Self-Aligned Top-Gate Zinc Oxide Thin Film Transistors Fabricated by Reactive Sputtering of Metallic Zinc Target

Meng Zhang, Zhihe Xia, Wei Zhou, Rongsheng Chen, Man Wong and Hoi-Sing Kwok
State Key Laboratory on Advanced Displays and Optoelectronics Technologies,
The Hong Kong University of Science and Technology, Kowloon, Hong Kong

Abstract
Self-aligned top-gate zinc oxide (ZnO) thin film transistors (TFTs) was fabricated by reactive sputtering of metallic zinc target. By optimizing deposition conditions, high-performance TFTs with a field effect mobility of 37.5 cm²/Vs and an on/off ratio of 3.8×10⁸ was obtained.

Author Keywords
Zinc oxide; thin film transistors; metal target; self-align.

1. Introduction
Metal oxide thin film transistors (TFTs) have made an impressive progress in display applications [1-2]. Compared to silicon-based films [3-4], the metal oxide film has a number of features such as transparent body and low temperature process [1-2]. Among different metal oxide material systems, zinc oxide (ZnO) [5] and its variation indium gallium zinc oxide (IGZO) [6] have been extensively investigated for the TFT application in a relatively short time. Compared to the polycrystalline ZnO film, the structure of the IGZO film is amorphous, resulting in better uniformity in the TFT applications across larger area panel. Nevertheless, the field effect mobility (μ_{FE}) of IGZO TFTs, only about 15 cm^2/Vs, is also limited by its amorphous structure [6]. Furthermore, the indium is a rare and toxic element [7]. Therefore, the ZnO film still has some particular advantages for generating high-performance and low cost TFTs in display applications.

The ZnO film are usually sputtered using ceramic targets [5]. Large targets are required to meet the increase of panel size in mass production lines [7]. However, it is difficult and expensive to fabricate the ceramic ZnO target with a large size. Furthermore, brittle ceramic targets are easily broken during sputtering process. Compared to the ceramic target, the metal target has no above issues. It is inexpensive, unbreakable and easy to make large. Therefore, metal zinc targets are more suitable for producing ZnO TFTs in mass production lines. However, until now only a few research works [7-8] have been performed on ZnO TFTs fabricated with metal zinc targets, and the performance of as-fabricated TFTs [7-8] cannot compete with ZnO TFTs fabricated with the ceramic ZnO target [5].

In this work, self-aligned top-gate ZnO TFTs are fabricated by reactive sputtering of the metallic zinc target. By optimizing the sputtering process, high-performance ZnO TFT with a μ_{FE} of 37.5 cm^2/Vs, a threshold voltage (V_{th}) of 1.87 V, a subthreshold swing (SS) of 0.26 V/dec and an on/off ratio of 3.8×10^8 is obtained.

2. Film Deposition and Characterization
ZnO thin films were deposited on both glass and silicon substrates utilizing radio frequency (RF) magnetron sputtering method. The metal zinc target with a 2-inch diameter was placed on the cathode. The O_2/Ar flow rate ratio (FRR) was varied from 1/9 to 1/1 with a fixed working pressure of 5mTorr. The input RF power density (p) was varied from 5.92 to 23.69 W/cm^2. The microstructures and the surface morphologies of ZnO films were evaluated by X-ray diffraction (XRD) and atomic force microscope (AFM).

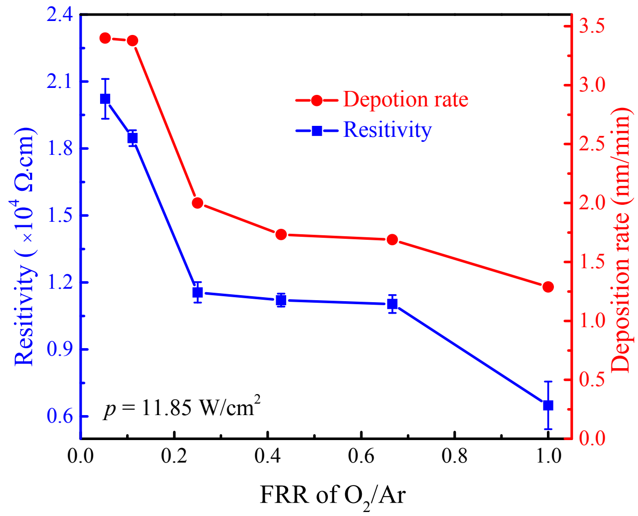

Figure 1. ZnO resistivity and deposition rate dependent on O_2/Ar FRR.

