Improvement of source-drain contact properties of organic thin-film transistors by metal oxide and molybdenum double layer

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Abstract

The contact resistance between organic semiconductor and source-drain electrode in Bottom Contact Organic Thin-Film Transistors (BCOTFTs) can be effectively reduced by metal oxide/molybdenum double layer structure; metal oxide layers including nickel oxide (NiOx/Mo) and moly oxide(MoOx) under molybdenum work as a high performance carrier injection layer. Step profiles of source-drain electrode can be easily achieved by simultaneous etching of the double layers using the difference etching rate between metal oxides and metal layers.

1. Introduction

In spite of the great amount of research on the organic device, it is not enough for application such as organic thin film transistors (OTFTs), and organic lighting emitting devices (OLEDs), because of several technical hurdles including the mismatching between the work function of electrode and the energy level of organic semiconductors, which disturbs the carrier injection from electrode into organic layer. To improve the carrier injection property, it would be useful that the metal oxide layers were placed between the organic semiconductor and S/D electrode. [1, 2]

In the previous study, lift-off technique was used to pattern the MoO_x as the carrier injection layer.[1] However, this technique is not a convenient method for the mass production.

In this paper, we have introduced an effective technology to satisfy most of requirements for nice S/D electrodes as lower contact resistance, higher conductance of data-bus line and easier processibilty; metal oxide/metal double layer with one step etching can carry out performance improvements and process simplifications at the same time.

2. Experimental

We have fabricate bottom contact OTFTs with various source-drain metallization including Au single layer, Mo single layer with surface oxidation by O_2 plasma, MoOx/Mo double layers, and NiOx/Mo double layers as shown in Fig.1.

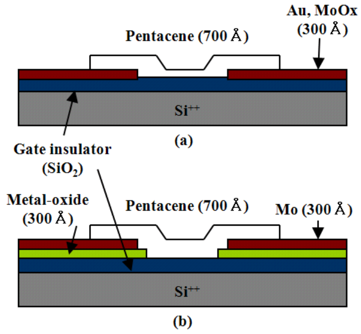

Figure 1. The device configuration of bottom-contact OTFTs with single metal layer (a) and metal oxide/Mo double layers (b).

Bottom contact OTFTs were fabricated on a heavily doped silicon wafers with a 300Å SiO_2 oxide layer. SiO_2 substrate was cleaned by acetone, methanol, and deionized water. In case of single metal layer, as shown in Fig. 1 (a), Au and Mo layer of 300Å thickness for source/drain electrode were deposited by a thermal evaporation and d.c sputter, respectively. For extrinsic MoOx layer on Mo surface, Mo layer was oxidized by O_2 plasma treatment. For the fabrication of double layers, as shown in Fig. 1 (b), MoOx and NiOx were deposited by thermal evaporation, followed by Mo layer deposition by magnetron sputter. After the formation of metal oxide/Mo double layers, thermal annealing was performed in 10^{-6} torr for 200℃, 1hr. After thermal annealing, all of the source-drain layers were patterned by the photo-lithography and wet etching with same chemical. Because the etching rate of MoO_x, NiO_x and Mo in room temperature were 0.7 Å/sec, 1 Å/sec and 5.46 Å/sec, respectively, metal oxide/Mo double layers can drive the step profile without additional process. Pentacene as a most common p-type organic semiconductor was deposited by thermal evaporation, keeping the rate of deposition as 0.2±0.1 Å/s in 10^{-6} torr and the substrate temperature as 80±1℃. Total thickness of the pentacene was 700±50 Å. The Channel width of 7500 ㎛ and the channel length of 5, 10 ㎛ is defined.

To extract the electrical properties, the performance of OTFTs was measured by the semiconductor parameter analyzer (HP4156) in dark spaced probe station

3. Results and discussion

Figure 2 shows the transfer characteristics of OTFTs with various source/drain electrodes.

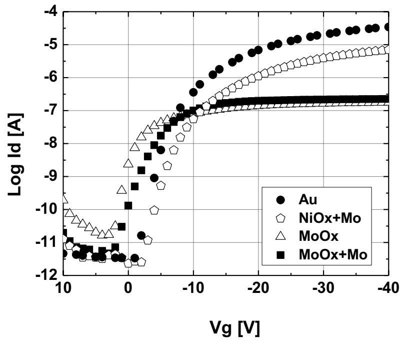

Figure 2. The electrical characteristics of OTFTs with Au, surface oxidized Mo, MoO_x/Mo and NiO_x/Mo double layered electrodes at V_D = - 20 V.

As shown in Table I, OTFTs with Au single layer and NiOx/Mo double layer present better field-effect mobility that with MoOx family, even though their work-functions are very similar.

Table I. Summary of the performance parameters for OTFTs.

L : 5 ㎛ W : 7500 ㎛	Vth (V)	S (V/dec)	μ ($cm^2V^{-1}s^{-1}$)
Au	-8.4	2.7	0.02
MoOx	1.4	1.2	$5 * 10^{-6}$
MoOx/Mo	-1.4	2.7	$1 * 10^{-5}$
NiOx/Mo	-8.7	2	0.005

Although the field-effect mobility of OTFTs with oxide layers is lower, other performances as threshold voltage and sub-threshold slope is better than those of reference device. This implies a better carrier injection property associated with metal work-function.

The work-function of various metals and metal oxides are given in Table II; work-function of metal-oxides are similar to that of Au layer and not too much different with HOMO level of pentacene as 5.2 eV.

Table II. Work functions of various S/D metals.

	Au[2]	Mo	MoO_x[2]	NiO_x[4]
Work function	5.1 eV	4.20 eV	5.3 eV	5.15 eV

4. Summary

We have studied OTFTs with various S/D electrodes materials as metal and metal oxides. The NiOx/Mo double layer for S/D electrodes gives best performance of OTFTs except for the mobility characteristic. The step profile of S/D electrodes by one step etching of metal oxide/Mo double layer can gives additional merits as good contact geometry and process simplification.

5. Acknowledgements

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6. References

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