Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS24-18 Room:106 Time:May 23 17:00-17:15

Abrasion of regolith particles on airless bodies: comparison between Itokawa and lunar regolith

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Preliminary examination of Hayabusa samples suggests that Itokawa regolith have experienced following processes on the airless body [1]. (1) Formation of fine particles (~100 um) by impact of small objects onto Itokawa [2]. (2) Irradiation and implantation of solar wind to particles on Itokawa's uppermost surface [3]. (3) Formation of space weathering rims (thin amorphous layers (<~100 nm) with Fe-rich nano-blobs and sometimes blisters) on the particle surfaces mainly due to implantation of solar wind He with the time scale of ~10^3 yr [4,5]. (4) Abrasion of the particles, called "space erosion", probably due to grain motion by impact-induced seismic waves in a regolith layer with time scale of sufficiently longer duration than 10^3 yr [1,2,6]. Processes (3) and (4) should be repeated [3]. (5) Final escape of particles from the asteroid by impact within the residence time of < 8 Myr [3].

Evidence for the abrasion is mainly based on their 3D shapes and surface micro-morphologies obtained by x-ray microtomography [2]. The shape distribution of Itokawa particles cannot be distinguished form that of fragments formed by high-speed impact experiments [7], indicating that the particles are consistent with fragments mechanically crushed by impact. About 3/4 of the particles examined have sharp edges while rest of them have rounded edges at least on a part of the particle surface, suggesting that the fragments have been abraded. The shape distribution of lunar regolith particles (Apollo 16 highland samples: 60501) [8] was also compared. It was suggested that they are more spherical than the Itokawa and impact particles [2]. However, the lunar regolith samples were not imaged grain-by-grain by tomography [8], and imperfect separation of grains might affect the shape distribution data.

In the present study, 3D shapes of lunar regolith particles were obtained by the same method as the Itokawa particles. Particles (~50-100 um) picked up from 60501 and 10084 (Apollo 11 mare sample) were imaged grain-by-grain at BL47XU of SPring-8 using imaging tomography system with the effective spatial resolution of 200 or 500 nm. The longest, middle and shortest axis lengths (a, b and c) were obtained by ovoid approximation of solid portion extracted from CT images. The 3D shape distributions in b/a vs. c/b diagram were compared using Kolmogorov-Smirnov (K-S) test.

The shape distribution of 60501 particles (number of particles: N=21) can be clearly distinguished from those of the Itokawa particles (N=59) and impact fragments (N=6201) with P=0 (P: probability in the K-S test) while this cannot be distinguished from the previous 60501 data (N=55) with P=0.80. The rest of the lunar particles (N~90) will be analyzed. It has been reported that the mean b/a and c/b ratios of mare lunar regolith (0.72-0.78 and 0.73-0.86, respectively [9]) is larger than those of impact fragments (0.71 [8]). The present results and the previous data show that lunar regolith is more spherical than the impact fragments although lunar regolith is clearly the product of impact on the lunar surface. This strongly suggests that the regolith was abraded. The cause of the abrasion may be grain motion during gardening by impacts. The degree of abrasion is larger than the Itokawa particles due to larger scale of impacts and longer regolith residence time.

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Keywords: Hayabusa mission, Apollo mission, space weathering, impact, x-ray tomography, SPring-8