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Effects of Rapid-Thermal Annealing on Resistive Switching of ZnO/Ti/ZnO RRAM Deposited on Flexible PEN Substrate

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1.Introduction

Nonvolatile resistive RAM (RRAM) has been considered as the one of the most potential candidtes for next generateion of memroy devices because of the simple structure, low power consumption, and high endurance [1-3]. This work investigates characteristics of Ti-inserted ZnO RRAM and the effects of RTA teeatment on the stacked structure of ZnO/Ti/ZnO RRAM deposited on flexible PEN substrate. The RTA is the post metal annealing (PMA). The characteristics of resistance ratio of high resistance state (HRS) and low resistance state (LRS), and endurance are improved by the PMA treatment. In addition, the retention of the RRAM can pass the 10 years of lifetime projection. The swithcing mechanism is also investigated in this work.

2.Experimental

Figure 1 shows the schematic of the Al/ZnO/Ti/ZnO/Al stack structure RRAM device, which is fabricated on poly(ethylene 2,6-naphthalate) (PEN) substrate. First, PEN substrates were cleaned with DI water, acetone and isopropanol. Next, a 100-nm-thick Al bottom electrode was deposited. Then, a 25-nm-thick ZnO layer, a 5-nm-thick Ti layer and a 25-nm-thick ZnO layer were deposited in sequence. The ZnO film was deposited using a ZnO target (99.99% purity) in an O_2 gas flow ratio of 33% [O_2(12sccm) / [Ar(24sccm) + O_2(12sccm)]. After that, a 100-nm-thick Al top electrode was deposited and patterned with a shadow mask with a diameter of 200 μm. The samples were divied into two groups. One is the as-deposited sample (or without PMA); the other group was treated by the PMA at 80℃ in 30 min in N_2 ambient.

3.Results and Discussion

Figure 2 shows the I-V curve of RRAM without and with PMA at various switching cycles. It can be seen that the sample after PMA treatment reveals larger resistance ratio of HRS/LRS, and there is no obvious degradation on the V_{SET} after switching. **Figure 3** shows SEM image of ZnO/Ti/ZnO RRAM without and with PMA. More dense strucure was obsrved in the PMA sample, and the PMA reduces the leakage current and thus increases the resistance ratio. **Figure 4** and **5** show the I-V cruve of the samples without and with PMA treatment, respectively, in logarithm scale from the **Fig. 2**. The slope of sample without and with PMA at low voltage (<2V) including LRS and HRS are near 1, which indicates the ohmic conduction mechanism [4,5]. The slope at high voltage region are 1.7 and 2.67 for without and with PMA samples, respectively. This is the space charge limit current (SCLC) mechanism [6,7]. Additionally, the PMA sample possesses the deeper oxide traps in the stacked structure at HRS state. Switching endurance cycles of the RRAM without and with PMA are compared and the sample with PMA treatment reveals higher endurance (216 vs. 83) and larger resistance ratio, as shown in **Figure 6**. **Figure 7** shows the cumulative distribution function (CDF) of the ZnO RRAM with and without PMA tretament. Higher resistance and little wider distribution for the HRS state were observed after PMA treatment. The retention characteristics of the sample without and with PMA are shown in **Figure 8** and **9**, respectively. The retention can pass 10 years of lifetime projection for the two group samples. **Figure 10** and **11** show the box plot of set/reset voltage and HRS/LRS resistance, respectively. Smaller set/reset voltage and larger resistance ratio of HRS/LRS were observed for the sample with PMA treatment. **Table I** shows the yield percentage of the ZnO RRAM with and wihtout PMA after switching cycle testing. The sample with PMA treatment reveals superior yield for the samples swithed cycle (from LRS->HRS->LRS) more than 5 times. Thus, the PMA will change the microstructure and it is beneficial for the RRAM swithcing.

The resistance switching mechansim is related to the conductive filament (or oxide traps or vacancies). **Figure 12** shows flicker noise (low frequency noise, LFN) of the ZnO RRAM with and without PMA treatment. The noise is larger for the samples without PMA. And the slope is larger for the PMA sample. From the LFN analysis, the RRAM possesses smaller fialment diamenter and deeper oxide traps in the stacked film [8,9], leading to the better RRAM characteristcis. The proposed switching model is shown in **Figure 13** for the ZnO RRAM with and without PMA treatment. The PMA treatment is beneficial to improve the characteristics of the ZnO/Ti/ZnO stacked structure RRAM.

4.Conclusion

This work investigates the effects of RTA teeatment on the stacked structure of ZnO/Ti/ZnO RRAM deposited on flexible PEN substrate. The CDFs of the Ti-inserted stack RRAM reveal superior characteristics for w/ and w/o PMA treatment. Additionally, the sample with PMA treatment reveals larger endurance and superior yield, and the retention can pass 10 years of lifetime projection. Thus, the PMA will change the microstructure and it is beneficial for the RRAM swithcing. The resistance switching mechansim was proposed and it is related to the conductive filament (or oxide traps or vacancies).

