Geophysical Research Abstracts
Vol. 19, EGU2017-12224, 2017
EGU General Assembly 2017

Understanding the Earth's Mantle Through Advanced Elasticity Measurements

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Constraints on the inner structure, chemical and mineralogical composition as well as dynamics of Earth's mantle can be derived through comparison of laboratory elasticity data to seismological observables. A quantitative knowledge of the elastic properties of mantle minerals, and their variations with chemical composition, at pressure and temperature conditions of Earth's mantle is key to construct reliable synthetic mineral physics-based seismic velocity models to be compared to seismic observables.

We will discuss results of single-crystal elasticity measurements on Earth mantle minerals that have been conducted using the combined Brillouin scattering and x-ray diffraction (XRD) system at BGI Bayreuth in combination with advanced sample preparation using the focused ion beam (FIB) technique [1] that allows for tailoring sizes and shapes of tiny single-crystals. In our experiments, multiple FIB-prepared single-crystals were loaded in a single sample chamber of a resistively-heated diamond-anvil cell (DAC). The possiblity to measure simultaneously acoustic wave velocities and density (unit-cell parameters) in the DAC in combination with the multi-sample approach facilitates direct quantification of the effects of chemical substitution on the elasticity and seismic wave velocities at non-ambient conditions. Our experimental approach eliminates uncertainties arising from the combination of data collected under (potentially) different conditions in several DAC runs, in different laboratories and/or from using different pressure-temperature sensors.

We will present our recent experiments on the elasticity of single-crystal Fe-Al-bearing bridgmanite in the lower mantle and discuss implications for the composition and oxidation state of Earth's lower mantle. We will further discuss our laboratory data on the effects of 'water' and iron on the seismic wave velocities of ringwoodite in Earth's transition zone and outline implications for mapping 'water' in the transition zone using geophysical observables.

[1] Marquardt, H. and K. Marquardt, 2012. American Mineralogist 97, 299-304.