The structural properties of oxide materials at the nanoscale have acquired an increasing interest in the last decade due to the wide range of newly improved applications. Metal oxides can be redesigned at the atomic scale creating interfaces or heterostructures that may lead to novel or improved functionalities (magnetic, superconducting, ferroelectric...). In this way, atomic resolution microscopy plays an important role in order to understand the influence that changes in structure and chemistry (strain, presence of defects, composition, oxidation state) may have on the physical properties of these materials.

In the present work, we choose two examples where by making use of aberration corrected scanning transmission electron microscopy (STEM) in its different working modes, we show state of the art analyses on different oxide systems. On one hand, we analyze the interaction of spontaneously segregated oxide nanoparticles (BaZrO3 and Ba2YTaO6) randomly distributed within YBa2Cu3O7 (YBCO) superconducting nanocomposite films. It is interesting to study the role of these nanoparticles on the generation of defects and incoherent interfaces with associated strain, which at the same time influence the flux pinning efficiency of these HTS superconductors. In this way, we have been able to unambiguously identify the atomic structure of the individual defects, their intrinsic self-assembling behavior as well as their interaction (Fig. 1) [1,2].

On the other, we analyze the case of CeO2 nanostructures. CeO2 has been deeply studied for its widespread range of applications: It is employed in solid oxide fuel cells (SOFTs) as ionic conductor; the variable oxidation state (OS) of cerium (Ce4+↔ Ce3+) makes ceria a suitable catalyst; but it also has interesting ionic conductivity and dielectric properties; and it is commonly used as buffer layer for oxide superconductors. Thus, it is important to determine the oxidation state at atomic scale, as well as localizing the position of the oxygen atoms (Fig. 2). We have used a combination of low angle annular dark field (LAADF), annular bright field (ABF) and STEM-EELS to study the presence of ordered oxygen vacancies in partially reduced CeO2 nanostructures (such as nanowires and nanopyramids).

References:

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Fig. 1: a) Atomic resolution HAADF image of an YBCO-BZO interface along the [001] direction. The enlarged areas correspond to the YBa2Cu3O7 (Y123) and Y2Ba4Cu8O16 (Y248) structures. b) Atomic models for the Y123 and Y248 structures along [001]. c) FFT filtered image of marked zone in a), showing the Y123-Y248 transition.

Fig. 2: a) Atomic resolution ABF STEM image obtained at a CeO2/LaAlO3 interface. b) Atomic model of the interface including the presence of Oxygen vacancies (Ce3+). c) ABF STEM image simulation.