American Mineralogist, Volume 92, pages 1436–1445, 2007

Pressure-induced slip-system transition in forsterite: Single-crystal rheological properties at mantle pressure and temperature

Paul Raterron,[1,*] Jiuhua Chen,[2] Li Li,[1,2] Donald Weidner,[1,2] and Patrick Cordier[1]

[1]Laboratoire de Structure et Propriétés de l'Etat Solide, Université des Sciences et Technologies de Lille, F-59655 Villeneuve d'Ascq Cedex, France
[2]Mineral Physics Institute and Department of Geosciences, Stony Brook University, Stony Brook, New York 11733-2100, U.S.A.

Abstract

Deformation experiments were carried out in a Deformation-DIA high-pressure apparatus (D-DIA) on oriented Mg_2SiO_4 olivine (Fo100) single crystals, at pressure (*P*) ranging from 2.1 to 7.5 GPa, in the temperature (*T*) range 1373–1677 K, and in dry conditions. These experiments were designed to investigate the effect of pressure on olivine dislocation slip-system activities, responsible for the lattice-preferred orientations observed in the upper mantle. Two compression directions were tested, promoting either [100] slip alone or [001] slip alone in (010) crystallographic plane. Constant applied stress (σ) and specimen strain rates ($\dot{\varepsilon}$) were monitored in situ using time-resolved X-ray synchrotron diffraction and radiography, respectively. Transmission electron microscopy (TEM) investigation of the run products reveals that dislocation creep assisted by dislocation climb and cross slip was responsible for sample deformation. A slip transition with increasing pressure, from a dominant [100]-slip to a dominant [001]-slip, is documented. Extrapolation of the obtained rheological laws to upper-mantle *P*, *T*, and σ conditions, suggests that [001]-slip activity becomes comparable to [100]-slip activity in the deep upper mantle, while [001] slip is mostly dominant in subduction zones. These results provide alternative explanations for the seismic anisotropy attenuation observed in the upper mantle, and for the "puzzling" seismic-anisotropy anomalies commonly observed in subduction zones.

Keywords: Upper mantle, olivine, high pressure, slip systems, rheological law, seismic anisotropy, subduction zone