FINE-GRAINED MATERIAL TRAPPED IN STARDUST TRACK WALLS. H. Leroux, D. Jacob and P. Cordier, Laboratoire de Structure et Propriétés de l'Etat Solide UMR CNRS 8008, Université des Sciences et Technologies de Lille, 59655 Villeneuve d'Ascq, France, hugues.leroux@univ-lille1.fr

Introduction: Samples from comet Wild 2 have been collected in the silica aerogel collector of the Stardust spacecraft [1]. The hypervelocity impact of comet particles at 6.1 km/s has left tracks in the aerogel which are terminated by one or several terminal particles. These terminal particles are usually coarse-grained silicate or iron-sulfide [2]. Abundant material is also present along the track walls as illustrated by synchrotron X-rays fluorescence spectroscopy [3,4]. This configuration suggests that the Wild 2 particles are made of poorly cohesive assemblages that have been broken and scattered during the impact into the aerogel. The study of material deposited along the track walls is important to understand the nature of the Wild 2 particles (structure of the aggregates, grain size and mineralogy of invidual components). Unfortunately the particles extracted from track walls are frequently strongly thermally modified. Their typical microstructure consists of a vesicular, silica-rich glassy matrix containing a high density of Fe-Ni-S nanophases [5]. Most of these samples show CI-chondritic composition, including sulfur. The composition and microstructure suggest that the comet fragments within the track walls originated from a fine-grained, loosely bound, dust aggregate, that were melted and mixed with molten aerogel, in contrast to the coarse-grained terminal particles which survived quite better to the capture process.

In this work we describe the microstructure of micro-tracks as studied by transmission electron microscope (TEM). The study of these micro-tracks has been rendered possible due to a new technique developed at the University of Washington for preparing ultra-thin sections for TEM [6].

Experimental: The studied sample originates from track 10. It has been prepared at the University of Washington [6]. A piece of aerogel was first extracted from the track wall, flattened between two glass slides, embedded into acrylic resin and then sliced by ultramicrotomy. Since acrylic is soluble it has been removed after ultramicrotomy. The main advantage of this preparation method is that it preserves all pieces of collected samples in the aerogel medium (see [6] for a full description of the method and discussion about the potential applications). Four ultra-thin slices have been studied using a TEM FEI Tecnai G2-20 equipped with Energy Dispersive X-ray Spectroscopy (EDX) (see [4] for a full description of the analytical procedure).

Results: The micro-tracks are typically made of elongated channel along which cometary particles are distributed as discret pieces (Fig. 1). Their apparent length is several tens of µm but they may be cut during the sampling process. Branching are common as well as crossings between several microtracks. The fragments dispersed along the micro-tracks are small, ranging from a few nm to 500 nm in diameter. Most of these fragments have a GEMS-like texture (Fig. 2) but their composition is strongly enriched in SiO_2, probably due to the mixing of the particles with the aerogel. The GEMS-like objects display a wide range of composition but on the average they are very close to the CI-composition. A few of them contain Al and Ca in significant proportion.

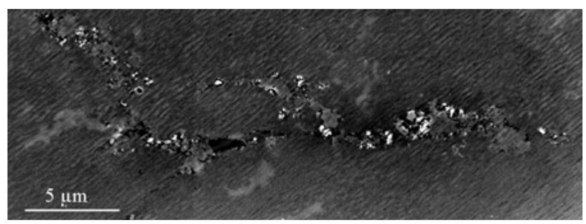

Figure 1: STEM dark field image showing one of the studied micro-tracks. Cometary material is distributed along the micro-tracks as discret fragments (here visible in bright). Almost all the fragments contain more or less Mg, Fe and S as major components (excepted SiO_2 due to the aerogel).

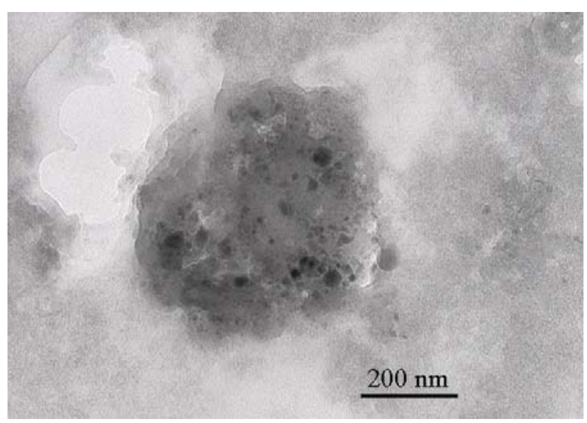

Figure 2: GEMS-like object in a micro-track. Most of them consist of a SiO_2-rich glassy matrix containing Fe-Ni-S nanophases.

