Sub-unit cell investigations of nanomaterials through aberration corrected electron microscopy

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The fast pace of technological development of our society continuously demands new nano-materials for applications areas such as data storage, sensors, spintronic devices or energy applications. Functionalities of interest can result from mechanisms related to static equilibrium (crystal structure, ground state electronic properties, etc), or also from dynamic processes involving mass or electronic transport under external stimuli. For instance, an electric bias can change the local concentration of O vacancies within the lattice of oxide materials, causing structural instabilities and changes of crystal symmetry, oxygen electromigration or other processes. Other examples may include local chemical fluctuations, strong electronic correlations, unusual cooperative behaviours like high Tc-superconductivity, colossal magnetoresistance, ferroelasticity or colossal ionic conductivity. In order to harness such phenomena, we need to be able to *both visualize and quantify* atomistic phenomena in conditions similar to those found in working environments. Now, more than ever, we need to be able to watch and track the properties atoms at work. This is a task that demands real space probes that can inspect matter at the atomic scale in both static and dynamic regimes, on an atom-by-atom basis. Aberration corrected scanning transmission electron microscopy (STEM) combined with electron energy-loss spectroscopy (EELS) has brought sub-Ångstrom electron beams to bear on this task resulting in unprecedented sensitivity for imaging and spectroscopy, including the feasibility of mapping electric and magnetic fields at the atomic scale. This talk will review some examples of applications of these techniques to interfaces and nanomaterials. Examples include local measurements of electronic and magnetic properties of ultrathin epitaxial films based on the ferromagnetic manganite $La_{0.7}Sr_{0.3}MnO_3$ (LSMO). STEM-EELS combined with density-functional calculations can be used to study the role of local structural distortions and electronic phenomena associated with point defects such as O vacancies on stabilizing interfacial magnetism. A second example including imaging of systems out of equilibrium can be found the study of Ni_3Fe nanoparticles for supercapacitors. Room temperature annealing in the objective lens magnetic field (close to 3T) induces a segregation of Ni and Fe species, in the form of small nanoclusters. Further heating induces Fe oxide segregation, resulting in core-shell like systems and Ni/NiO nanoclusters that have been identified as a major culprit for the pseudocapacitance enhancement. Work carried out in collaboration with G. Abellan, J. I. Beltran, E. Coronado, J. Grandal, A. Guedeja-Marron, C. Leon, S. G. Miralles, M. C. Muñoz, H. Prima-Garcia, J. Romero, J. Santamaria, J. Tornos. Research at UCM sponsored by grant# RTI2018-097895-B-C43.