OXYGEN ISOTOPE MEASUREMENTS OF COMET WILD 2 MATERIAL IN THE BULB OF STARDUST TRACK 184

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Introduction: NASA's Stardust mission returned rocky material from the coma of comet Wild 2 for laboratory study. Hypervelocity cometary particles captured in aerogel created different types of tracks. The "Type B" tracks [1] have an initial bulbous cavity tapering into a long, narrow stylus (or several). In these tracks, the impacting cometary particle was an aggregate of fine-grained material (<2 μm) which ended up in the bulb of the track, and coarse-grained terminal particles (>2 μm) at the ends of the track.

The fine-grained material in track C2052,2,74 (a large, 8 mm long, type B track) showed a very broad range of O isotopic compositions ($-70‰ < \Delta^{17}O < +60‰$) compared to the terminal particles from track 74 and several other tracks [2]. This implies that comet Wild 2 fines are either primitive outer-nebula dust or a very diverse sampling of inner Solar System compositional reservoirs that accreted along with a large number of inner-Solar-System rocks to form comet Wild 2.

Stardust cometary tracks show significant track-to-track heterogeneity [3]. It is possible that large tracks may be compositionally different than small tracks. Additionally, fines in small tracks may be better preserved (less mixing with aerogel) than fines in large tracks. For these reasons, we measured the O isotopic composition of bulb material in Stardust track C2086,20,184,0,0 ("Track 184"), a 0.3 mm type B track (Figure 1).

Methods: We compressed the bulb portion of Track 184 into indium using a Teflon-coated anvil and plunger press (Figure 2). The aerogel porosity was sufficiently reduced to allow a conductive ~20 nm C coat to be applied. The samples were then mounted under an Au-coated Si_3N_4 window with a ~300 μm ion-milled hole, to create a flat, conducting surface for SIMS analysis [4].

Figure 1: Optical image of Track 184 before compression into indium.

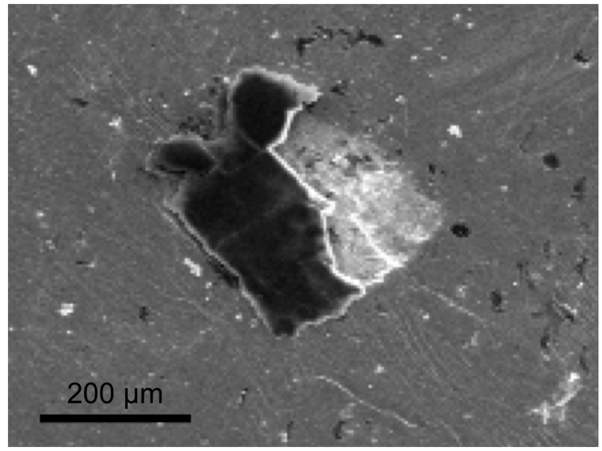

Figure 2: Secondary electron image of Track 184 pressed into indium.

We acquired 35×35 μm, 128×128 pixel scanning ion images using the Cameca ims 1280 ion microprobe at the University of Hawai'i. We used a <3 pA Cs^+ primary beam focused to ~250 nm. An electron flood gun was used for charge compensation. We simultaneously collected $^{16}O^-$, $^{17}O^-$, and $^{18}O^-$ on electron multipliers. We used a mass-resolving power of 5500 on $^{17}O^-$ to minimize the interference from $^{16}OH^-$. We used magnetic-field peak-jumping to collect $^{16}OH^-$ (to quantify any contribution to $^{17}O^-$), $^{24}Mg^{16}O^-$, $^{27}Al^{16}O^-$, and $^{56}Fe^{16}O^-$ (to distinguish cometary material from background aerogel). We collected 5000 total frames (88 hours of measurement). We monitored O isotope ratios of cometary particles during the analysis to identify any isotopically anomalous presolar grains, in which case the measurement would have been stopped so we would not sputter through these grains

Data Analysis: We registered each of the 5000 frames using the $^{16}O^-$ map to account for drift during the long measurement. We also registered the $^{17}O^-$ and $^{18}O^-$ total map to the $^{16}O^-$ total map. Counts for all species were corrected for electron-multiplier deadtime. We used the $^{24}Mg^{16}O^-$ and $^{56}Fe^{16}O^-$ maps to identify particles (Figure 3). Most particles were entirely sputtered away during the long measurement, so we identified the frames and pixels in each frame where each particle was present.

