Al-Doped ZnO Thin Film Transistors by Thermal Evaporation

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Abstract

In this paper, Al-doped ZnO thin film transistors (AZO-TFT) were fabricated by the thermal evaporation growth of AZO channel layer on a silicon substrate at temperatures below 250℃. A SiO_2 dielectric layer grown by the horizontal furnace was used as a gate. An active layer thickness of 10nm was measured by Atomic Force Microscopy (AFM), and its surface had root mean square (rms) roughness 12.688 nm, and crystallize height between 81.081 nm ~ 41.285 nm.

Keywords: AZO, thin film transistors.

1. Introduction

Flat-panel displays (FPD) will replace traditional CRT dsiplays. The Transparent conductive oxide (TCO) films are widely used in solar cell, thin film transistor liquid crystal display (TFT-LCD) and sensors. High- performance TCO films used in LCD should have a high optical transmittance, high electrical conductivity and high on-off ratios. Indium tin oxide (ITO) is the most commonly used material, but indium (In) is toxic and expensive. Since Zinc oxide (ZnO) has a good visible light transmittance and electrical conductivity, it has the opportunity to replace the ITO material [1-3].

Zinc oxide is a direct wide-band gap II-VI n-type semiconductor material with the structure of wurtzite hexagonal structure. Zinc oxide has energy bandgap 3.37 eV and exciton binding energy of 60 meV at room temperature [1-4]. The conduction mechanism of ZnO is to pass between the oxygen vacancy and interstitial zinc of the shallow donor levels. The ZnO structure consists of one zinc atom and four oxygen atoms. Al atoms of Al-doped Zinc oxide replace zinc atoms to provide more free electrons, and therefore increase the conductivity [5]. In the Al-doped ZnO (AZO) thin film forming technologies, there are many kinds such as pulsed laser deposition (PLD), molecular beam epitaxy (MBE), thermal evaporation, metal-organic chemical vapor deposition (MOCVD), radio frequency magnetron sputtering, and etc. [1-5] The advantages of thermal evaporation method are simple process and low cost. AZO thin films studied in this paper use the thermal evaporation method.

2. Experimental

The devices Structure is a bottom gate thin film transistor (TFT) shown in Figure 1**.** The device structure consist of a p-type silicon substrate of <100> orientation, SiO_2, AZO granules (ZnO/Al=97/3 99.95 %) and aluminum (Al, 99.98 %) as shown in Figure 2.

First, a p-type wafer was treated with the RCA clean to remove surface particles and metal ion contamination. Next, a 100 nm SiO_2 of gate dielectric layer was grown by the wet oxidation in the high temperature horizontal furnace. After the reactive ion etch (RIE) was used to remove the backside 100 nm SiO_2, the standard clean was then followed to prevent surface contamination. Then, a 10 nm AZO channel layer was formed by using the granules and thermal evaporation process. Finally, the final bottom Al gate was formed by using thermal evaporation, and then the Al for source and drain on the top was deposited and defined. The AZO thin films surface roughness was measured by Atomic Force Microscopy (AFM).

3. Results and Discussion

The AZO thin film surface flatness and roughness are analyzed by AFM. We can see that AZO thin films by AFM scanning conditions are shown in Figure 3(A) and Figure 3(B). The surface roughness and the uneven distribution of AZO grains are measured by scan size of 2 um * 2 um, scan rate 1.489 Hz and data scale 150 nm as shown in figure 3(C). The root mean square (rms) roughness of the AZO thin-film is 12.688 nm, and the section analysis of two size of crystallization measured in the background is shown in figure 3(D). Red points are the highest and lowest point of the underlying gap 81.081 nm, and the underlying gap of green points is 41.285 nm.

The AFM analysis revealed that AZO thin film surface roughness quality is not very good. If it is used as a channel layer, it will affect the carrier transport due to reduced poor electrical mobility. At present, we think that the thermal evaporation deposition rate is too fast, or the vacuum value is not enough.

4. Conclusion

The thermal evaporation is feasible for making for AZO thin film transistors. Although the surface roughness measured in this experiment is too high. We will drop the deposition rate of thermal evaporation process by improving the vacuum value so that the surface roughness can be significantly improved to enhance device performance. The next experiment will focus on changing the device structure or materials applied to improve the overall performance.

Finally, by using different types of substrates such as polymer, it can concentrate in the mainstream of flexible thin film transistors.

5. Acknowledgements

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6. References

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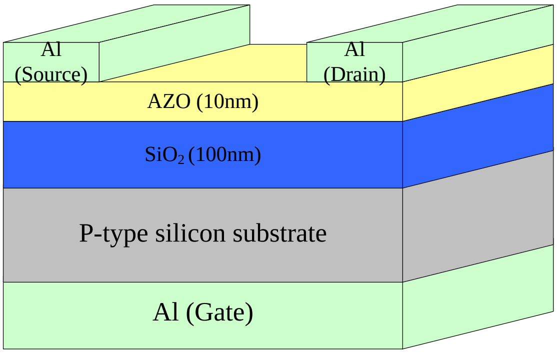


Figure 1. Bottom gate AZO-TFT.

