Real-Time Observation of Resistive Switching in TiO$_2$ Nanoparticles Using Electron Holography

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Resistive switching phenomena in binary and complex metal oxides have attracted great interest for applications in next-generation non-volatile memory devices. Recently, nanoparticles have been adopted as switching materials, both for use in smaller devices and as model systems for understanding resistive switching mechanisms in nanoscale materials [1,2].

Here, we investigate the origin of resistive switching behavior in individual nanoparticles that have an electrical bias applied to them in situ in the transmission electron microscope (TEM). We use current-voltage (I-V) measurements in the TEM to study resistive switching mechanisms in real time while simultaneously applying electron energy-loss spectroscopy (EELS) and off-axis electron holography to the same particles. The latter technique allows projected electrostatic potential distributions in materials to be recorded with nm spatial resolution [3], providing information about the role of heterointerfaces and conducting nanofilaments during switching processes.

We study TiO$_2$ nanoparticles that were synthesized using a sol-gel method and then vacuum annealed. We observe reproducible forming-free bipolar switching behavior in individual nanoparticles that are contacted electrically in the TEM using a moveable electrical probe. I-V curves obtained from single particles are correlated with local EELS and electrostatic potential measurements, providing direct information about nanoscale microstructural, compositional and electrical changes occurring single nanoparticles during resistive switching.