IR MICRO-SPECTROSCOPY AND MICRO-TOMOGRAPHY OF ISOLATED MURCHISON GRAINS IN PREPARATION OF THE HAYABUSA2 SAMPLE RETURN

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Introduction: The Hayabusa2/JAXA spacecraft has orbited and studied near-Earth object Ryugu [1]. Two sample collections have been performed and the spacecraft is currently on its way back to the Earth for an expected return in late 2020. A preliminary examination phase will follow [2], expected to elucidate the formation and evolution of Ryugu.

Considering the limited amount of material that will be retrieved by this mission, there is a need to optimize the analytical strategy, maximize the scientific outcome and minimize sample loss. A multi-analytical sequence from less destructive to more destructive techniques needs to be established.

Among the possible laboratory techniques, IR spectroscopy is important in being totally non-destructive and comparable to remote sensing observations of small bodies [3]. Thanks to IR imaging micro-spectroscopy, it is possible to detect and study the spatial distribution of molecular bonds associated to minerals, water and organic compounds, and their co-localization [4]. We consider IR three dimensional (3D) micro-tomography (IR-CT) an excellent starting point in a multi-analytical sequence to be applied on returned samples [5]. Here we report the preliminary results of the incorporation of IR-CT and IR hyper-spectral imaging in the multi-analytical sequence of the "MIN-PET CG" Hayabusa2 team (mineralogy and petrology of coarse grains) led by T. Nakamura.

Methods: Several isolated grains (sizing 20-50 µm) were extracted at Tohoku University (Japan) from three bulk samples of the Murchison CM meteorite: (1) unheated, (2) heated at 400°C, and (3) heated at 600°C [6]. The laboratory-controlled heating was applied to simulate potential heating undergone by Ryugu surface materials, as suggested by some Hayabusa2 observations [7]. Some of these Murchison grains were then mounted on tungsten needles by means of a platinum welding performed in IEMN-Lille (France) with a focused ion beam microscope (see Fig. 1).

We analyzed the Murchison samples using an IR micro-tomography setup installed at the SMIS beamline of the SOLEIL synchrotron (France). This setup has already been used for analyzing Hayabusa samples from asteroid Itokawa [8]. FTIR data were collected using an Agilent Cary 670/620 micro-spectrometer. We worked with its internal Globar source in transmission mode and used X25 objective and condenser (numerical aperture 0.81) coupled with high magnification optics (providing an additional X2.5 magnification) placed in front of a 128x128 pixels FPA detector. In this way, we obtained a projected pixel size of about 0.66 µm on the focal plane, and a field of view of about 84 µm. We collected hyperspectral data, i.e. for each pixel we obtained a whole IR spectrum in the 850-3950 cm^{-1} spectral range. The spatial resolution was diffraction-limited for the whole investigated spectral range. A reflectance mode was also considered for the largest samples (>40 µm), to produce useful data in the comparison with remote sensing observations of asteroid surfaces [7-9].

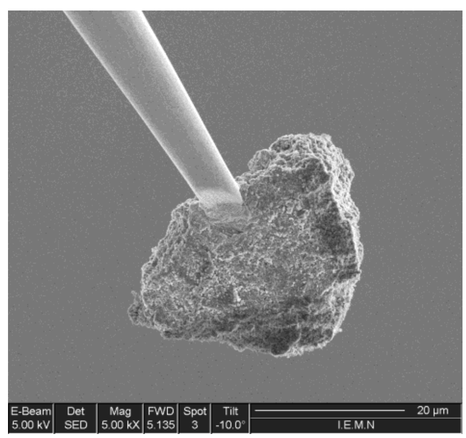

Fig. 1. Scanning electron image of a typical sample preparation for IT-CT analysis: an unheated Murchison grain welded on a tungsten needle, using a focused ion beam microscope.

Results: Infrared spectra show the presence of bending and stretching absorption bands of chemical bonds (C-H, O-H, Si-O, C=O, etc.) of different functional groups (see Fig. 2), as expected from literature IR spectra of Murchison [10,11]. The relative intensities of these bands are found to vary among different unheated grains, and their 3D spatial distribution is heterogeneous within individual grains (an example is provided in Fig. 3).

Noticeable differences are found between the IR spectra of unheated and heated samples, with a general trend of increasing the anhydrous to hydrated silicate content with respect to the increasing temperature, and reducing the organic content. A more detailed data analysis is ongoing.

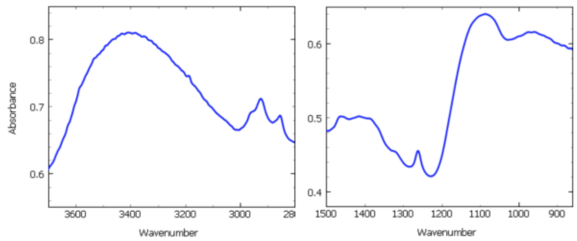

Fig. 2. A typical IR spectrum of an unheated Murchison sample mounted on needle, focused on the CH and OH stretching region (left) and on the region of fundamental vibrations of silicate and carbonate minerals (right).

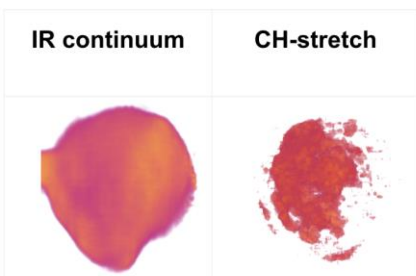

Fig. 3. Snapshots of 3D reconstructed distributions for the absorption of the IR continuum (left) and of the aliphatic CH-stretching bands (right).

Discussion and conclusions: IR-CT provides a first quick look at the composition, abundance and 3D distribution of carbonaceous materials at the scale of a few micrometers within individual grains up to several tens of micrometers in size. Once the organic components are revealed by IR measurements, thin sliced sections of the grains can be analyzed by more destructive techniques to retrieve the structure and the elemental and isotopic composition of the carbonaceous component and its mineral host, down to the nanometer scale. This top-down sequence will help us building a bridge between the remote sensing and in situ observations of Ryugu at macroscopic scale and the chemical and physical processes operating at the nanoscale.

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