IN-SITU TRANSMISSION ELECTRON MICROSCOPY OF FUNCTIONAL MATERIALS

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One of most exciting developments in nanomaterials characterization is the commercialization of aberration corrected TEMs and STEMs [1,2]. By correcting for spherical aberrations, these techniques allow for the imaging of atomic positions with a precision of a few picometers. Together with the integration of energy dispersive X-ray spectroscopy (EDS) and electron energy loss spectroscopy (EELS), the structural and elemental composition of nanomaterials can be determined at the atomic level. Recently, another exciting development in TEM has emerged, namely the use of special specimen holders for *in-situ* TEM measurements under various heating, cooling, and electrical bias conditions [3]. The combination of *in-situ* TEM/STEM imaging and EDS/EELS analysis is extremely powerful as it allows for real-time studies on nanoscale dynamical processes and their direct impact on macroscopic material properties. In the Nanomicroscopy Center at Aalto University, we have established a new platform for *in-situ* TEM characterization. Here, we review some recent experimental results, including (1) the observation of electron beam-induced structural phase transitions in epitaxial manganite films [4], (2) *in-situ* spectroscopy of electric-field controlled oxygen ion migration in metal/oxide heterostructures [5], and (3) simultaneous real-time analysis of resistive and structural phase transitions in complex oxide nanostructures [6]. We also present an outlook on the development of a combined optical/electrical probing holder for *in-situ* TEM measurements on perovskite solar cells. The new setup will be used to address reliability and durability issues of this promising new type of solar cell by simultaneous characterization of ion migration, ionic polarization, ferroelectricity, etc., at high spatial resolution. Realization of this measurement technique will be a major step in the field of *in-situ* TEM with direct implications for the development of perovskite solar cells and other opto-electronic devices. The project is financially supported by the Key Project Funding by the Academy of Finland, 2016.

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