High-pressure single-crystal elasticity measurements of Al-Fe-bridgmanite up to lower mantle pressures

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Abstract

The chemical composition of the Earth's lower mantle can be constrained by combining seismological observations with mineral physics elasticity measurements. Here, we report single-crystal elasticity data on Al-Fe-bearing bridgmanite using single-crystal high-pressure Brillouin spectroscopy and X-ray diffraction. Two crystals of (Mg0.9Fe0.1Si0.9Al0.1)O3 bridgmanite with different crystallographic orientations were cut using a focused ion beam and were loaded in the pressure chamber of a single diamond anvil cell. Elasticity and density measurements were performed at high-pressures on both samples using a combined Brillouin scattering and X-ray single crystal diffraction system at BGI. Our results show that the Fe/Al substitution in the MgSiO3 structure reduces the acoustic velocities at room pressure. Moreover the compressional wave velocities remain smaller at all pressures, whereas the larger pressure dependence of the shear velocities leads to a shear velocity crossover with MgSiO3 bridgmanite at pressures above 35 GPa. We employ our data to model seismic wave velocities in the top portion of the lower mantle assuming a pyrolitic mantle composition. We find good agreement between our mineral physics predictions and the seismic PREM down to at least 1200 km depth. A high Fe3+/Fe2+ ratio of about 2 in shallow lower mantle bridgmanite is required to match seismic data, implying the presence of metallic iron in an isochemical mantle. Our calculated velocities are in increasingly poor agreement with those of the lower mantle at depths > 1200 km, indicating either a change in bridgmanite cation ordering or a decrease in the ferric iron content of the lower mantle that has potential implications for geochemistry and geophysics.

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