Acknowledgements

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References

[1] Nuo Xu et. al., Applied Physics Letters (APL) 92, 232112 (2008).
[2] Lee, S et al., Applied Physics Letters, 95(26), 262113 (3pp) (2009).
[3] Yongbian Kuang, et al.,*IEEE EDL*, 31(7), pp.758-760 (2010).
[4] Xinjun Liu et al., Electrochem. Solid-State Lett., 14(1), pp. 9-12 (2011).
[5] Seungjae Jung et al., JECS, 157 (11), pp. 1042-1045 (2010).
[6] Seul Ki Hong et al., J. Appl. Phys., 110, 044506 (2011).
[7] Hee-Dong Kim et al., IEEE EDL 32(8), pp. 1125-1127 (2011).
[8] Daeseok Lee et al., IEEE TED, 32(7), pp.964-966 (2011).
[9] Daeseok Lee et al., IEEE Trans. Nucl. Sci., 58(6), pp.3317-3320 (2011).

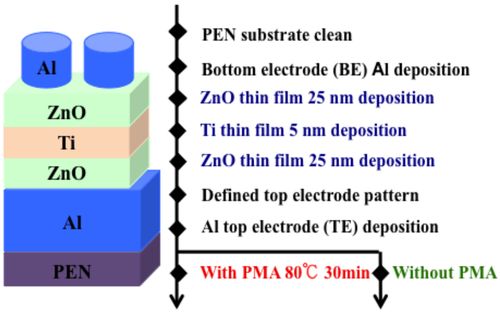

Fig. 1 The structure of Al/ZnO/Ti/ZnO/Al with and without PMA treatment, and sample preparation process steps.

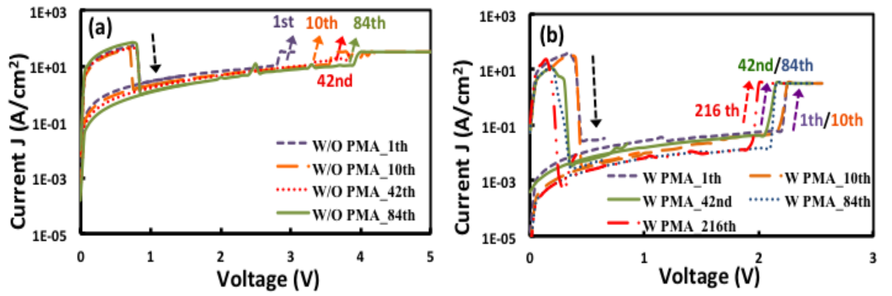

Fig.2 Current versus voltage (I-V) characteristics of ZnO/Ti/ZnO RRAM (a) without and (b) with PMA treatment at various swithcing cycles . A current compliance of 1 mA is used for the dc sweep from HRS to LRS.

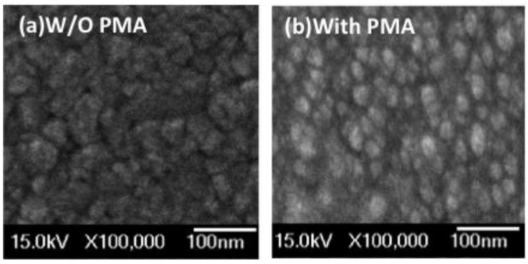

Fig.3 SEM plane view images of ZnO/Ti/ZnO/Al structure (a) without and (b) with PMA treatment.

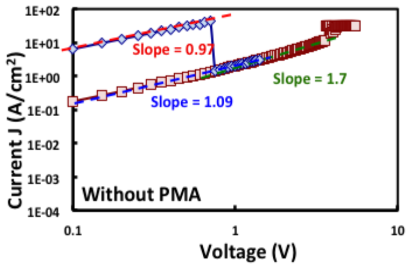

Fig.4 Current transport behavior of Al/ZnO/Ti/ZnO/Al RRAM without PMA treatment.

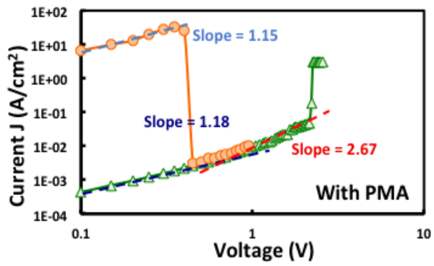

Fig.5 Current transport behavior of Al/ZnO/Ti/ZnO/Al RRAM with PMA treatment.

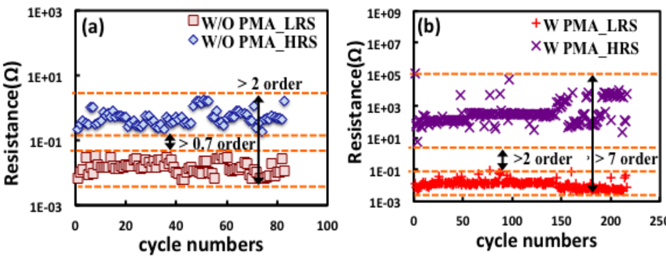

Fig.6 Switching endurance characteristics of Al/ZnO/Ti/ZnO/Al RRAM (a) without and (b) with PMA treatment, and the endurance cycles are 83 and 216, respectively.

