Effect of dipole electric field on low-voltage pentacene thin film transistors

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Abstract

We report on low-voltage pentacene TFTs with a Al2O3/OTS as a gate dielectric. Improving device characteristics, we performed chemical modification of self-grown Al2O3 surface with an octadecyltrichlorosilane(OTS) self-assembled monolayer(SAM). As the result of this combination , the mobility was improved from 0.3 to 0.45 cm^2/Vs. In addition, we examined that the SAM dipole electric field have an influence on gate leakage current, transfer and output characteristics.

1. Introduction

The OTFT has merits in fabrication such as simpler processes and lower cost. For such reasons, new attempts continue today so as to apply OTFT technology to advanced electronic applications including flexible displays, RFID, and any other portable devices[1-7]. However, a major problem is that current devices require high voltages to operate. Researches to reduce the operating voltage have been continuously carried out[8-10].

Here we report on low-voltage pentacene TFTs with a Al2O3/OTS as a gate dielectic. We also self-assembled molecules of octadecyltrichlorosilane on the self-grown Al2O3 surface in order to modify the surface from hydrophilic to hydrophobic. We show that the surface treatment with OTS can be successfully applied to metal oxide.

2. Experimental

The fabrication processes were as follows. First, an aluminum gate electrode was deposited on the substrate through a metal shadow mask by thermal evaporation. Subsequently, the surface of the Al gate was oxidized by means of an O2 plasma process in order to grow as Al2O3 layer directly on the Al gate electrode. The O2 plasma process was carried out for 60min at 145mTorr pressure with 10sccm O2 flow rate and 150W power. After oxidation, octadecyltrichlorosilane was deposited by immersing films in 10^{-3}M OTS in cyclohexane at room temperature for 1h. A pentacene active layer was then deposited by thermal evaporation with a growth rate of 3Å/sec up to 450Å thickness at a substrate temperature of 80°C. Finally, source and drain electrodes were evaporated on the pentacene layer through a metal shadow mask, yielding bottom gate and top contact structures, as shown in Fig. 1.

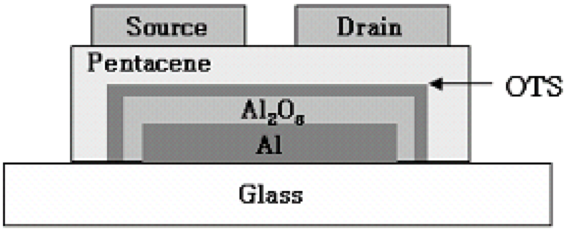


Fig. 1. The device structure of low voltage pentacene TFTs.

3. Results and discussion

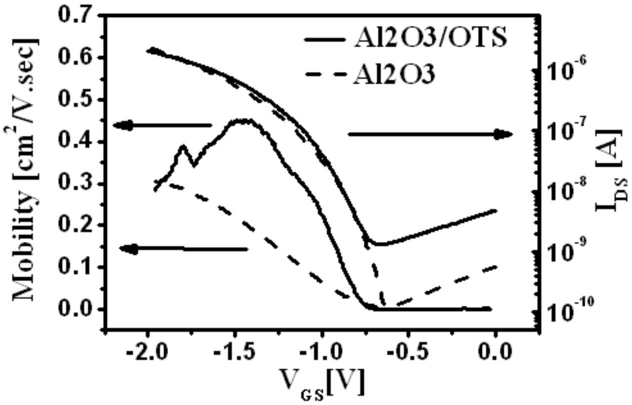
We examined the electrical characteristic variation after chemical modification of self-grown Al2O3 surface with an OTS self-assembled monolayer. Fig. 2 shows the mobility, transfer and output characteristics of pentacene-TFTs using Al2O3 and Al2O3/OTS gate dielectric. The field effect mobility was typically enhanced in case of Al2O3/OTS gate dielectric. The mobility characteristics have an influence on the drain saturation current. In the lower gate voltage region less than -1.75V, the drain saturation current of Al2O3/OTS gate dielectric was larger than that of Al2O3 gate dielectric. In the higher gate voltage above -1.75V, the drain saturation current of Al2O3 gate dielectric was less than that of Al2O3 gate dielectric.

The OTFT with Al2O3/OTS gate dielectric produced a larger off-stage current. In the output curve, the drain saturation current has a more convergent to 0A than that of Al2O3 gate dielectric. This is attributed to the gate leakage current. Fig. 3 shows the comparison of gate leakage current. In the negative gate voltage, the Al2O3/OTS gate has a lower gate leakage current which has an influence on convergence to 0A, but in the positive gate voltage, the Al2O3/OTS gate has a larger gate leakage current which has an influence on off-state current.