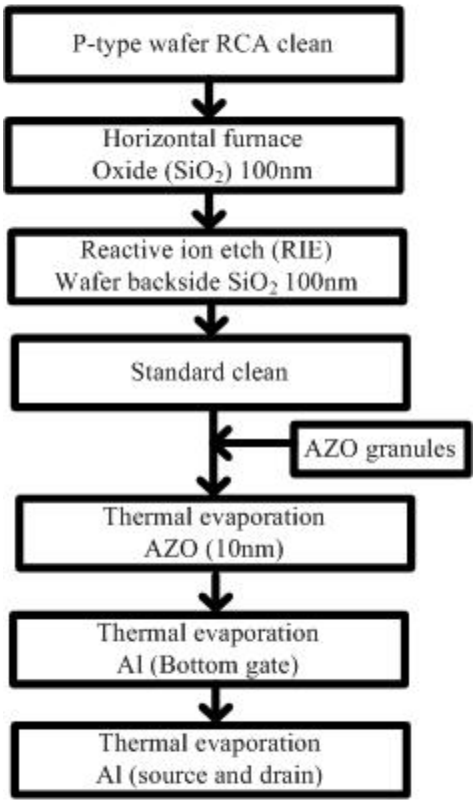
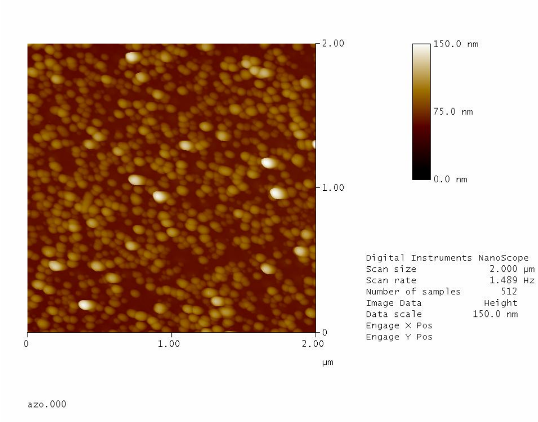
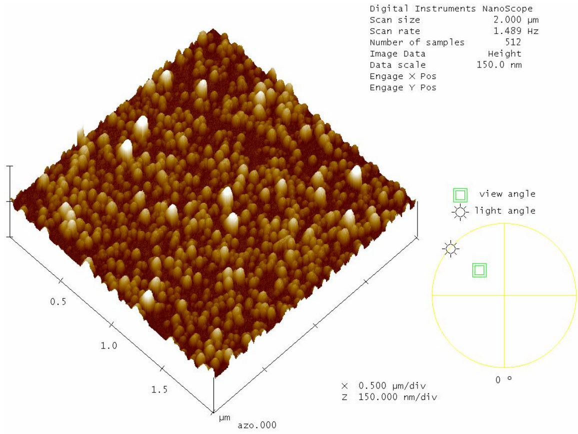


Figure 2. The thermal evaporation process used for the preparation of AZO-TFT.

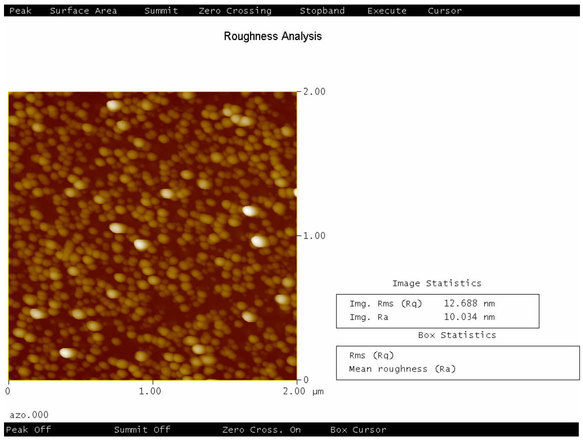
(A)



(B)



(C)



(D)

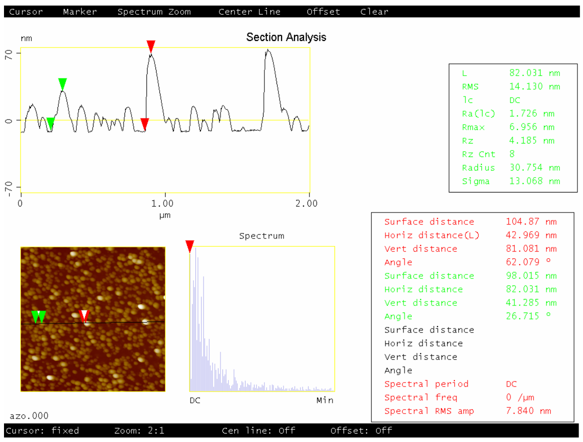


Figure 3. The AFM surface analysis: (A) scan rate= 1.489 Hz and data scale= 150 nm, (B) scan size of 2 um * 2 um top view, (C) rms=12.688 nm, (D) crystallize height 81.081 nm ~ 41.285 nm.