

**LABORATORY SIMULATION OF SOLAR WIND IMPLANTATION ON HYDRATED SILICATE MINERALS.** Y. Nakauchi<sup>1</sup>, M. Abe<sup>2,1</sup>, A. Tsuchiyama<sup>3</sup>, K. Kitazato<sup>4</sup>, K. Yasuda<sup>5</sup>, <sup>1</sup>The Graduate University for Advanced Studies, <sup>2</sup>Japan Aerospace Exploration Agency (JAXA), <sup>3</sup>Kyoto University, <sup>4</sup>University of Aizu, <sup>5</sup>The Wakasa Wan Energy Research Center.

**Introduction:** The Japanese Hayabusa-2 project aims at returning samples from C-type asteroid 1999 JU3. It is thought to contain water and/or organics from previous ground-based observations. It is important to characterize mineralogical and textural heterogeneities on the asteroid surface by remote sensing for the sampling site selection. Then the Hayabusa-2 spacecraft is planned to carry three on-board instruments; Near Infra-Red Spectrometer (NIRS3), Optical Navigation Camera (ONC) and Thermal Infra-Red imager (TIR). Also an artificial impact experiment using the Small Carry-on Impactor (SCI) is planned. The SCI impact is expected to excavate subsurface materials and make a small crater, which might enable to investigate the characteristics of unweathered materials.

In order to determine water contents of surface materials it is essential to understand spectral alterations by space weathering. The NIRS3 will measure reflectance spectra of asteroid surfaces in the wavelength range of 1.8–3.2  $\mu\text{m}$ . C-type asteroids would be composed show the different absorption features in its wavelength region [1]. This region includes features mainly related to OH and H<sub>2</sub>O. In the previous study, the feature of 2.9  $\mu\text{m}$  contains relation with the amount of water[2]. The spectral properties of surface, however, would have different trend to subsurface, because the surface of asteroids would be exposed to solar wind and micrometeorite. Thus we study its effect on near-infrared reflectance spectra by laboratory.

As for the reflectance spectrum of the moon, the absorption feature from 2.8  $\mu\text{m}$  to 3.0  $\mu\text{m}$  was reported in M<sup>3</sup> data[3]. Also, this feature is related to presence of OH and H<sub>2</sub>O. This feature was reported another exploration data, Deep Impact, Cassini and LCROSS [4, 5, 6]. It is thought that this feature was made by implantation of solar wind protons[7]. The solar wind protons will affect the spectral shape of 3 $\mu\text{m}$  region of air less bodies. Therefore knowing the effect of solar wind protons is important.

Here we report on a laboratory simulation of the implantation of the solar wind protons in the minerals contained in CI and CM chondrite.

**Methods:** The simulation of irradiation of solar wind protons was achieved using ion implantation device at the Wakasa Wan Energy Research Center (WERC), Fukui. This device can irradiate H<sub>2</sub><sup>+</sup> beam

with 10 keV. The irradiation chamber was drew vacuum under  $1 \times 10^{-5}$  Pa. The total amount of H<sub>2</sub><sup>+</sup> was  $10^{18}$  ion/cm<sup>2</sup>.

We prepared three samples, Olivine (San Carlos, California), Antigorite (Sangencyaya, Kyoto), Saponite (synthetic). Antigorite and saponite were sieved between 50  $\mu\text{m}$  and 75  $\mu\text{m}$  and olivine served between 75  $\mu\text{m}$  - 105  $\mu\text{m}$ , then they were hearted for 24 hours at 423 K. The samples were packed into Cu cups and pressed. Then they were formed pellets.

We were afraid about influence on absorption water. We made, then, two regions for the same pellets, which were irradiated region and not irradiated one (Fig.1). Their regions were same condition for absorption water because there were on same pellets. After irradiated the spectra were measured using FTIR, which resolution was 2.0 cm<sup>-1</sup>.

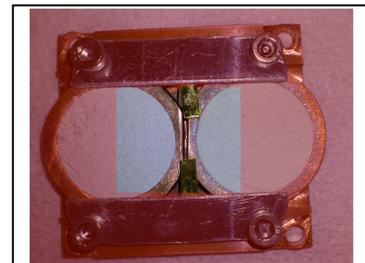


Fig. 1. Sample holder using implantation experiment. Red shadow region are masked to avoid being irradiated. Two samples were antigorite(left) and olivine(right).

