A comprehensive resistive memory characterization through the analysis of conductive filaments

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ABSTRACT

An in-depth characterization of thermal reset transitions in RRAMs has been performed by simulation. The simulator accounts for the electrical and thermal description of several coupled conductive filaments (CFs) as well as for the time-dependant filament destruction/creation mechanisms. All the equations involved in the device operation are solved self-consistently [1]. In addition, the CFs series resistance, including the contributions of the setup and Maxwell components, has been included in the calculations [2].

Using this simulation tool, we have reproduced I-V curves of several experimental devices. The reset voltage dependence on the initial resistance of the CF has been analyzed and the relevant role played by the CF shape has also been demonstrated. In this respect, devices with the same initial resistance but different CF shape can switch at different voltages. A simulation study of the reset voltage distribution obtained for these devices has also been performed in order to explain the variability of experimental samples.

In this contribution we present a study of the influence of CF shape on device resistance, reset current and voltage, and maximum current. For our analysis we use filaments with truncated-cone shapes, which are known to be a good approximation to the real CF shapes [3].

As shown in [4], for Ni/HfO_2/Si-n+ devices, there was found a big (tens of nanometers thick) filament, which is responsible for the main features of the reset process. For this reason, we study here a single filament structure, a good approach to characterize this kind of RRAM devices.

The initial CF shape determines the evolution of the device in the reset process. For narrow CFs, the current flowing through the CF is small because the initial Maxwell and CF resistances are high. For this reason, a higher voltage is needed in order to undergo a reset event.

References

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Figures

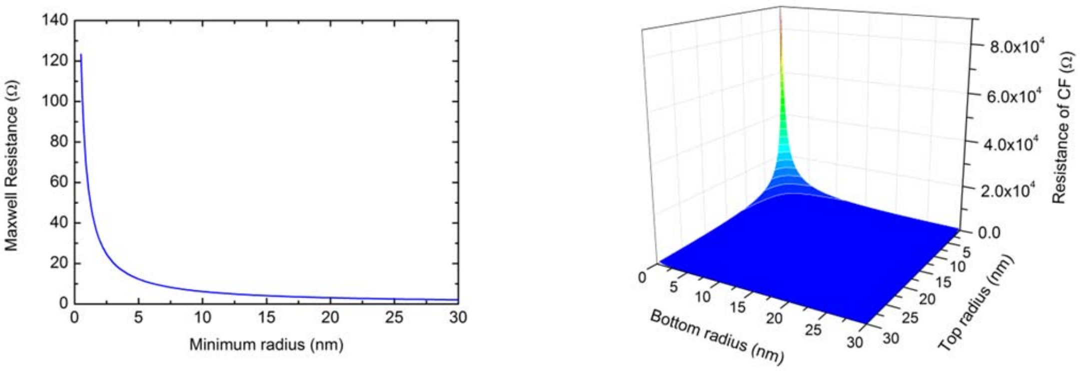

Fig. 1: Initial Maxwell resistance (left) and initial CF resistance (right) versus minimum CF radius. Maxwell resistance takes into account the funneling of current lines from the large metal electrodes to the narrow CF within the RRAM insulator [2]. All the CFs employed have truncated-cone shapes [3, 4].

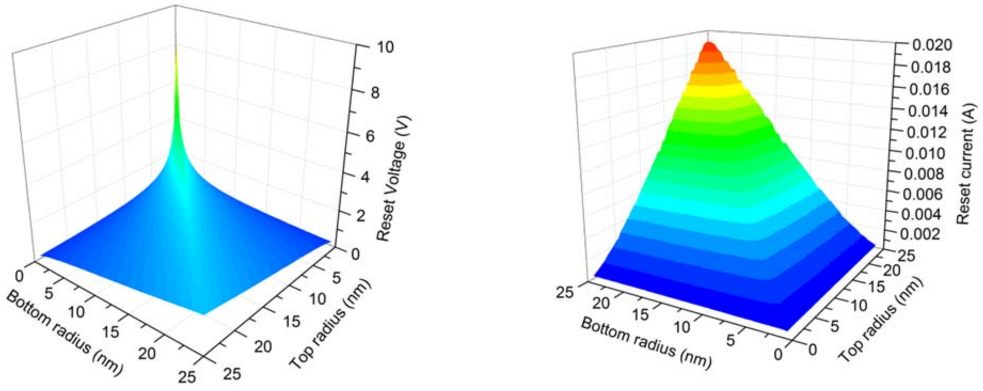

Fig. 2: Reset voltage (left) and reset current (right) versus CF radii. The reset voltage is defined as the voltage applied just before CF gets broken. After the rupture event the current of the device is zero.

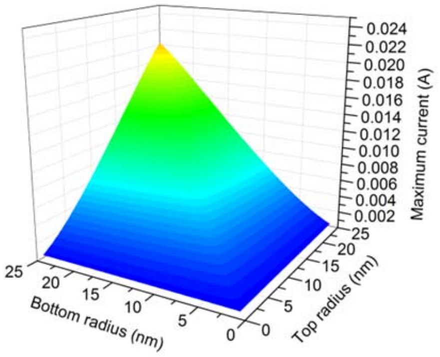

Fig. 3: Maximum current versus CF radii. Before the reset process takes place, the current is increased and consequently the filament temperature rises. When the critical temperature is achieved the current begins to drop off throughout the reset process.