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Resistive Switching Properties of SiO_x/TiO_2 Multi-Stack in Ti-electrode MIM Diodes

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Resistive switching in dielectrics has been attracting much attention with its application to the next generation nonvolatile memories from the viewpoints of high scalability, high-density integration, and low-voltage operation [1, 2]. Among various switching materials such as perovskite oxides and binary transition metal oxides, we focused on SiO_x because of good compatibility to current Si ULSI technology. In our previous work, we have investigated resistive switching properties of RF sputtered SiO_x ReRAMs with three kinds of Ti, TiN, and Pt electrodes [3, 4]. From the influence of post annealing in O_2 ambience on switching properties of SiO_x thin films, we found that the presence of initial defects in SiO_x presumably originating from the oxygen deficiency is an important factor to show the switching operation [3]. Supposing that the switching behaviors of SiO_x-ReRAMs are derived from chemical structural changes with reversible reduction and oxidation reactions, the ReRAM device performance highly depends upon the interfacial properties between the SiO_x and the electrodes. Actually, SiO_x-ReRAMs with a Ti-based top electrode show a significant increase in the initial current level and a decrease in the ON/OFF rate of resistance in comparison to the case with Pt top electrode, owing to the chemical reaction of SiO_x with the Ti electrode [4].

The purpose of this study is to increase in the ON/OFF ratio in resistance by an introduction of SiO_x/TiO_2 dielectric stack into Ti-electrode MIM diodes. Stacked structure with TiO_2 has a potential to decrease in the current levels without increasing operation voltages. Because the dielectric constant of TiO_2 is around 10~30 times higher than that of SiO_x, the potential change in the SiO_x layer by applying the voltage becomes much larger than that of TiO_2 layer. The influence of SiO_x/TiO_2 multi-stack on the switching properties has been examined in this work.

MIM structures were fabricated on 10 nm-thick SiO_2/p-type Si(100) wafers by RF sputtering, where power density was kept constant at 2.54 W/cm^2. Firstly, a 150 nm-thick TiN bottom electrode was deposited using a Ti target in Ar ambience at 1.1 Pa. Then, TiO_2 and SiO_x layer were alternatively deposited without air-exposure using Ti and SiO_2 targets, in which the Ar/O_2 gas flow ratio was set at unity (0.5 Pa). After the formation of SiO_x(5 nm)/TiO_2(5 nm)/Ti and SiO_x(10 nm)/TiO_2(5 nm)/SiO_x(5 nm)/TiO_2(5 nm)/Ti stacked structure, a 5 nm-thick TiO_2 barrier layer was deposited on SiO_x layer in order to reduce the sputtering damages during the Ti top electrode deposition. Finally, Ti top electrodes with a size of 8.62×10^{-3} cm^2 were formed through a stencil mask in Ar gas flow.

The resistive switching behaviors of MIM diodes with SiO_x/TiO_2 single- and double-stack were investigated from the I-V curves as shown in Fig. 1. Both diodes show a distinct bipolar-type resistive switching of counter-clockwise rotation with lower operation voltages below 1.5 V after an electro-forming process. Although electro-forming voltage for SiO_x/TiO_2 double-stack is about 3 times larger than that for single stack, the current level on high-resistance state (HRS) during the resistive switching is effectively decreased. For the SiO_x/TiO_2 double-stacked sample, the resistances on low-resistance state (LRS) and HRS were calculated from the current at -200 mV and at 200 mV, respectively, and summarized as a function of switching cycle (shown in Fig. 2). The ON/OFF ratios both in resistance and in current level were able to be controlled by the bias sweeping. By the sweeping from 1.5 to -1.5V during the switching, the ON/OFF ratio in resistance is around 10. After the voltage sweeping in the negative bias side was changed to -2.0 V, the resistance ON/OFF ratio was also increased up to 100.

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References

[1] International Technology Roadmap for Semicondutor, 2011 Edition. Emerging Research Devices. [2] A. Sawa, Mater. Today **11**, 6 (2008) 28. [3] A. Ohta et al., IEICE TRANS. on Elec., **E96-C** (2013) 702. [4] A. Ohta et al., Ext. Abstr. of ISPLasma2013, P1089, 113.

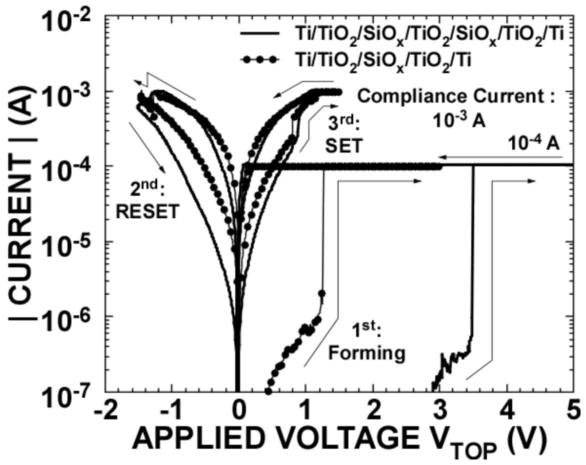

Fig. 1 I-V curves for MIM diodes with SiO_x/TiO_2 multiple stacks. The current compliance levels for electro-forming and SET processes were set at 1.0×10^{-4} and 1.0×10^{-3} A, respectively.

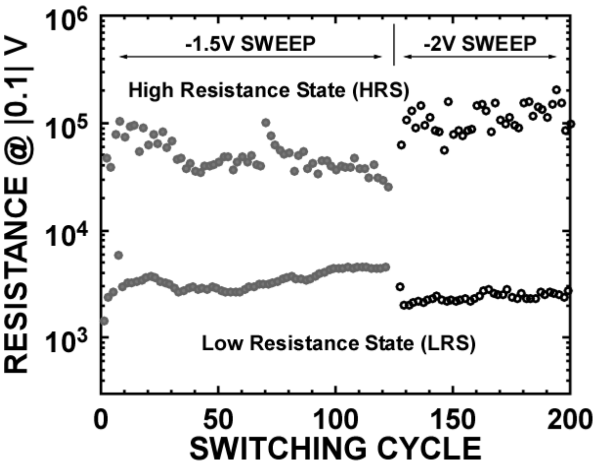

Fig. 2 Resistances on HRS and on LRS at bi-polar type resistive switching for the Ti/ TiO_2(5nm)/ SiO_x(10nm)/ TiO_2(5nm)/ SiO_x(5nm)/ TiO_2(5nm)/ Ti MIM diodes.