MICRO-STRUCTURES OF PARTICLE SURFACES OF ITOKAWA REGOLITH AND LL CHONDRITE FRAGMENTS. T. Matsumoto[1], A. Tsuchiyama[1], A. Gucsik[1], R. Noguchi[1], J. Matsuno[1], T. Nagano[1], Y. Imai[1], A. Shimada[1], M. Uesugi[2], K. Uesugi[3], T. Nakano[4], A. Takeuchi[3], Y. Suzuki[3], T. Nakamura[5], T. Noguchi[6], T. Mukai[2], M. Abe[2], T. Yada[2], and A. Fujimura[2], [1]Department of Earth and Space Science, Osaka University, Toyonaka, Japan (akira@ess.sci.osaka-u.ac.jp), [2]JAXA, Sagamihara, Japan, [3]JASRI/SPring-8, Sayo, Hyogo, Japan, [4]Geological Survey of Japan. AIST, Tsukuba, Japan, [5]Department of Earth and Planetary Material Sciences, Tohoku university, Aoba-ku, Sendai, Japan, [6]The collage of Science at Ibaraki University, Mito, Japan.

Introduction: Hayabusa spacecraft recovered regolith particles from S-type Asteroid 25143 Itokawa. The low density of Itokawa and boulder-rich surface, which were obtained by remote-sensing observation from the spacecraft, revealed that Itokawa is a rubble pile asteroid [1]. In preliminary examinations of Itokawa sample, about fifty particles of 30-180 μm in size were analyzed [2-7]. It was revealed that the chemical compositions of minerals [2], oxygen isotopic compositions [3] and modal mineral abundances [4] are similar to those of LL chondrites [2,3]. Textures of Itokawa particles indicate that most of the particles correspond to thermally metamorphosed LL5 or LL6 chondrites [2,4]. The maximum temperature of the metamorphism estimated from the analysis requires a parent asteroid larger than ~20 km, suggesting that a parent asteroid was catastrophically disaggreggated by impacts into many small fragments, and some of them were reaccreted and formed Itokawa as a rubble pile structure [2].

Three-dimensional (3D) shapes of the particles were determined by X-ray micro-tomography [4]. It was revealed that shape distribution of Itokawa particles cannot be distinguished from that of fragments generated in laboratory impact experiments, suggesting that the particles are consistent with fragments mechanically crushed by impacts. Some particles have rounded edges as well as sharp edges and considered to be formed as a results of abrasion as grains migrate during micro meteoroid impacts. Trasmission electron microscope observation shows that surface modifications of the particles were found indicating evidence of space weathering [6]. Implantation of solar wind noble gas to Iotkawa particles was also detected by noble gas isotope analysis [7]. Structures similar to micro- or nanocraters and impact melts were observed on Itokawa particle surfaces using a scanning electron microscope [8].

As mentioned above, recovered regolith particles have informations about surface activities of the asteroid and their formation histories. Espetially, surface micro-structure is an important key to understand surface processes on Itokawa, such as space weathering. However, systematic observation has not been made espetially in connection with comparison with the internal structures. It is also important to compare the surface micro-structures with those of mechanical fragments of LL chondrites, which have not been suffered any kinds of space wethering. Therefore, in this study, observation of particle surfaces of Itokawa regolith and LL chondrites were made using a field emission-scanning electron microscope (FE-SEM) together with 3D structures using X-ray micro-tomography to understand surface processes on Itokawa. Surface micro-structures of crushed olivine particles were also observed for comparison.

Experiments: Itokawa particles used in this study are samples picked up from room-A (RA-QD02-0017, 0033, 0049-2 and 0064) and room-B (RB-QD04-0006, 0023, 0025 and 0049) of the sample chamber. They were sampled in the smooth terrain of asteroid Itokawa called MUSES-C Regio [9]. Fragments of Tuxuac meteorites (LL5), Ensisheim meteorites (LL6) and olivine from San Carlos, Arizona, USA were crushed, and particles of similar sizes as the Itokawa particles were picked up for the surface observation (three particles of Tuxtiac, three paraticles of Ensisheim, and four particles of olivine). FE-SEM (JSM-7001F) observation were performed with an energy-dispersive X-ray spectroscopic (EDS) analysis at Osaka university. All the samples were not coated by any conductor, such as carbon, to avoid possible nano-size decoration by the coating. To avoid charge up effect during SEM observation, secondary electron (SE) images were obtained at a low accerelating voltage (2 kV) in vacuum for observation with high-resolution and back-scattered electron (BE) images were obtained at a normal accerelating voltage (15 keV) in low vacuum (30 Pa N_2) for EDX analysis. X-ray micro-tomography was made at beamline BL47XU of Spring-8, Hyogo, Japan. Details of the imaging experiments are described in [10].

Results and discussion: The Itokawa regolith surfaces can be divided into two types. One (Type 1) mainly consists of cleaved faces (Fig. 1a). On this type of surfaces, there are parallel steps, steps with bifurcation and steps with cusps. Cleavage steps with similar morphologies were also observed on cleaved surfaces of olivine fragments, LL5 and LL6 fragments. This type corresponds to broken surfaces of large grains of a mineral (olivine, pyroxene and plagioclase) with cleavages. Among Type1 surfaces can be subdivided into fresh and matured surfaces. Figure 1a shows a fresh surface, which has sharp edges. On the other hands, some Itokawa particles have surfaces with faint steps, which seemed to be abraded.

