Elasticity of KLB1 at High Pressure and High Temperature

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Introduction: The structure of the Earth's mantle has been understood primarily from seismic studies. However, the composition of the mantle has still remained in debate. Based on petrological and geochemical studies, various compositional models have been proposed in the past, such as pyrolite and piclogite. The common approach for justifying these models is to construct mineral physics models using laboratory elasticity data for individual candidate minerals obtained from high pressure and high temperature measurements. However, element partitioning data have been poorly studied for complex system. To solve this problem, we need elastic wave velocity measurements on samples with possible mantle compositions.

Methods and Materials: We measured elastic wave velocities on KLB1 peridotite using ultrasonic Interferometry in conjunction with X-ray diffraction. The sample was hot-pressed at 5 GPa 1400 degree centigrade using USCA-1000 high pressure apparatus at Stony Brook high pressure laboratory. It has ~ 1 mm in thickness and about 2.0 mm in diameter after final polishing for acoustic experiment. The acoustic experiment was performed in a DIA-type cubic anvil apparatus (SAM85) installed at the superwiggler beamline X17B1 at NSLS in Brookhaven National Laboratory. 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 enabled us to collect travel time data for both P and S waves in a single experiment. Cubic boron epoxy cube (6.15 mm edge length) was used as pressure medium. The sample was placed in the center of the boron epoxy cube with NaCl and BN as surrounding materials. An alumina buffer rod was inserted into the cell assembly between the WC anvil and the sample with gold foils (2 micron thickness) placed at the interface between sample and buffer rod as well as at the buffer rod and WC anvil interface to enhance the mechanical coupling. The sample pressure was determined using Decker pressure scale from the X-ray diffraction data for NaCl.

Results: P and S wave travel times were measured to 9 GPa and 1273 Kelvin. In the course of high pressure and high temperature experiment, the pressure was first increased to its designated pressure before heating. After reaching designated peak P-T condition, travel time data were collected during cooling to room temperature while the oil pressure was held constant. The reason for doing this is that the solid pressure medium exert deviatoric stress on the sample in the cold pressing process as well as at low temperatures. However, at temperatures above 400 degree centigrade, the NaCl surrounding the sample started flowing, providing a hydrostatic stress environment to the sample. The sample lengths at high pressure and high temperature were obtained from X-ray imaging technique. P and S wave velocities can be calculated from the measured travel times and sample lengths.

Conclusions: We have measured the elastic P and S wave velocities of KLB1 peridotite to 9 GPa and 1273 Kelvin using a DIA-type high pressure apparatus at X17B1, NSLS at Brookhaven National Lab. These results are important for constraining the composition of the upper mantle and the transition zone when they are directly compared with seismic data.

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