Extended Abstracts of the 2006 International Conference on Solid State Devices and Materials, Yokohama, 2006, pp. 930-931

D-9-3

Performance enhancement of Organic TFT by low-energy Ar ion beam treatment onto gate dielectric surface

[1]Sungku Kang, [1]Jaeyoung Park, [1]Sukmo Jung, [2]Hoo-Jeong Lee, and [1]Moonsuk Yi

[1]School of Electrical Engineering, Pusan National University, Busan, 609-735, Korea
[2]School of Advanced Material Science, SungKyunKwan University, Suwon, Korea
Phone:+82-51-510-2381, Fax:+82-51-515-5190, E-mail: msyi@pusan.ac.kr

1. Introduction

Recently, organic TFTs (OTFT) have received tremendous attention because they have a potential to enable the fabrication of large-sized displays on a plastic substrate at low costs in near future. Among organic semiconductors considered for active materials in OTFTs, pentacene is most widely used due to its outstanding field-effect mobility.[1] Such organic semiconductors are known to have a lot of defects inside the active layer and at the interface, which act as trap sites. Moreover, the electronic performance of the organic active film is very sensitive to the surface of the gate dielectric, because the current flow through the channel near the gate dielectric surface is dominant.[2,3,4] The interface states between dielectric surface and organic material would affect device performance directly and so a careful consideration of the interface would be critical to improve device performance. In this study, we carried out Ar ion beam treatment onto the gate dielectrics to enhance the electronic condition of the interface.

Although several methods were recently proposed to improve the condition of the interface states, only a few proved to be reliable and robust. One of the proposed methods is using a self-assembled monolayer (SAM) such as octadecyltrichlorosilane (OTS) to enhance the directionality of pentacene grain. The dielectric surface treatment with OTS is found to improve the mobility of OTFT. However, several reports suggested that OTS-treatment modulated the surface morphology of a pentacene thin film and that the OTS treatment onto dielectric led to smaller grains in the polycrystalline pentacene thin films.[3] Another dielectric surface treatment technique is O_2 plasma cleaning and subsequent HMDS deposition onto the dielectrics. Problems arising due to the O_2 plasma, which was applied to remove residues generated from previous photo lithography processes, were found to be a large number of trap states created during the cleaning process by assisting OH termination at the SiO_2 surface. Although subsequent HMDS layer is expected to reduce the number of traps and act as SAM,[2] the time-consuming wet processes used to apply SAM into the interface are unreliable and can cause other undesirable contaminations to the device

In this study, we adopted argon ion beam treatment to reduce trap states on the gate dielectric surface while minimizing damages on the surface structure. We compared the device performances of argon ion beam treated, O_2 plasma treated and non-treated TFTs and found that argon ion beam surface treatment displayed better off current control and an improved mobility. The improvements were explained by the reduction of the number of trap states at the pentacene and SiO_2 interface and the increased grain size of pentacene thin film.

2. General Instructions

A structure of organic TFT is illustrated in Fig.1. Highly doped n-type (0.005Ω-㎝)(100) Si wafers were used as a substrate for a back gate electrode. 600Å thick thermal SiO_2 was used as a gate insulator. The SiO_2 layer on the front for gate electrode was removed by soaking the substrate covered with patterned resist into buffered oxide etchant (BOE). Then the substrate was cleaned in trichloroethylene (TCE), acetone and methanol, successively.

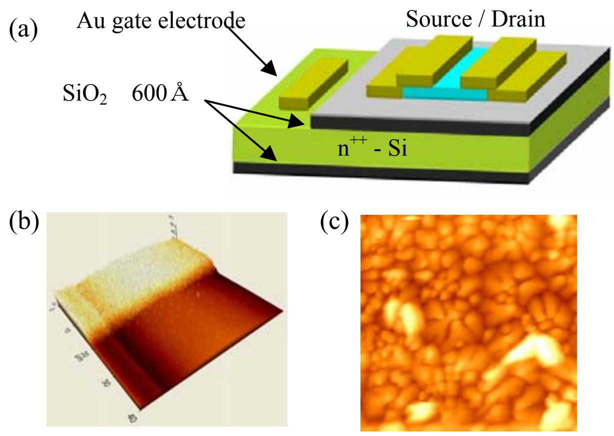

Fig. 1 (a) Schematic of a OTFT structure with top contact electrode. (b) AFM image of electrode-pentacene boundary. (50㎛X50㎛) (c) AFM image of pentacene grain (5㎛X5㎛)

To compare the effects of various treatments, we carried out three types of surface treatment onto SiO_2 dielectric layers. The first was treated by O_2 plasma (RF power from 25W to 100W for 5sec~60sec) onto SiO_2; argon ion beam treatment (from 25eV to 500ev for 30sec~90sec) was used for the second one; and the last did not receive any treatment as a reference. These three types of samples underwent the exact same process except the surface treatments.

Pentacene was purchased from Aldrich and used without any further purification. Pentacene films were grown in an Organic Molecular Beam Deposition (OMBD) chamber at a pressure of 1.0×10^{-6} Torr. During the active layer formation, the rate of deposition was maintained at 0.1Å/s and the final thickness was 30nm. After the channel layer deposition, 50nm thick Au top contacts were deposited using effusion cell. The channel width(W) was 2000㎛ for all TFTs, and channel lengths(L) were varied as 50㎛ and 100㎛.

The electrical property of the OTFTs was measured in a light-isolated probing station connected to a semiconductor parameter analyzer (HP 4155A) at room temperature in air. The I_{DS} vs. V_D curves were obtained by scanning V_D from 0V to -20V at the steps of V_{GS} from 0V to -20V by 5V.

