In-situ Measurements of the Elasticity of Calcium Silicate Perovskite at High Pressure and High Temperature

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Introduction: Elasticity measurements in the laboratory provide essential data for modeling the interior of the Earth and placing constraints on the composition of the Earth. However, some mantle phases are not stable at room conditions and not recoverable for characterization, such as calcium silicate perovskite, a possible phase causing the 520 km seismic velocity discontinuity. Therefore, measurements of the elastic properties of these phases have to be done at pressure and conditions that they are synthesized.

Methods and Materials: We have developed a new technique for in-situ elastic wave velocity measurements at high P and T using simultaneous X-ray diffraction, X-ray radiography, and ultrasonic interferometry. The experiment was conducted in a DIA-type cubic anvil apparatus (SAM85) installed at the superwiggler beamline X17B1 at NSLS in Brookhaven National Laboratory. Ultrasonic interferometry measurements were carried out using a dual mode Lithium Niobate transducer (10 degree Y-cut, 30 MHz for S wave and 50 MHz for P wave) mounted at the back of the WC anvil. Boron epoxy cube was used as pressure transmitting medium. The sample was placed in the center of a boron epoxy cube with NaCl and BN as surrounding materials. Alumina rods were inserted from both sides of the boron epoxy cube and one of them is used as the buffer rod for ultrasonic measurement. The sample inside the high pressure cell assembly was imaged by capturing the visible light generated by the florescent YAG crystal on the X-ray path using a CCD camera. In addition to providing mechanical coupling between sample and the buffer rod for acoustic wave propagation, gold foils between sample and alumina rods yielded enhanced contrast of the sample/alumina interfaces on the recorded images. X-ray diffraction data for the sample and NaCl were recorded for phase identification and sample pressure calculation, respectively.

Results: As a pilot experiment, we applied these techniques to $CaSiO_3$ perovskite, an unquenchable mantle phase existing at the transition zone and the lower mantle in the Earth. A polycrystalline sample of low pressure phase of calcium silicate was used as starting material. The formation of $CaSiO_3$ perovskite and the completion of the phase transition were confirmed by X-ray diffraction spectra. We collected travel time and image data of $CaSiO_3$ perovskite at 13 GPa 1123 K as well as in the pressure range of 8-11.4 GPa at room temperature and S wave travel times were measured to 9 GPa and 1273 Kelvin.

Conclusions: We have measured the elastic P and S wave velocities of calcium silicate perovskite to 13.5 GPa and 1223 Kelvin in a DIA-type high pressure apparatus at X17B1, NSLS at Brookhaven National Lab. These results are important for the constructing velocity-depth models to constrain the composition of the transition zone and the lower mantle when compared with seismic data.

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