We summed the counts of ^{16}O, ^{17}O, ^{18}O for each particle as well as the aerogel (pixels in the map that lack AlO, MgO, and FeO). We used the aerogel as our O isotope standard ($\delta^{18}O \approx -1.1‰$ and $\delta^{17}O \approx -0.5‰$ [5]), which was measured in the same frame and at approx-

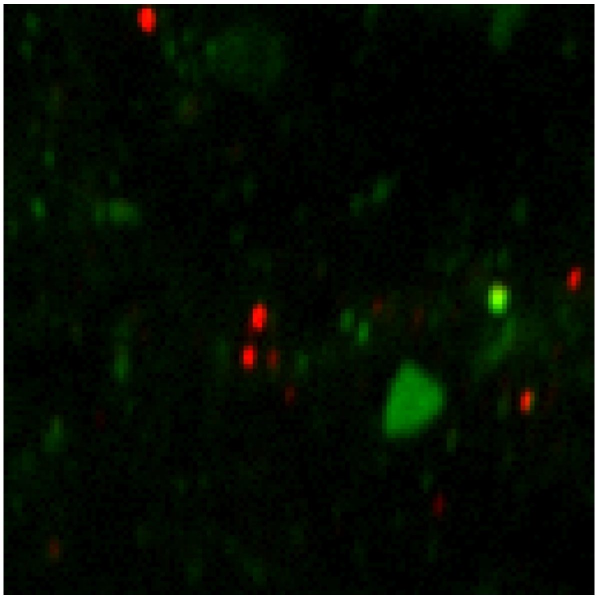

Figure 3: Scanning ion iron-magnesium map (Red=FeO, Green=MgO) summed over the entire 88-hour measurement of the bulb of Track 184. The map is 35×35 μm.

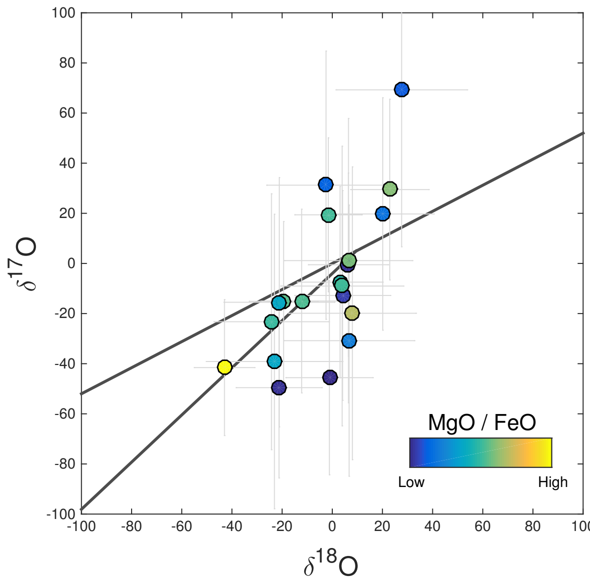

Figure 4: Oxygen 3-isotope plot of the 20 largest particles measured in the bulb of Track 184. The qualitative MgO/FeO ratio is shown by the colored markers. Error bars are 2σ.

imately the same ^{16}O count rate as the cometary particles. We used a Monte Carlo method to calculate the uncertainties for O isotope ratios of the cometary particles (described in detail in [2]). This method accounts for the variation in measured isotope ratios of the aerogel, which may arise from topography created in the sample by sputtering. Uncertainties calculated by this method were about 1.4× larger than statistical uncertainties for both δ^{18}O and δ^{17}O . Additionally, the MgO/FeO ratio were calculated for each particle. This ratio is qualitative because of unknown sensitivity factors for these species in the measured phases.

Results: We measured the O isotope ratios for 47 particles, 1–4 μm in size, in the bulb region of Track 184 (Figure 4).

Discussion: The range of δ^{18}O values in the Track 184 bulb material is smaller than that in the Track 74 bulb material. Track 184 lacks the ^{16}O-poor, Fe-rich material found in Track 74 [2]. Track 184 contains a 3–4 μm, high-Mg, ^{16}O-rich grain that may be similar to Mn-rich forsterite grains found in the comet Wild 2 samples [6]. This grain has not been sputtered entirely away and can be extracted by FIB for TEM analysis.

None of the 47 particles we measured in the Track 184 bulb had a significant O isotope anomaly. Combining this with the zero presolar grain detections in the Track 74 bulb material (63 particles), we calculate a 95%-confidence, single-sided upper bound of 2.7% for the abundance of oxygen-anomalous presolar grains in Wild 2 fines.

Conclusions: The described method of measuring O isotopes in the bulb of Stardust tracks is complementary to measurements of grains individually mounted in potted butts [e.g. 6, 7]. With this method we are able to measure a large number of grains at once, but compromise with larger uncertainties (20–40‰ vs. ∼2‰, 2σ) and less is known of each particle's mineralogy. With this lower precision data, we are able to estimate the spread of O isotopes in Stardust cometary fines, as well as identify interesting particles (^{16}O-poor, ^{16}O-rich, presolar grains) for further analysis.

References: [1] M. Burchell, et al. (2008) *Meteoritics & Planetary Science* 43(1-2):23. [2] R. C. Ogliore, et al. (2015) *Geochimica et Cosmochimica Acta* 166:74. [3] A. J. Westphal, et al. (2009) *The Astrophysical Journal* 694(1):18. [4] A. J. Westphal, et al. (2011) *74th Annual Meeting of the Meteoritical Society* 74:5274. [5] K. McKeegan, et al. (2006) *Science* 314(5806):1724. [6] D. Nakashima, et al. (2012) *Earth and Planetary Science Letters* 357:355. [7] R. C. Ogliore, et al. (2012) *The Astrophysical Journal Letters* 745(2):L19.