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Equation of state of Chromian spinel to 10 GPa at 300 K

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Introduction

Chromitite body is sometimes found in mantle section of ophiolite in the world. Although it is present only in small quantities, their presence has an interest for considering the tectonic setting of the formation of igneous section in ophiolite. Despite the considerable number of studies done about the origin of ophiolite, it still remains controversial as to where the igneous sequence of the ophiolite formed. For example, in Oman ophiolite, there are large chromitite-dunite bodies in mantle section, and Nicolas and his co-workers concluded that the Oman ophiolite formed at a fast-spreading mid-ocean ridge system [1]. On the other hand, chromitite is not found in the oceanic peridotites from mid-ocean ridges yet, except for mini-chromitite pod with rod shape, about 2 cm across and 10 cm long [2, 3]. One major limitation with the approach by using natural samples from ocean floor is the limitation of sampling area. But the chromitite in mantle can be detected by seismological observations. The advantages of using seismological observations in that the coverage of data is much wider than direct sampling.

The purpose of our study is to determine the isothermal bulk modulus and its pressure derivative precisely using diamond anvil cell and to understand the compressional property of chromian spinel with natural mantle composition The compressional property is used to calculate the seismic velocities of chromitite and surrounding peridotite. In this study, chromian spinel from Wakamatsu podiform chromitite ore in Tari-Misaka harzburgite-dunite-chromitite complex of Sangun Zone, Japan, was used as the starting material in the experiment

Experimental methods

The chromitite sample in Tari-Misaka complex was composed by chromian spinel and serpentinized olivine. Therefore chromian spinel crystals used in this study were separated from olivine and serpentine by hand from crushed fragment. The chemical composition ($(Mg_{0.77}, Fe^{2+}_{0.23})(Cr_{0.46}, Al_{0.50}, Fe^{3+}_{0.04})_2O_4$) was analysed using a scanning electron microprobe analyser (JEOL-JSM5600LV) with an energy-dispersive spectrometer (Oxford) at Ibaraki University.

High-pressure X-ray diffraction (XRD) experiments were performed using a diamond anvil cell high-pressure apparatus with a 50º open angle. A stainless steel plate was used as a gasket. A hole of approximately 150 μm diameter was electrically eroded as sample chamber. The chromian spinel powder and small ruby chips were loaded into the gasket hole and pressurised with a 4:1 methanol-ethanol mixture as the pressure-transmitting medium. Unit-cell parameter of chromian spinel was measured using angle dispersive XRD at the synchrotron beam line BL13A of the Photon Factory (PF) of High Energy Accelerator Research Organization (KEK), Japan. The experimental design for in situ XRD measurement at BL13A was presented by Ono et al. [4]. The incident X-ray beam was monochromatized to a wavelength of 0.4274 Å. The X-ray beam size was collimated to 30 μm in diameter. Angle dispersive XRD patterns were collected for 10 minutes using an online imaging plate system (Rigaku). Pressure was determined from the observed ruby fluorescence shift [5].

Results

Data were collected to 10 GPa at room temperature (300 K). Pressures were measured before and after each X-ray measurement. The pressures are the average of the pressures after X-ray measurements from six ruby grains at each pressure increment or decrease. The errors of one standard deviation were within 0.32 GPa

The unit-cell parameters and volume of chromian spinel with cubic system (*Fd3m*) were calculated by the least-squares technique using the 11 diffraction lines. The volume of chromian spinel decrease systematically with increasing pressures up to 10 GPa. The third-order Birch-Murnaghan equation of state (Birch 1947) fitted to the volume-pressure data. The results with the least-squares fit are V_0 = 560.6(2) Å^3, K_T = 192(7) GPa, and K_T' = 3.6(13).

References

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