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Hydrophobic Treatment Effect on Hole Mobility in Pentacene Thin Film Transistor

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1. Introduction

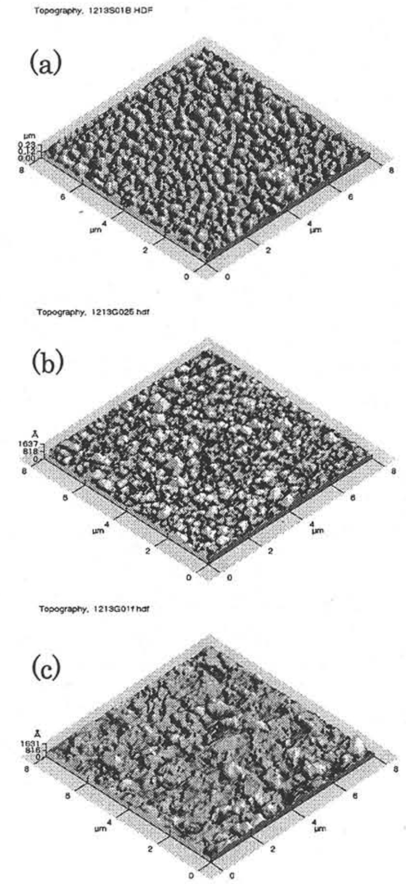
The organic thin film transistor (OTFT) is under development by several research groups in the world for special applications, such as the large-area flexible display and low-cost appliances [1-2]. The performance is approaching to that of α-Si TFTs. The most important factor to determine the performance is the molecular ordering of the organic active-layer, and the molecular ordering is mostly affected by the surface condition on which the organic active-layer is deposited. There were some reports on the effects of interface treatments between the organic film and the gate dielectric layer to improve molecular ordering [3] but the detailed investigation has not been reported. In this paper we investigated the effects of hydrophobic treatment with the self-assembly materials (OTS and HMDS) on the molecular ordering of the pentacene thin film and on the performance of pentacene OTFTs, especially on the hole mobility with the analysis of the temperature and gate voltage dependence.

2. Effect of Hydrophobic Treatment on Pentacene TFT's Performance

OTFTs were fabricated on the thermally oxidized Si substrate, which was heavily doped and used as the gate. Then, Au source and drain contacts were evaporated and patterned by lift-off process. Subsequently, the self-assembly material was coated to achieve the hydrophobic treatment prior to the deposition of pentacene poly-crystal with OMBD. The surface morphology and the hole mobility of pentacene poly-crystal were analyzed to investigate the effect of the hydrophobic treatment on the performance of OTFTs.

As shown in AFM images in Fig.1 the grain size and the surface roughness of pentacene poly-crystal treated by OTS produced the best results among the three cases: the non-treated, the HMDS-treated and the OTS-treated thin films. And also OTFTs with the OTS treated film exhibited the superior performance as shown in Table 1. Especially, the field effect mobility was about $0.3 cm^2/V.sec$, which was approaching to that of α-Si TFT. In addition, the off-state current was much reduced to 10^{-11}A, resulting in the high on/off current ratio of 10^6. The I-V characteristics were compared in Fig.2. All the above excellent results were attributed to the hydrophobic treatment with OTS, which modified the hydrophilic surface of SiO_2 to the hydrophobic termination, and enhanced the attraction of pentacene molecules to the surface of SiO_2.

Fig.1. AFM images of a) the non-treated, b) the HMDS-treated, and



c) the OTS-treated pentacene thin film.

Table I Performance parameters of OTFTs

	μ_{FET} ($cm^2/V{\cdot}s$)	V_T(V)	SS(V/dec)	$I_{on/off}$ ratio	Off-state leakage current
Untreated	$5.76x10^{-4}$	-2.37	2.01	$5.0x10^{3}$	$5.9x10^{-11}$
HMDS	0.04	-3.31	0.97	$1.0x10^{5}$	$1.0x10^{-10}$
OTS	0.26	0.00	1.05	$1.0x10^{6}$	$5.0x10^{-11}$

