XRD ANALYSES OF STARDUST TRACKS 170, 176, 177, 178: TERMINAL GRAINS FROM MAGNETITE-RICH, CHONDRITE-LIKE MATRIX

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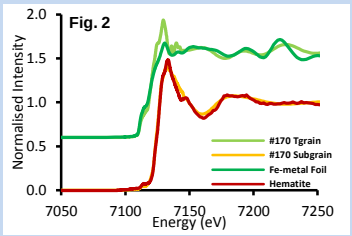
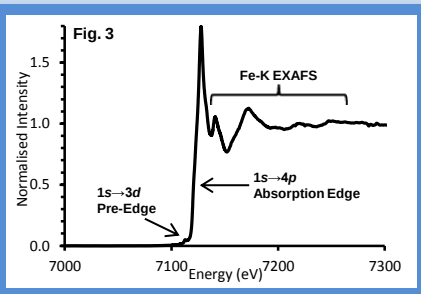
C2112,4,170,0,0 (#170)

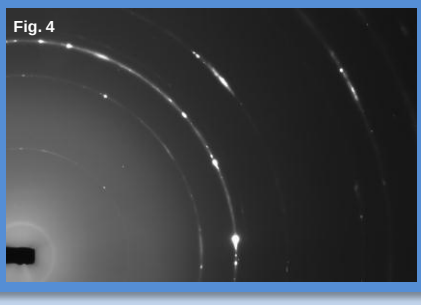
Track #170 is a Type A [1]. XRF maps of the #170 terminal grain showed the strong presence of Fe and Cr composition, but Fe-K XAS reveal similarities to pure Fe-metal foil (see Fig. 2). Further analysis, using Cr-EXAFS measurements, find Cr-O and Cr-O-Si bond lengths of 2.06 Å and 2.80 Å respectively, suggesting the terminal grain is a mixture of metallic Fe and Cr-bearing silicate [2]. Fe-K XAS of the subgrain material, found near the entrance of the track, has a structure similar to the Fe-K XAS of hematite. Both hematite and the #170 subgrain have a 1*s*→4*p* absorption edge position of ~7123 eV.



XRD and Fe-K XAS

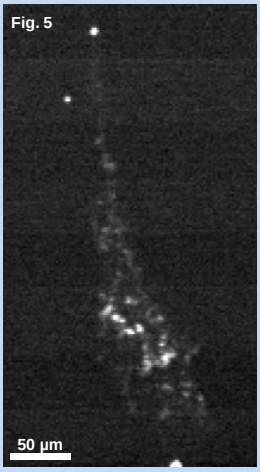
All measurements were taken at the *Diamond Light Source* Synchrotron, using Beamline I-18, capable of a beam spot size of 2.5 µm.
Fe-K XAS measurements range 6900-7500 eV at resolution 1.0-3.5 eV, with a resolution of 0.1 eV over the XANES region of 7090-7145 eV. Comparisons can be made with other materials, observing the absorption edge position and analysis of the EXAFS structure, to identify the mineralogy of the cometary grains.
Transmission XRD measurements were taken at 13 keV, with observable *d*-spacings ranging 9-1.5 Å, corresponding to 2θ = 5.5° to 38.4°. Fig. 4 shows the XRD pattern for a powdered magnetite standard.
XRF maps have also been produced of the terminal grains and subgrain track material at a pixel resolution of 2 µm, observing elements of Z >20.

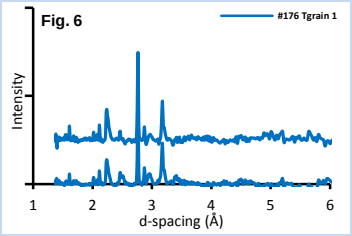


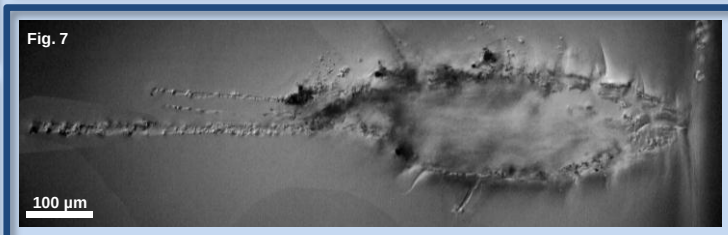


C2045,2,176,0,0 (#176)

Track #176 is a Type B [1]. Fig. 5 shows an XRF map of Fe concentration, revealing the location of the terminal grains from two styli, as well as subgrain material. XRD measurements of the main 6 µm #176 Tgrain 1 shows *d*-spacings at 3.177 Å, 2.873 Å, 2.465 Å, 2.115 Å, and 1.611 Å, which may suggest the presence of enstatite pyroxene. The terminal grain of the second stylus has similar *d*-spacings to the #177 Tgrain (see below) suggesting an olivine particle.

