SPACE WEATHERING OF ROCK SURFACE WITHOUT REGOLITH: LABORATORY SIMULATION OF SPECTRAL CHANGE

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Introduction: S-type asteroids show more overall depletion and reddening of spectra, and more weakening of absorption bands than ordinary chondrites. These spectral mismatches are explained by the so-called "space weathering". One proven mechanism of such spectral change is production of nanophase metallic iron particles [1], existence of which wa confirmed in the rim of lunar soil grains [2-4]. High-velocity dust particle impacts as well as sputtering by solar wind would be responsible for the production of nano-iron particles

Our group succeeded in reproducing the spectral change expected in space weathering, using nano-second pulse laser irradiation simulating high-velocity dust impacts [5-7]. We confirmed the formation of nanophase iron particles within the vapor-deposited rim of laser-irradiated olivine and pyroxene grains using TEM [8-10]. We also found that the olivine reflectance should decrease more with the increasing amount of nano-iron particles by ESR (Electron Spin Resonance) measurements [11].

Because we did not observe spectral change under the laser irradiation on a flat mineral surface [6], we considered regolith-like surface condition is essential for the spectral change of space weathering. When the surface consists of particulate materials, evaporated materials may condense on the surfaces of other particles to form amorphous rim containing nano-iron particles.

It was shown that size dependent transition from Q-type (ordinary chondrite-like) objects to S-type objects around the size range 0.1 to 5km using spectral slopes of near-Earth asteroids obtained through ground-based observations [12]. It was considered that presence of regolith should enhance the space weathering, and that regolith is scarce (abundant) on objects smaller (larger) than the transition size.

Observation of Itokawa: Between September and November 2005, Hayabusa spacecraft rendezvoused the S-type asteroid (25143) Itokawa (having size of 550m) and performed a color imaging by onboard camera AMICA [13]. Almost 80% of Itokawa's surface is rough and boulder-rich but it has a somewhat weathered spectrum on average. Optically, the surface of Itokawa is divided into brighter (and bluer) areas and darker (and redder) areas [14]. In rough zones, dark boulder-rich surfaces usually superpose on bright materials. We can interpret that removal of dark space-weathered boulder-rich surface materials by shaking caused by impacts or planetary encounters should lead to exposure of underlying relatively fresh bright area [13, 15]. High resolution images indicate that boulders are firmly covered with weathered fine particles or boulders' surface are optically weathered.

Pulse Laser Irradiation: In order to simulate space weathering, we use a solid-state Nd-YAG pulse laser beam with pulse duration of 6-8 nanoseconds [5-6], which is comparable with real dust impacts. We irradiate pulse laser on meteorite fragments with cut flat surface under vacuum (2 - 4x10^{-5} torr). Energy of each laser pulse is 5-15 mJ and pulse footprint on samples is 0.5 mm in diameter. A semi-automatic X-Y stage was used for a uniform irradiation. For comparison, we also irradiate pulse laser on pellet samples where particle size is smaller than 125 microns. An electric tungsten ball mill was used to crush metallic grains in meteorites. After the pulse laser irradiation, bidirectional reflectance spectra of samples were measured by instruments at University of Tokyo and at JAXA/ISAS. Both instruments are manufactured by JASCO and basically identical to each other. Incidence and emergence angles are 30 and 0 deg. from the vertical direction, respectively. Previously our group performed similar experiments on meteorite pellet samples such as Moorabie (L3), Allegan (H5), and NWA055 (L4). We observed a significant spectral change with every sample [16].

Rock weathering: In the present study, we irradiate on meteorites NWA1794 and Bensour. NWA1794 is an LL5 meteorite found in 2002. Bensour is an LL6 meteorite, which fell on Morocco desert on Feb. 11, 2002. These meteorites were chosen because they are fresh and because spectral observation of Itokawa suggested its similarity with LL5 and LL6 chondrites [17, 18]. We selected fresh