AN EXPERIMENTAL INVESTIGATION OF THERMAL STABILITY OF OH/H_2O FORMED BY SOLAR WIND IMPLANTATION ON LUNAR SURFACE.

Y. Nakauchi[1], M. Abe[2], T. Matsumoto[2], K. Kitazato[1], A. Tsuchiyama[3], [1]University of Aizu (Aizu-Wakamatsu, Fukushima Pref. 965-8580, Japan; nakauchi@u-aizu.ac.jp), [2]Japan Aerospace Exploration Agency, [3]Kyoto University

Introduction: The absorption band at the 3μm region was reported on reflectance spectra of the lunar surface [1]. This result indicates the presence of hydroxyl group and H_2O. That spectral features at the 3μm region were also reported by Deep Impact and Cassini data [2,3]. It is thought that the 3μm absorption band appeared due to implantation of solar wind protons and the formation of hydroxyl group and/or H_2O [4]. Furthermore, this spectral change was supported by an experiment using Apollo 16 and Apollo 17 soils [5]. The reflectance spectra of Apollo 16 and Apollo 17 soils irradiated by H_2^+ beam with 2.2 keV showed absorption feature at 3 μm. These results indicate that solar wind protons would generate hydroxyl groups and/or H_2O and change the absorption features around 3 μm on the lunar surface.

Japan Aerospace Exploration Agency (JAXA)'s Hayabusa2 was launched on December 3, 2014 (JST) from Tanegashima Space Center. It is cruising towards C-type asteroid Ryugu and it would carry the asteroidal samples to the earth in 2020 [6]. During before and after the Earth swing-by, Hayabusa2 observed the earth and moon using NIRS3 (near infrared spectrometer). Before the swing-by, it observed the Arctic region and after swing-by it observed the Antarctic region on the lunar surface [7]. The observational data was interpreted that the absorption feature is related with surface temperature [8].

However, the stability of these "OH / H_2O" at the lunar surface temperature has not been understood well. Therefore, we curried out hydrogen ion irradiation using ion irradiation equipment installed at the ISAS and measured reflectance spectra at the various temperature.

Experiment: We prepared San Carlos Olivine, which served from 50μm to 105μm. Before hydrogen irradiation, the sample was heated for 24 hours at 423 K in order to remove adsorbed water.

Ion irradiation was achieved using a cold cathode ion source ion gun at ISAS/JAXA. This device can irradiate H^+ beam with 1 keV. The irradiation chamber was drew vacuum under 1×10^{-5} Pa. The total amount of H^+ was 10^{17} ion/cm^2.

After irradiation, the reflectance spectra of irradiate sample were measured using FTIR. The sample were heated after H+ irradiation using a micro heating stage attached to a sample holder. The temperature of the sample was elevated from ~300K to ~400K. The reflectance spectra of each temperature can be measured without exposing the sample to the atmosphere. The optical path of FTIR can be purged with nitrogen. Therefore, the FTIR spectra of irradiated samples are obtained with minimized influences of adsorbed water and atmospheric fluctuations.

Result and Discussion: The reflectance spectra around 3μm was altered by proton irradiation (Fig.1 gray). This spectral change suggests that hydroxyl group and/or H_2O were formed, because the 3-μm band region related to presence of hydroxyl group and water molecules. This trend is consistent with previous study [9]. The 3μm band strength formed by proton implantation was decreased with increasing temperature up to ~373K.

Fig. 2 shows the reflectance ratio of 2.8μm and 2.7 μm to temperature. The ration corresponds to the absorption feature around 3μm formed by proton irradiation and this value is decreased when hydroxyl groups and H2O is produced in the samples. The ratio tends not to change over ~373K. This trend indicate that hydroxyl group and H_2O which formed by proton irradiation can exist at ~370K or less. This trend agrees well with lunar observational data. At the observational data, there is an absorption feature of 3μm at ~350K or less, and no clear 3μm absorption band has been observed in the region above ~370K [2]. The average temperature of the lunar observational area by NIRS3 was from 250K to 320K.

Summary: We curried out hydrogen ion irradiation using ion irradiation equipment installed at the ISAS and measured reflectance spectra at the various temperature. Our experiments support that the expectation as follows: (1) the 3μm absorption feature of the lunar observational data was formed by solar wind proton. (2) the abundance of hydroxyl group and H_2O on the lunar surface is related to the surface temperature, because the stability of hydroxyl groups and H_2O formed by solar wind proton depends on the temperature of minerals. (3) the 3μm absorption feature was observed by NIRS3 on the lunar surface.

Acknowledgements: Part of this work has been supported by the Japan Society for the Promotion of Science KAKENHI Grant Numbers JP15H05695, JP16H04044, Core-to-Core program (International Network of Planetary Sciences).

Reference: [1] Pieters, C. M., et al., (2009) Science, 326, 568 – 572. [2] Sunshine, J. M., et al., (2009) Science, 326, 565 – 568. [3] Clark, R. N., et al., (2009) Science, 326, 562 – 564., [4] McCord, T. B., et al., (2011) JGR, 116, E00G05., [5] Ichimura, A. S., et al., (2012) EPSL, 90 – 94, 345 – 348., [6] Tsuda, Y., et al., (2013) Acta Astronautica 91, 356-362., [7] Kitazato, K., et al., (2016) LPSC, #2158., [8] Kitazato, K., et al., (2016) UKAREN, #1G12., [9] (2014) JGR 119, 2017 - 2028

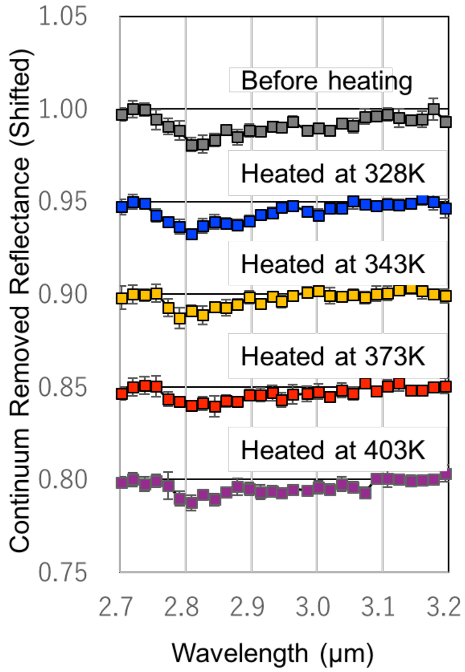

Fig. 1) The reflectance spectra of unheated and heated olivine: Each spectrum was resampled using NIRS3 resolution. They removed linear continuum connecting ~2.72μm and ~3.14μm.

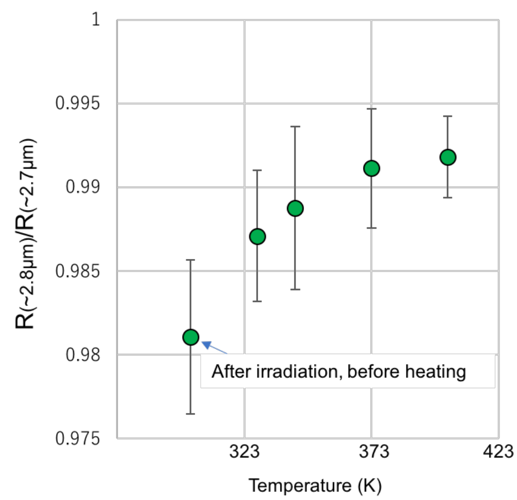

Fig. 1) The reflectance ratio of 2.8μm and 2.7 μm to temperature: As FTIR data was being resampled, 1σ error bars are attached.