
Low contact resistance a-IGZO TFT based on Copper-Molybdenum Source/Drain electrode

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Abstract

An interlayer (Mo) is introduced between the a-IGZO layer and Cu source/drain electrode to improve the contact property of the TFT. By applying the Mo interlayer, the effective contact resistivity and current transfer length is significantly decreased compared with the pure Cu source/drain electrode structure. Furthermore, Mo interlayer layer shows the potential in commercialization with its good adhesion and simple fabrication process.

Keywords: Copper electrode; Mo interlayer; a-IGZO; contact resistance

1 Introduction

TFT active-matrix is a key technology in display manufacturing such as AMLCD and AMOLED display. AMFPDs for the next generation require larger display area, higher resolution and faster response time, so the TFT technology is facing two major strategies: high mobility and low RC delay^[1]. For the high mobility requirement, amorphous Indium-Gallium-Zinc oxide (a-IGZO) TFT backplane is becoming a research hotspot because of its high mobility, good uniformity, low fabrication temperature and good compatibility to the a-Si:H production line^[2, 3]. For the low RC delay demand, copper (Cu) bus line should be a potential candidate due to its low resistivity that could reduce the RC delay significantly^[4-6]. As the reported work function of a-IGZO, Cu and Mo are 4.5eV^[7], 4.65eV and 4.5eV^[8] respectively, which are close thus will lead to low contact resistance (R_c). So it is reasonable to use Cu and Mo as the electrode for a-IGZO TFTs. Besides, Mo had no interfacial reaction with a-IGZO and the evolution of the electrical properties was barely noticeable^[9].

In this paper, low contact resistance Cu-Mo source/drain electrode TFTs were prepared. These TFT devices show low contact resistance (1072 Ω), short current transfer length (0.20 μm), and low effective contact resistivity (1.09 $\times 10^{-4}$ $\Omega\cdot\text{cm}^2$).

2 Experiment

The a-IGZO TFT structure is illustrated in Fig. 1. The fabrication process is given as follows. Firstly, a 300nm-thick Al gate was deposited on glass by DC sputtering and patterned by wet etching. Subsequently, the

film was anodized in the electrolyte consist of ammonium tartrate solution and ethylene glycol, forming a 200 nm-thick Al_2O_3 gate insulator on the Al gate ^[10]. Then, the a-IGZO film was deposited on Al_2O_3 by radio frequency (RF) magnetron sputtering and patterned by wet etching. Then, the device was annealed at 300 °C for 15 min. Finally, two types of S/D electrodes of Cu and Mo/Cu were deposited on the IGZO film respectively and patterned by the lift-off process. Samples with different channel length (L) were made to measure the contact resistance by the transmission length method (TLM) ^[11].

The interfacial structure between the S/D electrodes and a-IGZO was observed by high-resolution transmission electron microscopy (HRTEM). The electrical characteristics were measured in dark and room temperature using a semiconductor parameter analyzer (Agilent 4155C) with a probe station.

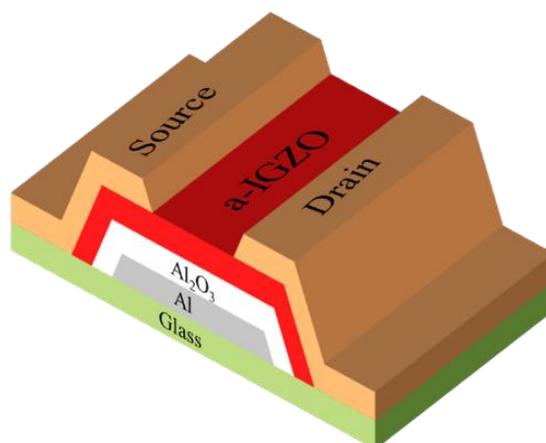


Fig. 1. Schematic of TFT structure

3 Results and Discussion

The transfer characteristics of the TFTs with different S/D electrodes are shown in Fig. 2 for devices with channel length (L) = 10 μm and width (W) = 100 μm , measured at drain-to-source voltages (V_{DS}) = 5.1 V. There is a positive shift of the turn-on voltage for pure Cu electrode samples. It is because that Cu diffused into the a-IGZO could be regarded as an acceptor that will decrease the carrier density in channel. We calculated the saturation mobility from the TFT transfer characteristics shown in Fig. 2. The TFT with pure Cu-Mo electrode has higher mobility (9.26 $\text{cm}^2\cdot\text{V}^{-1}\cdot\text{s}^{-1}$) compared to that with Cu electrode (8.43 $\text{cm}^2\cdot\text{V}^{-1}\cdot\text{s}^{-1}$). It might be attributed to the high resistance layer formed in the interface of Cu and a-IGZO.

