Synthesis and characterization of Yb^{3+} doped scandium oxide nanocrystals

<u>M. Galceran</u>[1], M.C. Pujol[1], J.J. Carvajal[1], X. Mateos[1], M. Aguiló[1], F. Díaz[1], C. Zaldo[2]
[1]Física i Cristal·lografia de Materials i Nanomaterials (FiCMA-FiCNA), Universitat Rovira i Virgili (URV), Campus Sescelades, c/ Marcel·lí Domingo, s/n, E-43007 Tarragona, Spain
[2]Instituto de Ciencia de Materiales de Madrid, Consejo Superior de Investigaciones Científicas, c/ Sor Juana Inés de la Cruz 3, E-28049, Madrid, Spain
montserrat.galceran@urv.cat

The rare earth sesquioxides are known as excellent hosts of laser ions due to their low thermal expansion, high thermal conductivity and large crystal field splitting of the electronic states of lanthanides [1] [2]. These suppose clear advantages over the classic YAG laser host, however single crystals of sexquioxides are difficult to grow due to the high melting temperature, ≈2700K. The synthesis of lanthanide-doped sesquioxide nanocrystals is of great interest as the first step for the preparation of ceramic lasers, an alternative to single crystalline lasers with improved thermal and mechanical properties.

Trivalent ytterbium (Yb^{3+}) is an interesting laser active ion as an alternative to Nd^{3+} in 1 μm range. Yb^{3+} presents a simple energy level scheme leading to low quantum defect between the pump and the laser photons, a long radiative lifetime, no excited-stated absorption or up-conversion losses, and weaker than Nd^{3+} cross-relaxation processes [3].

In the present study, the modified Pechini method was used to obtain Yb_x:$Sc_{2-x}O_3$ (x = 0.001 – 1) nanocrystals because of its several advantages such as low temperature processing, low cost and simplicity [4,5]. The structural characterization of Yb_x:$Sc_{2-x}O_3$ nanocrystals was carried out by powder X-ray diffraction, TEM studies and electron diffraction. Synthesized Yb_x:$Sc_{2-x}O_3$ nanocrystals belong to the cubic system with space group $Ia\bar{3}$.

Figure 1 shows a representative TEM image of the obtained nanocrystals to estimate the particle size and their dispersion. Most nanocrystals were in the range 15-25 nm with a mean and dispersion of 17.7 nm and 46 %, respectively. We applied two types of electron diffraction techniques: selected area electron diffraction (SAED) and convergent beam electron diffraction as nanobeam electron diffraction. Figure 2a shows the TEM image that consists in aggregates of Yb_x:$Sc_{2-x}O_3$ nanocrystals, the corresponding SAED pattern which confirms the no preferential orientation for the nanocrystals is shown in figure 2b. Each ring corresponds to a crystallographic plane, which can be indexed according with the space group ($Ia\bar{3}$). Figures 2c and 2d depict a TEM image of an individual Yb_x:$Sc_{2-x}O_3$ nanocrystal and its nanobeam electron diffraction pattern, it can observed the presence of four equivalent reflections (the most closest to the central beam) corresponding to $\{2\bar{2}2\}$ with interplanar distance of 2.8425 Å. Two other equivalent reflections correspond to $\{004\}$ with an interplanar distance of 2.4616 Å. The last one is $\{4\bar{4}0\}$ and its inter-planar distance is 1.7406 Å. From these reflections, the orientation of these nanocrystals can be indexed in the $[110]$ zone axis. Spectroscopic properties of nanocrystals have been measured and are equivalents respect to the bulk single crystal; this is a necessary condition to manufacture the laser.

References:

---

[1] J. Lu, K. Takaichi, T. Uematsu, A. Shirakawa, M. Musha, K.Ueda, H. Yagi, T. Yanagitani, A.A. Kaminskii, Appl. Phys. Lett. **81** (2002) 43244326.

[2] C.A. Morrison, R.P. Leavitt, Handbook on the Physics and Chemistry of Rare Earths, New York:1982.

[3] L.D. Deloach, S.A. Payne, L.L. Chase, L.K. Smith, W.L. Kway, W.F. Krupe, IEEE J. Quantum Electron. **29** (1993) 1179

[4] M. Galceran, M.C. Pujol, M. Aguiló, F. Díaz, J. Sol-Gel Tech. **42** (2007) 79.

[5] M. Galceran, M.C. Pujol, M. Aguiló, F. Díaz, Mater. Sci. Engineer. B **146** (2008) 7.

