CONFIRMATION OF WATER IN THE SPACE WEATHERED SURFACE OF ITOKAWA GRAINS.

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Introduction: Water has been found in the surfaces of silicates in cometary interplanetary dust particles (IDPs) and in silicate minerals irradiated with protons in the laboratory [1] demonstrating that solar wind irradiation of airless bodies may generate water signatures observed by remote spectroscopy, e.g. [2]. Regolith from the S-type asteroid Itokawa returned by the Hayabusa mission provides the opportunity to explore the effects of solar wind irradiation in our laboratories. Enrichments in water and hydroxyl in the solar wind-irradiated rim of an Itokawa olivine grain and a lab-irradiated olivine standard have been detected using atom probe tomography [3]; however, background signals from the chamber introduce uncertainty. In this study, we investigated local water signatures in the surface of another Itokawa olivine grain using electron energy loss spectroscopy (EELS).

Samples and Methods: Hayabusa regolith particle RA-QD02-0332 was carbon-coated for imaging and element-mapping in a focused ion beam-scanning electron microscope (FIB-SEM: FEI Helios 660 with Oxford Instruments EDS), and FIB sections of selected regions were extracted at Univ. Hawai'i using Pt protective straps. These were further analyzed on (scanning) transmission electron microscopes at the Molecular Foundry (S/TEM: FEI Titan ChemiSTEM with EDS, TEAM I with Gatan Continuum GIF for EELS).

Results: RA-QD02-0332 is ~48µm and consists olivine, pyroxene, plagioclase and, likely, K-feldspar. In SEM imaging, glassy melt splashes with degassing vesicles are visible in multiple locations on the surface. Fractures are observed as well as significant fine-grained adhering material, including angular fragments and spheroidal particles with melt droplet appearance. Two FIB sections crossing fine-grained material contain small mineral crystals of albitic plagioclase and fayalitic olivine with lesser amounts of high-Ca pyroxene and iron-sulfide. Fine grain sizes range from ~100 nm to several microns across, and grain shapes range from angular to euhedral to rounded, consistent with some brecciation on the parent body. Another FIB section contains a ~4 µm plagioclase grain with fracture and defects in the interior consistent with shock, an amorphized rim on one face that has lost most of its Na and some Ca relative to the underlying crystal, and surficial lacy Fe-rich material that is likely remnants of the impactor.

In a FIB section from the surface of olivine, a vesicular amorphous rim and melt splash glass are observed. Energy dispersive X-ray spectral mapping of the melt splash glass indicates it was likely generated by an impactor with plagioclase-like chemistry. The vesicular amorphous rim is ~40 nm in thickness. A spectrum obtained by EELS of a vesicle in the amorphous rim shows features on the volume plasmon at ~8 and ~13.5 eV features. These features correspond to the energy gap and H core scattering edge from hydroxyl and/or molecular water, like those we previously observed in cometary IDPs, liquid water, proton irradiated silicate standards and electron beam-damaged talc and brucite [1,4]. Weaker features are observed in the amorphous rim off the vesicle.

Discussion: The presence of melt splash glass and a vesicular amorphous rim demonstrate unequivocally that this grain was exposed on the surface of the Itokawa asteroid instead of representing fragments generated during sample collection. The detection of water by EELS confirms the prior atom probe tomography detection of water in a solar wind-irradiated rim on Itokawa olivine [3]. The intensity of the features observed here from the vesicle in the amorphous rim on Itokawa olivine is lower than that observed in vesicles in IDPs, consistent with a smaller amount of water generated by lower effective exposure ages of Itokawa.

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