Shape evolution of regolith particles on airless bodies; comparison with returned samples and impact and abrasion experiments.

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The shape of regolith particles in airless bodies has information about processes on their surfaces. 3D shapes of Itokawa (~15-150 μm) [1-3] and lunar regolith particles [4-6] (~30-450 μm) were measured using X-ray microtomography. Impact and abrasion experiments [7,8] were made for comparison with these regolith particles. In this paper, our studies on 3D shapes of the returned samples and the experiments are introduced and a model for the evolution of regolith particle shape is proposed.
The averaged 3-axial ratio, *L*:*I*:*S* (*L*, *I* and *S* are the longest, intermediate and shortest axial lengths, respectively), of Itokawa particles is close to 1: 1/√2:1/2 (=1:0.71:0.5) [1-3]. We call this ratio 2DSR (2D silver ratio), which was first proposed for *L*:*I*:*S* of impact experiment fragments [9]. The 3D shape (3-axial ratio) distribution cannot be statistically distinguished from an impact experiment of [10], suggesting Itokawa particles are impact fragments on the asteroid surface [1,2]. However, the impact conditions of [9] and [10] are limited (impact energy density, *Q*~5000 kJ/kg: catastrophic destruction) and impact fragment size (4 mm) is larger than Itokawa particles. Lately, impact experiments with a wide range of *Q* (100-15000 kJ/kg) were preformed [10]. It was found that *L*:*I*:*S*' s for 4 mm fragments do not always have 2DSR particularly for low *Q*. In contrast, *L*:*I*:*S*' s of fragments in the impact experiments of [10] with the size range of 30-200 μm have 2DSR irrespective of *Q* and their 3D shape distributions cannot be distinguished from Itokawa particles [7]. Thus, the impact origin of Itokawa particles was confirmed. However, we cannot estimate its impact condition.
It was revealed that lunar particles from highland [4] are more equant than Itokawa particles (*L*:*I*:*S* is larger than 2DSR) [1]. Further investigation of the 3D shapes of lunar regolith samples with different localities (highland and mare), maturities and size ranges indicates that the 3D size distributions cannot be distinguished from each other but can be distinguished from Itokawa particles and impact fragments, and *L*:*I*:*S*' s are almost the same (~1:0.75:0.58) [5,6].
The external 3D shapes and surface nano-micromorphologies of Itokawa particles examined by X-ray microtomography and SEM showed that particles with rounded edges were suffered by mechanical abrasion [1,12]. Abrasion of lunar particles were also observed [13]. Abrasion experiments of mineral grains showed two modes of abrasion; (1) gradual abrasion without chipping of grain edges, where *L*:*I*:*S* is almost unchanged and (2) intense abrasion with chipping edges, where *L*:*I*:*S* increases (the shape becomes equant) [8].
Lunar particles must originally be impact fragments. If impact occurred onto a regolith layer, regolith particles became equant by intense abrasion in a fluidal particle flow while particles in week impact regions were gently abraded by grain motion without changing their average 3-axial ratios. Fracturing of particle and new impact fragment formation simultaneously occurred. By repeated impact events, the average 3-axial ratios became saturated. In contrast, small-scale impacts occurred on Itokawa, where only gentle abrasion occurred together with fracturing, and thus the average 3-axial ratios were unchanged and close to 2DSR.
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Keywords: Luna regolith particles, Itokawa regolith particles, Three-dimensinal particle shapes, impact, abrasion

