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Deformation and strength of mantle relevant garnets: Implications for the subduction of basaltic-rich crust

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Abstract

Garnet is an important mineral phase in the upper mantle as it is both a key component in bulk mantle rocks, and a primary phase at high pressure within subducted basalt. Here, we focus on the strength of garnet and the texture that develops within garnet during accommodation of differential deformational strain. We use X-ray diffraction in a radial geometry to analyze texture development in situ in three garnet compositions under pressure at 300 K: a natural garnet ($Prp_{60}Alm_{37}$) to 30 GPa, and two synthetic majorite-bearing compositions ($Prp_{59}Maj_{41}$ and $Prp_{42}Maj_{58}$) to 44 GPa. All three garnets develop a modest (100) texture at elevated pressure under axial compression. Elasto-visco-plastic self-consistent (EVPSC) modeling suggests that two slip systems are active in the three garnet compositions at all pressures studied: $\{110\}\langle 1\bar{1}1\rangle$ and $\{001\}\langle 110\rangle$. We determine a flow strength of ~5 GPa at pressures between 10 to 15 GPa for all three garnets; these values are higher than previously reported yield strengths measured on natural and majoritic garnets. Strengths calculated using the experimental lattice strain differ from the strength generated from those calculated using EVPSC. $Prp_{67}Alm_{33}$, $Prp_{59}Maj_{41}$, and $Prp_{42}Maj_{58}$ are of comparable strength to each other at room temperature, which indicates that majorite substitution does not greatly affect the strength of garnets. Additionally, all three garnets are of similar strength as lower mantle phases such as bridgmanite and ferropericlase, suggesting that garnet may not be notably stronger than the surrounding lower mantle/deep upper mantle phases at the base of the upper mantle.

Keywords: High-pressure experiment, diamond-anvil cell, garnet, texture, strength, radial X-ray diffraction