ATEM STUDY OF FOUR THERMALLY MODIFIED STARDUST PARTICLES FROM TRACK 80. J. Stodolna, D. Jacob and H. Leroux, Laboratoire de Structure et Propriétés de l'Etat Solide UMR CNRS 8008, Université des Sciences et Technologies de Lille, 59655 Villeneuve d'Ascq, France, julien.stodolna@ed.univ-lille1.fr.

Introduction: The Stardust mission brought to earth samples from the comet 81P/ Wild 2. The cometary material is believed to be the most primitive material in the solar system and the return of the samples provides information about the prevailing conditions of the early solar system.

The samples have been trapped in silica aerogel at 6.1km.s^{-1} and the hypervelocity impacts have generated deceleration tracks in the aerogel [1] along which the cometary material is unevenly distributed in various proportions [1-3]. The deceleration induced a heat increase that modified the sample microstructure [4-7]. For number of samples, the microstructure gives clear evidence of melting of the cometary dust and mixing with molten aerogel. We know that the particles have been modified during the collect but what is the extent of the thermal-induced modification? Is it possible to deduce the original particle size and composition? The aim of this work is to characterize samples from a single parent track (#80), in order to firstly, compare their relative microstructure and chemical composition, and secondly, gain in the understanding of the modification evolution during the deceleration.

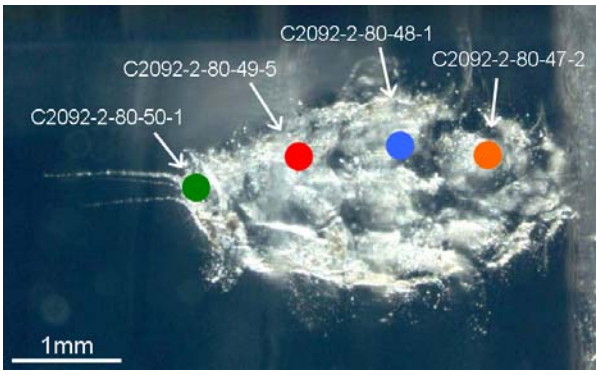

Fig.1 Localization of the four samples in track80

Samples and experimental procedures: The studied samples are four particles extracted from the walls of the bulb of track 80 (fig.1). Details about extraction, manipulation and TEM preparation by ultramicrotomy can by found in [8]. Results have been obtained using a TEM FEI Tecnai G2-20 twin equipped with Energy Dispersive X-ray Spectroscopy (EDX) (see [4] for a full description of the analytical procedure).

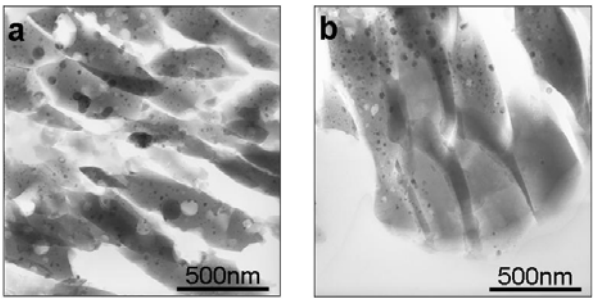

Fig.2 Bright field TEM images showing the glassy matrix (a) with and (b) without inclusions and vesicles.

Results: The microstructure is the same for the four samples. It consists of a silica-rich glassy matrix embedding a large number of small Fe-Ni-S inclusions and vesicles (fig. 2a). Size of the Fe-Ni-S droplets extends from a few nm to a hundred of nm. In general this microstructure is homogeneous within the samples. The compositions are rich in SiO_2 due to mixing with molten aerogel. The amount of analyzable cometary material is low, typically 5% compared to the aerogel contribution. In some cases, beads free areas, enriched in Mg, are found at the rim of the sample (fig. 2b). The Mg concentration can reach values up to 15 at. %. These areas probably correspond to Mg-rich silicates precursors, forsterite or enstatite. Due to the mean low amount of cometary material compared to the aerogel, only the major element Mg, Fe and S are studied (Si and O are mainly from the aerogel). Their distribution has been studied by elemental distribution mappings. It is comparable within the four samples. Mg is found mainly as discrete patches, Fe and S are found localized in the Fe-Ni-S nanophases. Figure 3 shows the bulk and sub-areas compositions plotted in a Fe-Mg-S ternary diagram for sample C2092-2-80-49-5. The analyzed surface is typically several µm² for the bulk analysis and 400x400nm² for the sub-areas. Data are scattered along a line joining approximately the Mg corner to the Fe-S join, indicating some (Mg/Fe+Mg) ratio variation within the sample. The same kind of distribution is obtained for all the samples. When plotted on the Fe-Mg-S diagram, bulk data from the whole samples are also distributed along the same line (fig. 4).

