Characterization of resistive memories using micro-beam RBS

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In the last years the search for new computing memory technologies has increased considerably. Different concepts of memory have been attempted to replace magnetoresistive random access memories (MRAM), the phase change and ferroelectric RAM. Recently, the resistive RAM has been investigated as possible substitute for usual MRAM [1]. Memories based on resistive switching have a capacitor-like structure composed of a semiconductor material sandwiched between two metal electrodes. This system can assume two resistance states, low and high, which is controled by the voltage bias applied over the insulator. A recent study has shown that the switching speed time can be faster than several nanoseconds [2].

For some devices, the switching phenomenon is caused by the formation of conducting metallic filaments inside the insulator. In systems where the top electrode is an electrochemical active metal and the bottom is an inert one, atoms from the top electrode move into the insulator via redox-based mechanism. This kind of system is known as Electrochemical Metallization Memories (ECM) [3]. It is also possible to observe a similar effect in systems with both electrodes being chemical inert, in which the change in resistance is attributed to the movement of oxygen vacancies inside the electrolyte.

In this work, we study devices based on TiO_2 with a platinum inert electrode and copper as active. The sample was deposited via physical vapor deposition technique (sputtering). The top copper electrode was deposited over a shadow mask to create a circular pad of 250µm diameter.

To induce the movement of copper ions into the oxide, the system requires a process called electroforming step or "soft breakdown". In this step a certain positive voltage is applied over the copper electrode in the virgin device, which has high resistance. With the increasing voltage, the microstructure of the oxide reorganizes to create a copper conduction path. When the filament connects the electrodes, the device's resistance has a sudden drop, as is possible to observe in the electric measurements. There is maximum current (compliance) to positive voltages to ensure the device does not break definitively.

After the device is properly on the set state, we perform the RBS micro-beam measurement, focusing the beam only over one device. Accomplishing data over virgin and setted devices, it was possible to observe evidences indicating the movement of the copper inside the TiO_2. The data were obtained with a 10µm x 16µm beam in the middle of the pad, approximately were the electrical contacts were. These results will be discussed at the conference in connection with the ones measured by MEIS after removing the copper layer by chemical etching.

References

[1] J.Yang et al., Nature Nanotechnology 8, 13–24 (2013).
[2] C.Yoshida et al., Appl. Phys. Lett. 91, 223510 (2007).
[3] L.Yang et al., Appl. Phys. Lett. 95, 013109 (2009).