Geophysical Research Abstracts
Vol. 20, EGU2018-13148, 2018
EGU General Assembly 2018

Velocity-Density Systematics of Fe-Si Alloys at Extreme Conditions: Constraints on Si content in the Earth's Inner Core

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The physical properties and dynamics of the Earth's core are critically dependent on its chemical composition. As there is no direct method for sampling core materials, compositional models are obtained by comparing seismological observations to profiles of density, compressional sound velocity (Vp), and shear velocity (Vs) established by experiments or calculations on candidate materials. However, while core formation models based on metal-silicate equilibration point at silicon as one of the major light element in the inner core, existing work on the study of Fe-Si alloys is scarce, mostly limited to alloys unrealistically enriched in Si, and limited to techniques which often indirectly measure Vp of the alloy.

To this end, we carried out a multi-technique study on Fe-5wt%Si. We performed synchrotron X-ray diffraction measurements in a laser-heated diamond anvil cell to generate a P-V-T equation of state for this alloy up to pressures and temperatures exceeding 1 Mbar and 2100K. Additionally, picosecond acoustics experiments were performed to measure Vp under quasi-hydrostatic conditions up to 1.1 Mbar. The combination of these studies provide reliable velocity-density data, and when extrapolated to inner core conditions, show that a binary Fe-Si alloy can account for inner core density but is unlikely to explain seismic observations of compressional sound velocity.