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Weathering effect of solar wind proton on hydrated silicate minerals

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NIRS3 is an on-board near infrared spectrometer of Hayabusa-2 project which is aimed at returning samples from C-type asteroid 1999 JU3. In this project, it is important to characterize mineralogical and heterogeneities on the asteroid surface for the sampling site selection. Observing wavelength of NIRS3 is including the 3 μm band which is charactering C-type asteroid (*Rivkin et al. LPSC 2002, Milliken et al. 2007*). The NIRS3 will measure reflectance spectra of asteroid surface in the wavelength range of 1.8 - 3.2 μm. This wavelength region includes features mainly related to OH and H_2O.

The spectral properties of the surface, however, would have different trend to the subsurface, because the surface of asteroids would be exposed to solar wind and micrometeorite. As for the reflectance spectrum of the moon, the absorption feature from 2.8 μm to 3.0 μm was reported in M^3 data (*Pieters et al. 2009*). It is thought that the implantation of solar wind proton is one of the causes (*McCord et al. 2011*). The solar wind protons will affect the spectral shape of 3μm region of air less bodies. Thus we study effect of irradiation of solar wind protons on near-infrared reflectance spectra by laboratory experiment.

We executed the simulation of irradiation of solar wind protons using ion implantation device at the Wakasa Wan Energy Research Center (WERC), Fukui. This device can irradiate $H_2{}^+$ beam with 10 keV in a vacuum (under 1×10^{-5} Pa). The total amount of $H_2{}^+$ was about 10^{18} ion/cm^2. Three samples were prepared; olivine (San Carlos, Arizona), antigorite (Sangenchaya, Kyoto), saponite (synthetic: Kunimine Industries Co., Ltd.). Antigorite and saponite were sieved between 50 μm and 75 μm and olivine served between 75 μm and 105 μm, and then they were heated for 24 hours at 423 K. They were packed into Cu cups and formed pellets. After irradiated the spectra were measured using FTIR, which resolution was 2.0 cm^{-1} in wavenumber. We adopted the analysis method of *Ichimura et al. (2012)*, which is to compare the reflectance spectra of altered sample, R, with unaltered sample, R_0, to determine the alteration ratio of spectra, R/R_0, without absorption water.

The alteration ratios of irradiated samples were different between minerals. The alteration ratio of olivine showed increasing of broad absorption feature from 2.8 μm to 3.8 μm due to OH/H_2O production. In antigorite and saponite, the alteration ratio, additionally, showed characteristic change related to coupling state of -OH. In the alteration ratio of antigorite, stretching of -OH bonded water molecule (-OH $\cdots$ ^{H}OH) at 2.77 μm and stretching of -OH $\cdots$ ^{H}OSi at 2.85 μm was increased conspicuously. On the other hands, the alteration ratio of saponite was changed conspicuously at 2.77 μm.

We think that the difference of the bands which showed conspicuously change is related with structure of minerals. Antigorite have -OH into the crystal. Therefore the irradiated protons broke bonds of Si-O and produced newer hydrogen bonds which are -OH $\cdots$ ^{H}OH or -OH $\cdots$ ^{H}OSi. Saponite has H_2O as interlayer water. It would be similarly broken bands of Si-O and produced newer hydrogen bonds which are -OH $\cdots$ ^{H}OH. These spectral changes can explain same process. These features support that the irradiated protons react with bonds of Si-O in the crystal.

In this study, we showed that the alteration of feature related with OH/H_2O is different from each mineral. Next step, we will examine the other minerals against determination minerals and the amount of water from reflectance spectra.

Keywords: Hayabusa-2, space weathering, solar wind, OH/H_2O, C-type Asteroid, proton implantation