Abstract Submitted
for the MAR06 Meeting of
The American Physical Society

Resistive Switching of Individual Dislocations in Insulating Perovskites – A Potential Route Towards Nanoscale Non-Volatile Memories. KRZYSTOF SZOT, WOLFGANG SPEIER, GUSTAV BIHLMAYER, RAINER WASER, CNI & IFF, FZ Juelich — Electrically controlled resistive switching effects have been reported for a broad variety of binary and multinary oxides in recent years. In particular, titanates, zirconates, and manganites have been in the focus of the studies. In many cases, the mechanism of the switching and the geometrical extension of the phenomenon (filaments vs. bulk) are still under discussion. In this work, we present evidence for a redox-based switching mechanism and we indicate a potential route towards highly scalable non-volatile memories based on this switching effect. The challenge our work is to utilize resistive switching mechanism with the aim to construct *active* electronic elements on a real nanoscale level, here by reversibly switching the electrical properties of individual dislocations by electrical stimuli. We demonstrate that standard undoped $SrTiO_3$ single crystals, utilized as a model system, exhibit a switching behavior along filaments based on dislocations, mediated by oxygen transport. For this, we employed a three-step procedure: the crystals were, at first, annealed at elevated temperatures under reducing conditions, then exposed to 200mbar O_2 pressure at room temperature, and finally subjected to an electric field under ultrahigh vacuum (electroformation). This treatment induced in a metal-insulator ($SrTiO_3$)-metal (MIM) system a transition to metallic state. A hysteretic behavior appears after dynamical polarization of the MIM structure at the maximum electroforming currents. The shape of the I/V curve has the typical signature for bi-stable switching known for these types of perovskites. The positive temperature dependence of the resistance of the low- (LRS) and the high-resistance (HRS) state clearly identifies both states to be metallic in character. The inhomogeneity of the electrical transport becomes directly evident from a simple optical inspection and the conductivity maps as measured by LC-AFM of a planar structure. One can trace the formation of the filaments, emerging from the cathode and propagating towards the anode during the electroformation process. These filaments are well-oriented along the <100>-axis of the crystal and show a discrete and granular substructure on the nano-scale. The similarity in lateral distribution of exit points (spots) of conducting nano-filaments with respect to the distribution of etch pits suggests that the electrical transport along dislocations determines the micro- and meso-scopic electrical transport phenomena. Our results suggest that a dedicated contact arrangement is required to handle the filamentary conduction in a practical way by using macroscopic electrodes. At the same time, it emphasizes the need to control the relevant processes on the level of individual dislocations. With LC-AFM it is possible to specifically address single dislocations crossing the surface with adequate spatial resolution and use the conducting cantilever as the nano-electrode through galvanic point contact. We succeeded to initiate the local electroformation process for a single dislocation by applying a dc bias to the tip of the cantilever. Such nano-prepared dislocations reveal bi-stable switching behavior between a linear and a non-linear I/V-characteristics. The dynamic range of the electrical resistance covers at least 3 to 4 orders of magnitude at read-out voltages of 0.1 V. In order to develop a microscopic model for the filament, we performed first-principles calculations of extended, linear defects in $SrTiO_3$. Our analyse of electronic structure

Rainer Waser
FZ Juelich

Date submitted: 03 Dec 2005 Electronic form version 1.4