Several crystalline silicates have been detected in the micro-tracks (Fig. 3). All of them are polycrystalline assemblages with sharp cohesive grain boundaries. The apparent crystallite size ranges from 20 to 300 nm, depending on the studied polycrystalline fragment. Most of the polycrystalline assemblage is made of olivine, low-Ca orthopyroxene, diopside and Mg-Al-Cr-spinel. Olivine and pyroxene are dominant, with a Fe/(Fe+Mg) ratio in the interval 0.10-0.15, whatever the polycrystalline fragment studied. Several, relatively large, iron-sulfide grains have been identified. Selected area diffraction reveals a pyrrhotite structure. Their Ni concentration ranges from 0.2 to 1.5 at. %.

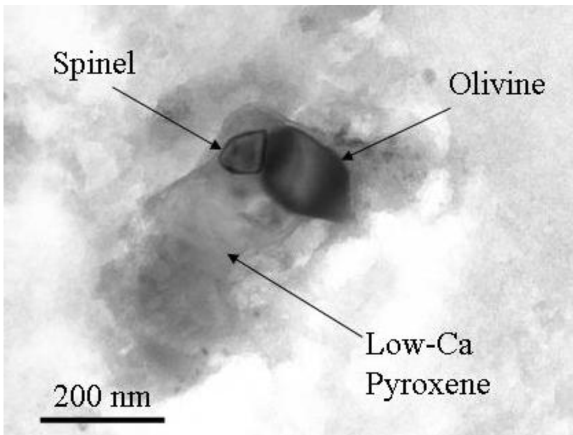

Figure 3: Bright field TEM image showing one of the polycrystalline assemblage detected in the micro-tracks. The polycrystalline area is sourrounded by a dense SiO_2-rich glass with occasional Fe-Ni-S nano-phases.

Discussion: Sample preparation with acrylic embedding is useful to study the fine-grained cometary material encased into the aerogel close to the track walls. The micro-tracks studied here are from the parent track #10, and they likely represent secondary structures that emanate radially from the parent track. In this study we show that cometary material is unevenly distributed along micro-tracks. Most of this matter is found as discrete fragments with highly variable compositions. This material is dominated by GEMS-like objects having high silica concentration, revealing that the incoming cometary material has been melted and intermixed with melted aerogel. The compositions of the GEMS-like objects are in agreements with the mixing of various proportions of sulfides and ferro-magnesian silicates, with occasional Ca- and Al-rich components. This microstructure was established during the hypervelocity impact of the grain into the aerogel and is typical for the highly thermally modified grains of Stardust [5,7]. An estimate of the size of individual components can be made if we remove the contribution of the molten aerogel. This calculation leads to the conclusion that this material likely originated from an ultrafine matrix, CI-like in composition, that could be comparable to those found in IDPs [8] or in fine-grained micrometeorites [9].

The micro-tracks also contain crystalline silicates and iron-sulfides. They correspond to material which has survived to the capture. All the assemblages are found polycrystalline, with a comparable Mg/(Fe+Mg), suggesting there are related one to each other. They differ only slightly by their grain sizes.

Conclusion: The presence of material along most track walls clearly demonstrate that the Wild 2 dust was composed of aggregates of poorly cohesive grains. During the hypervelocity impact, the aggregates broke apart by loosing small sub-particles. These small fragments continued their deceleration and penetrated radially the aerogel along the wall of the parent track. Some of them formed number of micro-sized tracks adjacent to the parent track. In track 10, material was deposited in these micro-tracks as discret submicro-sized fragments. The pieces of cometary material show a wide range of thermal processing due to the capture itself. Some of them are crystalline with olivine and pyroxene as major phases. Most of the material is found melted and mixed with aerogel. Their size and composition suggest that they derive from an ultrafine matrix, CI-like in composition.

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