Single-Crystal Elasticity of (Al,Fe)-bearing Bridgmanite at High Pressure: Implications to Seismic Anisotropy in the Lower Mantle

Suyu Fu[1], Jing Yang[1,2], Noriyoshi Tsujino[3], Takuo Okuchi[3], Narangoo Purevjav[3], Jung-Fu Lin[1]

[1]Department of Geological Sciences, Jackson School of Geosciences, The University of Texas at Austin, Austin, TX78712, USA

[2]Now at Geophysical Laboratory, Carnegie Institution of Washington, DC, USA

[3]Institute for Planetary Materials, Okayama University, Misasa, Japan

While the lower mantle is believed to be mostly isotropic, ~1-2% shear wave (V_S) radial anisotropy has been observed at the topmost lower mantle near subduction regions at ~670-1000 km depths[1]. The V_S radial anisotropy has been attributed to crystallographic preferred orientation of constituent materials under mantle convection[2]. Thus, knowledge of the single-crystal elasticity of bridgmanite, the most abundant mineral in the lower mantle, is key to understanding the aforementioned seismic observations. An early study by Kurnosov, et al.[3] measured the single-crystal elasticity of bridgmanite, $Mg_{0.9}Fe_{0.1}Al_{0.1}Si_{0.9}O_3$, up to 40 GPa, however, a recent comment[4] questioned the reliability and uncertainties of the modeled elasticity in Kurnosov, et al.[3]. Furthermore, Fe and Al contents in bridgmanite can change with depth and regionally due to chemical heterogeneity in the lower mantle[5]. All these can affect our understanding of the elasticity and elastic anisotropy of bridgmanite and thus the interpretation of seismic anisotropy at the topmost lower mantle. Here, we measured the compressional and shear wave velocities of single-crystal bridgmanite with two compositions of $Mg_{0.95}Fe^{2+}_{0.033}Fe^{3+}_{0.027}Al_{0.04}Si_{0.96}O_3$ (Fe6-Al4-Bgm) and $Mg_{0.89}Fe^{2+}_{0.024}Fe^{3+}_{0.096}Al_{0.11}Si_{0.89}O_3$ (Fe12-Al11-Bgm) at high pressures using the combination of impulsive stimulated light scattering and Brillouin light scattering techniques. Based on experimental measurements on crystal platelets of each composition with crystallographic orientations that are sensitive for reliable full elastic constant derivations, we derived the full elastic tensor of Fe6-Al4-Bgm and Fe12-Al11-Bgm at high pressures. Combining the single-crystal elasticity data of Fe6-Al4-Bgm and Fe12-Al11-Bgm with the crystallographic preferred orientation results of deformed bridgmanite at relevant lower-mantle pressure-temperature (P-T) conditions from literature[6], we modeled the seismic V_S radial anisotropy of deformed (Al,Fe)-bearing bridgmanite near a subducting slab at conditions relevant to the topmost lower mantle. Taking into account the Fe and Al contents in (Al,Fe)-bearing bridgmanite with depth at topmost lower mantle, the modeled results could provide explanations to the distinct seismically-detected V_S radial anisotropies at the topmost lower mantle near subducted slabs, especially in the Tonga-Kermadec subduction region.

References:

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