High resolution chemical analysis of grains from the Itokawa asteroid by FIB-ToF-SIMS

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The Hayabusa spacecraft collected dust particles from the Itokawa asteroid; a stony sub-kilometer sized object in near Earth orbit. Over 1500 rocky particles were successfully returned to Earth [1] and in this study four of those grains were extensively characterised. Analysis by BSE, EDS and EBSD revealed polymineralic grains composed of olivine, high/low Ca pyroxene and plagioclase with some grains also containing troilite (FeS), taenite (FeNi) and kamacite (FeNi). One grain (RB-CV-0082) contained an amorphous melt phase (as determined by low band contrast in EBSD) with very fine variations in elemental composition which could not be spatially resolved using SEM-EDS.

ToF-SIMS using a Ga^+ focused ion beam primary source was used to study the melt phase, as well as a finely twinned plagioclase grain in particle RA-QD02-0010. FIB-ToF-SIMS was able to produce elemental (ion) maps with a spatial resolution ≤50 nm and had particular sensitivity to K which was of specific interest for subsequent geochronology studies. The melt was found to be finely partitioned with small islands or lamella shaped regions rich in Ca-Mg-Fe or Si-Al. Within the Si-Al-rich regions the alkalis were further segregated into even finer lamella shaped structures, alternating over 100 nm length scales. Slightly broader regions, a few microns across, exhibited discrete differences in Ca composition, suggesting the local elemental abundance was inherited from various pre-existing phases that were present prior to melting. Analysis of the twinned plagioclase grain revealed a depletion of K at the twin boundaries as well as feather-like features along grain boundaries, which were highlighted by an increase in K concentration.

It has been reported that the regolith from the Itokawa asteroid underwent long-term thermal annealing and subsequent impact shock [1]. The melt phase is likely to be the result of an impact event with the segregated composition a result of partitioning during cooling. The feather-like features in the plagioclase are believed to be antiperthite exsolutions. Nanoscale analyses by TEM and APM are also being undertaken to characterise these regions of interest in order to further understand the formation and modification of the Itokawa asteroid.

[1] Nakamura, T., et al., *Itokawa Dust Particles: A Direct Link Between S-Type Asteroids and Ordinary Chondrites.* Science, 2011. **333**(6046): p. 1113-1116.