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The bias-crystallization mechanism on structural characteristics and electrical properties of Zn-In-Sn-O film

K. J. Chen[1], F. Y. Hung[2,4*], S. J. Chang[3], T. S. Lui[4], S. P. Chang[3], Z. S. Hu[3], T. P. Chen[3], T. Y. Liao[3]

[1]Institute of Nanotechnology and Microsystems Engineering, The Instrument Center, National Cheng Kung University, Tainan 701, TAIWAN
[2]Institute of Nanotechnology and Microsystems Engineering, Center for Micro/Nano Science and Engineering, National Cheng Kung University, Tainan 701, TAIWAN
[3]Institute of Microelectronics & Department of Electrical Engineering, Center for Micro/Nano Science and Engineering, National Cheng Kung University, Tainan 701, TAIWAN
[4]Department of Materials Science and Engineering, National Cheng Kung University, Tainan 701, TAIWAN
[5]Institute of Electro-Optical Science and Engineering, Center for Micro/Nano Science and Technology, National Cheng Kung University, Tainan 701, TAIWAN

[*]Corresponding author Email: fyhung@mail.ncku.edu.tw

1. Introduction

Annealed can improve the electrical properties of TCO films, but higher temperature may result in the deterioration of film crystallization [1-2]. In addition, some TCO films were treated by plasma ions bombarded to enhance the film conductivity [3-4]. However, the above treatments consumed more power and needed expensive equipments.

The application of bias-crystallization mechanism (BCM) was a familiar technology that has been used in different fields in the past, such as electrical discharge machining [5], welding [6] and drawn wire [7]. Notably, the post-treatment of TCO film using a biasing technology has still not studied, and in particular, BCM process at room temperature is worthy of further investigation. In this work, ZITO/In samples were treated by biasing technology to adjust the quality. The effects of the bias-crystallization mechanism (BCM) on ZITO film were investigated to understand the contribution of ions diffusion. In addition, the efficiencies of BCM and the annealed in the furnace were discussed.

2. Experimental procedure

The ZITO/indium double layers were deposited onto the glass substrate. Firstly, the indium layer of 600 nm thickness was deposited by the DC magnetron sputter deposition as the current transmittal layer. And then, the 160 nm ZITO film was performed at a pressure of 1.9×10^{-1} pa by RF power of 80 W (for ZnO target) and DC power of 40 W (for ITO target) using co-sputtering system (ULVAC/Model ACS-4000-C3) [8]. **Figure 1** shows the schematic illustration (Cross-section view and top view) and the photograph of bias-crystallization mechanism (BCM) for ZITO film. The positive and negative poles were sited on the middle edge of the indium layer, respectively. The electrical current passed through from positive pole to negative pole via the indium layer (impedance).

3. Results and discussions

Table1 shows the resistivity of ZITO/In samples under the different biasing duration (0~30 min). The resistivity of un-biased ZITO film was 3.08×10^{-4} Ω*cm. As the biased of 4 V for 10 min, the resistivity of ZITO film reduced to 1.24×10^{-4} Ω*cm. With increasing the biasing duration, the film resistivity gradually reduced and then had a stable value after biasing duration of 20 min. This result shows the BCM can promote the indium atoms to diffuse into upper ZITO film. Additionally, the reduction of film resistivity may attribute to the improvement of ZITO crystallization by BCM. The un-biased ZITO/In sample and the ZITO/In sample with biased of 4 V for 20 min were subjected to XRD analysis as shown in **Figure 2**. After biased, the intensity of In_2O_3 and In phases substantially decreased. The main reason is that the BCM caused the indium to form In_2O_3 structures and embedded into ZITO matrix, and deteriorated the crystallization of ZITO/In sample.

The depth profile of the elements distribution for un-biased and biased ZITO/In film (4 V for 20 min) was performed using SIMS (**Figure 3**). After biased (**Figure 3 (b)**), the variation of all elements distribution mainly occurred in the surface (Zone II) and the interface (Zone I) between ZITO film and indium layer. In zone I, it clearly showed that the content of zinc, indium and tin ions in the bottom film region had increased. In particular, the variation of zinc ions was more obvious, and its diffusion path was about 50 nm. The variation of zinc, indium and tin ions content in zone II (in surface region) was affected and their diffusion path was about 38 nm. These results were attributed to the BCM. In addition to indium layer, BCM also caused the migration of other metal atoms. Due to micro SnO_x phases combined with In_2O_3 phases easily, some tin ions had diffused from interface region into ZITO matrix. [8-9].

The film resistivity and required power of conventional annealing treatment (annealed at 500 °C for 20 min) were compared with that of the biased ZITO/In sample (**Figure 4**). Considering the energy for both treatments, the energy of the annealing and biasing treatments was estimated, respectively. As a result, the required energies of annealing and biasing treatment were calculated using the Joule's law, and the value was about 9.8×10^{6} J and 4.8×10^{2} J, respectively. In short, the consumed energy of BCM not only was greatly reduced but also acquired a better film conductivity.

