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Measurement of thermal expansion coefficients of the upper mantle minerals at high pressures and temperatures

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The temperature gradient in the mantle is considered to be nearly adiabatic. The thermal expansion coefficient is the most important parameter to estimate the adiabatic temperature gradient in the Earth. The thermal expansion coefficient is also important to understand the slab dynamics because the driving force of the subduction would be the negative buoyancy due to the low temperature. The thermal expansion coefficient can significantly vary with pressure and temperature. Therefore, we have to determine the thermal expansion coefficient of the mantle minerals at the realistic temperature and pressure conditions for the mantle. In this study, we measured thermal expansion coefficient of forsterite and wadsleyite at high pressures and temperatures.

The most practical method to determine thermal expansion coefficient at high P-T conditions is the volume measurement by means of in situ X-ray diffraction. However, previous volume measurements are not precise enough to determine thermal expansion coefficient as a function of pressure and temperature. By the technical improvements, the pressure and cell parameters can be measured with precisions of 0.03 GPa and 0.0003 aungstrom by means of in situ X-ray diffraction, which makes it possible to estimate the thermal expansion coefficients precisely.

The volume measurement for forsterite was conducted at pressures of 3 to 16 GP and temperatures of 300 to 1900 K. We found that the thermal expansion coefficient of forsterite considerably decreases with increasing pressure. For example, it decreases from 5.4x10(-5) to 3.4x10(-5) with increasing pressure from 0 to 13 GPa. The Anderson-Grueneisen parameter is found to be 5.6.

The volume measurement for Mg2SiO4 wadsleyite was conducted at pressures of 11 to 19 GP and temperatures of 300 to 1700 K. The thermal expansion coefficient under the P-T conditions at the upper part of the transition zone (15 GPa & 1700 K) is found to be 2.8 x 10(-5) /K, which is a little higher than that of ringwoodite (2.4 x 10(-5) /K). We found that the thermal expansion coefficient of Mg2SiO4 wadsleyite decrease with increasing pressure with a relatively small ratio. The Anderson-Grueneisen parameter is found to be 4.4.