

Phase relations of aegirine at high pressures and its effect on the transformation pressure to post-perovskite-type MgSiO₃

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INTRODUCTION

The behavior of sodium and its effect on the transformation pressure of the lower mantle minerals have not been clarified sufficiently. The incorporation of sodium with ferric iron to the MgSiO₃-perovskite can be described in terms of the substitution: 2Mg²⁺-to-(Na, Fe³⁺), leading to the NaFe³⁺Si₂O₆ composition. This is the chemical formula of the mineral aegirine. Here, we have investigated that the phase relation of aegirine at high-pressure and high-temperature in order to find a perovskite containing sodium and ferric iron at the lower mantle conditions. Secondly, we have experimentally determined the effect of the incorporation of sodium and ferric iron into pure MgSiO₃ perovskite on the post-perovskite transformation.

EXPERIMENTS

The high-pressure X-ray diffraction experiments were performed using a LHDAC high-pressure apparatus (BL13A, KEK-PF). For aegirine experiments, fine powdered natural aegirine was loaded with fine Al₂O₃, NaCl, or KCl powder, which works as a pressure medium, a thermal insulator and a pressure standard. For MgSiO₃ - NaFe³⁺O₂ system, the starting material was prepared as a powder mixture of MgSiO₃-glass and *b*-NaFe³⁺O₂ with 9:1 in mol. The palletized starting material was coated with gold, which works as a laser absorber and a pressure standard. The sample was sandwiched between pure samples that were not coated with gold. They were compressed with a rhenium gasket and diamond anvils. Angle-dispersive X-ray diffraction patterns were recorded repeatedly at room temperature before and after heating at high pressure.

RESULTS AND DISCUSSION

Aegirine was stable after heating at 2000K up to 15 GPa. Above 20 GPa, aegirine dissociated into an assemblage of SiO₂-stishovite, unknown cubic phase and another unknown phase, which has weak peaks, after heating. The unit cell parameter of the cubic phase is 4.33 [Å] at ambient pressure and corresponds to Fe²⁺_{0.99}O wustite. However, in our study, the cubic phase did not transform to rhombohedral phase upon quenching to room temperature at high pressure. Thus, the cubic phase is not Fe²⁺_xO wustite. Above 40 GPa, this assemblage changed to SiO₂ phase with CaCl₂ structure plus NaFe³⁺SiO₄ phase with calcium ferrite structure after heating. Above 60 GPa, the diffraction pattern corresponding to SiO₂ phase with CaCl₂ structure plus orthorhombic perovskite structure was observed after heating. This phenomenon indicates that perovskite including sodium and ferric iron was synthesized.

The diffraction pattern of perovskite was observed clearly after heating the 0.9MgSiO₃ + 0.1NaFe³⁺O₂ sample at 99 GPa. After heating at 135 GPa, the perovskite was solely stable without post-perovskite phase. After release pressure, weak and broad diffraction peaks of MgO periclase were observed, indicating that the NaFe³⁺O₂ component dissolves into MgSiO₃ perovskite and MgO periclase crystallize instead.

The present results indicate that perovskite including sodium and ferric iron can exist under the deep lower mantle conditions and addition of sodium and ferric iron expands the stability of MgSiO₃ perovskite relative to post-perovskite.