4. Conclusion

ZITO films were deposited onto indium/glass substrate by co-sputtering system, and then successfully was enhanced ZITO conductivity by BCM for a short time. The BCM mainly caused indium diffusion resulting in the increment of carrier concentration and enhanced film conductivity. After BCM, the In_2O_3 phases reduced the crystallization of ZITO/In structure. From SIMS analysis, the metal atoms diffused associated with BCM. Under the same post-treated duration (20 min), the resistivity of ZITO film with the biased of 4 V was lower than that of the thermal annealed of 500 °C. The BCM possessed excellent save energy and low temperature applications.

Acknowledgements

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References

[1] C. G. Huang, M. L. Wang, Z. H. Deng, Y. G. Cao, Q. L. Liu, Z. Huang, Y. A. Liu, W. Guo and Q. F. Huang: J. Mater. Sci.-Mater. Electron. **21** (2010) 1221-1227.

[2] K. J. Chen, F. Y. Hung, Y. T. Chen, S. J. Chang and Z. S. Hu: Mater. Trans. **51** (2010) 1340-1345.

[3] J. M. Lee, K. K. Kim, S. J. Park and W. K. Choi: Appl. Phys. Lett. **78** (2001) 3842-3844.

[4] J. S. Park, J. K. Jeong, Y. G. Mo, H. D. Kim and S. I. Kim: Appl. Phys. Lett. **90** (2007) 262106.

[5] O. Yilmaz and M. A. Okka: Int. J. Adv. Manuf. Technol. **51** (2010) 185-194.

[6] H. G. Dong, L. Q. Yang, C. A. Dong and S. D. Kou: Mater. Sci. Eng. A-Struct. Mater. Prop. Microstruct. Process. **527** (2010) 7151-7154.

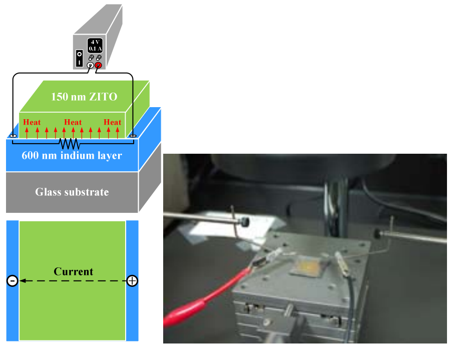
[7] K. R. Narayanan, I. Sridhar and S. Subbiah: Comput. Mater. Sci., 49 (2010) S119-S125.

[8] K. J. Chen, F. Y. Hung, S. J. Chang, S. P. Chang, Y. C. Mai and Z. S. Hu: J. Alloy. Comp. **509** (2011) 3667-3671.

[9] K. J. Chen, F. Y. Hung, S. J. Chang and Z. S. Hu: Appl. Surf. Sci. **255** (2009) 6308-6312.

Table 1 The relation of biasing duration and film resistivity under the biasing voltage of 4 V with 0.1 A

Biasing duration (min)	**As-grown**	**10**	**20**	**30**
Resistivity (Ω*cm)	3.1×10^{-4}	1.2×10^{-4}	6.6×10^{-5}	6.3×10^{-5}



(a) (b)

Figure 1 (a) The schematic illustration and (b) the photograph of bias-crystallized for ZITO film.

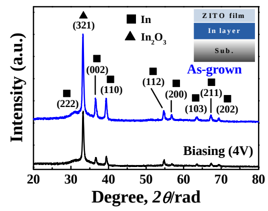
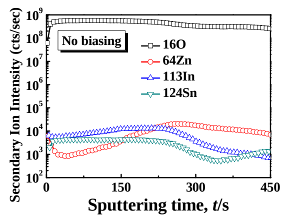
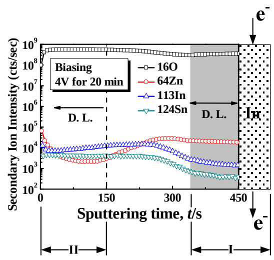


Figure 2 XRD patterns of un-biased ZITO/In sample and ZITO/In sample with biased of 4V.



(a)



(b)

Figure 3 SIMS depth profile of ZITO/In samples: (a) un-biased and (b) after biased of 4 V for 20 min (D.L. = Diffusion Layer).

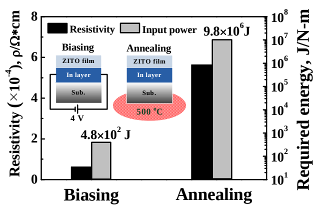


Figure 4 Schematic illustration for resistivity and required energy of ZITO/In film with different treatments.