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Single-crystal elasticity of (Al,Fe)-bearing bridgmanite up to 82 GPa

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Abstract

Thermoelastic properties of mantle candidate minerals are essential to our understanding of geophysical phenomena, geochemistry, and geodynamic evolutions of the silicate Earth. However, the lower-mantle mineralogy remains much debated due to the lack of single-crystal elastic moduli (C_{ij}) and aggregate sound velocities of (Al,Fe)-bearing bridgmanite, the most abundant mineral of the planet, at the lower mantle pressure-temperature (P-T) conditions. Here we report single-crystal C_{ij} of (Al,Fe)-bearing bridgmanite, $\mathrm{Mg_{0.88}Fe_{0.1}Al_{0.14}Si_{0.90}O_3}$ (Fe10-Al14-Bgm) with $\mathrm{Fe^{3+}/\Sigma Fe}$ = ~0.65, up to ~82 GPa using X-ray diffraction (XRD), Brillouin light scattering (BLS), and impulsive stimulated light scattering (ISLS) measurements in diamond-anvil cells (DACs). Two crystal platelets with orientations of (–0.50, 0.05, –0.86) and (0.65, –0.59, 0.48), that are sensitive to deriving all nine C_{ij}, are used for compressional and shear wave velocity (v_P and v_S) measurements as a function of azimuthal angles over 200° at each experimental pressure. Our results show that all C_{ij} of singe-crystal Fe10-Al14-Bgm increase monotonically with pressure with small uncertainties of 1–2% ($\pm 1\sigma$), except C_{55} and C_{23}, which have uncertainties of 3–4%. Using the third-order Eulerian finite-strain equations to model the elasticity data yields the aggregate adiabatic bulk and shear moduli and respective pressure derivatives at the reference pressure of 25 GPa: $K_S = 326 \pm 4$ GPa, $\mu = 211 \pm 2$ GPa, $K'_S = 3.32 \pm 0.04$, and $\mu' = 1.66 \pm 0.02$ GPa. The high-pressure aggregate v_S and v_P of Fe10-Al14-Bgm are 2.6–3.5% and 3.1–4.7% lower than those of $\mathrm{MgSiO_3}$ bridgmanite end-member, respectively. These data are used with literature reports on bridgmanite with different Fe and Al contents to quantitatively evaluate pressure and compositional effects on their elastic properties. Comparing with one-dimensional seismic profiles, our modeled velocity profiles of major lower-mantle mineral assemblages at relevant P-T suggest that the lower mantle could likely consist of about 89 vol% (Al,Fe)-bearing bridgmanite. After considering uncertainties, our best-fit model is still indistinguishable from pyrolitic or chondritic models.

Keywords: Single-crystal elasticity, bridgmanite, lower mantle, pyrolite, chondrite