Surface alteration of silicate particle exposed to hydrogen plasma

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A component of crystalline silicates was detected in IR spectra of some evolved stars or around some young stars. On the other hand, amorphous silicates are suggested as the carrier of a broad 9.7 and 18micron absorption feature detected in interstellar medium (ISM). The disappearance of crystalline silicates in ISM is supposed to be due to their amorphization caused by a continuous processing such as annealing or shockwave in interstellar environments. Ion irradiation experiments aimed at simulating process due to shockwave have showed that crystalline silicates are transformed into amorphous structures. Ion and solid reactions with high energy ion bombardment lead to physical sputtering and formation of defects in their structure. During their life cycle of silicate dusts, the dusts are supposed to suffer from a processing due to an ionized gas such as hydrogen plasma. In order to study reaction between silicate and an ionized gas, we exposed crystalline silicate powder to hydrogen plasma with low energy. We investigated the alteration of their powder before and after hydrogen plasma treatment.

Powder of olivine containing Fe was used as starting materials. The silicate powder, which was placed on a quartz boat, was set into discharge tube. After doing vacuum exhaust, hydrogen gas was supplied into the tube. The silicate powder was exposed to hydrogen plasma generated by microwave discharge at 2.45GHz. The pressure of hydrogen gas was kept to be 15Torr, and energy of electron was estimated to be about 10eV. When the olivine powder was exposed to the plasma, the color of the powder changed from white to brownish gray. On the other hand, the color of powders treated with Ar plasma didn't change.

Transmission electron microscopic images revealed that the surface of olivine particles changed from angular shape to round shape and many small grains with about 1nm in diameter were produced on the surface. This result suggests that the particles react with hydrogen plasma to cause the alteration. A strong ESR signal was detected in the plasma-treated samples. The g-value was estimated to be 2.07, which was very close to the value of Fe-bearing meteorites. ESR spectra suggest that an iron ion in silicates is reduced to give a ferromagnetic material by hydrogen plasma treatment. ESR signal were not detected in the samples with Ar plasma treatment. The difference is caused by a highly reactive effect due to hydrogen atom in plasma. The reflectance of olivine powder treated with hydrogen plasma decreased in the range of visible wavelength. The decrease of the spectral intensity is supposed to be due to a change of scattering effect resulted from the alteration of the surface or the formation of Fe particles.

When the silicate particles were exposed to hydrogen plasma, hydrogen-containing species, for example H_2, H, and H^+, UV-rays, and microwave are considered to affect the surface of particles. Under these conditions, thermal effect and non-thermal effect is reported. Thermal effect leads to low temperature crystallization of amorphous structure due to an increase of temperature. It is known that non-thermal effect leads to decrease of activation energy and promotes a reaction by enhancing hydrogen atom mobility and diffusion. We guess that chemical reaction of hydrogen-containing species is important process for the alteration of the silicate surface and sputtering is not a main process of the alteration. The temperature of samples exposed to microwave hydrogen plasma is elevated to about 600K. However, samples heated at about 600K were hardly changed into the nature. The hydrogen plasma is considered to promote effectively chemical and structural changes of silicates even at a low temperature of about 600K. The alteration of their surface is caused by the effect of highly reactive sputtering due to hydrogen plasma.