

Hydrothermal alteration experiments of amorphous silicates in the system of MgO-SiO₂ with different Mg/Si ratios

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Meteorites have information on evolution process of materials in the early solar system. Carbonaceous chondrites are the most primitive meteorite class. Most of them, particularly CI, CM, CR chondrites, contain layer silicates, such as serpentine and saponite and have experienced aqueous alteration in their parent bodies. In order to understand evolution process of the early solar system, it is important to understand aqueous alteration process. Experimental studies to understand aqueous alteration have been performed so far. For example, aqueous alteration experiments using enstatite crystals were carried out, and conditions for serpentine and saponite formation were discussed [1]. On the other hand, it has been accepted that amorphous silicates are original building bricks of solid materials in the solar system, and thus it is important to understand aqueous alteration process of amorphous silicates.

Aqueous alteration experiments of an amorphous silicate with Fe, Ni and S free CI chondritic composition were performed [2]. In the experiments, serpentine and saponite formed easily from the amorphous silicate with pure water. However, some of layer silicates formation was not been well understood.

In the present study, aqueous alteration experiments of amorphous silicates were performed in the simple system MgO-SiO₂-H₂O to understand process of layer silicate formation. We focused serpentine (Mg₃Si₂O₅(OH)₄) and examine effect of the Mg/Si ratio of the starting material to formation of serpentine (Mg/Si=1.5).

The starting materials are nano particles of amorphous silicates (~10 nm in diameter), which were synthesized by induction thermal plasma method. Five types of starting materials with different Mg/Si ratios (1.15, 1.25, 1.50, 1.75, 2.02) were prepared. They were sealed in a Teflon vessel with pure water (water/rock ratio: 5.0) and heated at 150°C for 8, 24, 72, 168, 504 hours (pressure: 3.0 bar). Run products were examined by X-ray diffraction (XRD) for mineral identification. Some of run products were observed by field emission scanning electron microscope (FE-SEM) and transmission electron microscope (TEM) and the chemical compositions were obtained by EDX equipped in FE-SEM and TEM.

Layer silicates formed in all run products. Brucite (Mg(OH)₂) and magnesite (MgCO₃) formed in runs with the Mg/Si ratio of more than 1.5 (carbon in magnesite was probably from Teflon). Basal reflections of the layer silicates are broad. Generally, with increasing the Mg/Si ratio, the layer spacing continuously decreases, and the peak intensity increases. In runs with Mg/Si=2.02, the layer spacing decreases with increasing time. Layer silicate in 504 hr run has the layer spacing mostly close to that of serpentine, and serpentine did not easily form from the amorphous silicate with Mg/Si=1.5.

FE-SEM observation showed that run products are composed of aggregates more than a few μm in size, and signature of the original 10 nm particles disappeared. The Mg/Si ratio of run products are always less than that of the starting material. These results indicate that Mg in the starting material selectively dissolved into water, and layer silicates and brucite (and magnesite) formed from the aqueous solution.

The relation between the Mg/Si ratios of run products with the layer spacing suggest that layer silicates might be randomly interstratified mineral with serpentine and stevensite (a kind of smectite with the talc composition). In TEM observation, layer structure seemed to be observed, but more detailed observation is required for further study to confirm the layer silicate structures.

[1] Ohnishi and Tomeoka (2007) Meteoritics & Planetary Science, 42, 49-61. [2] Noguchi (2010) JpGU Meeting, PPS009-10.

Keywords: aqueous alteration process, carbonaceous chondrite