NON-DESTRUCTIVE X-RAY, RAMAN AND IR IMAGING OF QUARANTINED MARS RETURN SAMPLES

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Introduction: In preparation for the upcoming international Mars Sample Return mission, bringing to Earth samples containing potential biohazards, we have implemented a hyperspectral method of analysis of grains performed in BSL4 quarantine conditions, by combining several non-destructive imaging diagnostics. This methodology was tested on meteorites [1, 2] and cometary grains from the recent NASA Stardust mission [3-6].

Synchrotron Radiation protocols: Diffraction, X-ray fluorescence and absorption micro-imaging were performed on chondritic samples using focused beams at the ESRF synchrotron in Grenoble, France. 2D maps of grain composition (down to *ppm* concentrations) and polycrystalline structure have simultaneously been acquired, followed by XAS on elements of $Z \geq 26$. In a future version, absorption micro-tomography will be performed in full-beam mode to record the 3D morphology of the grain followed by fluorescence-tomography in focus-beam mode to complement the picture with a 3D elemental image of the grain.

Lab-based protocols: Raman and IR spectroscopies of the few nanometer-thick outer layers of the grains were performed in reflection mode for mineralogical imaging using commercial microscopes. Spatial resolution varied in the 1-10 μm range. Laser spectroscopy allows. Raman mineralogical maps are now routinely acquired at sub-μm scales through the 3 container walls of the holder, followed by IR few-micrometer spot measurements of C-based and potential H_2O alteration distributions.

Sample Holder: A miniaturized sample-holder [7] has been designed and built to allow direct analyses of a set of extraterrestrial grains confined in a sealed container implementing three layers of containment and remotely positioned in front of the X-ray or laser beams of the various setups. The grains are held in several thin walls (10 μm) ultrapure silica capillaries which are sufficiently resistant for manual/remote-controlled micro-manipulation but semitransparent for the characteristic X-rays, Raman and IR radiations. Miniaturized pressure/temperature sensors located in each container periodically monitor the integrity of the ensemble, ensuring leak proof conditions.

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