Access to Rare Earth Elements (REE) and Platinum Group Metals (PGMs) is nowadays considered a major limiting factor for the development of Green Technologies. Aiming to contribute to the improvement in the efficient use of such strategic materials in the field of Heterogeneous Catalysis, novel nanocatalysts, based on ceria (CeO$_2$) are being investigated in our lab, featuring the following characteristics: low lanthanide contents and a noble-metal free formulation.

The strategy to synthesize the new materials consists in structuring the ceria component as nanometer thick surface layers coherently grown onto the surface of a carrier oxide (ZrO$_2$, YSZ, MgO). The analysis of the Redox properties of this new type of catalysts, which play in fact a key role in their catalytic performance in a variety of reactions, indicates a large improvement with respect to materials based on bulk ceria [1]. A better performance is observed both in H$_2$-reducibility at low temperatures as well as in the stability of the redox response against aging treatments at very high temperatures.

STEM analysis of these new materials has been key both to check the success in the nanostructuration targets proposed for their synthesis and, what’s more important, to understand the behavior observed at macroscopic level in their redox properties. Thus, by combining experimental HAADF-STEM and HREM images recorded on these materials, Figure 1, with simulated ones, Figure 2, it has been possible to detect the presence of a variety of nanostructures ranging from isolated, atom-like, Ce-species, up to 3D, well-faceted, nanoparticles, going through patch or raft-like 2D nano-objects. Such exotic, highly dispersed, nanostructures pose challenges not only to their detection but also to their ultimate 3D-characterization by Electron-tomography and to the analysis of their chemical nature by STEM-EELS or STEM-XEDS. All these aspects will be covered during the lecture.

References

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Fig. 1: (a) HAADF-STEM image of a 2-atomic planes thick CeOx surface structure recorded on a 4% mol. CeO2/MgO catalyst; (b) HREM view of the same catalyst showing at the same time both highly dispersed, atom-like, Ce-species and nanosized CeOx-rafts.

Fig. 2: Structural models (a,c) and HREM simulated images (b,d) of isolated Ce-species (top row) and 1-atom thick CeOx nano-rafts (lower row) supported on MgO.