Formation of forsterite crystal induced by ultraviolet irradiation of water ice ice on amorphous Mg_2SiO_4 particles

*Akira Kouchi[1], Yuki Kimura[1], Yasuhiro Oba[1], Tetsuya Hama[1], Naoki Watanabe[1], Shogo Tachibana[2], Akira Tsuchiyama[3], Satomi Enju[3], Takafumi Ootsubo[4]

1. Institute of Low Temperature Science, Hokkaido University, 2. UTokyo Organization for Planetary and Space Science, University of Tokyo, 3. Graduate School of Science, Kyoto University, 4. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency

In comets, both crystalline and amorphous silicates have been observed by infrared telescopes. It has been proposed that crystalline silicates were formed by annealing of amorphous silicates, direct condensation in hot region of proto-solar nebula, or heating due to radical recombination in organic refractory mantle. In the present study, we have experimentally investigated another possibility, heating due to radical recombination in water ice by ultraviolet (UV) irradiation.

Three amorphous silicate fine particles made by gas condensation using induction thermal plasma (ITP) were used as starting materials: Mg_2SiO_4, $MgSiO_3$, and GEM-like composition (SiO_2-rich). Amorphous fine particles were put on amorphous Si thin film (5 nm in thickness), and cooled to 10 or 82 K in ultra-high vacuum transmission electron microscope. Amorphous water ice was prepared by vapor-deposition on the sample, and irradiated with a D_2 lamp. During UV irradiation, structural change was observed by electron diffraction.

We observed the formation of forsterite crystals from amorphous Mg_2SiO_4 at 82 K, whereas the crystallization did not occur at 10 K. No crystalline phase was observed for amorphous $MgSiO_3$ and amorphous GEM-like silicate at 10 and 82 K.

These results could be explained by radical-radical recombination reactions following the photodissociation of water molecules by UV-rays, reactions (1) and (2),

H_2O + UV --> OH + H. (1)

OH + H --> H_2O + 4.8 eV. (2)

The formation of forsterite crystals can be induced by the energy released by reaction (2) only for amorphous Mg_2SiO_4, because the value of 4.8 eV is sufficiently larger than the activation energy for crystallization of amorphous Mg_2SiO_4 (3-4 eV), but smaller than that of amorphous $MgSiO_3$ (9 eV) and amorphous GEM-like silicate. No forsterite formation at 10 K may be explained by the low mobility of H atoms and OH radicals at the ice/Mg_2SiO_4 interface at 10 K, which strongly decrease the efficiency of reaction (2) compared with 82 K.

From these results, we propose a new route for the formation of crystalline forsterite in cometary coma by solar UV irradiation with ice-covered amorphous Mg_2SiO_4 particles. Comparison with observation will be presented.

Keywords: Amorphous silicate, Photochemical reaction, Crystallzation, Forsterite

