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Mo-doped ZnO electrode for IGZO transparent thin-film transistor – Its hard-saturation behavior

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1. Introduction

Recently, transparent thin-film transistor (TTFT) is emerging as a candidate for the next display technologies [1]. One of the key issues is a transparent electrode, which can guarantee electronic performance as well as good transparency. The conventional transparent conductive oxide (TCO) is ITO (indium-tin oxide, 90:10, weight percent) [2]. However, the indium material is being exhausted, and higher priced, because of a limited amount and increased needs. A possible candidate is an oxide-metal-oxide (OMO), which shows outstanding advantages such as low resistivity, high transparency, and smooth surface roughness [3]. However, OMO has two shortcomings to be overcome in the side of electrode processing, namely, to find a reliable etching process and to reduce a contact resistance. In order to solve these problems, we will propose a metal-doped TCO, specially, Mo-doped ZnO. From the similar point of view, Delahoy and Guo reported that In_2O_3-based metal doped TCO had a low resistivity comparable to ITO, which could be fabricated by the reactive-environment, hollow cathode sputtering (RE-HCS) [4]. In this study, using the conventional DC and RF magnetron sputtering methods, Mo-doped ZnO electrode will be formed and applied to the top-gate indium-galium-zinc-oxide (IGZO)-TTFT.

2. Experimental results

As a potential candidate for ITO electrode in TTFT applications, Mo-doped ZnO could be fabricated by the co-sputtering method, where Mo was sputtered by DC magnetron sputter with a relatively low DC power (sputtering rate), and ZnO was deposited by RF magnetron sputter with much higher RF power, respectively. Additionally, the target to substrate distance was 8 cm in case of ZnO sputtering, while that in case of Mo sputtering was 15 cm. From these two conditions, the composition of Mo in ZnO film could be controlled from ~0.5 to ~10% even using the same size of sputtering targets (3 inches). Finally, it was very important that the sputtering chamber should not have any oxygen gases so as to form a metallic network of Mo in ZnO matrix.

Figure 1 shows the change of transmittance of Mo-doped ZnO thin films (100nm) as a function of DC power of Mo sputtering gun, namely, 15, 30, 45 W (at the constant RF power of 300 W in case of ZnO sputtering). The sputtering pressure was 5 mTorr, and Ar flow rate was 20 sccm. From the AES analysis, the composition of Mo in the zinc oxide films was ~ 2.7, ~ 6.0, and ~ 10.2 %, respectively. The transmittance decreased gradually with the amount of Mo material, as expected. The transmittances of Mo-doped ZnO films at 550 nm were 84, 78, and 71, respectively.

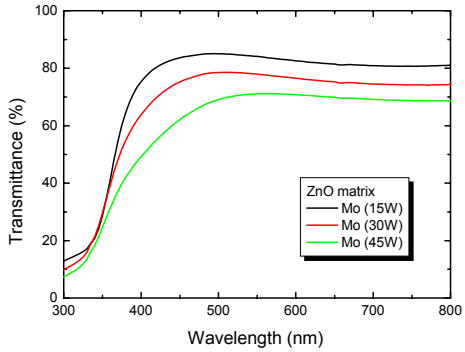

Fig. 1 Transmittance of Mo-doped ZnO films.

The resistivity of the Mo (30 W)-doped ZnO film was the lowest value among above three samples.

Figure 2 indicates the XRD results from the same films in figure 1. The peak intensity was the strongest in the sample of Mo (15 W)-doped ZnO, which sustains the basic structure of ZnO film. However, the remainder of (002) peak indicates the change of lattice parameter due to the insertion of Mo to ZnO matrix. There is a phase seperation between (002) peak and similar peak in the sample of Mo (30 W)-doped ZnO film, and there is some relationship between this phase separation and low resistivity.

