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Modification of Surface States of Gate Insulator for the Enhanced Performance of Pentacene TFT

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1. Introduction

Organic thin film transistor(OTFT) is a representative application of organic materials to electronic devices[1]. OTFTs are composed of the metal contacts, gate insulator, and semiconductor active layer. Although at the present the active layer is replaced by organic semiconductor, in future all components are supposed to be made of organic materials. The electrical characteristics of OTFTs strongly depend on the interface states between the organic active layer and the gate insulator[2]. The field effect mobility, which is a typical parameter to determine the performance, is usually determined by the surface roughness of gate insulator, the grain size of active thin film layer. Therefore, in order to enhance the field effect mobility some treatments should be employed on the surface of gate insulator prior to deposition of pentacene.

In this paper, we present enhancement of field effect mobility by modifying the surface condition of gate insulator on which pentacene molecules are deposited. Several treatments were applied such as O_2 plasma treatment, the application of molecular mono-layer, the replacement of inorganic SiO_2 insulator with a new novel organic insulator. The effects of each surface treatments has been compared with the others and analyzed.

2. Surface Treatments of OTFTs

OTFs were fabricated on the highly doped Si substrate on which SiO2 was thermally grown as gate insulator. For the source and drain contact Au was evaporated and patterned by lift-off process. Pentacene was deposited by OMBD as the organic semiconductor active layer. Prior to deposition of pentacene the surface of gate insulator of some devices were treated as mentioned above in order to enhance the performance. The effects of surface treatment have been examined.

3. Results

At the initial stage of growth of pentacene thin film the nucleation is generated on the thermodynamically stable sites. The nucleate sites grow as the molecules diffuse and merge into the sites. The grain size depends on how far the molecules diffuse on the surface, which depends on the growth rate and the surface conditions. The diffusion length X is expressed by

$$X = \sqrt{2}a\exp\left(\frac{Q_{des} - Q_{dif}}{kT}\right) \qquad (1)$$

The surface barrier energy against diffusion, Q_{dif} and the desorbtion energy from the surface., Q_{des} can be modified by chemical and physical treatment.

The current-voltage characteristics of OTFTs are plotted in Fig.1 for comparison of surface treatment effects. And the performance parameters are summarized in Table 1. The O2 plasma treatment enhanced performance, especially the contact resistance. It is very effective to apply organic mono-layer such as octadecyltrichlorosilane (OTS) for channel coating and 2-Mercapto 5-nitrogenzimidazole (MNB) for source and drain metal coating. However, the simultaneous deposition of OTS as well as MNB has been found to be less effective. It might be the chemical reaction between OTS and MNB. Thus, we need to find new derivatives of MNB which do not react with OTS molecule. Recently, we developed a new novel organic material in order to use it as an organic insulator instead of the inorganic SiO2. The function is to enhance the adhesion with substrate and the electrical insulation as well as the diffusion of pentacene molecules on the surface. As indicated by the mobility of about $2cm^2/V.sec$, which is comparable to the world record, the organic insulator dramatically improved the performance. However, the insulation, as shown by the leakage current of 9.56 nA, is not good enough yet.

4. Conclusion

The surface energy of gate insulator have been modified by the various surface treatments. And it has been found that the surface treatment is very effective way to enhance the performance of pentacene OTFTs just carried by simple process. The most effective way is to apply the custom-designed organic insulator instead of the conventional SiO2. In this case we could obtain the

Table 1. Summary of performance parameters of OTFTs

	Mobility (cm^2/vs)	SS (V/dec)	V_T (V)	Ion/off	Off-state current(A)
Non-treated	0.0046	3.2	-0.7	2.4×10^{3}	2.2×10^{-9}
O_2 plasma	0.065	0.5	0.5	2.3×10^{7}	5.5×10^{-12}
MNB	0.036	3.2	-2.3	2.0×10^{4}	1.0×10^{-9}
OTS	0.36	0.5	-0.2	3.2×10^{7}	9.3×10^{-12}
OTS+MNB	0.11	0.3	-0.6	1.3×10^{7}	1.2×10^{-11}
SiNx /glass	0.0085	2.1	3.6	1.7×10^{4}	8.81×10^{-11}
Organic insulator	1.92	3.3	-9.6	1.7×10^{3}	9.6×10^{-9}

mobility of 2cm^2/V.sec.

