SPACE-WEATHERING FEATURES ON TWO HAYABUSA PARTICLES IMAGED BY HELIUM ION MICROSCOPY

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Introduction: Particles returned from the S-type asteroid Itokawa by JAXA's Hayabusa mission show evidence of space weathering [e.g. 1]. Quenched melt splashes, shock lamellae, and microcraters decorate the outer surfaces of Hayabusa particles. These features can be very small (<1 μm in size) and very shallow (within a 100 nm of the surface). The smallest space-weathering surface features and textures are difficult to resolve by secondary electron (SE) imaging in a field-emission SEM (FEG-SEM): SEs created from backscattered electrons from the incident beam, electron-electron scattering in the sample surface, and a relatively high mean SE energy degrades spatial resolution and surface sensitivity. TEM has excellent spatial resolution, but it is difficult to reconstruct the three-dimensional structure of surface features from electron-transparent thin sections. By using He ions instead of electrons, He ion microscopy (HIM) can produce a smaller probe size (< 0.1 nm) than FEG-SEM as well as a smaller surface interaction volume for SE imaging [2]. Additionally, HIM has 5–10× the depth of field of FEG-SEM. SE images produced by HIM can resolve the smallest and shallowest surface space-weathering features that cannot be seen in a FEG-SEM.

Methods: We used the Zeiss Helium Ion Microscope at the Environmental and Molecular Sciences Laboratory at the Pacific Northwest National Laboratory to image two Hayabusa particles: RB-QD04-0062 ("#62": 40 μm, olivine and plagioclase) and RB-QD04-0091 ("#91": 43 μm, olivine and plagioclase). We imaged with a 35 keV, ~0.6 pA He ion beam. The particles were removed from their glass slides with a Sutter micromanipulator and tungsten needle and then stuck on a SEM stub with a thin layer of Post-It note glue. The stub was coated with ~6 nm of carbon for electrical conductivity. We collected SE images of the surfaces of the two Hayabusa particles with magnifications up to 190,000×.

Results: Both Hayabusa particles show variable surface textures, a variety of splash melt features, adhering grains, and small holes. Two porous particles, with structures reminiscent of chondritic-porous interplanetary dust particles, were found adhering to the surface of the Hayabusa grains (a 1.2 μm object on #91, a 350 nm object on #62). Much of the surface of #62 is covered with small bumps 25–100 nm in size, whereas other regions (usually obvious cleavage faces) are free of small bumps. There is a large, 6 μm quenched melt splash feature on the surface of #62. We also imaged a 30 μm grain of lunar soil which had a much higher density of sub-μm splash melt features than the Hayabusa grains. We saw no obvious impact craters (holes with raised rims). A face of #91 shows multiple concoidal fractures and splash melt droplets and pancakes, but fewer and smaller surface bumps compared to #62.

Conclusions: Helium ion microscopy images of the surfaces of two Hayabusa grains revealed diverse space-weathering features on scales from several nm to several μm. The variations in surface textures indicates that these grains experienced a complex history of fracturing and exposure to space-weathering processes on the surface of asteroid Itokawa.

References: [1] E. Nakamura et al. 2012. *Proceedings of the National Academy of Sciences* 109:11 E624–E629. [2] B. W. Ward et al. 2006. *Journal of Vacuum Science & Technology* 24:6 2871–2874.