Resistance Switching Enhancement in Multi-step Deposition by Multi-deposition and Multi-anneal

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Abstract

In this paper, we present the enhanced performance of resistive RAM devices with multi-step deposited and annealed oxides. By using multi-step deposition and low temperature multi-step annealing, forming-free Re-RAM is achieved with lower operation voltages and larger resistive ratio than those of conventional Re-RAM with typical single deposited oxide.

1. Introduction

Re-RAM(Resistive Random Access Memory) has been extensively studied from the 1960s to early 1980s for memory devices.[1] Resistance switching indicates two states of different resistivity between high-resistance state(ON state) and low-resistance state(OFF state). This switching effect has been observed at sandwich structure with chalcogenides, semiconductors, binary oxides[2], nitrides, fluorides, polymerized films, and organic films.[3] Resistance switching effect was also observed in the doped perovskite materials and ferroelectric material lately.[4] However these materials have complicated crystal structures and stoichiometry. Re-RAM process competes with the conventional CMOS process. For example, no other dedicated facility or process, non-volatility, low power, high density, high temperature performance and multi-bit operating memory compare with CMOS.

2. Experimental

Metal-Insulator-Metal(MIM) structure memory devices were fabricated on p-type silicon substrate. It has Pt/ binary oxide(TiO_2)/ Pt structure. TiO_2 was deposited by RF magnetron sputtering methods under the base pressure of 1.0×10^{-6} Torr. For the complete curing of the oxygen vacancy in a deposited oxide, multi-step deposition and annealing was conducted Fig. 1 shows fabrication procedures for MIM structures by single-step deposition method and multi-step deposition method. For the multi-step oxide, thermal treatment for every thin single layer was performed by using a furnace at 250℃ for 30min in oxygen ambient. After top Pt electrode deposition, both single- and multi-step deposited samples were annealed by Rapid Thermal Anneal(RTA) techique at 800℃ for 30sec in N_2. Spectroscopic ellipsometry was used to measure the film thickness of binary oxide. The current-voltage (I-V) characteristics were measured by a semiconductor-parameter analyzer (HP4155A).

3. Results and Discussions

Fig. 2 presents the X-ray diffraction (XRD) spectra of Ti02 thin films on Pt/ Si substrate, which were deposited by single- and multi-step methods with final RTA at 800℃ for 30min with N_2. Both binary oxide thin films have the same structure due to the final high temperature treatment even though both samples were deposited with different methods.

Typical reversible resistance switching characteristics of single-deposited TiO_2 including the electro-forming process are shown in Fig. 3. To initiate resistance switching phenomena, voltage sweep was performed up to 8V where sudden increase of current flow appears. Current was limited by 0.01A for a soft breakdown, and this process is called an eletro-forming process. If voltage is applied to the same sample after the electro-forming process, current increases with low resistance state. But it suddenly decreases with negative resistance, and then current will slightly increase and hard breakdown will finally happen. If voltage stress is cutted off soon after negative resistance, the dielectric will recover again. This process called a reset process. For the coming sweep, the current increases slowly till breakdown with higher resistance value. The breakdown of the set process can also be limited at a certain current value like forming process. After the electro-forming process, these well-known reset (low resistance state) and set (high resistance state) processes can be repeated and can be used as memory states.

However, Re-RAM device with TiO_2 thin film fabricated by multi-step deposition shows different features compared to the single-step deposition. These different switching behaviors of multi-deposited TiO_2 are decipted in Fig. 4. Even at the first voltage sweep, it shows low resistance state without electro-forming process. The operation voltages of reset and set processes for multi-step deposited TiO_2 thin film are much lower than those for single-step deposited TiO_2. Also, the resistance ratio of the high resistance state to low resistance state is larger with multi-step deposited TiO_2 thin film compared to the single-step deposited TiO_2. (Fig. 5)

4. Conclusion

We fabricated Re-RAM on Si substrate with Pt/ TiO_2/ Pt structure using multi-step deposition method. The resistance switching characteristics with multi-step deposited dielectric were significatly improved compared to those of single-step film. They show forming-free switching, lower operation voltages and larger resistance ratio.

Acknowledgments

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References

[1] H. Pagnia and N. Sotnik, Phys. Stat. Sol. (a) Vol.108, pp.11(1988)

[2] I. G. Baek, M. S. Lee, S. Seo, M. J. Lee, D. H. Seo, D.-S Suh, J. C. Park, S. O. Park, H. S. Kim I. K. Yoo, U-I. Chung, and J. T. Moon, International Electron Devices Meeting Tech. Dig. 2004, pp.587(2004).

[3] D. Adler, M. S. Shur, M. Silver, and S. R. Ovshinsky, J. Appl. Phys. Vol.51, pp.3289(1980)

[4] Y. Watanabe, J. G. Bednorz, A. Bietsch, Ch Gerber, D. Widmer, A. Beck, and S. J. Wind, Appl. Phys. Lett. Vol.78, pp.3738 (2001).

