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Abstract of Doctoral Thesis

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Title of Doctoral Thesis

Perovskite phase relations in the system of
MgSiO₃-MnSiO₃-CaSiO₃ at the Earth's lower mantle conditions
(下部マントル条件下における MgSiO₃-MnSiO₃-CaSiO₃系ペロブスカイトの相関係)

Silicate perovskites of MgSiO₃ and CaSiO₃ are considered to be major constituent minerals in the Earth's lower mantle. These silicate perovskites are not chemically pure phases and should form a certain range of solid solutions with other cations. In this study, I investigated perovskite phase relations in the system of MgSiO₃-MnSiO₃-CaSiO₃ at the lower mantle conditions. Experimental synthesis of perovskite phases in this ternary system was performed at high pressure and high temperature, by using laser heated diamond anvil cell. Product phases were identified by in-situ synchrotron X-ray diffraction measurements and their chemical compositions were quantitatively analyzed mainly by analytical transmission electron microscopy (ATEM).

At first, perovskite phase relations on the MgSiO₃-MnSiO₃ join were investigated. The existence of a complete solid solution was confirmed on this join. The (Mg,Mn)SiO₃ perovskite produced is orthorhombic and changes of the unit cell parameters of this perovskite as the proportion of Mn incorporated in the mineral lattice changes seems to obey Vegard's rule at 50 GPa. The orthorhombic distortion, judged from the axial ratios of a/b and $\sqrt{2} a/c$, monotonically decreases from MgSiO₃ to MnSiO₃ perovskite at 50 GPa. The orthorhombic distortion in (Mg_{0.5},Mn_{0.5})SiO₃ perovskite is almost unchanged with increasing pressure from 30 to 50 GPa. MnSiO₃ is the first chemical component confirmed to form a complete solid solution with MgSiO₃ perovskite at the P-T conditions of the lower mantle.

As for perovskite phase relations on the CaSiO₃-MnSiO₃ join, quite wide range of solid solution was confirmed at 40-60 GPa. However, quantitative chemical analyses by ATEM indicated that there is an immiscibility gap in a compositional range from (Ca_{0.45},Mn_{0.55})SiO₃ to (Ca_{0.2},Mn_{0.8})SiO₃, unlike the case of the MgSiO₃-MnSiO₃ join. Judging from the extinction of specific peaks in the X-ray diffraction patterns, it was suggested that (Ca,Mn)SiO₃ perovskite on the CaSiO₃ side of the immiscibility gap is cubic, but on the other hand (Ca,Mn)SiO₃ perovskite on the MnSiO₃ side is orthorhombic. It should be noted that MnSiO₃ is the first chemical component confirmed to form such a wide compositional range of solid solution with CaSiO₃ perovskite at the P-T conditions corresponding to the lower mantle, because it has been known that CaSiO₃ perovskite is difficult to form solid solutions with other cations.

Finally, perovskite phase relations in the ternary system of MgSiO₃-MnSiO₃-CaSiO₃ were investigated. It was confirmed that the addition of MnSiO₃ component strongly affects the mutual solubility between MgSiO₃ and CaSiO₃. There are two perovskite regions with an immiscibility gap between them in the ternary system. Crystal structure of Ca-bearing (Mg,Mn)SiO₃ perovskite

is orthorhombic, and that of Mg-bearing (Ca,Mn)SiO₃ perovskite is cubic. The compositional range of Mg-bearing (Ca,Mn)SiO₃ perovskite in the ternary system expands dramatically to the Mg-rich side with increasing MnSiO₃ component.