Slip in, and Strength of, Natural Pyropic and Majoritic Garnets at High Pressures

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Garnet is an important mineral phase in the upper mantle as it is both abundant in normal mantle, and a primary phase within high-pressure subducted basalt. The upper mantle is seismologically heterogeneous; the sources of the heterogeneity have been explained by preferred orientation of upper mantle minerals, chemically distinct previously subducted material, phase changes in minerals and partial melting. In this study, we focus on crystallographic preferred orientation that develops within garnet as accommodated by differential deformational strain. Subducted slabs have been observed to contribute to the seismic anisotropy of the upper mantle. We have used X-ray diffraction in a radial geometry within the diamond anvil cell to analyze texture development in three garnet compositions under pressure using gold as an internal standard. Our samples are a natural pyropic garnet ($Py_{67}Alm_{33}$) and two synthetic solid solutions, $Mj_{59}Py_{42}$, and $Mj_{41}Py_{59}$, which are probed to pressures of 45 GPa. All three garnets develop a modest (100) texture at elevated pressure under differential strain. Elasto viscoplastic self-consistent (EVPSC) modeling suggests that two slip systems are active: {110}<1-11> and {001}<110> at all pressures studied. The low degree of texturing associated with deformation (as documented by our calculated inverse pole figures) coupled with the elastic isotropy of garnets (from single crystal studies; e.g., Sinogeiken and Bass 2000), indicates that garnet will remain seismically isotropic at high pressures in a relatively anisotropic upper mantle. We are able to determine a flow strength of ~5 GPa at pressures between 10 to 15 GPa for all three garnets; this implies that the majorite substitution does not greatly affect the strength of garnets. These flow strength values are higher than previously measured yield strengths on natural and majoritic garnets (Kavner et al. 2000; Kavner 2007). Additionally, these garnets are of generally comparable strength to lower mantle phases such as perovskite (flow strength of ~4 GPa at 10 GPa; Merkel et al. 2003) and ferropericlase (flow strength of ~8 GPa at ~10 GPa; Merkel et al. 2002), implying that garnet may not be notably stronger than the underlying material if a garnet-rich layer is sequestered at the base of the upper mantle.