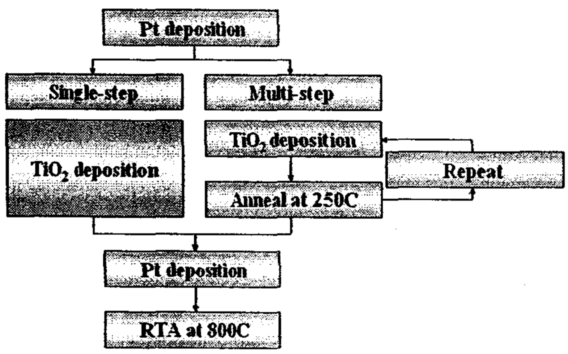

Fig. 1 Fabrication schemes of single-step and and multi-step deposited TiO_2.

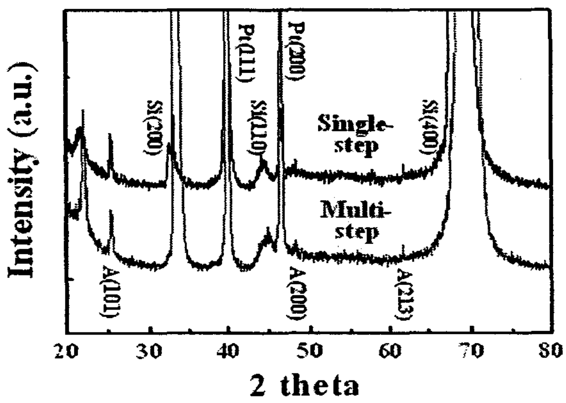

Fig. 2 X-ray diffraction (XRD) spectra of single step deposited and multi-step deposited TiO_2.

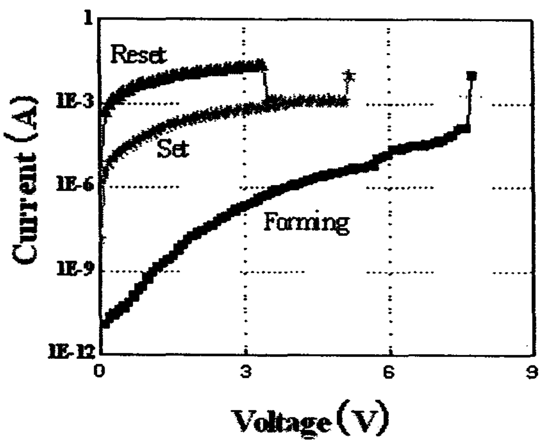

Fig. 3 Voltage sweep switching of single-step deposited TiO_2 including the electro-forming process.

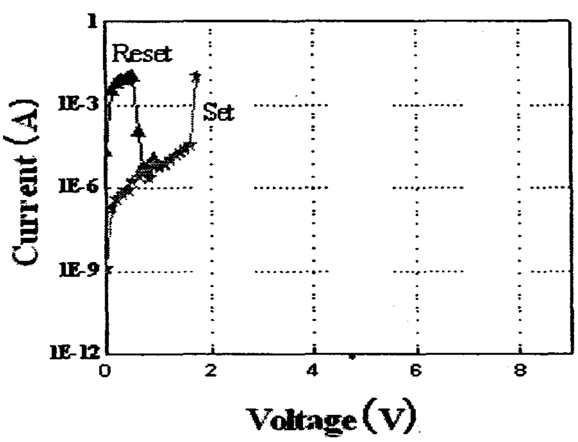

Fig. 4 Voltage sweep switching of multi-step deposited TiO_2 without the electro-forming process.

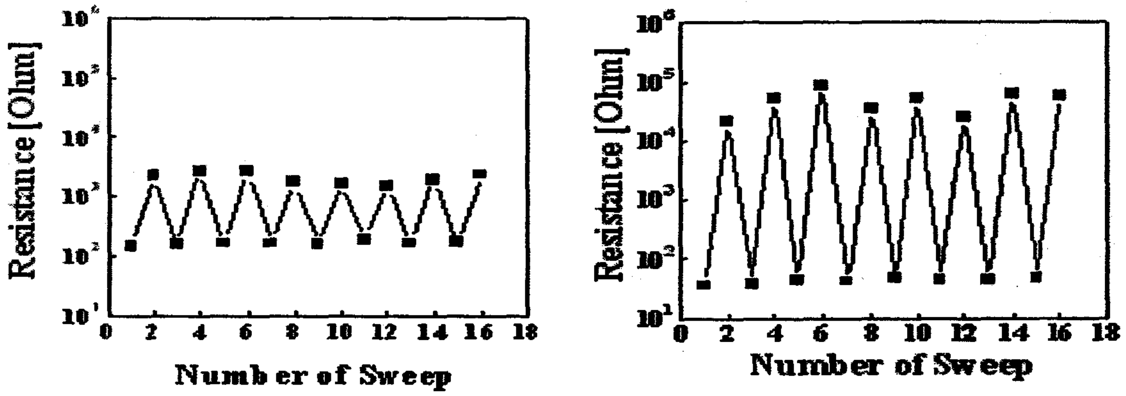

Fig. 5 On/ Off pulse results of (a) single-step deposited and (b) multi-step deposited TiO_2