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Comparative analysis of surfaces of Itokawa regolith, LL chondrite and experimentally shocked olivine fragments

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Hayabusa spacecraft recovered regolith particles from S-type Asteroid Itokawa, which is a rubble pile asteroid [1]. In preliminary examinations of the particles [2-7], it was revealed that most of the particles correspond to the thermally metamorphosed LL5 or LL6 chondrites [2-4]. Three-dimensional shape distribution of Itokawa particles suggests that the particles are consistent with fragments mechanically crushed by impacts [4]. On the surface of the particles, evidence of space weathering [6,7] and structures similar to micro-or nanocraters [8] were also found.

Thus, surface activities of the asteroid and their formation histories can be revealed from analysis of recovered regolith particles. However, systematic observation for microstructure on the surface especially in connection with comparison with the internal structures has not been made. Observation for mechanical fragments in LL chondrites, which have not been suffered space weathering, and recovered fragments of shock experiments is also important. Therefore, in this study, observation of these particle surfaces was made using a field emission-scanning electron microscope (FE-SEM). FE-SEM images were compared with 3D structures obtained by X-ray micro-tomography [9].

Itokawa particles (four particles from room-A, four particles from room-B), three fragments of Tuxtuac meteorite (LL5), three Ensisheim meteorite (LL6) were used in this study. FE-SEM (JSM-7001F) observation was performed with an energy-dispersive X-ray spectroscopic (EDS) analysis at Osaka University. In order to evaluate shock-induced microstructures of Itokawa particles, manually crushed olivine and experimentally shocked olivine fragments were also observed. Shock experiments were performed using Gekko XIIat Institute of Laser Engineering, Osaka University. The maximum pressure of shock experiments was approximately 38 GPa. X-ray micro-tomography for Itokawa regolith and LL chondrites was made at beamline BL47XU of Spring-8, Hyogo, Japan [9].

As a result of FE-SEM observation, Itokawa regolith surfaces can be divided into two types. First type (Type 1) mainly consists of cleaved faces and another type (Type 2) consists of grain boundaries. Similar cleavage surfaces like Type1were also observed on crushed olivine fragments, LL5 and LL6 fragments. Type 1 surfaces may correspond to broken surfaces of large grains of a mineral (olivine, pyroxene and plagioclase) with cleavages. Surfaces like Type 2 structures were also observed in LL chondrites. The both type surfaces of Itokawa regolith can be subdivided into fresh and matured surfaces. Fresh surfaces have sharp edges and steps. On the other hands, matured surfaces have rounded edges and eroded surfaces, which were not observed in olivine particles and LL chondrites. Objects similar to melt drops and melt splashes were usually observed on the matured surfaces. They might be formed by the hypervelocity impacts of meteoroids. The matured surfaces were probably formed by space weathering as mechanical abrasion by grain motion [4] and/or sputtering of solar wind and cosmic ray radiation [6] on surfaces of Itokawa and/or its parent body. Recovered shocked olivine fragments have many cracks and cleavage in various directions due to plastic deformation, which feature is not observed on Itokawa regolith and LL chondrites. The results suggest that particles experienced such a high pressure might escaped from asteroidal surfaces.

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