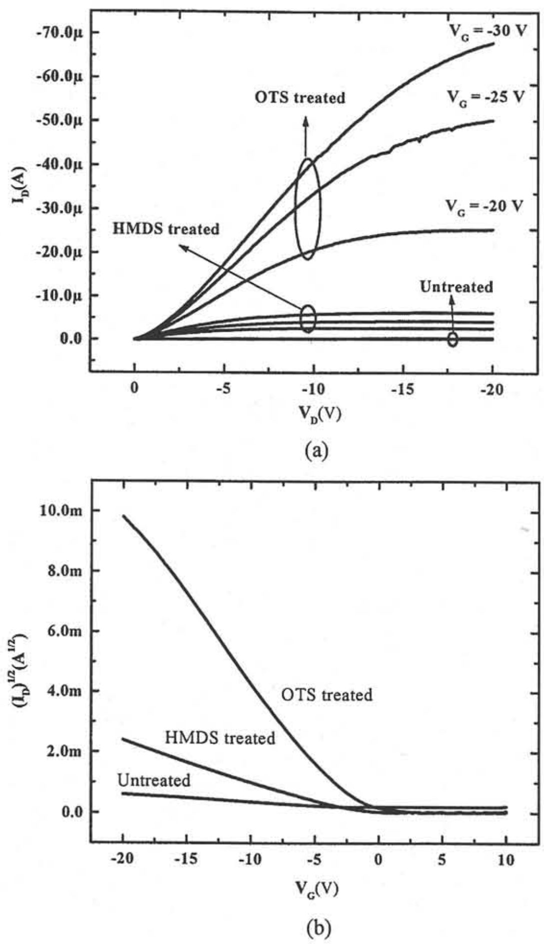


Fig.2. a) I_{DS}-V_D, and b) I_{DS}-V_G characteristics of OTFTs with and without the hydrophobic treatment.

The field effect mobility of holes in pentacene OTFTs were measured and analyzed with respect to the temperature and the gate voltage variation as shown in Fig.3. As the gate voltage increases, the more holes are injected into the channel and the hole density in the grain p increases. According to the model of mobility in poly-crystal [4] it reduces the trap barrier E_B, resulting in increasing the grain boundary mobility μ_{GB} and the hole mobility μ as well. As the temperature decreases, the electrons trapped in the grain boundaries attract the holes to reduce the hole mobility. Therefore, the hole mobility strongly depends on the grain boundary properties and the OTS-treated pentacene OTFTs producing the largest mobility were identified to possess the least grain boundaries, which is identical to AFM images in Fig.1.

$$\frac{1}{\mu}=\frac{1}{\mu_B}+\frac{1}{\mu_{GB}}, \mu_{GB}=\mu_O \exp\left(-\frac{E_B}{k_B T}\right), E_B=\frac{qn_t^2}{8\varepsilon_S p}$$

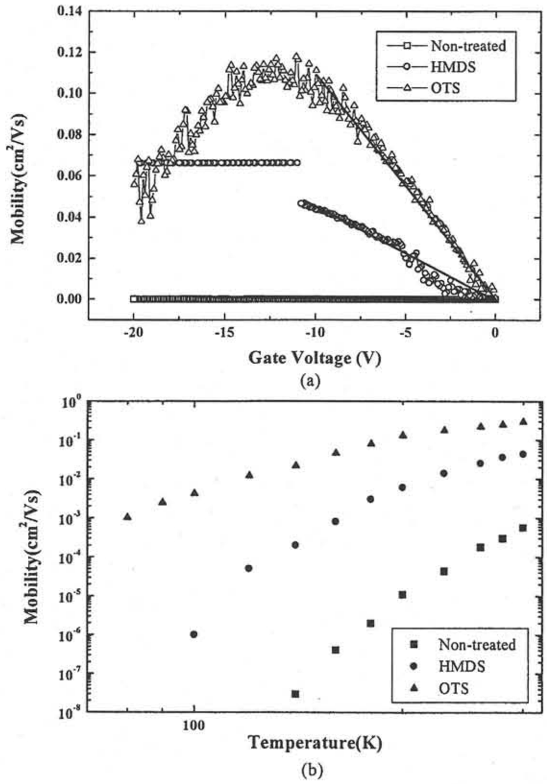


Fig.3. a) The gate voltage dependence, and b) the temperature dependence of the hole mobility in pentacene

3. Conclusions

In this paper, the effect of hydrophobic treatment with the self-assembly materials such as HMDS and OTS on the molecular ordering of the pentacene thin film and the improvement of pentacene OTFT's performance is investigated. The field effect mobility of OTFTs treated with OTS was enhanced to 0.3cm^2/V•sec, and the off-state current reduced to 10^{-11}A, resulting in increasing the on/off current ratio to 10^6. And also we have observed the temperature and gate voltage dependence of hole mobility in the pentacene poly-crystal, and analyzed the grain boundary properties as well as their effect on hole mobility.

Acknowledgments

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