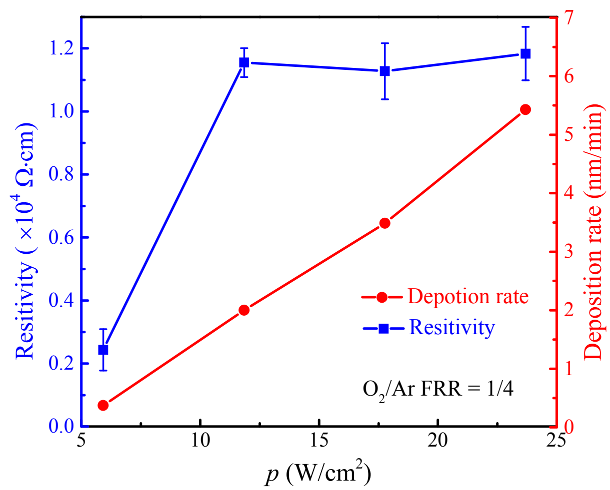

Figure 2. ZnO resistivity and deposition rate dependent on p.

Shown in Fig. 1 are resistivity (ρ) and deposition rate of deposited ZnO films dependent on O_2/Ar FRR at p = 11.85 W/cm^2. With the increase of the O_2/Ar FRR, the ρ of ZnO first decreases, then almost keeps constant and lastly decreases, which is different from the previous observations [7]. The deposition rate follows the similar trend. Shown in Fig. 2 are the ρ and deposition rate of deposited ZnO films dependent on the p at the O_2/Ar FRR = 1/4. With the increase of the p, the ρ first increases, then keeps a constant. For small p, oxidation of Zn seems unsufficient, resulting in the low ρ. The deposi-

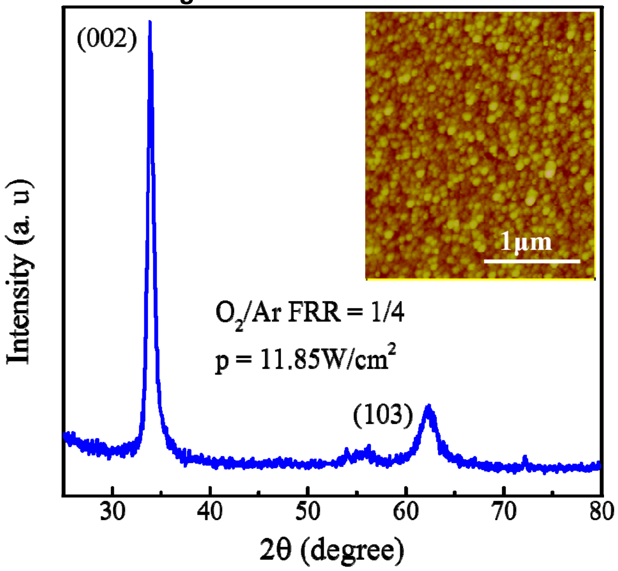

Figure 3. XRD spectra of ZnO film deposited at O_2/Ar FRR = 1/4 and p = 11.85 W/cm^2. The inset is its AFM surface morphology.

-tion rate has a linear dependence with the p. By comparing the XRD results and AFM images of different deposited ZnO films, the O_2/Ar FRR of 1/4 at p = 11.85 W/cm^2 gives the largest roughness and grain size, indicating the best crystallinity of the ZnO film, as shown in Fig. 3.

