In situ analyses of extraterrestrial grains trapped in aerogel using Synchrotron X-ray microfluorescence techniques

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Introduction

Extraterrestrial grains of cometary origin can be found in Low Earth Orbit (500 km altitude). As witnesses of the early times of the Solar System, 4.5 billion years ago, their study helps in understanding its formation. They are collected in aerogel (density < 0.1). Their analyses requires high spatial resolution techniques, among which Synchrotron X-rays MicroFluorescence (SR-XRF) can be an excellent candidate, especially for in-situ investigation. Pieces of aerogel a few hundreds of microns large that contain an incident grain and its penetration track, called "aerogel keystones", can now be produced self supported on "microforklifts".

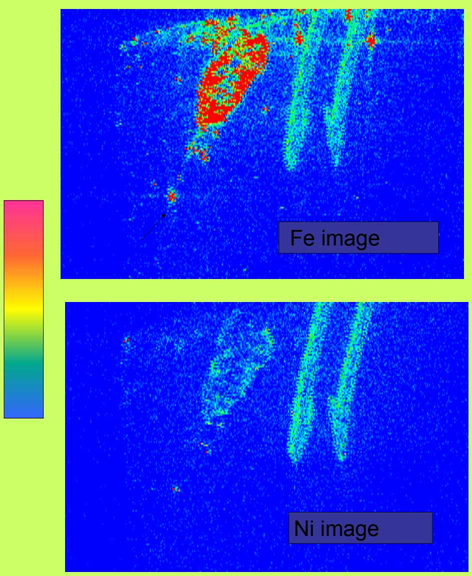
Optical micrograph of sample LC01B2. The arrow indicates the position of the grain, less than 5 microns in size. The entrance track is optically visible and measures ~ 200 μm long and 50 μm large.

Experimental set-up

On beamline ID22, devoted to high resolution microprobe techniques.

- **A Kirckpatrick-Baez (KB) mirror-pair was used as focusing optics, that demagnifies the incident beam to micron-sizes (HxV: 1x1 μm^2) with a flux ~ 10^{11} photons.s^{-1} in the energy range used (7 to 14 keV), allowing high resolution mappings of the samples.**
- **These incident energies are well adapted to the excitation of the K-lines of all the elements down to Z = 18 (Ar) and of the L-lines of the heaviest elements.**
- **For each sample, we proceeded first to a scan of the complete keystone, before focusing on the analysis of the elements distributed along the track and at its end, in the grain.**

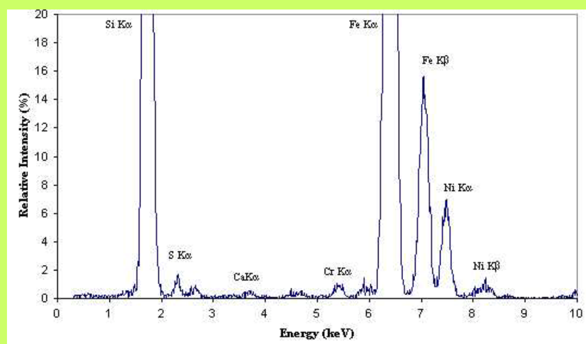
Main results



Distribution of the Fe-Kα and Ni-Kα characteristic X-ray lines.

The microfork tips are clearly distinguished, containing traces of Au, Fe and Ni (apart from Si).

X images of sample LCO1B2 (1 μm resolution)



X ray fluorescence spectrum of the terminal grain

• Peak intensities have been normalized to [FeKα] = 100
• The main elements that can be identified in this spectrum are Si, S, Ca, Cr, Mn, Fe and Ni.
• Gaining precise quantitative information about the repartition of the different elements in the grain and along the track is difficult due to the unknown self-absorption within the grain.
•The [Fe]/[Ni] abundance ratio in the terminal grain is roughly estimated by comparing the net peak intensity of the Fe-Kα line to that of the Ni-Kα line; it is about 17.
•Spectra of deposits along the track show the same elements, but in different proportions relative to Fe.

Discussion and conclusion

• In most studies regarding the identification of extraterrestrial materials, the criterion chosen is the chondritic composition. Here, in a first step, we rely on the [Fe]/[Ni] ratio for determining the origin of the grain, since it peaks around 18 in extraterrestrial matter and is higher than 600 in terrestrial basalts or crust. So the found value (about 17) clearly suggests an extraterrestrial origin for the grain. This argument is corroborated by the presence of other chondritic elements (S, Ca, Cr, Mn). Further analysis of this grain and the track is in progress.
• In January 2006, the Stardust mission will return, trapped in aerogel, the first samples of cometary and contemporary interstellar dust origins. The non-destructive techniques developped on ID22 might be among the only ones possible for analysing the interstellar grains trapped in the Stardust aerogel and for those cometary grains that might have lost most of their material along the penetration track.