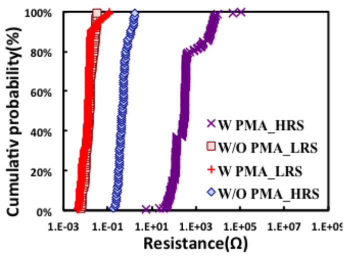

Fig.7 Cumulative distribution of high and low resistance state (HRS and LRS) of RRAM at reading voltage of 0.1V.

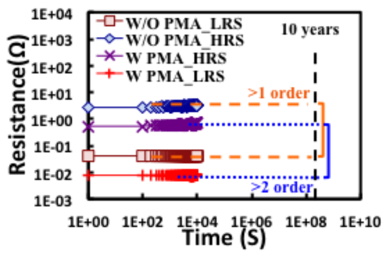

Fig.8 Retention characteristics of HRS and LRS of both structures at reading voltage of 0.1V. No stress voltage was applied in retention measurement.

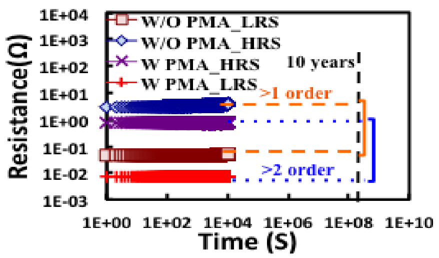

Fig.9 Retention characteristics of HRS and LRS of both structures at reading voltage of 0.1V. The sample was applied at 0.1V in retention measurement.

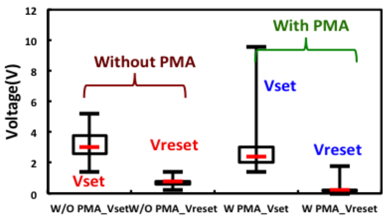

Fig.10 Box plot of the set and reset voltages of Al/ZnO/Ti/ZnO/Al RRAM with and without PMA treatment.

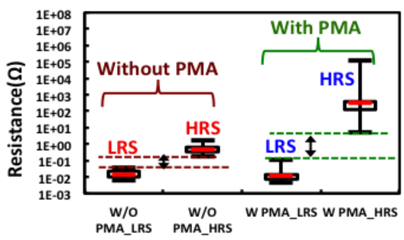

Fig.11 Box plot of the HRS and LRS of Al/ZnO/Ti/ZnO/Al RRAM with and without PMA treatment.

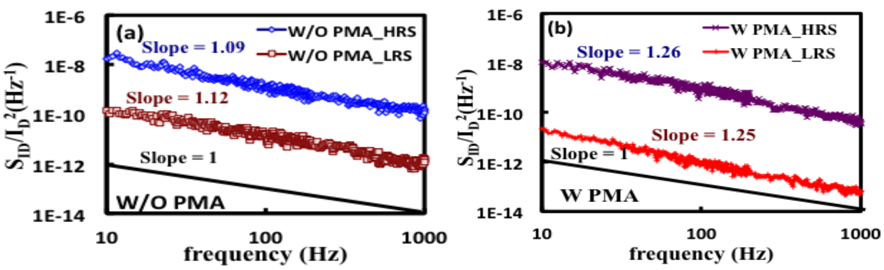

Fig.12 Flicker noise (LFN) of Al/ZnO/Ti/ZnO/Al RRAM (a) without and (b) with PMA treatment.

Table.1 Yield percentage of Al/ZnO/Ti/ZnO/Al RRAM with and without PMA treatment.

Sample	Yield					
	Switching More than five times			Switching More than one time		
	Usable	Total	Percentage	Usable	Total	Percentage
With PMA	10	11	91%	10	11	91%
Without PMA	17	40	42.5%	36	40	90%

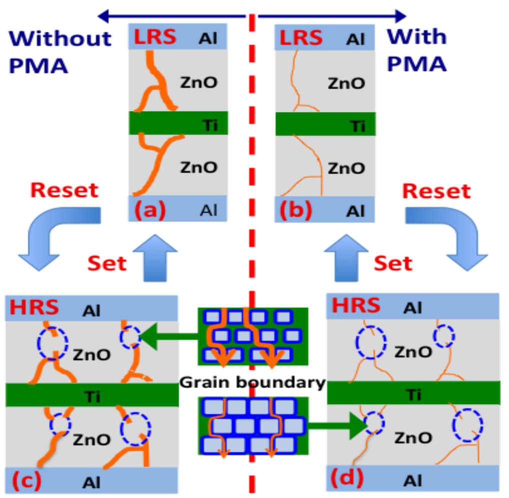

Fig.13 Schematic switching mechanism of Al/ZnO/Ti/ZnO/Al RRAM.(a) without and (b) with PMA treatment.