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ALD HfO_2 Based RRAM with Ti Capping

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***Abstract*—**HfO_x based Resistive Random Access Memory (RRAM) is one of the most widely studied material stack due to its promising performances as an emerging memory technology. In this work, we systematically investigated the effect of metal capping layer by preparing sample devices with varying thickness of Ti cap and comparing their operating parameters with the help of an Agilent-B1500A analyzer.

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

I. Introduction

RRAM had received great attention over the past decade as various research groups reported promising capabilities such as fast programming speed, high scalability, good endurance and long retention [1], [2]. In addition, HfOx as the resistive switching layer was also acknowledged as one of the most favorable material [3], [4].

It is generally agreed that the mechanics behind the resistance switching (RS) as demonstrated by RRAM devices are related to reduction oxide reaction resulting in oxygen vacancy assisted conduction filaments formation and destruction [5], [6]. Therefore, we believe that the switching properties can be improved by increasing the density of oxygen vacancies and storing them in a so-called *"oxygen reservoir"* with the help of a metal electrode with high oxygen affinity. In our case, this is achieved with a Ti capping layer in between the RS layer and the top electrode.

II. Experiment

After lasermark and RCA clean, a 500Å thick TiN layer was deposited on 8" silicon wafers as the bottom electrode (BE) by reactive sputtering. An 80Å HfO_x RS layer is then deposited using Atomic Layer Deposition (ALD) on top of the BE. A varying thickness of Ti capping layer was covered on top of the RS layer followed by a 500Å TiN top electrode (TE) and then patterned with photo-lithography and dry etched to the BE. See Table I for the Ti capping split table. Electrical measurements are then performed using an Agilent-B1500A parametric analyzer.

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TABLE I
Ti Capping Thickness Split

Wafer	BE	HfO_x	Cap (Ti)	TE
S02	500Å	80Å	10Å	500Å
S05	500Å	80Å	50Å	500Å
S06	500Å	80Å	100Å	500Å
S07	500Å	80Å	200Å	500Å

III. Electrical Characterization

It is observed that the devices without a sufficient thickness of Ti capping layer does not demonstrate switching behavior; S01 (data not shown) and S02 which have no Ti cap and 10Å Ti cap respectively shows the forming process but failed in RS. S03 and S04 (data not shown) with 20Å and 30Å Ti cap respectively shows forming process as well as RS behavior, however, the on/off ratio of the device is very small <2 in all of the devices tested. It is worth mentioning that from S05 onwards with a Ti capping thickness of ≥50Å, the device shows vast improvement in switching characteristics, surging from the <1 on/off ratio to >10 with a 50Å Ti thickness and >50 with a 100Å Ti thickness.

The result corresponds to previous reports made [7] and is most likely in agreement with our argument on an *"oxygen reservoir"*.

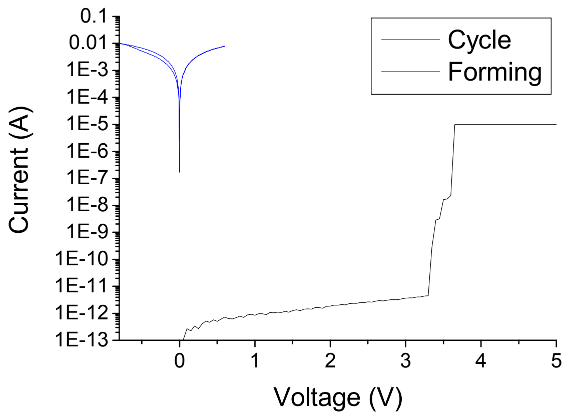

Fig. 1 S02 with 10Å Ti cap shows forming process in all the tested devices, but fail in resistance switching

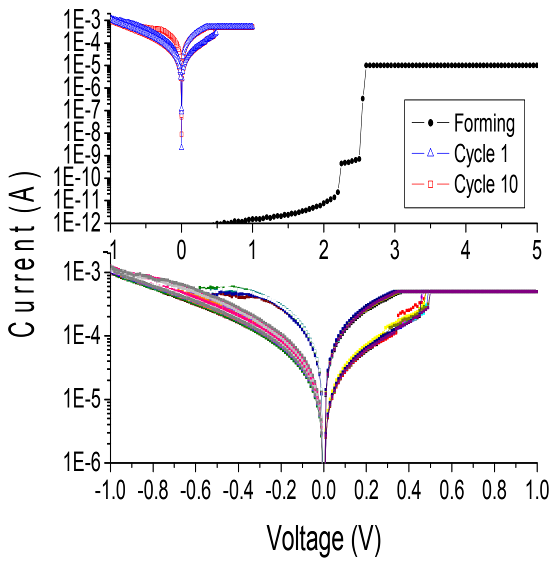

Fig. 2 S05 with 50Å Ti cap shows forming process and resistance switching but with small on/off ratio

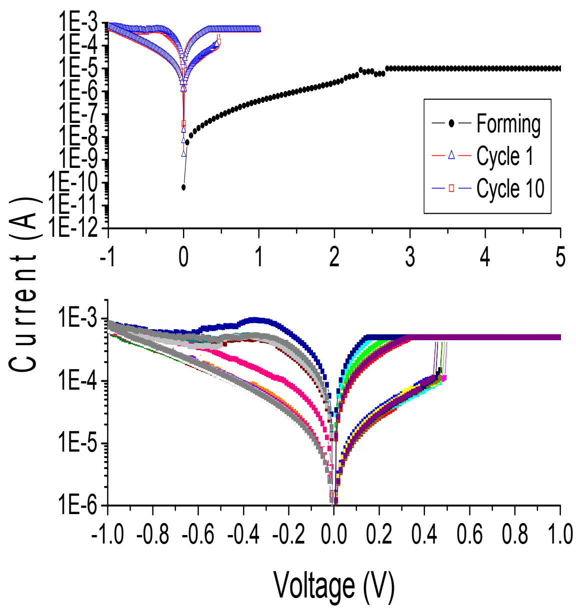

Fig. 3 S06 with 100Å Ti cap shows forming process and resistance switching with good on/off ratio

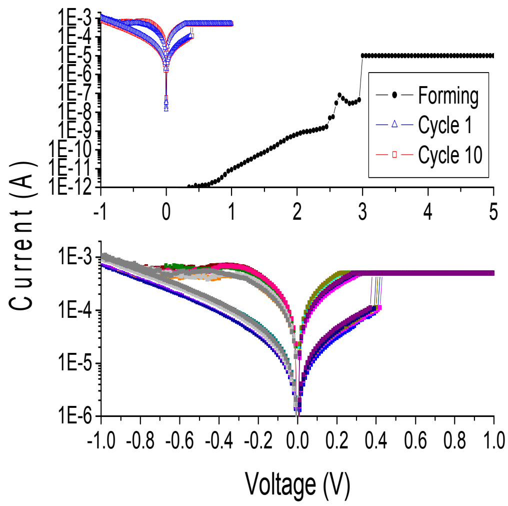

Fig. 4 S07 with 200Å Ti cap showing better uniformity and good on/off ratio as compared with S06

IV. Conclusion

To conclude, we have studied the phenomena of resistance switching which is correlated to the redox reaction of oxygen vacancy related conductive filament formation and destruction. By investigating the effect of an "oxygen reservoir" with the help of a Ti capping with high oxygen affinity, we found that the performances of the same stack device such as uniformity, switching capability and on/off ratio can be improved dramatically with a thick enough capping layer, in our case >50Å.

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