

Solubility relations and structure variations of perovskites under the lower mantle conditions

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Under the lower mantle conditions, various cations enter into (Mg,Fe)SiO₃ and CaSiO₃ perovskites, and some of those substitutions may produce structure phase transformations. These substitutions and structure variations will affect the mineral compositions and physical properties of the lower mantle. To understand these phenomena in the lower mantle, laser-heated diamond anvil cell experiments of the systems (Mg,Fe)SiO₃-Al₂O₃ and CaSiO₃-CaTiO₃ were performed at 30-60 GPa and 1800-2000 K and at 30 GPa and 1800 K, respectively.

The synthesized samples were analyzed by synchrotron X-ray diffraction and analytical electron microscopy. The results show the following points. In the system (Mg,Fe)SiO₃ - Al₂O₃, the product phases were perovskite, magnesiowustite and stishovite for 0 and 5 mol percent Al₂O₃ and corundum joined the above phase assemblage for 25 and 50 mol percent Al₂O₃. The chemical analyses of the perovskite phase showed that the Fe content in perovskite increased with the Al content with nearly the same amount, and metal iron was recognized to coexist with perovskite. These results indicate that the endmember FeAlO₃ where Fe is ferric iron was formed in perovskite under the aluminous condition. This suggests that under the Al-rich circumstances in the lower mantle, Mg-perovskite contains the higher iron content than under the less aluminous circumstances.

In the system CaSiO₃-CaTiO₃, only the perovskite phase was present in the whole region of this system at 30 GPa and there seems no two-phase region. Synchrotron X-ray diffraction showed that there exists double perovskite phase whose unit cell is double of the cubic perovskite in the wide area of the intermediate region of this system. It showed the diffraction peaks of all even or all odd indices, that is peaks of the face-centered cubic lattice, at high pressure and high temperature, while it showed the extra peaks which violate the face-centered cubic lattice. This indicates that Ca(Si,Ti)O₃ perovskite is the double perovskite phase with a face-centered cubic lattice under high pressure and high temperature, but it inverts to the lower symmetry phase with a simple cubic lattice by the Si-Ti ordering at room temperature. Although this substitution is not expected to occur in the lower mantle, it will give some reference for the cation substitutions at the octahedral sites of CaSiO₃ perovskite in the lower mantle.