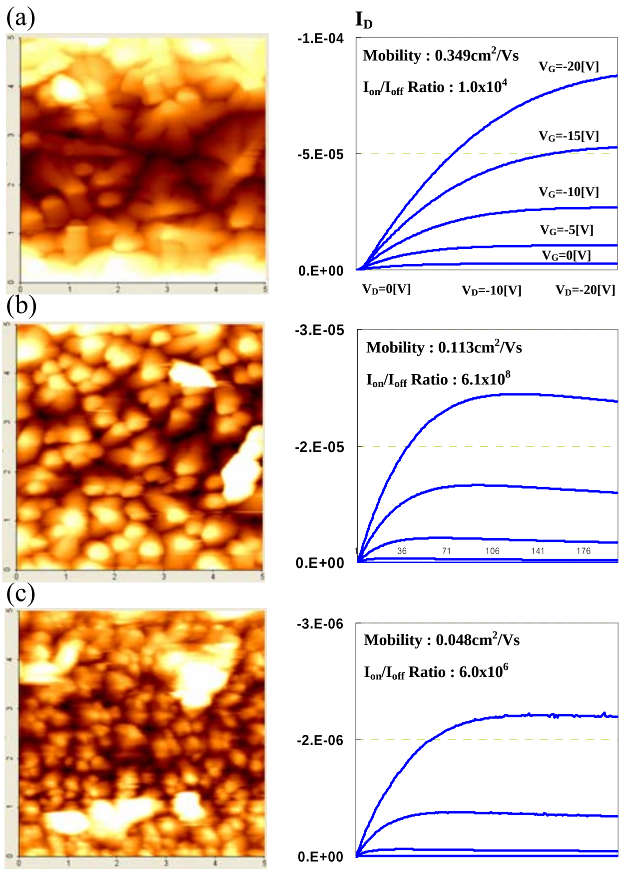

Fig. 2 (a) AFM Image(5㎛X5㎛) of pentacene and I_{DS} vs V_D curve at O_2 plasma(RF 50W,30sec) treatment. (b)Argon ion beam (150ev,60sec) treatment (c)Non-treated substrate as a reference.

Surface Treatment	Grain Size (㎛)	Mobility (cm^2/Vs)	I_{On}/I_{Off} (A)	I_{Off} (A)	SS (V/dec)
O_2 Plasma	2.1	0.349	1.0x10^4	~10^{-7}	4.6
Ar beam	1.2	0.113	6.1x10^8	~10^{-11}	0.5
Non-treated	0.9	0.048	6.0x10^6	~10^{-10}	1.5

Table I Pentacene grain size, mobility, I_{On}/I_{Off} ratio and sub-threshold swing for three treatment conditions used in this study.

AFM images shown in Fig.2 display remarkable differences in the grain sizes of the three samples. The grain sizes measured from these images are listed in Table I. The sample treated in O_2 plasma exhibits the largest grain size while the reference sample shows the smallest size. The Ar-treated sample shows a grain size somewhat larger than that of the reference sample but significantly smaller than that of the O_2-treated sample. This trend matches completely with the tendency of the mobilities obtained from I_{DS} vs. V_D curves shown in Fig. 2. That is, a sample with larger grains (0.349cm^2/Vs for O_2 sample) has a mobility higher than that with smaller grains (0.048cm^2/Vs for the reference sample). The Ar-treated sample shows a mobility moderately higher than that of the reference sample.

The comparison of I_{on}/I_{off} current ratios demonstrates the advantage of using Ar treatment. Table I also shows the data of I_{on}/I_{off} ratios estimated from the I_{DS} vs. V_D curves shown in Fig. 2. Although the O_2 plasma treatment sample shows the largest grain size and the highest mobility, it suffers from a very low I_{on}/I_{off} ratio (only 10^4). This low ratio arises from a high off current, which indicates a high leakage current possibly due to a high trap density at the interface. In contrast, the Ar-treated sample shows an on/off ratio of 6x10^8, much better than that of the reference sample, 6x10^6. This remarkable improvement in the I_{on}/I_{off} ratio suggests that the Ar ion beam treatment successfully reduced the trap density without altering the surface state of the dielectric layer.

Also shown in Table I are sub-threshold swings (SS) of the three samples. The data signify that the sub-threshold swing of the argon ion beam-treated TFT is smaller than those of the O_2 plasma sample and the reference sample. This result corroborates our argument from the I_{on}/I_{off} ratio data: Ar ion beam treatment successfully reduced the trap density while O_2 plasma resulted in a high density of trap sites. We believe that this difference is connected to a unique nature of argon ion beam treatment: that is, since argon is inert gas, it could clean the surface effectively without generating many trap sites.

3. Conclusions

In this study, we demonstrated the possibility of using Ar ion beam treatment to enhance the interface states between pentance and dielectrics. After the treatment, the grain size increased moderately, resulting in doubling the mobility. More importantly, the I_{on}/I_{off} current improved significantly to 10^8 from 10^6 for the reference sample. In particular, this high I_{on}/I_{off} ratio is in a sharp contrast with the low I_{on}/I_{off} ratio of O_2 plasma sample, which suffered from high defect density probably generated during the aggressive plasma treatment. In conclusion, Ar ion beam treatment is capable of reducing the defect density and hence improving an I_{on}/I_{off} current ratio effectively.

References

[1] P.V. Necliudov, M.S. Shur, D.J. Gundlach, and T.N. Jackson, J. Appl. Phys. **88** (2000) 6594.

[2] I.Tahi, K.Tsukagoshi, and Y. Aoyagi, Appl. Phys. Lett, **86** (2005) 103502.

[3] D. Knipp, R. A. Street, and A. R. Volkel, Appl. Phys. Lett. **82** (2003) 3907.

[4] M. Shtein. J. B. Benziger, and S. Forrest, APL. **81** (2002) 268.