Figures:

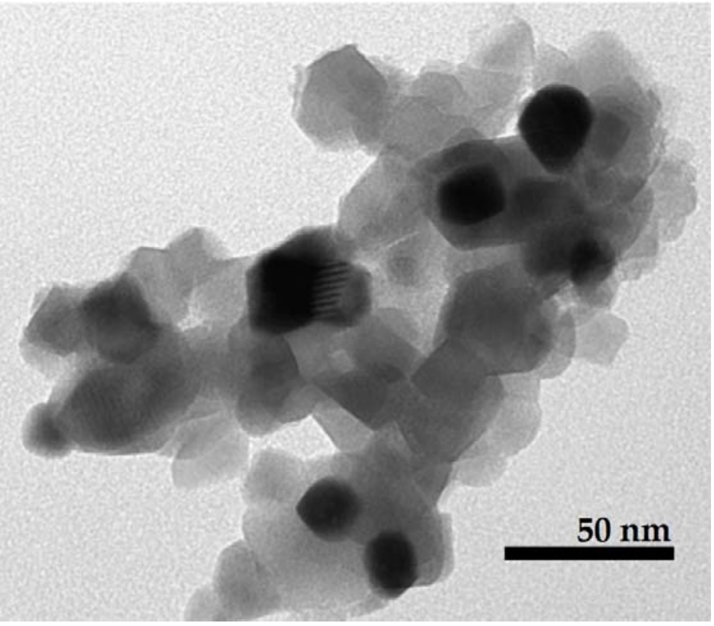

Figure 1. Representative TEM image of Yb_x:$Sc_{2-x}O_3$ nanocrystals

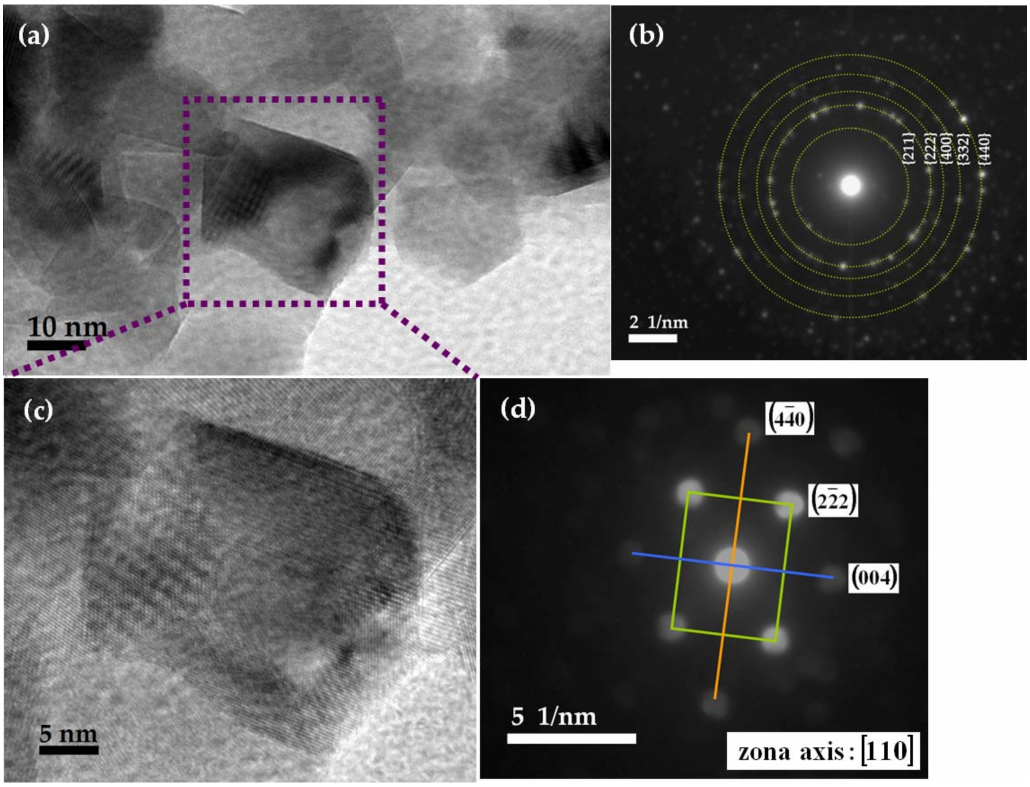

Figure 2. (a) TEM image of an aggregate of Yb_x:$Sc_{2-x}O_3$ nanocrystals, (b) SAED pattern of (a), (c) zoomed part of (a) showing a small nanocrystal with visible lattice planes and (d) Nanobeam electron diffraction pattern of (c).