# Synchrotron Nanoprobe Analysis of Space Weathered Itokawa Grains

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Space weathering on Itokawa is largely the result of the bombardment by electrons and protons from the Solar Wind. Its effects are manifested by darkening and reddening of the affected surfaces [1]. In order to make the most detailed and accurate mineralogical analyses possible of space weathering effects in grains of Asteroid Itokawa, returned by the *Hayabusa* mission, we perform a multi technique characterisation of their mineralogy and isotopes at the sub-micron scale.

Five Itokawa grains allocated to this study are RB-QD04-0063, RB-QD04-0080, RB-CV-0089, RB-CV-0011, RB-CV-0148. Each were embedded in epoxy resin and ultramicrotomed for ultra-thin (~100 nm) sections which were observed using a JEOL JEM-ARM200F at the Ultramicroscopy Research Center, Kyushu University. The original potted butts were embedded again in epoxy resin to prepare polished samples 8 mm in diameter for SHRIMP analysis by using Leica EM TXP. From these embedded grains, FIB-SEM sections were obtained for TEM analyses and X-ray synchrotron nanoprobe analyses.

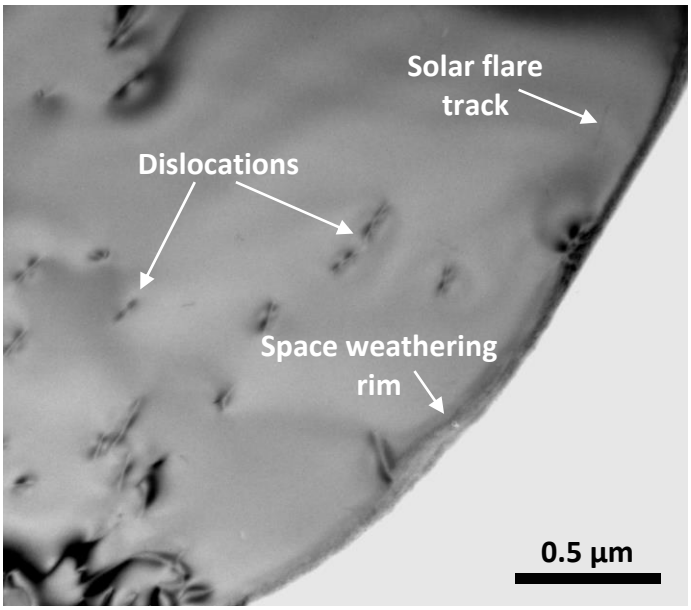


Figure 1. Bright-Field TEM image of RB-CV-0089, a low-Ca pyroxene grain featuring a <1 µm thick space weathering rim.

TEM-EDS chemical composition measurements have been performed on the FIB sections using a JEOL JEM-3200 FSK. Four of the five Itokawa grains are olivines, whereas RB-CV-0089 (shown in Figure 1) is a low-Ca pyroxene featuring high-Ca pyroxene inclusions. RB-QD04-0063 olivine grain also features plagioclase inclusions. All of the FIB sections have space weathering rims.

X-ray synchrotron analyses will be performed using the I-14 nanoprobe Beamline at *Diamond Light Source*, UK. The I-14 Beamline is capable of measuring a wide energy range (5-23 keV) down to a spatial resolution of 50 nm, and raster scanning to produce XRF/XANES mapping. Based on Fe-K X-ray Absorption Spectroscopy (XAS), we obtain high resolution XRF/XANES maps, XAS spectra, and ptchography imaging, analysing the five Itokawa grains in detail, with particular emphasis in the Fe redox changes and associated textures of space weathering. A typical Fe-K XAS measurement, for analysing the Fe redox, ranges from 7000 to 7300 eV with a higher resolution range of energy increments over the XANES features (~7100-7150 eV). The raw XAS and XANES data is then processed using *Athena 0.8.056* and *DAWN 1.9* [2]. Analysing the shifts in the Fe-K absorption edge and 1*s*→3*d* pre-edge peak centroid, and comparing to ferromagnesian silicate reference materials of known ferric-ferrous content, it is possible to semi-quantitatively deduce the oxidation state of our samples, similarly to previous studies of Itokawa, Comet Wild 2, and martian meteorite samples [3,4,5,6]. The high spatial resolution of I-14 will allow us to map the variation in Fe oxidation state across Itokawa grains and relate this to metallization associated with potential space weathering in the grains.

This X-ray nanoprobe analysis of Itokawa samples will reveal new insights into the redox changes associated with space weathering, informing further studies of other airless Solar System bodies such as the returned samples of asteroids Ryugu and Bennu from the *Hayabusa 2* and *OSIRIS-REx* missions.

**References**

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