DISCOVERY OF PRESOLAR SIC FROM COMET WILD-2. S. Messenger[1], D. Joswiak[2], M. Ito[1], G. Matrajt[2], and D. E. Brownlee[2], [1]Robert M. Walker Laboratory for Space Science, ARES, NASA JSC, 2101 NASA parkway, Houston TX 77573; scott.r.messenger@NASA.gov, [2]University of Washington, Department of Astronomy, Seattle, WA.

Introduction The preliminary examination of Stardust samples has yielded a number of surprising findings, such as the presence of large refractory mineral grains, including materials resembling CAIs, chondrules, and AOA fragments [1-3]. Furthermore, intact organics and fine grained materials are unexpectedly rare in Stardust tracks [4,5]. The fact that intact fine grained materials are uncommon may be related to the apparent rarity of presolar grains in Stardust samples [1,6].

So far, 3 presolar grains have been found in Stardust samples – all identified by O isotopic imaging of crater residues [6]. Although the mineralogical identity of these presolar grains is uncertain, their estimated abundance (11 ppm) is strikingly lower than silicate stardust grains in primitive meteorites (100 – 300 ppm; 7,8) or interplanetary dust particles (300 – 10,000 ppm; 9-11). Furthermore, O isotopic measurements of all silicate minerals extracted from tracks have fallen within the range of meteoritic materials [1-3]. These observations suggest that either [1] comet Wild-2 materials are less pristine than meteorites and IDPs, [2] fine grained materials and presolar grains were preferentially destroyed during capture, or [3] have been segregated from the typically studied 'terminal particles' e.g. in bulbous track walls.

Searches for presolar grains have focused on silicate stardust because this is the most abundant presolar grain phase in meteorites and IDPs. Here we report C, N, and Si isotopic measurements of a SiC grain identified within a melt-dominated particle from the wall of track #141 (hereafter *Coki*).

Experimental: Coki is a 2 mm type B track [12] having a very large, bulbous cavity. The track was prepared by flattening a keystone extracted from aerogel block C2061, and embedding the entire flattened track in acrylic resin. Orthogonal strips were then cut from the track and microtomed into < 100 nm thick slices and placed onto Cu TEM grids with 10 nm thick carbon thin-films. The microtomed slices were examined with a 200 kV Tecnai F20 FEG TEM/STEM using standard techniques including bright- and dark- field imaging, electron diffraction, high resolution imaging and EDX compositional analysis.

Isotopic measurements were performed with the JSC NanoSIMS 50L ion microprobe in two separate sessions. In the first analysis, C and Si isotopic images were taken simultaneously, acquiring images of $^{12}C^-$, $^{13}C^-$, $^{28}Si^-$, $^{29}Si^-$, $^{30}Si^-$, and $^{12}C^{28}Si^-$ in multidetection with electron multipliers. The sample was subsequently analyzed for C and N isotopes by measuring $^{12}C^-$, $^{13}C^-$, $^{12}C^{14}N^-$, $^{12}C^{15}N^-$, $^{28}Si^-$, and $^{12}C^{28}Si^-$ The images were obtained by rastering a <1 pA, <100 nm Cs^+ beam over a 10 μm fields of view which covered the target SiC grain and surrounding melt grain. These images were repeatedly acquired for a total of 20 image layers in each analysis. Sample charging was minimized with the use of an electron flood gun. Carbon, nitrogen, and silicon isotopic images were acquired from 10 μm grains of USGS 24 graphite, 1-hydroxybenzotriazole hydrate, and a Si wafer (respectively) as external isotopic standards.

The isotopic compositions of the SiC grain, melt, acrylic embedding medium, and standard minerals were determined with custom written image processing software, in which corrections are made for electron multiplier deadtime, QSA, and instrumental mass fractionation. The outlines of the SiC grain were determined in each image layer to minimize isotopic dilution effects from adjacent material.

Results: The 300 nm SiC grain was identified within a ~10 μm vesicular region of aerogel/projectile melt [Fig. 1]. The grain was readily revealed by darkfield imaging as the only crystalline material in the sample other than small metal and sulfide beads.

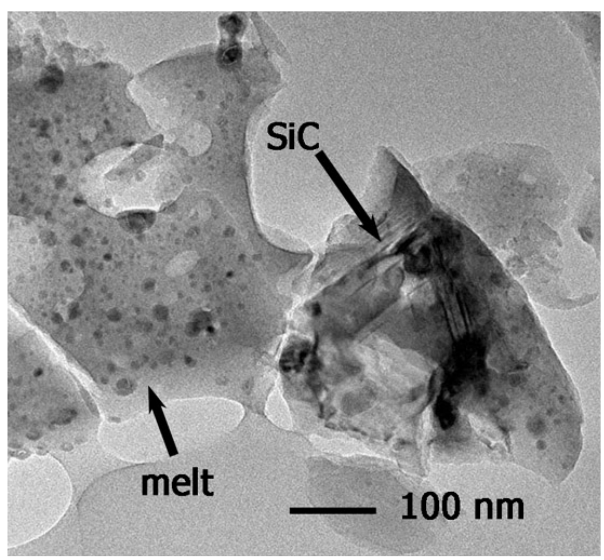

Figure 1: Brightfield TEM image of SiC grain adjacent to and partially coated with silicate melt.

