# Deformation mechanisms of olivine compressed at 300 MPa and 800-1100°C

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Rheology of mantle rocks at lithospheric temperatures remains poorly constrained, since most experimental studies on creep mechanisms of olivine single crystals ($(MgFe)_2SiO_4$, *Pbnm*) and polycrystalline olivine aggregates were performed at high-temperatures (T >> 1200°C). In this study, we have performed deformation experiments on oriented single crystals of San Carlos olivine and polycrystalline olivine aggregate at temperatures relevant of the uppermost mantle (ranging from 800 to 1090°C) in tri-axial compression. The experiments were carried out at a confining pressure of 300 MPa in a high-resolution gas-medium mechanical testing apparatus at various constant strain rates (from $7 \times 10^{-6}$ $s^{-1}$ to $1 \times 10^{-4}$ $s^{-1}$). Mechanical tests yield differential stresses ranging from 88 to 1076 MPa. All samples were deformed at constant displacement rate and for finite strains ranging from 4 to 23 %, to provide insight into possible effects of hardening, softening or stick-and-slip. The single crystals were compressed along several crystallographic directions to test the possibility of activating different slip systems (*e.g.* [100](001), [001](100), [001](010) and [100](010)). We will present the characterization of the dislocation microstructures performed in the TEM. In particular, we present some slip plane characterizations for [001] dislocations based on electron tomography.

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# The disposal of spent nuclear fuel: The effect of high energy surface sites on dissolution rate

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High energy surface sites, including grain boundaries, step edges and naturally occurring surface defects are expected to play a role in the dissolution of mineral surfaces. Spent Nuclear Fuel (SNF), composed primarily of ceramic $UO_2$, has grain boundaries and oxygen vacancy defects as a result of high temperature annealing within a nuclear reactor. In the safety case for the geological disposal of nuclear waste, the release of radioactivity from the repository is controlled by the dissolution of the SNF in groundwater, therefore the dissolution characteristics arising from surface features must be determined.

In this study, we demonstrate the effect of high energy surfaces sites on the dissolution rate of $CeO_2$, a SNF analogue, which approximates as closely as possible the characteristics of fuel-grade $UO_2$. Due to the highly refractory nature of $CeO_2$, dissolution was conducted at 90 °C and pH 2 (nitric acid). $CeO_2$ was powdered to several different size fractions and subject to dissolution. It was found that large size fractions exhibited a greater dissolution rate than small size fractions ($0.81 \times 10^{-4}$ g $m^{-2}$ $d^{-1}$ for 75 – 150 $\mu$m compared to $0.45 \times 10^{-4}$ g $m^{-2}$ $d^{-1}$ for 25 -50 $\mu$m). Annealing the powders at high temperature removed some of the high energy surface sites and resulted in a less rapid dissolution rate ($0.21 \times 10^{-4}$ g $m^{-2}$ $d^{-1}$ for 25 -50 $\mu$m). Monolith samples of $CeO_2$ were subject to dissolution and analysed periodically by AFM and ICP-MS. Initially, grain boundary dissolution was rapid (460 nm increase in grain boundary depth over 7 days), concurrent with a rapid dissolution rate (0.57 ppm $d^{-1}$). The dissolution rate decreased (0.15 ppm $d^{-1}$) when there was no longer any change in the grain boundary depth. $CeO_2$ powders were annealed under reducing conditions ($H_2/N_2$), forming non-stoichiometric $CeO_{1.93}$, concurrent with the formation of oxygen vacancy defects. The dissolution rate of these powders was three orders of magnitude greater than for $CeO_2$ powders. These results demonstrate that high energy surface sites are important in controlling the dissolution rate of SNF and provide quantitative information to reduce uncertainty in the safety case for SNF disposal.

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