Precise determination of thermal expansion coefficient of $MgSiO_3$ perovskite at the top of the lower mantle conditions

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The temperature gradient in the mantle is considered to be nearly adiabatic. The adiabatic temperature gradient in the Earth $(\Delta T/\Delta z)_s$ is expressed as $(\alpha_P\ g\ T)\ /\ Cp$, where α_P and Cp, respectively, are the thermal expansion coefficient and heat capacity at constant pressure of the constituent material, and g is the gravitational constant. The g and Cp are nearly constant in the mantle and, therefore, thermal expansion coefficient is essential to estimate the adiabatic temperature gradient in the Earth.
Mg-perovskite is the major constituent mineral of the lower mantle. Therefore, its P-V-T relations are studied extensively [Mao et al., 1991; Wang et al., 1994; Utsumi et al., 1995; Funamori et al., 1996; Fiquet et al., 1998]. However, these experiments are not precise enough to determine thermal expansion coefficient of perovskite as a function of pressure and temperature. In this study, we have precisely determined thermal expansion coefficient of $MgSiO_3$ perovskite by means of *in situ* X-ray diffraction in a multi-anvil apparatus by the following improvement of the experimental technique.
Firstly, we have improved the techniques of high pressure and temperature generation to make it possible to generate 30 GPa and 2300 K simultaneously using a WC anvils with a fairly large truncated edge length (2.5 mm). It allows us to obtain diffraction patterns of relatively large amount of perovskite at fairly uniform P-T conditions. Secondly, we have utilized oscillation system equipped with the multi-anvil apparatus, which enables us to obtain high-quality diffraction patterns against grain growth. Thirdly, we have developed an analysis program of diffraction patterns, which is optimized to determine the unit cell parameters precisely. This program renders it possible to determine the pressure and cell parameters with precisions of 0.03 GPa and 0.0003 Å.
Using these techniques, we have measured lattice volume of $MgSiO_3$ perovskite at pressures of 17 to 30 GPa and temperatures of 300 to 2300 K with much higher precision than the previous studies. The thermal expansion coefficient under the P-T conditions at the top of the lower mantle (23 GPa & 1900 K) is found to be $3.5 \times 10^{-5}\ K^{-1}$, which is considerably higher than that of ringwoodite ($2.4 \times 10^{-5}\ K^{-1}$). We found that the thermal expansion coefficient of $MgSiO_3$ perovskite rapidly decreases with increasing pressure. Its Anderson-Grueneisen parameter is found to be 10.6(2). The adiabatic temperature gradient at the depth of 660km is estimated to be 0.47 K/m, and decreases to 0.26 K/m at 1200 km depth.