Effects of the Oxide Film Density on the Resistive Switching Characteristics of Atomic Switches

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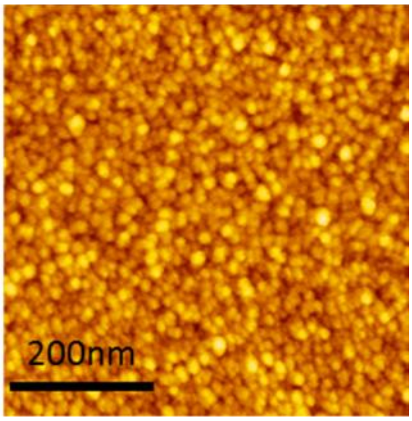
The on-going downscaling of Si-based Flash memories has reached physical limitations, difficult to overcome. Resistive switching memories based on cation migration in a thin oxide film (we call an 'atomic switch') are considered as one of good candidates for next generation non-volatile memory applications, due to their promise high density, high speed, low power consumption, low fabrication cost, and Back-End-Of-Line (BEOL) compatibility with CMOS technologies, insured by a basic Metal-Insulator-Metal (MIM) structures [1].

In a previous work, we have reported that moisture has an impact on the operational characteristics of oxide-based atomic switches [2]. Here, we present how the oxide film density affects the switching behavior, in relation to the influence of moisture. Cu/Ta_2O_5/Pt stacking structures with a junction size of 5 μm were fabricated, in which Ta_2O_5 thin films were obtained by two physical vapor deposition (PVD) methods: rf sputtering (SP) and electron-beam (EB) deposition. The Ta_2O_5 films were amorphous for both deposition processes, as confirmed by Attenuated Total Reflectance (ATR) and X-ray diffraction (XRD) experiments. Atomic force microscopy (AFM) measurements revealed a similar mean grain size for both films (an image of the EB film is shown in Fig. 1), but X-ray reflectometry (XRR) indicated that the EB film presented a lower density than the SP film (a higher porosity rate of the EB film).

Figure 1 shows the variation of the SET (from a high-resistance (OFF) state to a low-resistance (ON) state) voltages measured under different ambient conditions. The mechanisms at the origin of the resistive switching for this type of cells have been previously investigated [3]. The SET processes correspond to the formation of a Cu filament by inhomogeneous nucleation, in which Cu ions are released by ionization process of Cu at the anode interface. The RESET process (from the ON state to the OFF state) is attributed to the dissolution of the metal filament due to thermochemical reactions assisted by Joule heating (data are not shown here). The SET voltages of the cell with SP films exhibited almost constant values regardless of the ambient condition, as indicated by the red dashed line. In contrast, the operational voltages of the cell with EB films increased when the ambient was evacuated, as shown by the blue dashed-dotted line. Oxide films formed by any PVD method typically exhibit nanoporous structures, which can absorb moisture from the ambient atmosphere. The observed dependence of the operational voltages on the ambient conditions can be attributed to different absorption abilities of the cells to moisture, resulting from different film densities of the Ta_2O_5 films. A detailed relation between the thin film morphology and the switching characteristics will be discussed.



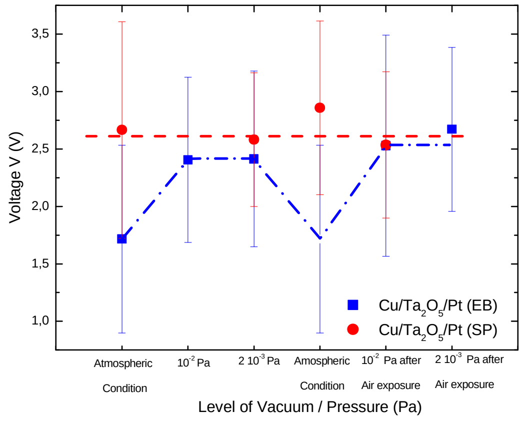


Figure 1 Left: AFM image for (20nm-EB) Ta_2O_5/Pt. The average grain size is about 19 nm. Right: SET voltages of Cu/Ta_2O_5/Pt cells with different deposition processes (SP and EB), measured under different conditions.

References: [1] I. Valov *et al.*, *Nanotech.* **22** (2011) 254003. [2] T. Tsuruoka *et al.*, *Adv. Funct. Mater.* **22** (2012) 70-77. [3] T. Tsuruoka *et al.*, *Nanotechnology* 21 (2010) 425205.