FTIR MICRO-TOMOGRAPHY COUPLED TO X-CT ON EXTRATERRESTRIAL MATERIALS

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Introduction: Laboratory analyses of meteorites and interplanetary dust particles originating from asteroids and comets give us the opportunity to study directly the components that formed in the protoplanetary disk, but they also have intrinsic limits and biases, some of which are overcome by sample return space missions [1]. In the near future a new generation of sample return missions (Hayabusa2, OSIRIS-REx, MMX, etc.) will collect samples from small Solar System bodies. To maximize the scientific outcome of laboratory studies and minimize the loss of precious extraterrestrial samples, an analytical sequence from less destructive to more destructive techniques needs to be established. Among the possible techniques, infrared (IR) spectroscopy is important for being totally non-destructive and comparable to remote sensing observations of small bodies [2]. Thanks to IR imaging microspectroscopy, we are able to study the spatial distribution of molecular bonds associated to minerals, water and organics [3].

Materials and methods: In this work, we present the results of a Fourier-Transform infrared (FTIR) micro-tomography study of five particles from asteroid Itokawa collected during the Hayabusa mission (JAXA) and of several fragments of selected carbonaceous chondrites (CM Paris and Cold Bokkeveld, C2-ung Tagish Lake, CK NWA 5515). All samples size 20-50 µm and are mounted on needles. The FTIR measurements are performed at the SMIS beamline of synchrotron SOLEIL (France) with a spatial resolution that is diffraction-limited and a voxel size of about 0.66x0.66x0.66 μm^3. Complementary X-ray micro-tomography analyses are performed at the PSICHE beamline of SOLEIL and at beamline BL47XU of the SPring-8 synchrotron (Japan) [4] with voxel sizes of about 0.127x0.127x0.127 μm^3 and 0.084x0.084x0.084 μm^3 respectively.

Results: Supported by X-ray micro-tomography analyses providing a shape model and 3D structures of the samples, the FTIR analyses allows the detection of mineral phases, water and organics, and their spatial co-localization in three dimensions. We show that a combined IR and X-ray micro-tomography analytical approach is able to provide a non-destructive 3D physical and chemical characterization of individual extraterrestrial particles. The two techniques together surmount the intrinsic limitations of each one, giving access to the identification and spatial distribution of individual components inside the analyzed particles, as well as their 3D structure and porosity. In addition, we show that it is possible to recover the samples after the analyses.

Discussion: We propose these techniques as an efficient first-step in a multi-technique analytical sequence on samples collected by space missions. In particular, we consider FTIR 3D micro-tomography an interesting starting point, as it will be able to provide a first quick look on the composition, abundance and 3D distribution of carbonaceous materials and water at the scale of few microns within individual grains sizing up to several tens of microns. Once the organics are revealed by IR measurements, thin sliced sections of the samples can be prepared to be analyzed by more destructive techniques, in order to retrieve the structure and elemental/isotopic composition of the carbonaceous component and its mineral host, down to nm scale. This top-down sequence applied to Ryugu samples collected by the Hayabusa2 mission (JAXA), may build a bridge between the observations at macroscopic scale [5] and the chemical and physical processes operating at the nano-scale.

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