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Magnetite in Stardust Terminal Grains: Evidence for Hydrous Alteration in the Wild2 Parent Body

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Abstract

We use synchrotron X-ray Diffraction and other techniques to show the presence of magnetite in terminal grains from *Stardust* cometary tracks. This suggests that the parent body of Comet Wild2 underwent hydrous alteration, and gives further evidence for the varied mineralogical history of this early Solar System body from the Outer Solar System.

1. Introduction

At the time of the preliminary *Stardust* examination work summarised in [1,2] no obvious signs of aqueous alteration had been identified within Wild2 samples. However, as more tracks have been harvested (~200 in total to date) we are gaining a more complete inventory of minerals upon which to base our comparisons and we are now in a position to make direct links to known planetary materials, such as different chondrite groups, with more confidence. In particular, the presence of significant quantities of Fe oxide and magnetite that we have identified here and previously [3] argues strongly for some water-rock interaction. Here we report on recent synchrotron analyses of magnetite terminal grains in Type B Stardust tracks – which are thought to be relatively volatile rich [4] – to show the growing evidence for this mineral signature on the Wild2 parent body.

1.1 Samples and Methods

A set of terminal grains found in tracks C2112,4,187,0,0; C2045,4,178,0,0 178 (Fig. 1) and also C2112,4,170,0,0; C2045,3,177,0,0; C2045,3,189,0,0; C2045,4,190,0,0 (Tracks #187, #178, #170, #177, #189, #190) were taken from the cometary side of NASA's *Stardust* mission sample collector. In order to maximise the scientific return, it is vital that analyses of the samples are undertaken using as many different, non-destructive, techniques as possible - preferably on particles whilst they are still embedded in aerogel using, for example, microRaman spectroscopy [5]. Here we report on Fe-K absorption edge X-ray Absorption Analyses (XAS) and synchrotron X-ray Diffraction (SR-XRD) measurements at Beamline I18 of the *Diamond* synchrotron, UK. A spot size of 2.5 × 2.5 μm was used and Fe-K XAS was measured with the highest resolution over the Fe-K XANES region (7090-7125 eV), from which an absorption edge was estimated at 0.5 normalized intensity, and the 1s→3d centroids were estimated as the intensity-weighted average of baseline-subtracted pre-edge peaks. The transmission SR-XRD measurements were taken between 9 - 15 keV, with a 2θ range of ~4.3° to ~41.7° corresponding to d-spacings of ~1 Å up to ~18 Å.

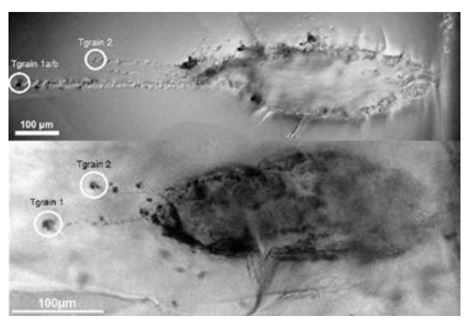

Fig. 1: (Top) Terminal grains 1a/b, 2 from track #178. (Bottom) Terminal grains 1 and 2 from track #187. Both are Type B tracks [4].

2. Results

Track #178: X-ray data confirms the presence of magnetite for the main terminal grain 1a and terminal grain 2 (Fig. 2). Terminal grain 1a has a 1s→3d pre-edge centroid position nearly identical to magnetite, although the absorption edge measures ~2eV higher than that of the magnetite (Fig. 3). MicroRaman analyses at the University of Kent revealed significant carbonaceous content around the subgrain bulb region of this track, implying an organic rich particle embedded with magnetite, perhaps holding it together like a 'glue' [5]. **Track #187**: The main terminal grain 1 has an iron-oxide type composition, with a (degraded) Raman spectrum indicative of magnetite mixed with some hematite. X-ray data confirms the presence of magnetite (Fig. 2). Fe-K XANES shows it has a 1s→3d pre-edge centroid position within 0.3 eV of magnetite, although the absorption edge measures ~3 eV higher than that of the magnetite (Fig. 3).

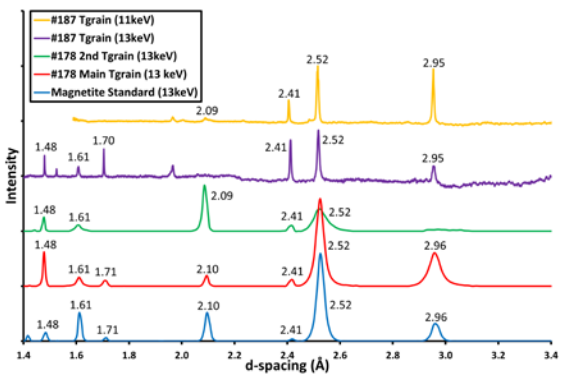

Fig. 2: SR-XRD identification of magnetite in the terminal grains of Tracks #178 and #187 by comparison of the 2θ peaks to a powdered magnetite standard.

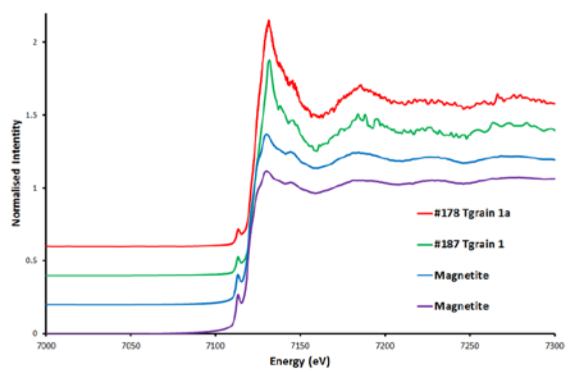

Fig. 3: Fe-K XANES plots of Track #178, #187 terminal grains compared to a powdered magnetite standard.

Other mineralogy identified: Fe-K XANES features and Raman spectrums [5] show the terminal grain in track #177 and terminal grain 1b in track #178 to be olivine. Similarly, terminal grains in tracks #189 and #190 have Fe-K XANES features corresponding to pyroxene. The terminal grain in track #170 shows near-identical Fe-K XANES and EXAFS comparisons to a Fe-metal foil standard, while XRF maps reveal Cr-rich content and a trace of calcium, thought to be a Cr-bearing silicate phase [6]. A Raman spectrum revealed a close match between forsterite and the silicate phase in this terminal grain [7].

3. Discussion

The presence of magnetite in Wild2 is similar to its occurrence within the matrices of many carbonaceous chondrites. It is assumed to be the result of the hydrous alteration of co-existing ferromagnesian minerals, which are also present in the Wild2 terminal grains analysed here and by others [1,2]. There is a variety of growing evidence for both low temperature hydrous processes such as magnetite formation, and also high temperature processing and the formation of chondrules in the Wild2 solid precursors [8]. This new understanding of the composition of comets will inform models of the early Solar System which require either radial mixing from the inner Solar System [9] or melting and alteration processes on planetesimals in the outer Solar System [1,10].

References

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