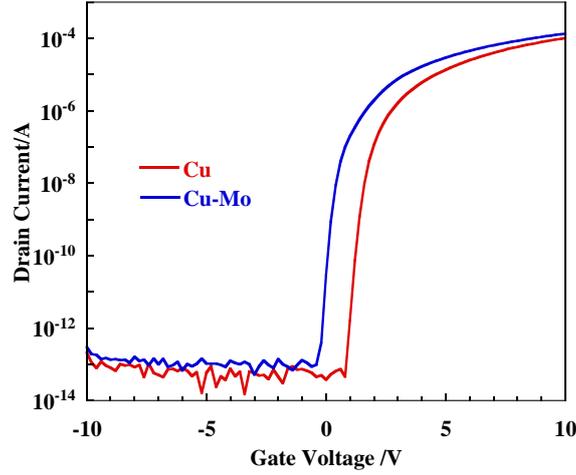


Fig. 2. Transfer characteristics of Cu and Cu-Mo electrode TFT

To evaluate the S/D contact performance of devices, TLM was adopted using a series of TFTs with different channel lengths. The total ON resistance (R_T) can be expressed as:

$$R_T = \frac{V_{DS}}{I_{DS}} = r_{ch}L + R_{DS} = r_{ch}(L_{eff} - 2L_T) + R_{DS} \quad (1)$$

Where r_{ch} is the channel resistance per unit channel length, R_{DS} is the series resistance at the S/D contacts. L_T is current transfer length; L_{eff} is effective channel length, as schematically shown in Fig. 3. V_{DS} fixed at 0.1V was used to exclude the space-charge-limited current, which can be observed at a higher drain voltage. When current flow from metal electrode into semiconductor in a limited area, If $d \gg L_T$, L_T can be reduced to:

$$L_T = \frac{R_{DS}}{2r_{ch}} \quad (2)$$

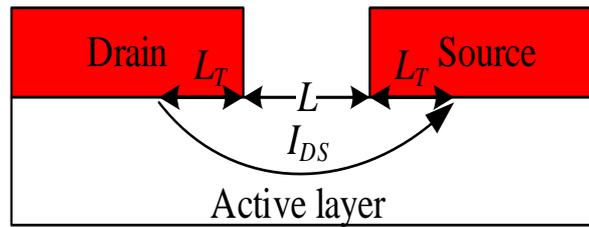


Fig. 3. Schematic of the current transfer length

For precise evaluation of the contact performance, effective contact resistivity R_{c-eff} are required which combined the contact area and resistance. It can be express as:

$$R_{c-eff} = \frac{R_{DS}L_TW}{2} \quad (3)$$

Fig. 4 demonstrates the variation of R_{DS} , r_{ch} , L_T and R_{c-eff} versus different V_{GS} for Cu-Mo and Cu S/D electrodes. TFTs with Cu-Mo electrode show lower contact resistance, shorter transfer length and lower effective contact resistivity. We presumed that Cu in the interface are oxidized which can rise the potential

barrier thus results in the high contact resistance. As shown in Fig. 4 (b), the channel resistance per unit length changed slightly, indicating the electrode materials have eligible influence on channel.

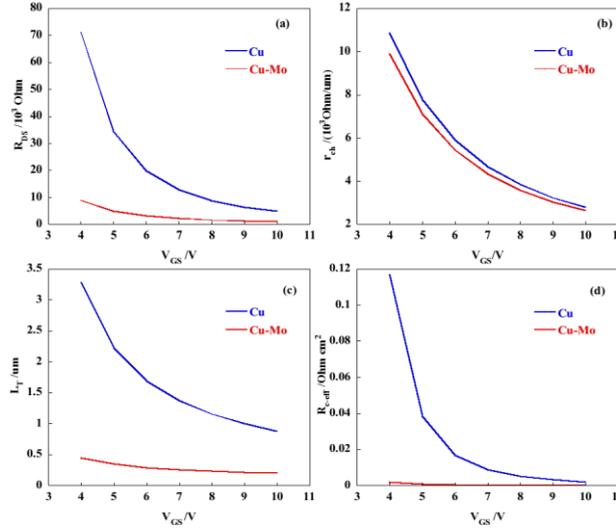


Fig. 4. Electrical contact performance comparison of Cu and Cu-Mo electrodes: (a) contact resistance R_{DS} ; (b) channel resistance per unit length r_{ch} ; (c) current transfer length L_T ; (d) effective contact resistivity R_{c-eff} .

The interfacial structures are observed by HRTEM, shown in Fig. 5. No interlayer can be found between Mo and a-IGZO while a 2 nm-thick layer is formed in the interface between Cu and a-IGZO. It implies that Mo can prevent the Cu oxidation on the interface with a-IGZO.

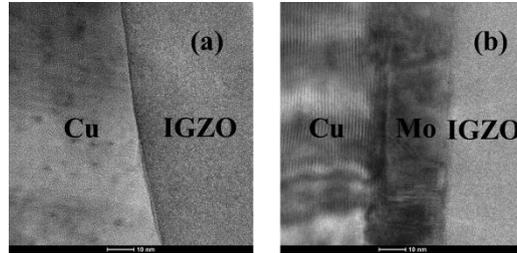


Fig. 5. Photographs of HRTEM in the interface between metal electrode and semiconductor (a) Cu/a-IGZO; (b) Cu/Mo/a-IGZO.

4 Conclusion

TFT devices with Cu-Mo Source/Drain electrodes show higher mobility and lower turn-on voltage. Through the R_c calculation by TLM and HRTEM images, it is concluded that the insert of Mo interlayer can improve the contact performance by preventing the formation of CuOx interlayer. It suggests the optimistic application potential of Cu-Mo electrode in the future advanced display.

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