3. Device Fabrication and Characterization

Shown in Fig. 4 is the schematic of self-aligned top-gate ZnO TFTs. First, A 70 nm thick ZnO active layer was sputtered on the top of thermally oxidized silicon wafer by RF magnetron sputtering of a metal zinc target. The working gas ambient was a mixture of Ar and O_2. After patterning, the ZnO active layer was wet-etched. A 100 nm thick SiO_2 layer was deposited by plasma enhanced chemical vapor deposition as the gate dielectric, followed by a 100 nm thick tin oxide (ITO) sputtered as the gate electrode. Phosphorous ions at 80 keV with a dose of 5×10^{15} /cm^2 was implanted through the SiO_2 to form the S/D. After implantation, the SiO_2 layer covered on S/D was etched for TFT test.

Shown in Fig. 5 is the transfer curve of the ZnO TFT fabricated at the O_2/Ar FRR = 1/4 and p = 11.85 W/cm^2. The ZnO TFT exhibits a μ_{FE} of 37.5 cm^2/Vs, a V_{th} of 1.87V, a SS of 0.26 V/dec and an on/off ratio of 3.8×10^8, as summarized in Table. 1.

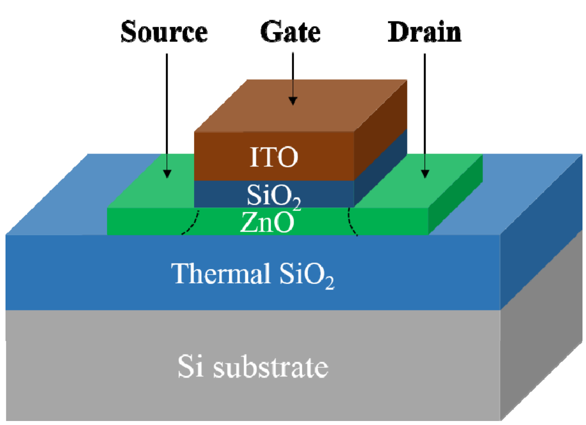

Figure 4. Cross-sectional schematic of self-aligned top-gate ZnO TFTs.

Table 1. Parameter comparison among different kinds of ZnO TFTs fabricated by sputtering of the metal zinc target.

	This work	Ref [7]	Ref [8]
μ_{FE} (cm^2/Vs)	37.5	7.4	1.5
V_{th}	1.87	5.9	15.9
SS	0.26	0.58	1.1
I_{on}/I_{off}	3.8×10^8	10^7	10^6

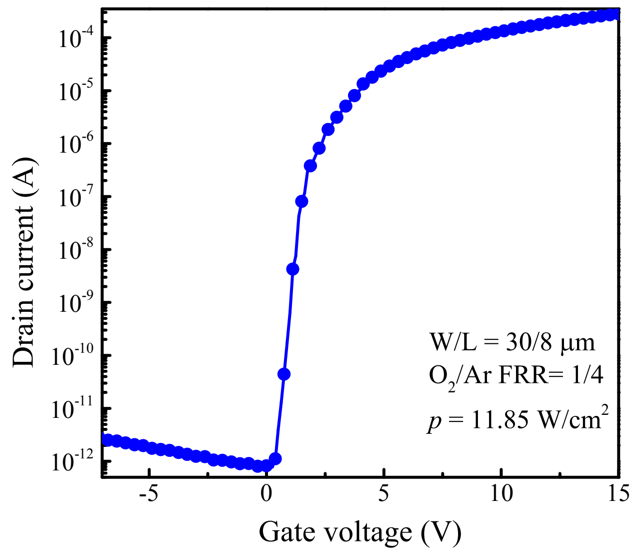

Figure 5. Transfer curve of ZnO TFT fabricated at O_2/Ar FRR = 1/4 and p = 11.85 W/cm^2.

4. Conclusion

In this work, self-aligned top-gate ZnO TFTs was fabricated by reactive sputtering of the metallic zinc target. Consistent to the film characterization, the best performance of ZnO TFTs is obtained at the FRR = 1/4 and the p = 11.85 W/cm^2.

5. Acknowledgements

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6. References

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