**In-situ** Transmission Electron Microscopy Study of Oxygen Vacancy Ordering and Dislocation Annihilation in Undoped and Sm-doped CeO2 Ceramics During Redox Processes

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Ceria (CeO₂) based ceramics have been widely used for many applications due to their unique ionic, electronic, and catalytic properties. Here we report our findings in investigating into the redox processes of undoped and Sm-doped CeO₂ (Sm₀.₂Ce₀.₈O₁.₉, SDC) ceramics stimulated by high-energy electron beam irradiation within a transmission electron microscope (TEM) [1].

The reduced structure with oxygen vacancy ordering has been identified as the CeO₁.₆₈ (C-Ce₂O₃₊δ) phase via high-resolution TEM (HRTEM). Figure 1 gives the HRTEM images from the same SDC grain projected along different orientations. While the insets are simulated images using standard CeO₁.₆₈ structure, which match the experimental ones pretty well. The reduction of Ce⁴⁺ to Ce³⁺ has been monitored by electron energy-loss spectroscopy. The decreased electronic conductivity of the SDC is revealed by electron holography, as positive electrostatic charges accumulated at the surfaces of SDC grains under electron beam irradiation, but not at CeO₂ grains.

The formation of the reduced CeO₁.₆₈ domains corresponds to lattice expansion compared to the CeO₂ matrix [2]. Therefore the growth of CeO₁.₆₈ nuclei builds up strain inside the matrix, causing annihilation of dislocations inside the grains. By using *in-situ* high-resolution TEM and a fast OneView camera recording system, we investigated dislocation motion inside both CeO₂ and SDC grains under electron beam irradiation. As displayed in Figure 2, the dislocation prefers to dissociate into Shockley partials bounded by stacking faults. Then the partials can easily glide in one of the {111} planes to reach the grain surfaces. Even the Lomer-Cottrell lock can be swept away by the phase change induced strain field. Our results revealed the high mobility of dislocations inside CeO₂ and SDC grains during their respective redox processes [3].

References:

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Figure 1. HRTEM images of SDC along different incident electron beam directions: (a) [001]; (b) [101]; (c) [112]; (d) [111]. The FFT patterns and simulated HRTEM images are inserted.

Figure 2. A series of HRTEM images recorded in time sequence from the same area of a CeO2 grain.