Microstructural development in olivine aggregates during dislocation creep under hydrous conditions

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Since hydrogen plays an important role in dynamic processes in the mantle, we conducted high-strain torsional shear experiments on aggregates of Fe-bearing olivine [$(Mg,Fe)_2SiO_4$; Fo50] under hydrous condition. Olivine with a composition of Fo50 was used because of its enhanced grain growth kinetics and low strength relative to Fo90. Two pieces of an oriented San Carlos olivine crystal were embedded in each aggregate to monitor water fugacity both before and after deformation. We deformed samples to high enough shear strain≈ 5, to achieve a steady-state microstructure.
A non-linear, least-squares fit to the stress versus strain rate data yielded a stress exponent of $n \approx 3.5$, indicative of deformation involving dislocations. The water content determined from Fourier transform infrared (FTIR) spectroscopy analyses of the single crystals demonstrated that the samples were water saturated after deformation. Fabric analyses of the polycrystalline olivine samples, determined using electron backscatter diffraction (EBSD), indicate that the strength of the lattice preferred orientation (LPO) increases with increasing strain. Further, the LPO of olivine changes as a function of strain due to competition among three slip systems: (010)[100], (100)[001], and (001)[100]. Observed strain weakening can be attributed to geometrical softening due to LPO development, which reduces the stress by ~1/3 from its peak value in constant strain rate experiments. The evolution of fabric can be applied to investigations of upper mantle seismic anisotropy especially in a mantle wedge or in a shear zone, locations in which hydrous conditions prevail.

Keywords: olivine, high strain deformation, dislocation creep, geometrical softening due to LPO development

