SOLAR WIND HYDRATION OF ITOKAWA OLIVINE

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Introduction: Space weathering affects surfaces exposed to the vacuum of space and results from the combination of solar wind irradiation, ultraviolet radiation, micrometeorite impacts and galactic cosmic rays [1]. Spectrometry shows that irradiation of silicate minerals by H ions from the solar wind can produce water [2], and Fe nanoparticles in 20-40 nm amorphous, vesiculated rims [1, 3]. However, direct mass-charge measurement of the concentration and distribution of OH or H_2O has not been undertaken. We present the first detection of OH and H_2O ions in space-weathered particles by atom probe tomography (APT) analysis of Itokawa grains from *JAXA's* Hayabusa mission [3].

Methods: Itokawa particle RA-QD02_0279 was mounted on a rod. The grain's surface was characterised by scanning electron microscopy (SEM) imaging, then sputter coated with a 200 nm thick layer of Cr for protection. An electron transparent lamella was extracted for transmission electron microscopy (TEM) imaging using a focused ion beam (FIB)-SEM instrument at Curtin University (CU). Two areas of the grain's surface were characterized with a FIB-time of flight secondary ion mass spectrometer (FIB-TOF-SIMS) at CU collecting positive and negative ions datasets. Finally, two sets needle-like specimens with 100 nm diameter tips were extracted for APT from the 'front' and 'back' sides of the grain at CU. To calibrate the Itokawa asteroid results, we also measured a San Carlos olivine (SCO) (n-SCO), a He^+ irradiated SCO (He-SCO) and a D^+ irradiated SCO (D-SCO) using the same approach.

Results and discussion: SEM imaging of Itokawa particle RA-QD02_0279 showed it is free of micrometeorite impact craters, suggesting that it has experienced a minimal duration of space weathering. This conclusion is corroborated by TEM results showing that it has a 40 nm thick space weathered rim characterized by slight density variations; Fe nanoparticles are absent (Fig. 1B). The beam sensitivity of the space weathered rim suggests it may be volatile rich. FIB-TOF-SIMS data from this grain indicate that the rim is rich in ^{16}O (Fig. 1A), ^{14}N and ^{12}C which is consistent with the isotopic composition of the solar wind e.g. [4]. APT results revealed density variations consistent with the TEM observations as well enrichment of H within the outermost 40 nm of the rim. This H enrichment is predominantly detected as OH^+ and H_2O^+ ions 1-3 at. % above normal background (Fig. 1C). APT analysis of the n-SCO and He-SCO reference materials indicate that H enrichment is not a property of olivine grain surfaces or the irradiation process, as they did not have a comparable profile of enrichment in OH or H_2O. The outermost part of the D-SCO sample was enriched in D_2, DO, and D_2O; importantly, no comparable enrichment in OH or H_2O was observed. These results demonstrate that solar wind hydrogen irradiation of olivine grain surfaces does indeed produce water, and space weathered rims retain at least part of their volatile abundances and isotopic signature over curatorial timescales.

The amount of water that can be implanted into mineral surfaces by solar wind irradiation is significant, particularly for grain sizes <10 µm where solar wind derived water could represent between 0.1-4 at. %. As such, fine-grained space weathered particles could represent a significant reservoir of isotopically light water in the Solar System.

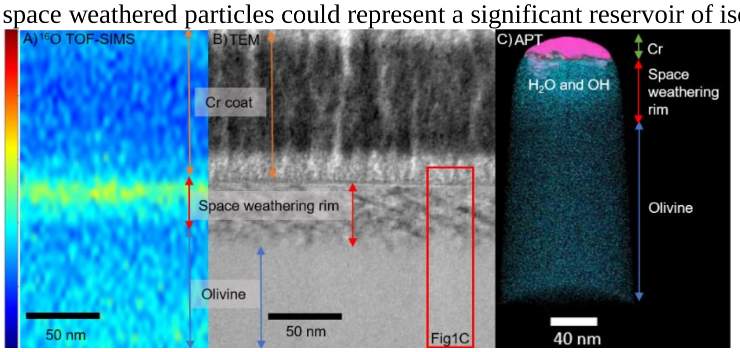

Figure 1: Space-weathering analysis of Itokawa particle RA-QD02_0279 A) TOF-SIMS depth profile data showing ^{16}O enrichment (yellows and reds) of the space weathering rim. B) TEM image of the space-weathering induced damage layer. C) APT dataset showing a direct detection of water enrichment in the space-weathered rim. Pink dots are Cr atoms and blue dots are H_2O and OH atoms.

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