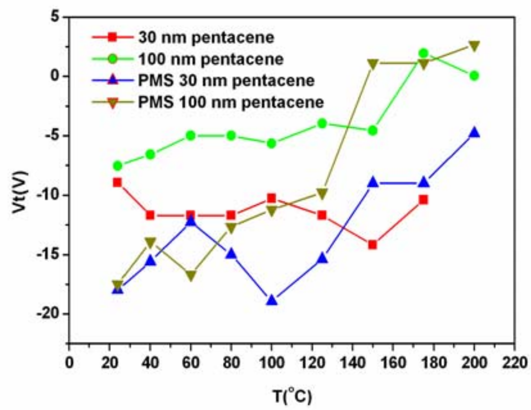

Fig. 5 Temperature dependent threshold voltage of the OTFT

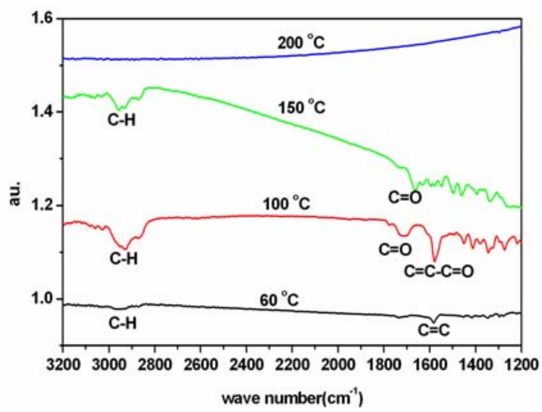

Fig. 6 FTIR spectra of Pentacene OTFT