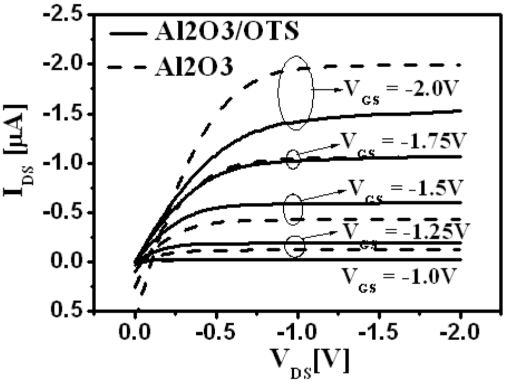
For the Al2O3 gate dielectric, the I-V curve was asymmetric along the positive and negative voltage axes. This is attributed to the work function difference between the Al and Au electrode, as shown in Fig. 4(a). However, for the Al2O3/OTS gate dielectric, the I-V curve was symmetric. This change in the I-V curve is attributed to SAM dipole electric field, as shown in Fig. 4(b).

TABLE 1. Summary of performance parameters extracted from OTFTs with Al2O3 and Al2O3/OTS gate dielectric.

Gate Dielectric	W/L	μ_{FET} [cm^2/V.sec]	I_{on}/I_{off}	SS [V/dec]
Al2O3	1025/60	0.3	2.2×10^4	0.1
Al2O3/OTS	1033/65	0.45	1.6×10^3	0.18



(a)



(b)

Fig. 2. Comparison of (a) mobility, transfer and (b) output characteristics of pentacene TFTs using ultra-thin Al2O3 and Al2O3/OTS gate dielectric.

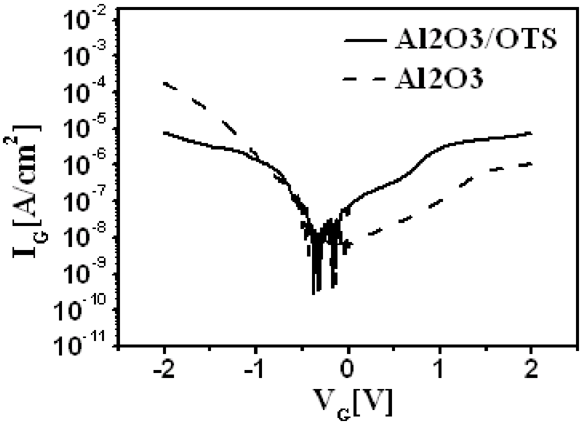
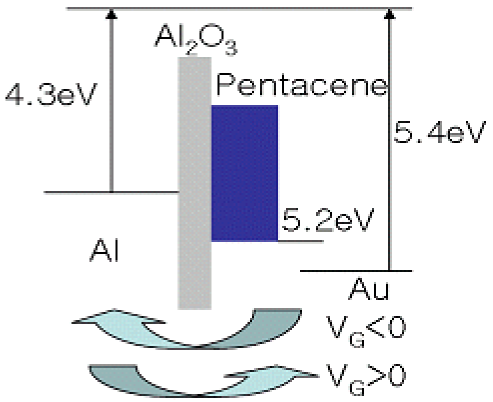
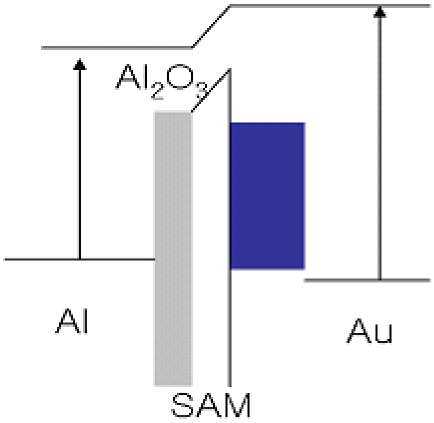


Fig. 3. Comparison of gate leakage current of pentacene TFTs using ultra-thin Al2O3 and Al2O3/OTS gate dielectric.



(a)



(b)

Fig. 4. Schematic Energy band diagram (a) for an Al2O3 gate dielectric and (b) for an Al2O3/OTS gate dielectric.

4. Summary

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We fabricated low-voltage pentacene thin film transistors with an Al2O3/OTS gate dielectric. Owing to the surface modification from hydrophilic to hydrophobic, the OTFT exhibit the mobility of 0.45cm^2/V.s. We find that the SAM dipole electric field effects on gate leakage current, transfer and output characteristics.

5. References

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