Irradiation experiments on CM chondrites: To estimate surface textures of the returned samples by Hayabusa 2

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Introduction: In 2020, Hayabusa 2 spacecraft will return the surface and sub-surface samples from the asteroid (162173) Ryugu, a C-type asteroid. We will have an opportunity to investigate pristine materials from a C-type asteroid. Because CM chondrites contain solar gases and because most of they contain abundant subangular mineral and lithic fragments, they are regolith breccias (e.g. [1], [2], [3] and references therein). Although solar noble gases are restricted to the clastic matrix [1], [2], textures related to the solar wind irradiation and/or micrometeoroid impacts have not been identified among CM chondrites. Although there are many spectroscopic studies of CM chondrites (e.g. [4]), only a few studies are focused on the textural changes related to the micrometeoroid impacts and solar wind irradiation on CM chondrites (e.g. [5], [6]). In this study, we performed spectrum measurements, micro-petrographic study, and C Kα X-ray absorption near-edge structure measurement of irradiated CM chondrites. These studies will serve to understand the space weathering on the surface of fine-grained Ryugu grains because it is highly likely that space weathering will be found on the surface of Ryugu grains.
Samples and methods: We performed irradiation of 4 keV He^+ ions on Murchison CM chondrites at Takasaki Advanced Radiation Research Institute, Japan Atomic Energy Agency (TARRI, JAEA). The fluences are 5×10^{16} and 5×10^{17} He^+/cm^2, which correspond to ~10^2- and ~10^3-year irradiation at 1.1 AU (the averaged orbital radius of Ryugu). Reflectance spectra of the irradiated surface were measured at JASCO Co. Ltd. by using JASCO V-670 absorption spectrometer with an integrating sphere. The irradiated samples were observed by field-emission scanning electron microscope (FE-SEM) at JAEA and Kyushu University. We observed the samples by using 2 or 3 kV acceleration voltage to avoid structural changes during observation. Thin samples were prepared by using scanning electron microscope-focused ion beam sample preparation machine and low acceleration voltage Ar milling machine at Kyushu University. They were observed by transmission electron microscope (TEM) at Kyushu University.
Results and discussion: Reflectance spectrum of the sample irradiated by a fluence of 5×10^{16} He^+ does not show remarkable difference from the spectra of an un-irradiated sample. By contrast, a broad absorption from 0.7 to 1.4 μm, related to the absorption by Fe-rich serpentine group minerals, is disappeared in the case of the sample irradiated with 5×10^{17} He^+. These data suggest that 1000-year equivalent solar wind irradiation gives an effect on the shape of reflectance spectra, which is similar to the effect by dehydration [4]. There is no remarkable difference in surface morphology of the sample irradiated by a fluence of 5×10^{16} He^+ from those of un-irradiated sample. On the other hand, the sample irradiated with 5×10^{17} He^+ shows blistering on both matrix and chondrules. The surface of fine-grained matrix has a ~30-nm thick amorphous layer. In the amorphous layer, a small amount of nanoparticles is observed. Their 0.2-nm lattice fringes suggest that they are nanophase Fe^0. In the case of the sample irradiated with 10^{17} He^+ has ~60-nm amorphous rim containing abundant bubbles (blistering), which is especially remarkable in cronstedtite-tochilinite intergrowth. Just below the amorphous layer, both cronstedtite and tochilinite show sharp lattice fringes. The amorphous rim contains abundant nanoparticles is observed. They also show 0.2-nm lattice fringes, suggestive of nanophase Fe^0. This result is consistent with [5].

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