DEFORMATION MECHANISM OF CERIUM OXIDE NANOCUBES - AN IN SITU TRANSMISSION ELECTRON MICROSCOPY STUDY

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Cerium oxide nanoparticles are used in many industrial products, among which solid oxide fuel cell electrodes or catalysts. However, their mechanical properties are rarely taken into account and few studies dealt with the determination of their deformation mechanism [1, 2].

This study deals with the determination of the deformation mechanism in cerium oxide monocrystalline nanocubes. Cerium oxides nanocubes (20-130 nm in size) are compressed using a dedicated Hysitron PI 95 sample holder in an environmental transmission electron microscope (ETEM). Plastic deformation of the nanocubes is analyzed using live High-Resolution TEM imaging. Two main phases of cerium oxides are investigated in this study: CeOx has a fluorite structure (space group Fm-3m) when x ranges between around 1.75 and 2, while it crystallizes in bixbyite (space group Ia-3) when x is less than about 1.75. The oxygen content and the corresponding space group can be monitored in situ by changing either the gaseous environment (high vacuum or air) or the electron dose rate conditions (high or low dose rate).

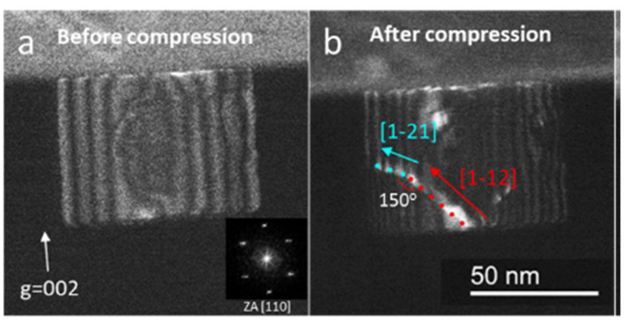

Figure 1 – Dark-field TEM images of (a) before and (b) after compression along [001], with zone axis [110]

We will first present dislocation indexation during in situ tests, through the analysis of dislocation movements in fluorite nanocubes during compression. Dark Field images acquired on nanocubes before and after compression, with different orientations (see Figure 1), are also used to further determine the dislocation vector. With both methods, we will show that [110]{111} are the main slip systems determined in fluorite CeO_x. This is in agreement with simulation results.

Moreover, we will show results obtained on tests performed on cubes irradiated using a high dose rate. Many stacking faults are formed under compression in the bixbyite structure. This occurs with a significant decrease of the yield stress. To better understand this phenomenon, cycles will be presented on a nanocube with different electron dose rates. We will show that the formation of stacking faults and the decrease of the yield stress are repeatable and reversible. According to the evolution of defects and yield stress changes, the deformation mechanism in fluorite and bixbyite phases appears to be different and will be discussed.

[1] T;X.T. Sayle et al., Nanoscale 3 (2011) 1823.
[2] Y. Ding et al., J. Appl. Phys. 120 (2016) 214302.