

The surface environment of Venus estimated from the decomposition rate of pyrite

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The surface of Venus is at high temperature and high pressure, and it is thought that the chemistry between the atmosphere and the solid controls the surface environment. However, due to the difficulty in directly observing the surface because of the global thick H₂SO₄ clouds, minerals at the surface are not determined yet. It is, thus, important to understand the chemical reaction rates among surface minerals and gas species and phase changes between gas and the clouds of Venus to evaluate the surface environment of Venus.

There are two models that describe the surface environment of Venus, the carbonate model (Urey 1952; Lewis 1970, etc.) and the pyrite model (Hashimoto and Abe, 2001). The former assumes the presence of carbonate on the planetary surface and its chemical interaction with the atmosphere, and explains the CO₂ abundance in the atmosphere, whereas the latter assumes the presence of pyrite on the planetary surface and pyrite-magnetite conversion, and explains the observed surface temperature and the SO₂ abundance in the atmosphere. However, which (or neither) model describes the climate system cannot be easily determined. Even if the direct observation of the surface is made, the stability of the surface environmental system over a long period of time should be evaluated theoretically.

Fegley et al. (1995) experimentally measured the stability of pyrite under the temperature and the CO₂ conditions of Venus. As a result, they concluded that the decomposition of pyrite is extremely rapid, and pyrite cannot exist on the surface of Venus for a long term. However, because the experiment was carried out in the open system and input gas streams contained no S₂, Wood and Brett (1997) pointed out that this experiment result was not able to be applied to Venus.

In the present study, we determined the stability of pyrite under the conditions relevant to the Venus surface environment, with particular interest to the CO₂ pressure and openness of the system. As the first step, experiments were carried out under 1atm and different CO₂ flow rate conditions to determine the decomposition rate of pyrite. Natural pyrite, which was cut into parallelepiped about 3x2x1mm size, was used as a starting materials, and they were kept in a vertical furnace for 1-18 hours at 500C and CO₂ flow rate of 600cc/min or 900cc/min. Pyrite reacted with CO₂ and pyrrhotite (and hematite in some conditions) had been formed at the surface of pyrite. The width of pyrrhotite (and hematite) layers was measured.

The thickness of a reacted layer increases linearly with time at the two CO₂ flow rate conditions, indicating that the reaction is controlled by surface reactions. Combining the present results with the reaction rates by Fegley et al. (1995) at CO₂ flow rate of 100cc/min, the reaction rate increases with the increase of CO₂ flow rate. It suggests that pyrite is extremely unstable in CO₂ gas under the conditions of 1atm and surface temperature of Venus, and the decomposition rate is rapid. The rapid decomposition of pyrite is consistent with the conclusion by Fegley et al. (1995), but it differs from their result that reaction rate is dependent on the CO₂ flow rate. However, further study will be needed whether pyrite is stable or not under the high CO₂ pressure of Venus (90atm).