An Innovative Metal/Insulator/Metal Structure for Application of Damping Oscillator within One-Selector-One-Resistance

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Abstract: This paper presents a comprehensive study of oxide-based selector characteristics with universal model for interface-type threshold switching (TS) phenomena. The thermal-induced TS transition and electrical-induced TS transition at interface have been confirmed by versatile material and structure systems. The physical understanding of evolution in energy barrier and MIT metallic state modulation have been studied with proposed innovative vanadium electrode. The selector with vanadium electrode owns better characteristic. After series to a resistance, it shows the damping characteristic under fixed input voltage, which can be applied to be a promising oscillator.

Keywords: Vanadium, electrode, vanadium oxide, MIM, damping oscillator.

Introduction

Threshold switching (TS) devices, also known as selectors, are one of the important components in the emerging memory array chip because of its ability to suppress the sneak-path current for unselected devices as well as provide a reliable information storage with reduced misreading. Generally, selectors function as a resistive switching-type device, with a volatile state switch (in contrast to a nonvolatile state switch emerging memory device), which has been demonstrated to be a versatile integration into RRAM, PCRAM, MTJ-MRAM, FeRAM for potential 2D/3D SCM arrays. [1-4]

In this work, a universal model for interface-type TS phenomena with the study of oxide-based selector characteristics was proposed by analyzing VOx systems, and the vanadium electrode device was constucted. Our key results include:

1) Confirm the thermal-induced TS transition and electrical-induced TS transition at the interface.
2) Modeling current transportation as Schottky/thermal emission which provides additional evolution insights of energy barrier and MIT metallic state modulation.
3) Applying the vanadium electrode structure to be a promising damping oscillaotr.

Experimental Setup

With previous research results [5], the vanadium electrode device as shown in Figure 1 with the better selector characteristic in only metal-insulator-metal (MIM) three-layer structure.

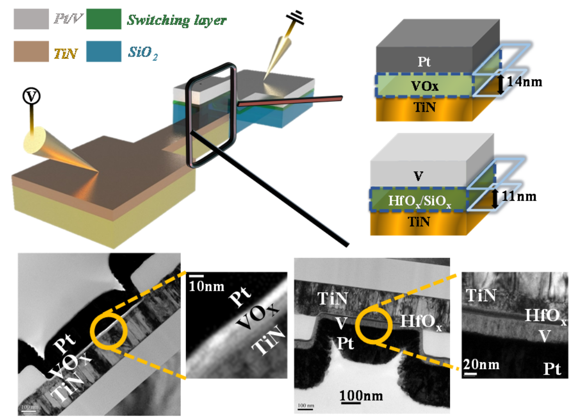

Figure 1. Schematic structure of 3D via-based Pt/VOx/TiN and V/HfOx/TiN devices. The figure shows below are the tunnel emission microscope (TEM) images.

Results and Discussion

Figure 2 shows that the VO_2 middle layer selector property, raising temperature experiment and both the electrical and thermal simulation results. The non-linearity/selectivity of this device is about 10^2, which can stably operate at ±1.2V. The threshold voltage is ±1.1V, and the hold voltage is less than 0.1V. The metal insulator transition is influenced by both electrical field (E-MIT) and thermal field (T-MIT). The increasing high resistance state during direct current (DC) sweep cycling confirms the existence of a filament.

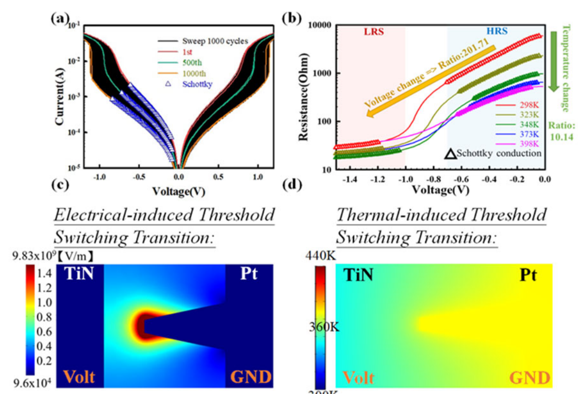

Figure 2. Fig. 2 (a) High resistive state current degradation in the $Pt/VO_2/TiN$ structure device. (b) Increase in the ambient temperature for the $Pt/VO_2/TiN$ structure. (c) COMSOL electrical simulation. (d) COMSOL thermal simulation.