In analysis, we adopted the method of [8]. His method is to compare the spectra of altered sample,  $R$ , with the spectra of unaltered sample,  $R_0$ , to determine the alteration ratio of spectra,  $R/R_0$ , without absorption water.

**Discussion:** The alteration ratios of irradiation region are different between minerals. The alteration ratios of reflectance spectra are shown in Fig. 2.

The alteration ratio of olivine shows absorption feature from 2.8  $\mu\text{m}$  to 3.8  $\mu\text{m}$  due to OH/H<sub>2</sub>O production (Fig.2 a). The spectra of altered region appear that there are peaks near 2.82  $\mu\text{m}$  and 2.91  $\mu\text{m}$ . The peak near 2.8  $\mu\text{m}$  might be related with stretching of -OH $\cdots$ <sup>H</sup>OH near 2.77  $\mu\text{m}$  and stretching of -OH $\cdots$ <sup>H</sup>OSi which feature contain peak from 2.84  $\mu\text{m}$  to 2.86  $\mu\text{m}$  [9]. The other peak at 2.91  $\mu\text{m}$  might be related with OH stretching vibrations [8].

On the other hands, the alteration ratio of antigorite had variations (Fig.2 b). In antigorite spectra, the bands related to coupling state of -OH were changed con-

spicuously, for example, -OH stretching band at 2.72  $\mu\text{m}$  and stretching of -OH bonded water molecule (-OH $\cdots^{\text{H}}\text{OH}$ ) at 2.77  $\mu\text{m}$  [9]. There are six noticeable points, 1) the whole alteration ratio is different between alteration region No.2 and No.3, 2) stretching of metal-OH at 2.33  $\mu\text{m}$ ; at this band, the reflectance decreased in altered region No.2 but it increased in altered region No.3 from the unaltered reflectance,  $R_0$ , 3) -OH stretching band at 2.72  $\mu\text{m}$ ; in the altered region No.2, the band depth is more decrease than the altered region No.3, 4) stretching of -OH $\cdots^{\text{H}}\text{OH}$  at 2.77  $\mu\text{m}$ , 5) stretching of -OH $\cdots^{\text{H}}\text{OSi}$  at 2.85  $\mu\text{m}$ ; both bands are increased at both altered regions and 6) over 3 $\mu\text{m}$  region; the alteration ratio from near 2.9  $\mu\text{m}$  to 4  $\mu\text{m}$  would show same shape with the altered region of olivine.

The difference of alteration ratio is caused by difference of ion flux or surface condition. The irradiated region might be exposed by  $\text{H}_2^+$  beam un-uniformly, because the surface charged up might not be able to leak uniformly. In addition, in altered region No.2 (Fig.2 b), the amount of absorptions decrease greatly at 2.33  $\mu\text{m}$  and 2.72  $\mu\text{m}$ , but they increase one of No.3 region. This difference might be due to same reasons. The region No.2 might be broken the bond of metal-OH and/or Si-OH by irradiation.

The other bands indicate same alteration trend in antigorite; the spectra indicate same peak at 2.77  $\mu\text{m}$  and 2.85  $\mu\text{m}$  and same shape over 3 $\mu\text{m}$  region. The peak at 2.77  $\mu\text{m}$  and 2.85  $\mu\text{m}$  suggest that the -OH $\cdots^{\text{H}}\text{OH}$  at 2.77  $\mu\text{m}$  and stretching of -OH $\cdots^{\text{H}}\text{OSi}$  were produced by proton implantation. Antigorite have -OH into the crystal. Therefore the irradiated protons broke bonds of  $\text{SiO}_2$  and produced newer bonds which are  $\text{SiOH}$  ( $\text{SiO}_2 + \text{H}^+ \rightarrow \text{SiOH} + \text{O}^-$ ) or  $\text{H}_2\text{O}$  ( $\text{SiO}_2 + 2\text{H}^+ \rightarrow \text{Si}^{2+} + \text{H}_2\text{O}$ ).