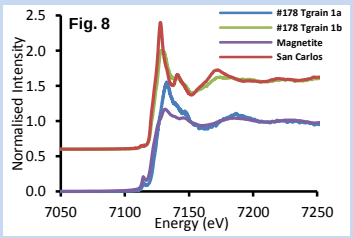


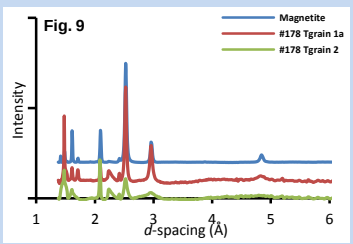


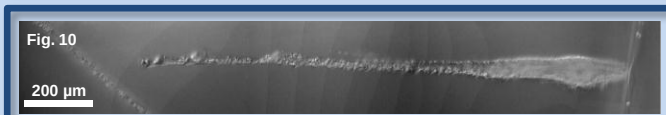


C2045,4,178,0,0 (#178)

Track #178 is a Type B [1]. The main stylus has a terminal grain with two particles measuring 10 µm in diameter (#178 Tgrain 1a) and 6 µm (#178 Tgrain 1b). The Fe-K XAS in Fig.8 shows the spectrum of Tgrains 1a to be very similar to a magnetite reference standard in terms of the EXAFS structure. The spectrum of Tgrain 1b is very similar to a measurement of San Carlos olivine. However, with an increased shift in the 1*s*→3*d* pre-edge centroid from 7111.8 eV (in San Carlos) to 7112.6 eV, this would suggest that Tgrain 1b may have a ferric composition of $Fe^{3+}/\Sigma Fe \leq 0.5$ [3]. Fig. 9 shows XRD measurements for the Tgrain 1a particle and the second stylus terminal grain (Tgrain 2) with *d*-spacings at 4.839 Å, 2.957 Å,2.525 Å, 2.419 Å, 2.085 Å, 1.714 Å, 1.611 Å, and 1.478 Å, which are nearly identical to our magnetite standard.

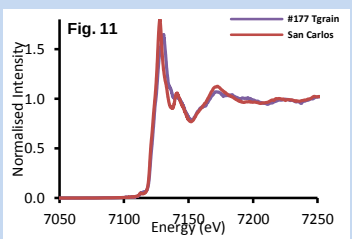






C2045,3,177,0,0 (#177)

Track #177 is a Type A [1]. The XRD measurements of the ~4 µm terminal grain shows *d*-spacings at 3.496 Å, 2.454 Å, 2.262 Å, 1.730 Å, 1.618 Å, and 1.573 Å. Unfortunately a significant comparison of these *d*-spacings has not been found with reference standards. However, the Fe-K XAS (see Fig. 11) would suggest the presence of olivine with a characteristic olivine XAS structure.



Conclusion

Transmission XRD together with XAS, and complementary Raman analyses [4] allow the non-destructive mineralogical identification of Comet Wild2 terminal grains and subgrain material, including Fe-oxides, ferromagnesian silicates, and Fe-metals, consistent with previous findings [5-7]. The cometary assemblage is probably associated with a chondritic matrix [8,9], and is volatile-rich, shown by the carbon-rich content of the #178 subgrain material. This is consistent with our identification of low-temperature forming magnetite in the terminal grains of #178, which is also typical of carbonaceous chondrite matrices. The nanometre-micron scale subgrain Fe-oxides present in the *Stardust* tracks (e.g. #170, #176, and #178) are fragments of larger magnetite and hematite grains.

References: [1] Burchell, M. J. et al. (2008) *MAPS*, *43*, 23-40. [2] Bridges, J. C. et al. (2012) *LPSC XLIII*, #2214. [3] Hicks, L. J. et al. (2014) *GCA* (in rev.). [4] Price, M. P. et al. (2014) *LPSC XLV*, #1252. [5] Bridges, J. C. et al. (2010) *MAPS*, *45*, 55-72. [6] Changela, H. G. et al. (2012) *GCA*, *98*, 282-294. [7] Stodolna, J. et al. (2010) *LPSC XLI*, #1657. [8] Burchell, M. J. et al. (2008) *MAPS*, *43*, 23-40. [9] Zolensky, M. E. et al. (2008) *MAPS*, *43*, 261-272.