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Path-Dependent Phase Transformations of Bridgmanite under Dynamic Compression

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Bridgmanite ($MgSiO_3$-perovskite), the most abundant mineral in Earth's lower mantle, is predicted from static high-pressure experiments to transform to post-perovskite (pPv) near the core-mantle boundary. Whether this transformation proceeds under dynamic compression, however, remains incompletely constrained. Here we synthesize dense polycrystalline bridgmanite using a multi-anvil press and employ these materials as starting samples for laser-driven dynamic compression experiments.

Shock compression experiments performed at the Dynamic Compression Sector (Advanced Photon Source) reached peak pressures of ~391 GPa. Diffraction patterns collected during pressure release (~153 GPa) showed no features attributable to post-perovskite, indicating that bridgmanite persisted along the shock pathway despite peak stresses far exceeding the equilibrium pPv transition pressure (~125 GPa).

In contrast, ramp compression experiments conducted at the OMEGA laser facility to pressures exceeding ~350 GPa produced diffraction signatures consistent with transformation to post-perovskite. The differing outcomes between shock and ramp loading indicate a strong dependence of phase evolution on the thermodynamic compression pathway, as the two techniques access distinct pressure–temperature trajectories.

These results demonstrate that phase stability inferred from static equilibrium experiments cannot be directly extrapolated to dynamic compression conditions. Kinetic and pathway-dependent effects must be considered alongside equilibrium thermodynamics when interpreting phase transformations under dynamic compression.