Two Competing Switching Mechanisms in Epitaxial Strontium Titanate-Based Resistive Switches

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Resistive switching oxides are a class of non-volatile memories with the potential to improve today’s transistor-based information technology. Their typical hysteretic current-voltage (I-V) profiles allow addressing a high and a low resistance state within ns and at a low switching energy. Strontium titanate (SrTiO$_3$) is a material with well-known defect chemistry and also a well-studied resistive switching oxide. Despite the many reports in literature, the exact defect-related switching mechanisms and electric-field inflicted changes thereof remain elusive.

In this study, we prepare model device structures with 5 nm thin (100) SrTiO$_3$ epitaxial PLD films to study mechanistic details of the resistive switching process. We observe bipolar resistive switching and pinched hystereses in current-voltage profiles for electric field strengths $\leq 4 \times 10^8$V/m with $R_{on}/R_{off}$ ratios of 5-25. Excitingly, two competing switching mechanisms were observed at higher field strengths ($\geq 6 \times 10^8$V/m) that lead to changes in the switching direction (clockwise vs. counter-clockwise), in kinetics and in the number of I-V crossovers (1-3). By impedance spectroscopy, TEM, and AFM, more details on the two switching processes were accessible: One process is showing filament-characteristics, and the other process relies on altering charge carrier concentrations. High stability of both processes allows to control of $R_{on}/R_{off}$ resistance ratios for individual switches, and are a new possibility to tune the functionality of memory devices.