The other type (Type 2) of the surfaces mainly consist of grain boundaries. Figure 2a shows a hexagonal convexed structure, which correspond to a small mineral grain, on a fresh surface of Tuxtuac LL5 chondrite fragments. On this convexed surface, concentric steps are seen, and these concentric steps must be developed on the surface of a grain boundary. Figure 2b shows a similar structure with matured features on an Itokawa particle; steps are not observed and the edges are rounded. 3D structures of particles with these convexed mineral grains show that these grains are not attached to the surfaces but continue inwards. One Itokawa particle has surfaces totally consisting of small grains with rounded edges (Fig. 3). This particle consists of small mineral grains in CT images, and may be broken along grain boundaries and eroded.

Objects similar to melt drops and melt splashes are usually observed on matured surfaces. They might be formed by impact of meteoroids. The matured surafeces were probably formed by "space weathering" in a wide sense, such as mechanical abrasion due to grain motion [4] and/or sputering due to solar wind and cosmic ray radiation [6] on surfaces of Itokawa and/or its parent body.

In future work, we are going to observe experimentally shocked olivine fragments to examine shocked features of Itokawa particles.

References: [1] Fujikawa A. et al. *Science*, *312*, 1330-1334. [2] Nakamura, T. et al., 2011. *Science*, *333*, 1113-1116. [3] Yurimoto H. et al., 2011. *Science*, *333*, 1116-1119. [4] Tsuchiyama, A. et al., 2011. *Science*, *333*, 1125-1128. [5] Ebihara M. et al., 2011. *Science*, *333*, 1119-1121. [6] Noguchi T. et al., 2011. *Science*, *333*, 1121-1125. [7] Nagao K. et al., 2011. *Science*, *333*, 1128-1131. [8] Tsujimori T. et al. (2011) JGU, U005-15.[9] Yano H. et al. (2006) *Science*, *312*, 1350-1353. [10]Tsuchiyama, A. et al., this volume

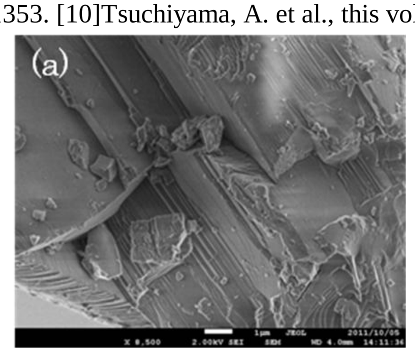

Figure 1: An SE FE-SEM image of cleavage steps on an Itokawa particle surface (RB-QD04-0023).

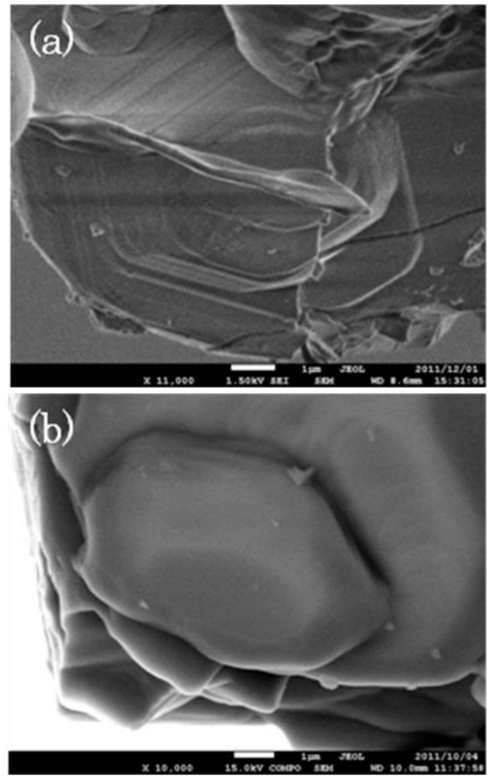

Figure 2: SE FE-SEM images of convex structures showing grain boundaries. (a) A surface of Tuxtuac chondrite. (b) A surfaces of Itokawa particle (RB-QD04-0006).

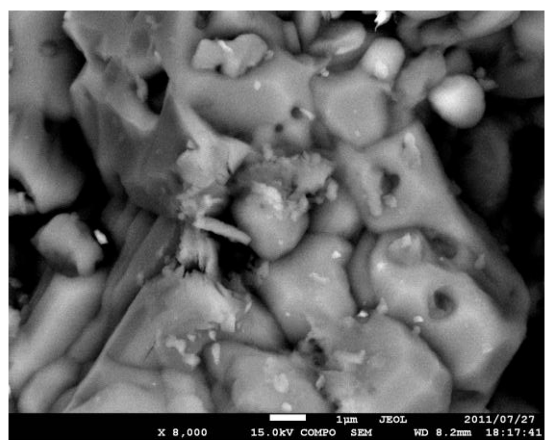

Figure 3: An BE FE-SEM image of a Itokawa particle surface (RA-QD02-0033) consisting of small mineral grains with rounded edges.