Nonvolatile resistance switching in electrodeposited metal oxide thin films

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Resistance switching (RS) in metal oxides has been studied for decades.[1] However, reversible RS (*memristive* behavior) had not been demonstrated until Strukov et al.[2] showed that TiO_2 deposited onto crossbar-structures act as a nonvolatile memory. Since then, there has been extensive research on the use of metal oxides for highly-scalable, resistance random access memory (RRAM).[3] A variety of novel logic architectures have also been proposed based on nonvolatile resistance switching in TiO_2, such as latch switches, flip-flops or even a defect tolerant computer.[4]

We have focused our attention on the electrodeposition of metal oxides such as Bi_2O_3, Co_3O_4, and Mn_3O_4 that exhibit unipolar resistance switching. These materials are all highly resistive in the native state, but become conductive after application of a large electric field. We attribute this switch in conductivity to the formation of nanometer-scale metallic filaments which are produced by dielectric breakdown. A gap can then be formed in the filaments by applying a bias to the filament causing it to exceed a compliance voltage. We will show in this talk that Bi_2O_3, Co_3O_4, and Mn_3O_4 all exhibit unipolar resistance switching.

As an example, resistance switching in an electrodeposited Co_3O_4 film is shown in Figure 1. The measurements were performed in a 2-point probe arrangement, normal to the film plane (inset of Figure 1). In the forming process, conductive filaments are formed at high electric field, and the material changes its initial high resistance state (HRS) to a low resistance state (LRS). A compliance current (CMPL) is used in this process to prevent a full dielectric breakdown in the material. The forming is followed by a reset (RST) process, in which one side of the filament is ruptured by electrochemical and/or thermal oxidation.[3] The LRS changes to the HRS, however, of lower resistance than the initial HRS prior to forming. RST is performed without a CMPL current at high currents and at low electric fields. The layer can be switched back to the LRS by performing the setting process (SET). SET is performed the same way as forming. However, only a thin insulating layer has to be formed and this occurs at much lower electric fields compared to the initial forming process. An endurance test has shown that the material can be switched back and forth hundreds of times. Both the LRS and the HRS are persistent for at least 10^5 s (duration of the test). Electric transport measurements have shown that the filaments have metallic behavior. The resistance decreases as the temperature is decreased. The HRS behaves as an insulator. The metallic behavior of filaments was further confirmed by impedance spectroscopy. The filaments show magnetoresistance (MR) at 300 K, which vanishes at 70 K. This strongly suggests that the filaments are metallic Co.

References:

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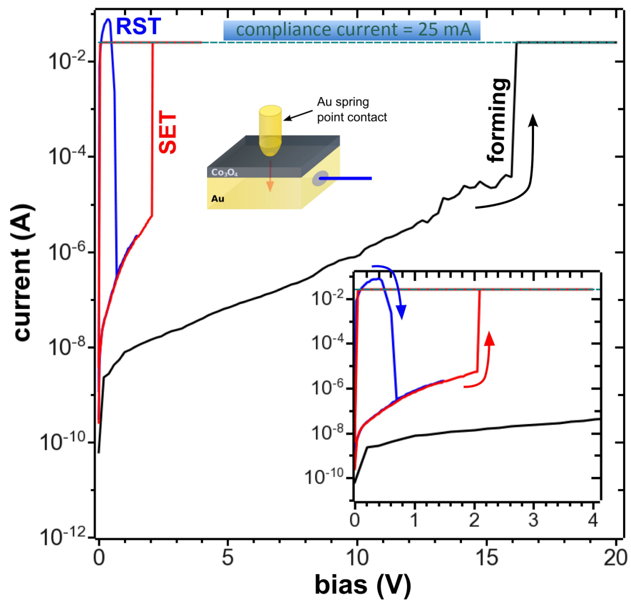

Figure 1. Unipolar resistance switching in a 2 µm thick Co_3O_4 film deposited at 0.25 mA cm^{-2}.