The identification of the mineral as SiC was determined by electron diffraction and EDX measurements. The SiC diffraction pattern was indexed to cubic 3C, β−SiC.

The SiC grain in Coki is shown to be ^{13}C-rich in C isotopic images [Fig. 2], having $\delta^{13}C = +147 \pm 22‰$ (1σ). The location of the isotopically anomalous C is clearly associated with the SiC grain from the $^{28}Si^{12}C$ image. In the second analysis, the SiC was also anomalous ($\delta^{13}C = +227 \pm 90‰$), although the data are less precise as the grain was partially consumed in the previous measurement. However, both the Si and N isotopic data are inconclusive, overlapping with both terrestrial values and in the range of presolar SiC grains [13] within error: $\delta^{29}Si = 4 \pm 25‰$, $\delta^{30}Si = -40 \pm 29‰$, $\delta^{15}N = -290 \pm 90‰$ (1σ). The N data are further complicated by significant contributing signal from adjacent material.

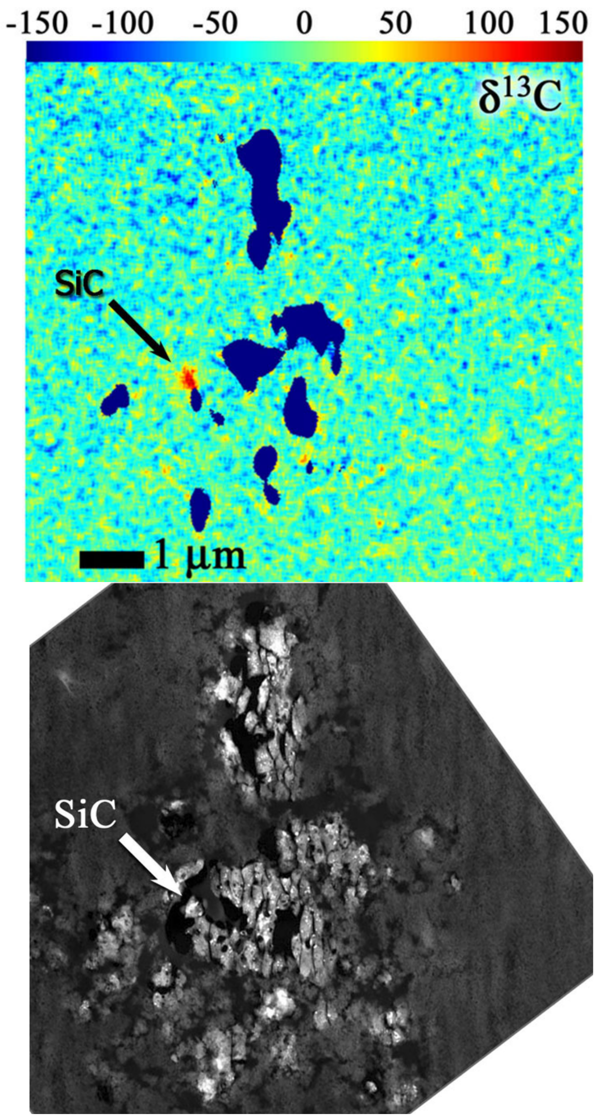

Figure 2: (top) δ^{13}C image of Coki-2-B, an acrylic-embedded melt particle containing an SiC grain. The SiC grain is associated with the ^{13}C-rich spot in the image. Areas with very low C-contents (silica/melt) are masked dark blue regions. (bottom) HAADF TEM image of Coki-2-b, a melt-dominated particle containing a 300 nm SiC grain.

Discussion: The C isotopic composition of the SiC falls near the most common value of mainstream SiC grains, which originated from red giant and asymptotic giant branch stars. The Si isotopic composition, although indistinguishable from terrestrial, also falls within the range of mainstream SiC grains. The SiC grain polytype (cubic 3C) is also consistent with the most common of the two polytypes observed in presolar SiC grains [14].

Presolar SiC has been extensively studied, and occurs in a range of primitive meteorites, interplanetary dust particles, and Antarctic micrometeorites [15,16]. However in those materials, presolar SiC abundances [~10 ppm; 17] are typically far lower than silicate stardust grains [~100 – 10,000 ppm; 7-11]. It is therefore surprising that this SiC grain is the first presolar grain identified in a Stardust aerogel track, and the first presolar grain to be identified mineralogically by TEM. However, the fact that the SiC was located within a silicate-melt particle underscores the differing survivability of silicate minerals and SiC during the capture process.

References:

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