

Nano-oxides in Chemistry / Catalysis

Marcos Fernández-García

¹*Instituto de Catálisis y Petroleoquímica, CSIC, C/Marie Curie 2, 28049-Madrid, Spain*

Tel: +34-91-5854939, Fax: +34-91-5854760, E-mail: mfg@icp.csic.es

Abstract

Metals oxides play an important role in many areas of chemistry, physics, and material science. The metal elements are able to form a large diversity of oxide compounds and can adopt a vast number of geometries with an electronic structure that can exhibit metallic, semiconductor, or insulator characteristics [1,2].

In the emerging field of the nanotechnology, a capital goal is to make nanoarchitectures with special properties with respect to bulk or single (e.g. isolated) species. Oxide nanoparticles can display unique chemical properties due to their limited size [2]. Oxide materials with technological implications, such as MgO, Al₂O₃, Fe₂O₃, ZnO, TiO₂ or CeO₂, can be used in single component configurations or as part of materials containing several phases/components and, particularly, as supported oxide systems. Among the first, the nanostructure allows the modulation of the structural and electronic properties of the systems, with consequences in their chemical activity, while in the second type of systems interface effects add complexity to the interpretation of the physico-chemical properties. In this talk we will analyze nanostructure effects on both types of systems, mono and multiphasic materials, giving relevance to the establishment of firm structure-activity relationships in order to interpret the chemical, particularly catalytic, properties of oxide systems.

In a general review of the oxides properties, we will consider ceria as a proto-typical material to exemplify to current status of the art. Starting with the influence of the nanostructure on structural properties, we will discuss the intimate interplay occurring between the presence of (mostly punctual) defects and primary particle size, and the consequences on cell parameters/volume and strain. Similarly, consequences (of defects and primary particle size) in electronic properties will be also detailed and a brief list can include the modification of the metal-oxygen bond nature, the discretization of the electronic levels and subsequent band gap alteration, the presence of gap states and, finally, the absence of band bending at interfaces [2,3].

Considering multiphasic systems and the influence of interface effects on physico-chemical properties we will focus our attention on the analysis of redox properties of alumina-supported ceria nanosystems [4,5].

In a second part of the talk we will discuss the most challenging aspects of the nanostructure effects on physico-chemical properties and will use titania to exemplify first, how to control all morphological (and not only primary particle size) parameters while using modern, appropriate preparation methods, and second, the influence of such morphological properties beyond primary particle size on structural/electronic properties and then on the final, chemical, catalytic properties of nanostructured oxides [6,7]. We will close this contribution by analyzing the doping of titania by several cations like V, Mo, Nb, and W, and how the doping process is affected in its structural/electronic characteristics by the nanostructure of the oxide and the consequences in the photo-catalytic properties of the nano-materials [7].

References

1. "Nanomaterials: Synthesis, Properties and Applications". Edelstein A.S.; Cammarata R.C.; Eds. Institute of Physics Publishing, London, 1998. M.
2. M. Fernández-García, A. Martínez-Arias, J.C. Hanson, J.A. Rodríguez, *Chem. Rev.* 104, 4063 (2004).
3. M.D. Hernández-Alonso, A.B. Hungría, J.M. Coronado, A. Martínez-Arias, J. Soria, J.C. Conesa, M. Fernández-García, *Phys. Chem. Chem. Phys.* 6, 3524 (2004); *Appl. Catal. B* 50, 167 (2004).
4. M. Fernández-García, A. Martínez-Arias, A.B. Hungría, A. Iglesias, J.C. Conesa, J. Soria, *J. Catal.* 194, 385 (2000); *Phys. Chem. Chem. Phys.* 4, 2473 (2002).
5. I.E. Wachs, *Catal. Today* 100, 79 (2005).
6. M. Fernández-García, C. Belver, X. Wang, J.C. Hanson, J.A. Rodríguez, *J. Phys. Chem. C* 111, 674 (2007); *J. Am. Chem. Soc.* 129, 13604 (2007).
7. M. Fernández-García, A. Fuerte, A. Martínez-Arias, J.C. Conesa, *J. Phys. Chem. B* 109, 6075 (2005); *Appl. Catal. B* 74, 26 (2007); *J. Catal.* 254, 272 (2008).