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Switching Behaviors of TiN/HfO_x/Pt Based RRAM

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Abstract**—**Resistive Random Access Memory (RRAM) had received great amount of attention from various research efforts in recent years, owing to its promising performance as a next generation memory device. In this paper, samples based on TiN/HfO_x/Pt stack were prepared and its electrical switching behaviors were characterized and discussed in brief.

Keywords**—**HfO_x, resistive switching, RRAM.

I. Introduction

WITH the recent advancements in portable smart devices and phones, the growing demand for more compact, higher capacity, faster memory became insatiable. Obeying Moore's law, the Flash memory technology had been aggressively scaled in the past decades with the help of various breakthroughs in both design and fabrication process level. However, like many other memory technologies that came to past, the Flash memory technology will inevitably face obsolescence in the near future due to physical and electrical limitations.

RRAM is nominated as one of the most promising emerging memory technology due to its low power consumption, high scalability, fast programming speed and CMOS compatibility [1], [2]. In this work, TiN/HfO_x/Pt stack are demonstrated and the switching behaviors of such stack are also introduced.

II. Experiment

A blanket 200Å thick Ti layer was deposited on 8" silicon wafers to act as an adhesion layer, followed by a 500Å thick Pt layer as bottom electrode (BE) by Electron Beam Physical Vapor Deposition (EBPVD). A thin resistive switching layer of 50Å HfO_x is then deposited by PVD on top of the BE followed by a 400°C Nitrogen gas annealing for 30s. Finally, a 500Å TiN top electrode (TE) is deposited on top of the stack by reactive sputtering and then patterned with photo-lithography and dry etched to the BE. Electrical measurements are then performed using an Agilent-B1500A parametric analyzer.

See Fig. 1 for a pictorial presentation of the device stack.

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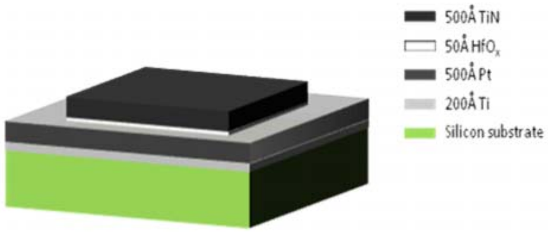

Fig. 1 Cross-section diagram of TiN/HfO_x/Pt stack RRAM

III. Electrical Characterization

Fig. 2 shows the cross section image of the stack taken with transmission electron microscopy (TEM) to ensure that the stack was properly fabricated as per specifications.

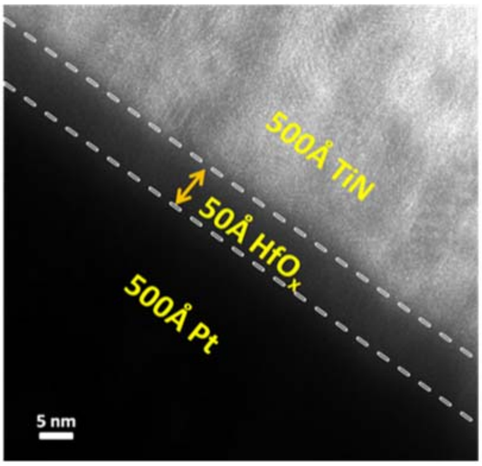

Fig. 2 TEM image of the TiN/HfO_x/Pt stack

A higher than usual operation voltage is required to initialize the electro-forming process which may have been due to the forming and rupture of conductive filament as discussed by various other research groups [3], [4]. This process is known as the forming process and typical forming voltage (V_F) ranges from ~1.8V to ~2.2V in this device stack under study. Fig. 3 shows that a 2V V_F is needed to initialize the device switching behavior.

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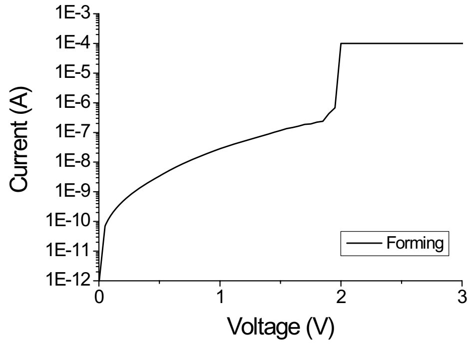

Fig. 3 Forming process for the device stack

A typical initial bipolar switching cycle of the device stack is shown in Fig. 4. Resistive switching occurs when an external electrical stimuli is introduced to the RRAM device, resulting in a change from a high resistance state (HRS) to a high resistance state (LRS) also known as the Set process, and the vice versa is called the Reset process. A 500uA compliance current (CC) is applied on the parametric analyzer for the Set process in order to prevent a hard breakdown of the device; no CC is required for the reset process however.

A voltage sweep from -2V to 2V was applied on the device stack and it is observed that the typical set voltage (V_{Set}) is ~1.1V and reset voltage (V_{Reset}) is ~-1V. An on/off ratio of >10^3 is achieved in most of the initial cycle of the stack. An endurance screening was done by switching the device consecutively for 100 cycles and the results were characterized in Fig. 5. It is noticed that the subsequent V_{Set} ranged from ~0.8V to 1.2V and the V_{Reset} were generally more uniformed at a constant ~0.8V. This could probably be explained as the forming of the conductive filaments are largely random, i.e. there could be more filaments formed during a cycle compared to the next, hence the less uniform V_{Set}, however, the energy required to rupture the already formed filaments should more or less be the same, varying only minimally. The on/off ratio was also seen to drop from its initial >10^3 to ~10^2, this could most likely be attributed to the degradation of the filaments formed.

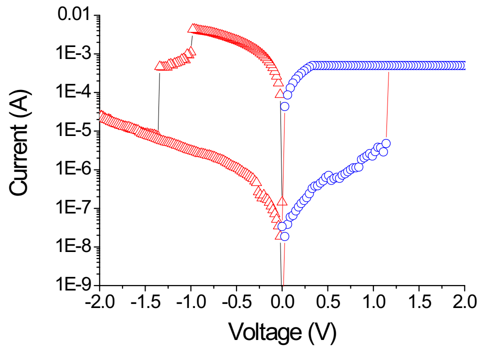

Fig. 4 A typical cycle of bipolar resistance switching from low resistance state to high resistance state (Reset) and vice versa (Set) for the test device stack

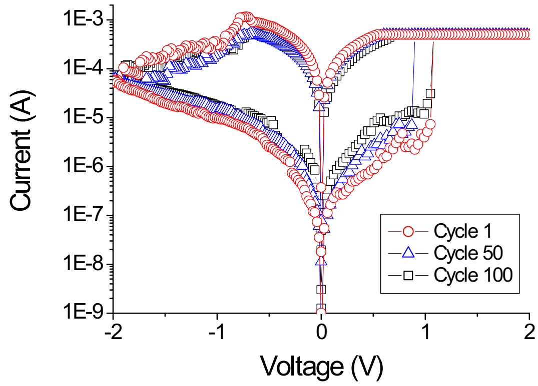

Fig. 5 100 Cycles of RS for endurance screening

IV. Conclusion

In conclusion, HfO_x based RRAM generally shows good resistive switching capabilities with acceptable on/off ratio of >10^2 and good endurance performance of up to 10 years projected. However, moving forward, investigating the physical mechanism behind RS is an important aspect in order to improve the uniformity of the device operating parameters. Different approaches such as introducing an impurity in the form of doping to assist in the formation of conductive filaments and different material stacks and structures are actively studied by various research groups [5], [6], [7].

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