A previous study [5] has indicated that a negative forming process is necessary to obtain the selector characteristic in V top electrode device. After the forming process, the selector behavior appears in this device, as shown in Figure 3. Figure 3(e) shows the TEM images, we can clearly distinguish that in the device that has not undergone forming, the vanadium is pure and without having been oxygenized.

One of the promising features of an ovonic threshold switching device is a damping oscillator. As a result of better characteristic selector, it would shows the better damping results. After identifying the superior performance of the V top electrode device, we connect it in series with a resistor to make an oscillator. Figure 4(a) shows the basic setup of the experiment, where we use a breadboard to connect the tri-axial cables to selector devices. By measuring the voltage between the resistance and the measurement instrument (Agilent DSO9254A), we can distinguish whether pulse damping occurs or not. In the VO_2 middle layer device shown in Figure 4(b), we tried different voltage and pulse conditions, but the pulse remains the same as input voltage. However, in the V top electrode device, the oscillator clearly shows the damping characteristic, in Figure 4(c).

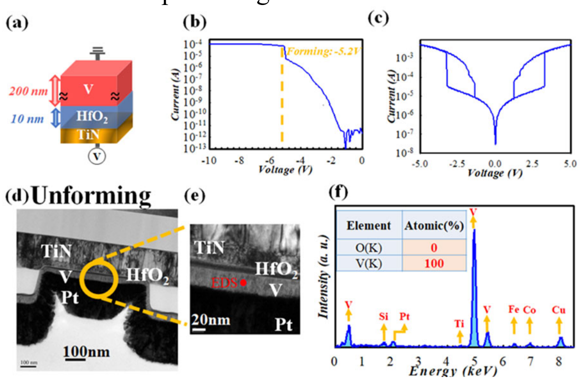

Figure 3. (a) The structure of the vanadium top electrode device. (b) The forming process of the top vanadium electrode device. (c) The I-V curve after the forming process. (d)(e) The TEM image. (f) The EDS experiment result.

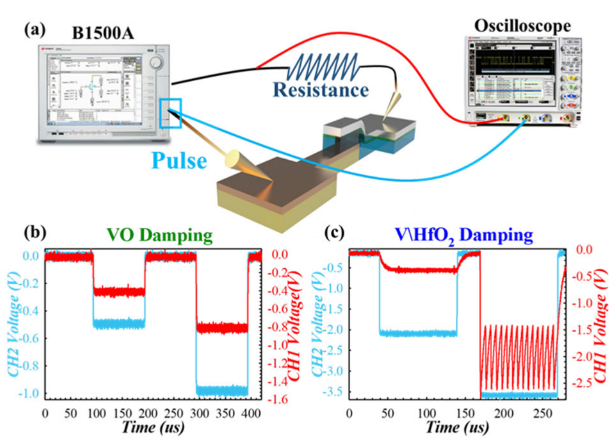

Figure 4. (a) Experimental setup for damping oscillation. (b) The VO device does not exhibit the oscillation phenomenon. (c) The V top electrode device exhibits a high amplitude damping characteristic.

Conclusion

In this article, we comprehensively investigate the mechanism of a vanadium-based selector with $Pt/VO_2/TiN$ structure by electrical measurement and material analysis. Using the current analysis result and simulation, $V/HfO_2/TiN$ was designed. Material analyses and TEM results confirmed that this vanadium top electrode device was oxygenized after the forming process. Unlike a traditional VO_2 middle layer device, the fabrication process of such a vanadium top electrode is compatible with the BEOL process. In addition, with the electrical transition efficiency is twice that of the vanadium oxide middle-layer device, as evidenced by thermal-cycling material analysis. In addition, endurance reliability increased to 10^7 at 65 ºC (theoretical transition temperature is 67ºC). The reliability test and performance of the V top electrode device was better than the VO_2 middle layer device. With the better selector characteristic, the selector with V top electrode which series with a resistance is applied to the be the damping oscillator with better results. This suggests that a localized transition vanadium top electrode can be introduced for practical applications.

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