SPM Characterization and Conductive Tip Induced Resistive Switching in Hafnium Oxide Nanoislands Grown on Au(111).

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On the road towards high-density Resistive Random-Access Memory (RRAM) devices, the scalability of memristive materials is an important factor. To create reliable nanosized memristive devices, it is also necessary to understand the nanoscale processes behind the switching mechanism to precisely control the device behavior. Nanoislands of HfO_2, one of the most prominent memristive materials, were previously shown to exhibit a bulk-like bandgap by Schmidt et al.[1], sparking further interest in the nanoislands electronic behavior. Conductive tip Atomic Force Microscopy (cAFM) would facilitate the investigation of resistive switching behavior in single nanoislands.

To achieve this, the Pulsed Laser Deposition (PLD) growth of HfO_2 nanoislands was first transferred to the Au(111) surface, providing large atomically flat surfaces. The islands are then characterized in-situ in UHV by cAFM, yielding high resolution topography and current response images. Furthermore, resistive switching in a single nanoisland is performed for the first time. Here, the bias is applied via the cAFM tip, which acts as a mobile nano-sized top-electrode kept steady in a predefined position. The observed I-V behavior is heavily dependent on the applied current compliance (CC). At a higher CC of 300 nA and above, the device consecutively sets to lower resistive states, until the nanoisland shorts. At a CC of 100 nA or lower, resistive switching behavior with SET and RESET cycles is observed. We propose a mechanism of two simultaneously occurring processes of oxygen ion dynamics within the HfO_2 nanoisland as origin of the observed behavior.

We demonstrate that resistive switching behavior can be observed locally in single nanoislands of only few tenths of nm, and even below 10 nm, in diameter, using cAFM. We gain new insights into the extreme scalability of HfO_2 as memristive material and further understanding of nanoscale processes that facilitate memristive switching, especially the role of interfaces.

[1] N. Schmidt et al., ACS Appl. Nano Mater., 6 (1), 148-159, 2023.