In the region over 3  $\mu\text{m}$ , the same shape is shown between olivine and antigorite. This feature suggests that spectral alteration was created in the same process. This feature supports that the irradiated protons react with bonds of  $\text{SiO}_2$  in the crystal.

The feature near 3.4  $\mu\text{m}$  is caused by contamination [10].

**Summary:** The 3  $\mu\text{m}$  region of reflectance spectra of minerals contained in C-type asteroid was altered by proton implantation. Their change was relatively simple in olivine which is anhydrous minerals. Hydrated minerals, antigorite, showed conspicuous change at the bands related to bonding state of -OH.

In this study, we showed that the alteration of feature related with OH/ $\text{H}_2\text{O}$  is different from each minerals. Our next step is that the other minerals must be

research against determine minerals and the amount of water from reflectance spectra.

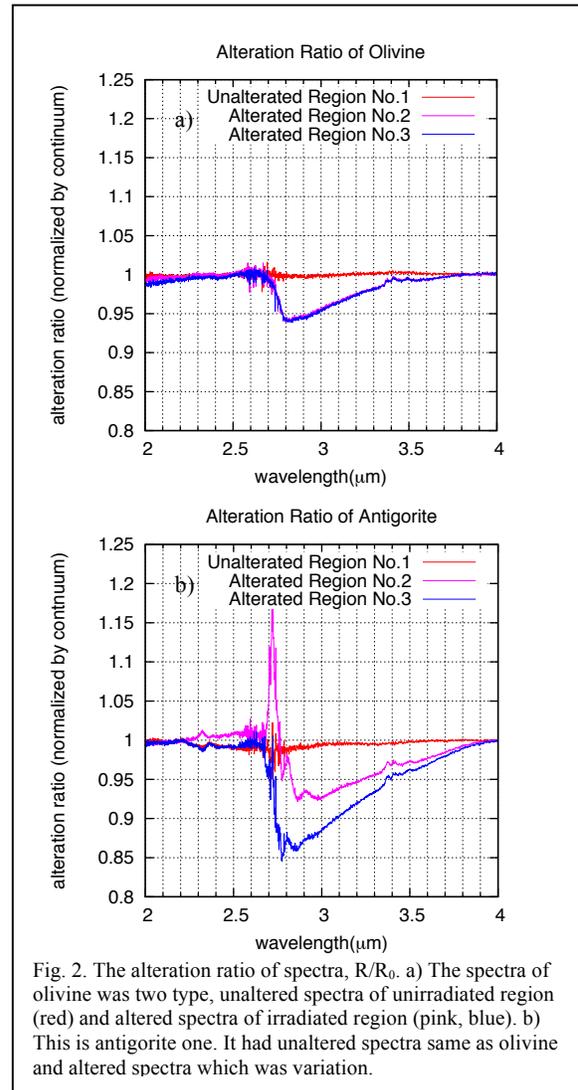


Fig. 2. The alteration ratio of spectra,  $R/R_0$ . a) The spectra of olivine was two type, unaltered spectra of unirradiated region (red) and altered spectra of irradiated region (pink, blue). b) This is antigorite one. It had unaltered spectra same as olivine and altered spectra which was variation.

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**References:** [1] Takir, D. & Emery, J.P. (2012) *Icarus*, 219, 641-654. [2] Milliken, R. E., & Mustard, J. F., et al., (2007) *JGR*, 110, E12001. [3] Pieters, C. M., et al., (2009) *Science*, 326, 568 – 572. [4] Sunshine, J. M., et al., (2009) *Science*, 326, 565 – 568. [5] Clark, R. N., et al., (2009) *Science*, 326, 562 – 564. [6] Colaprete, A., et al., (2010) *Science*, 330, 463 – 468. [7] McCord, T. B., et al., (2011) *JGR*, 116, E00G05. [8] Ichimura, A. S., et al., (2012) *EPSL*, 90 – 94, 345 – 348. [9] Davis, K. M., and Tomozawa, M., (1996) *J. Non-Cry. Soli.*, 201, 177 – 198. [10] Kebukawa, et al., (2008) *JpGU*, P168-P001.