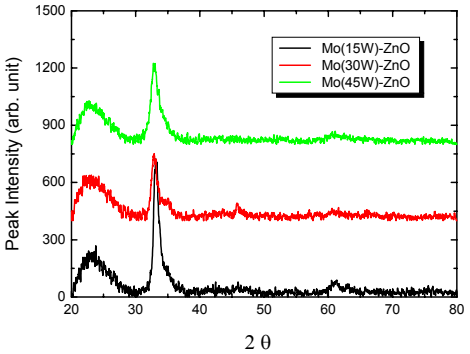

Fig. 2 XRD results from Mo-doped ZnO films

We coated Mo film with 2.3 nm thickness on the Mo-doped ZnO film (100nm) so as to improve the contact resistance bewteen source & drain electrode and active channel, or between metal pads. Addtion of this shallow Mo layer drove the transmittance to decrease from 78 to 60, but the sheet resistance decreased from 2150 to 400 Ω/□ .

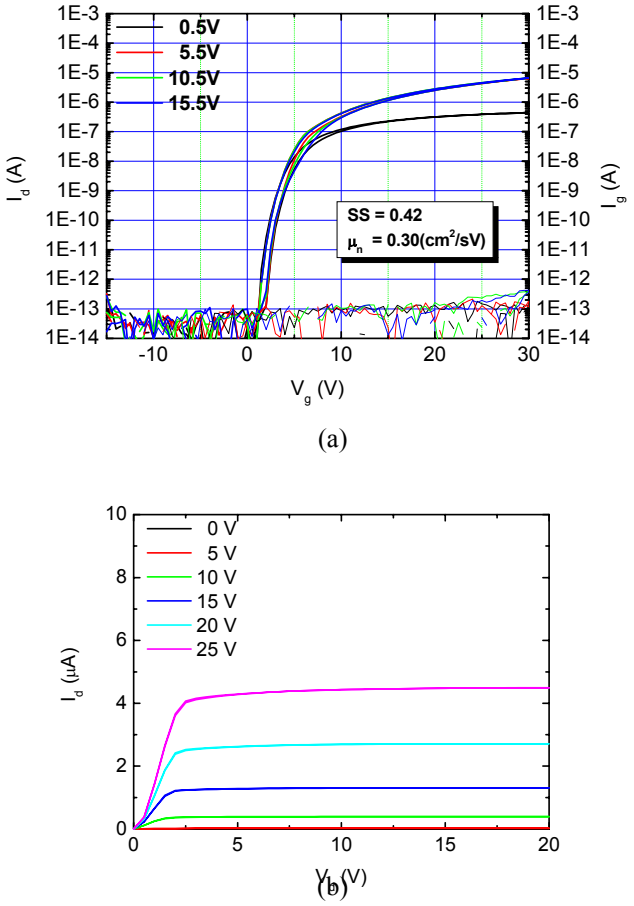

Figure 3. The electronic properties of IGZO-TTFT, where (a), and (b) illustrate the output curves [Id-Vd] for IGZO-TTFT and dc transfer characteristic [log(Id)-Vg] & gate leakage current [log(| Ig |)-Vg] curves of the optimized IGZO-TTFT, after the annealing process at 300℃-1 hour in O_2 ambient, respectively.

We used the Mo-doped ZnO electrode as the source & drain electrode for IGZO-TTFT. The IGZO semiconductor and AlO_x gate insulator were deposited as reported in elsewhere [5]. Figure 3-(a), and (b) illustrate the dc transfer characteristic [log(Id)-Vg] & gate leakage current [log(| Ig |)-Vg] curves of IGZO-TTFT, and output curves [Id-Vd], respectively. The transfer plot shows a drain current on-off ratio of ~ 10^7, a subthreshold-swing (SS) of 0.42 V/decade, and a saturated mobility of 0.30 cm^2/sV. The V_{on} was 1.3 V, and the hysteresis was ~0.8 V in the clockwise directon, meaning the electron trapping in the interface between channel and gate insulator. As shown in output curves of figure 3-(b), there are some contact resistance and hard saturation behavior even at the low drain voltage (~2 V). It is considered that this hard saturation behavior was caused by both the schottky barrier interaction and the resistance of Mo-doped ZnO electrode. The artificailly controlled hard saturation behavior can be used as a driving device for OLED, which operates by the method of current-driving.

3. Conclusions

In this study, Mo-doped ZnO electrodes could be fabricated successfully by the co-sputtering method in the non-oxydizing atmosphere. The top-gate IGZO-TTFT with Mo-doped ZnO electrode showed a hard-saturation behavior even at the low drain voltage (~2 V), which can provide effective applications, for example, OLED-driving.

Acknowledgements

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