Strain hardening, texture and microstructure evolution during plastic deformation of olivine at 1000-1200 °C

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As the major constituent of Earth's upper mantle, olivine largely determines its physical properties. In the past, deformation experiments were usually run until steady state or to a small value of finite strain (creep test). Additionally, few studies were performed on polycrystalline aggregates at low to intermediate temperatures (<1100 °C). For the first time, we study the mechanical response and correlated microstructure as a function of finite strain. Deformation experiments are conducted in uniaxial compression in an internally heated gas-medium deformation apparatus at temperatures of 1000-1200 °C, strain rates of $10^{-5}s^{-1}$ and 300 MPa of confining pressure. Sample volumes are large with > 1.2 cm^3. Finite strains range from 0.5 to 9.9 % and corresponding differential stresses from 71 to 659 MPa. Deformed samples were characterized by high resolution (submicron) electron backscatter diffraction (EBSD) and transmission electron microscopy (TEM). For the first time in olivine, EBSD maps with step sizes as low as 0.05 μm were acquired without introducing artifacts. Accounting for sectioning bias (factor of 1.5), the true mean grain diameter ranges from 2.3-2.9 μm, with no significant changes between samples. Likewise, statistical parameters for texture (J- and BA-index), density of geometrically necessary dislocations, spread of grain orientation, mean misorientation over subgrain boundaries, subgrain boundary spacing, grain shape and aspect ratio do not change significantly in between samples or as a function of finite strain. From TEM imaging, all samples show a sizeable subset of grains that are mostly undeformed. Thus, even at steady state, plasticity does not necessarily affect grains in unfavorable crystallographic orientations. We find no strict confirmation of dislocation entanglements being the reason for strain hardening in the deformed samples. Our results suggest other, yet not understood, mechanisms affecting the strength of deformed polycrystalline olivine.