Visible-IR and Raman micro-spectroscopic investigation of three Itokawa particles collected by Hayabusa

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HAYABUSA grains offer a unique perspective to better understand the link between asteroids and cosmomaterials available in the laboratory and to get an insight on the early stages of surface space weathering. The scientific objectives of our consortium are threefold: (i) the characterization of asteroidal surface processes (e.g., space weathering alteration); (ii) the assessment of parent-body alteration processes; (iii) the search for a possible association between S-type asteroids and micrometeorites. To this aim, our strategy is based on a combination of analytical techniques. Here we report a first series of results obtained through Visible-Infrared and Raman spectroscopy of three Itokawa particles (RA-QD02-0163, -0174, and -0213) collected by the Hayabusa spacecraft and provided by JAXA for our consortium.

In a first step, our main objective was to collect maximum information without altering the particles. Reported results were thus obtained on the raw particles, both (i) in their original containers, and (ii) deposited on diamond windows. Raman and IR confocal spectra were acquired at the SMIS beamline of the French national synchrotron facility SOLEIL and at the Lyon Raman national facility using spots of 2 µm for the Raman, and 10–20 µm for the IR analyses. Point analyses and automatic mapping were performed. Analytical parameters (e.g., laser power on the sample) were optimized to prevent any damage. Diffuse reflectance spectra ($i = 45°$, $e = 0°$) in the visible and near-IR wavelengths were obtained with an IAS-CSNSM in-home system coupling a fiber spectrometer to an optical microscope, providing a 20-µm spot on sample.

In the case of particle -0163, Raman and IR results reveal a heterogeneous mixing of minerals, mostly olivine (Fo76), and Ca-rich (En50, Wo50) and Ca-poor (En85) pyroxenes. The modal distribution of these minerals is determined based on the spectral maps. The mineral compositions of -0163 are consistent with those previously reported on distinct Hayabusa particles [e.g., 1]. The Itokawa materials are compatible with an LL4-6 chondrite classification based on O isotopes and chemical compositions of minerals (e.g., [1,2]). In particular, -0163 might be related to the least metamorphosed particles (LL4), based on the high Fo content of the olivine [1].

The diffuse reflectance VIS-NIR spectra are consistent with the presence of the mineral groups detected via Raman and IR. In particular, the spectra of particles -0163 and -0213 are also compatible with the ground-based observations of the asteroid Itokawa [3] both in terms of the 1-µm band depth and the spectral slope. Particle -0174 has a similar 1-µm band depth but higher (redder) spectral slope, possibly indicative of the presence of a larger amount of nanophase metallic iron, a by-product of space weathering induced by solar wind, similarly to what has been detected on other Itokawa particles [4].

Future work: A noble gas study of the particles will be performed. We will determine the noble gas (He-Ne-Ar) and nitrogen abundance and isotope characteristics of the two grains by CO_2 laser heating or UV laser ablation. By identifying and quantifying the proportion of solar and cosmogenic volatiles in Itokawa samples, we will be able to better constrain the residence time of dust particles on the surface of the asteroid, and to determine if any primordial volatile component has survived in the regolith material.

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