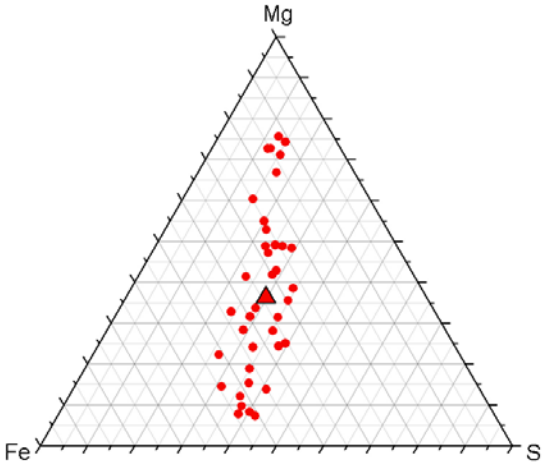

Fig.3 Bulk (triangle) and sub-areas (disk) compositions of the C2092-2-80-49-5 sample plotted in a Fe-Mg-S ternary diagram.

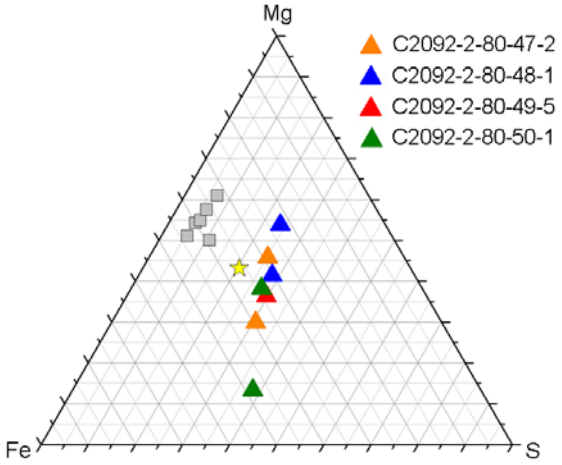

Fig.4 Average compositions of the four samples in the ternary Fe-Mg-S diagram (CI and meteorites compositions from [9]). Some samples present two separate parts with various compositions.

Discussion: In the ternary Fe-Mg-S diagram, the compositions of the samples as well as that of sub areas in a given sample are distributed along a line which passes close to the Mg corner. This line represents a constant Fe/S ratio, suggesting that all the iron is localized in Fe-Ni-S nanophases. Consequently the silica-rich glassy matrix is FeO-poor. By the study of local areas of different track samples, Leroux et al. [5] proposed a nanophase formation model based on a redox reaction process that likely happened during the high temperature stage of the capture. The reduction occurred between the FeO-bearing silicates and the carbonaceous matter coming from either the incoming particles or the residual organics of the aerogel. The resulting iron precipitates reacted with gaseous sulfur and formed iron sulfide.

The composition variation observed within each sample shows that the element redistribution was very local during the capture heating (except for S). The four samples studied from track 80 differ from their bulk composition, suggesting that they originated from an aggregate which broke up during the hypervelocity impact. Their different chemical compositions are probably due to variation in the relative proportion of silicate and iron-sulfide in the individual fragments which were deposited along the track during deceleration. Apparently no chemical mixing occurred in the track, despite the fact that all the samples suffered from thermal modification at comparable level, whatever their position in the bulbous region of the track. Finally the majority of the studied samples show composition enriched in Fe and S compared to the CI composition (fig. 4). All these compositions are far from the composition field of other meteorite classes.

Summary: The thermally modified samples from track 80 display evidence for chemical reactions at high temperature. The Fe-Ni-S phases within the glassy matrix are likely the result of a reduction reaction process of Fe-bearing silicates in presence of carbonaceous material. This study shows that this reaction occurred for all the samples. Bulk composition of the four studied samples suggests that the initial particle was an aggregate of grains with various compositions and that there was no extending chemical mixing in the bulb during the deceleration.

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References: [1] Hörz F. et al. (2006) *Science*, *314*, 1716-1719. [2] Zolensky M. E. et al. (2006) *Science*, *314*, 1735-1739. [3] Flynn G. J. et al. (2006) *Science*, *314*, 1731-1735. [4] Leroux H. et al. (2008) *Meteoritics & planet. Sci.*, *43*, 97-120. [5] Leroux H. et al. (2009) *Geochim. Cosmochim. Acta*, in press. [6] Rietmeijer F.J.M. et al. (2008) *Meteoritics & planet. Sci.*, *43*, 121-134. [7] Ishii H. et al. (2008) *Science*, *319*, 446-450. [8] Zolensky M. E. et al. (2008) *Meteoritics & planet. Sci.*, *43*, 261-272. [9] Wasson J. T. and Kallemeyn G. W. (1988) *Phil. Trans. R. Soc. Lond.*, *325*, 535-544.