EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

Experiment Report Form

Experiment title: XRF and XRD nano-analysis of unmelted micrometeorites from the Sør Rondane Mountains, Antarctica		Experiment number: ES-676
Beamline:	Date of experiment: from: 27/10/2017 to: 31/10/2017	Date of report:
Shifts:	Local contact(s): Jussi-petteri Suuronen	*Received at ESRF:*

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Report:

Micrometeorites, extraterrestrial dust particles ranging from 10 to 2000 µm (Rubin & Grossman, 2010), form the main part of mass accreting on the Earth's surface annually (± 40000 tons/year) (Love & Brownlee, 1993). While cosmic spherules, i.e., completely molten particles that survived atmospheric entry, have been studied in great detail over the last two decades, unmelted micrometeorites have received little attention due to their rarity and fragile nature. However, unmelted micrometeorites, mostly less than 100 µm in diameter, are perhaps even more important, because they represent unique material that largely preserved the original petrographic, mineralogical and geochemical properties of the precursor, often within a crust of secondary magnetite. As a result, they are close analogues to the cosmic dust population present in the Solar System. Previous work (e.g., Genge et al., 1997, 2004) has suggested that the majority of fine-grained unmelted particles share strong similarities with the most primitive meteorites (e.g., CI chondrites) currently known within our Solar System. Other, rarer, unmelted particle types, such as the ultracarbonaceous micrometeorites, are believed to be directly linked to cometary bodies (e.g., Duprat et al., 2010; Dobrică et al., 2012). Considering the thin (µm-level), dense magnetite rim often surrounding unmelted micrometeorites (Fig.1), synchrotron radiation-based X-ray diffraction (XRD) coupled with fluorescence (XRF) might be the only analytical tool capable of mapping chemical variations and tracing their parent body materials. This will ultimately help to verify their heritage from CI chondrites and, potentially, comets.

During the experiment, multi-modal analysis combining nano-XRF, holotomography, XRD and XRF-tomography was used to analyse a set of 9 unmelted micrometeorites. Before the ESRF experiments, laboratory based µCT and 2D XRF were used to get preliminary information. Further analysis was planned using a wide variety of methodologies, making the non-destructive nature of the synchrotron radiation based experiments of crucial importance.

Excellent results were obtained with the holotomographic measurements, serving both as valuable information on the internal structure of the micrometeorites and a guideline to select regions of interest for combined XRF/XRD analysis. The retrieved elemental distributions, coupled to XRD results, will give a unique insight in the composition of these pristine materials.

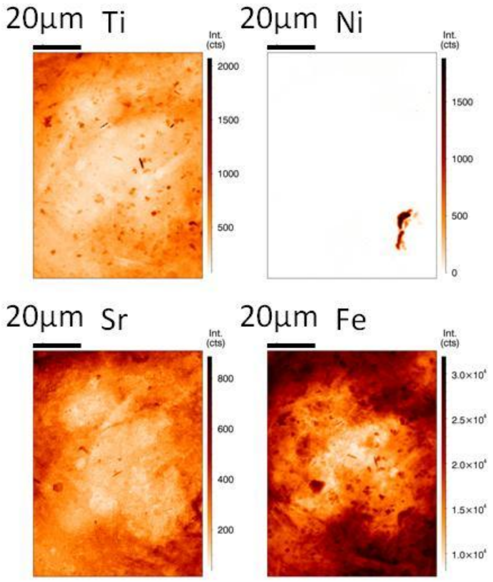

Fig.1 XRF overview scan (200nm steps)

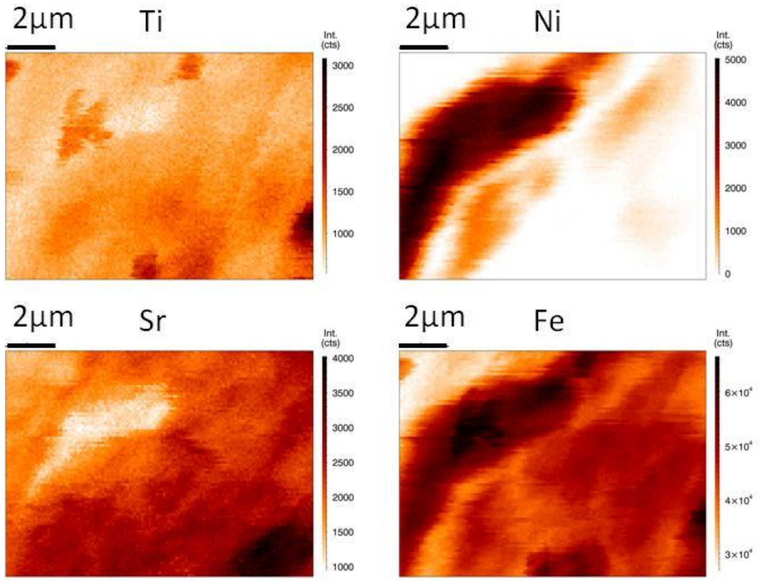

Fig.2 XRF detail scan (50nm steps) revealing submicron structures

Even though the samples were relatively small (100 – 200 µm diameter) only one was small enough the efficiently analyse with XRF-CT. Coupled with the holotomographic data, this scan revealed the internal structure of the micrometeorite in great detail.

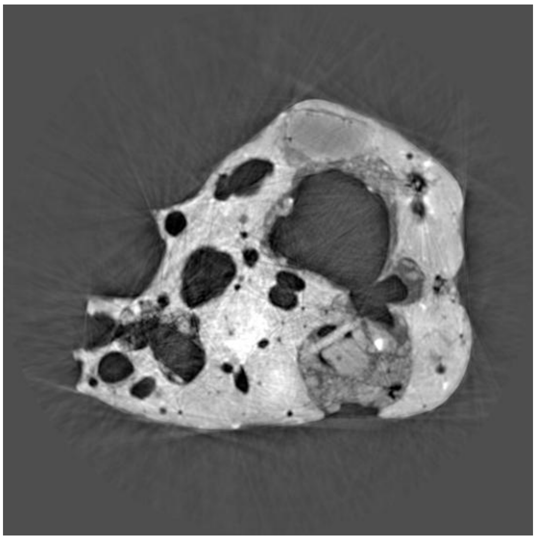

Fig. 3 reconstruction of holotomography scan on micrometeorite
The displayed particle had a diameter of 160 µm