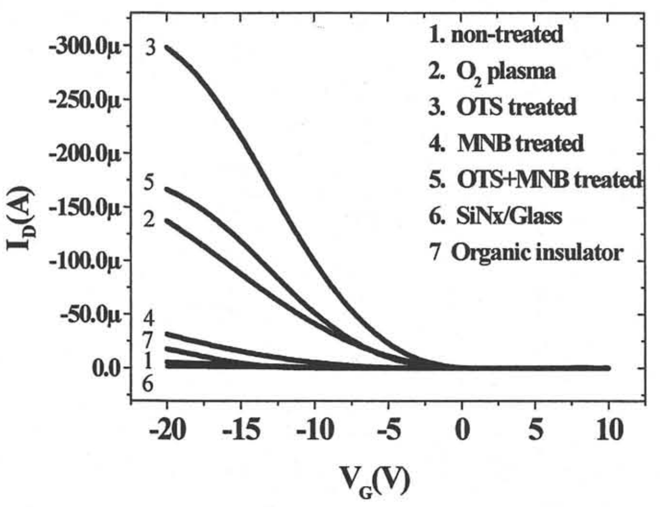
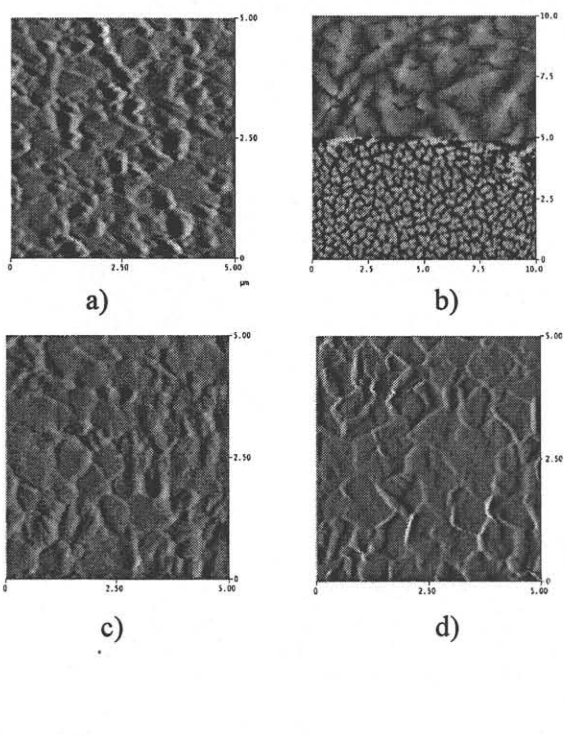


Fig.1 The current-voltage characteristics of OTFTs



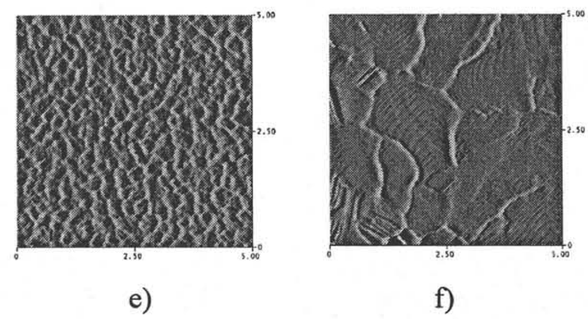


Fig 2. The AFM images of pentacene thin film deposited on the various surface conditions of gate insulator; a) the non-treated , b)O_2 plasma , c) OTS treated , d) MNB treated , e) on SiNx , f) on the organic insulator

Acknowledgments
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References

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