MICROSTRUCTURAL STUDY OF AN ^{18}O-POOR PRESOLAR SILICATE GRAIN FROM THE METEORITE HILLS 00426 CR2 CHONDRITE.

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Introduction: The majority of presolar silicate and oxide grains derive from low-mass red giant and asymptotic giant branch (AGB) stars of ~solar metallicity (Z). A small subclass of presolar O-rich grains (<7%) is thought to originate from stars having lower-than-solar Z. These "Group 3" [1] grains have depletions in ^{18}O and ^{17}O that typically fall along or above the Galactic chemical evolution (GCE) line. Other Group 3 grains show greater ^{17}O than ^{18}O depletions and most likely have supernova (SN) origins. Owing to their rarity, only two Group 3 silicates have been mineralogically examined in detail [2, 3]. Here we present a mineralogical study of a Group 3 presolar silicate to explore its formation conditions and interstellar history.

Experimental: Silicate matrix grains ~0.1 – 1.5 μm in diameter from the MET 00426 CR2 meteorite were separated by repeated freeze-thaw, ultrasonication and centrifugation. The grains were deposited from an isopropanol and water solution onto cleaned Au foil. O and Si isotopic analyses were performed over 20 μm fields of view by NanoSIMS 50L raster ion imaging with a ~1.4 pA Cs+ primary ion beam. Negative secondary ions of ^{16}O, ^{17}O, ^{18}O, ^{28}Si, ^{29}Si, ^{30}Si, and ^{24}Mg^{16}O were collected simultaneously and an electron flood gun was used for charge mitigation. From the isotopically anomalous grain identified, we selected a relatively large, isotopically rare ^{18}O-poor grain (1_2_2b) for further study. An electron transparent cross-section of this grain was produced by focused ion beam (FIB) milling and the microstructure and chemical composition were determined by transmission electron microscopy (TEM).

Results and Discussion: Grain 1_2_2b (Fig. 1) is ~1×2 μm in size and is depleted in ^{18}O (δ^{18}O = -99 ± 15‰; δ^{17}O = -29 ± 35‰) with ~solar Si isotope composition (δ^{29}Si = 39 ± 28‰ δ^{30}Si = -22 ± 34‰). The grain showed much greater Si^- and MgO^- ion yields relative to surrounding grains. The O isotopic ratio of this grain lies above the GCE line and suggests a low-Z star origin. The Si isotopic ratio also supports a low-Z source, as most AGB silicate and SiC grains are comparatively more ^{28}Si-poor [4]. However, some Group 3 and Group 4 SN silicate grains also have similar Si isotopic compositions [e.g., 5, 6, 7]. Only one Group 3 silicate has been analyzed for isotopic ratios beyond O and Si [7]. These measurements can constrain the stellar source and Mg isotope analysis of grain 1_2_2b is planned.

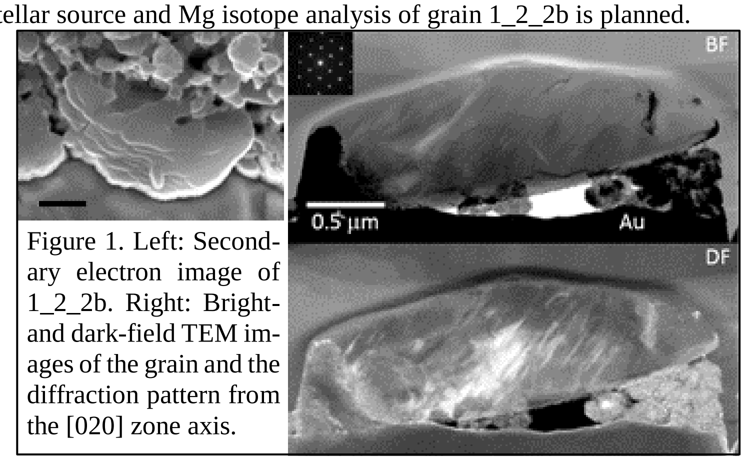

Figure 1. Left: Secondary electron image of 1_2_2b. Right: Bright- and dark-field TEM images of the grain and the diffraction pattern from the [020] zone axis.

TEM analysis of 1_2_2b showed it is a single forsterite crystal (Fig. 1) having trace Mn, Cr, and Fe. This chemical composition is similar to LIME (low-Fe, Mn-enriched) olivine that likely formed by condensation [8]. The grain shows strain contrast and dislocations that are likely related to parent body compaction and lithification, but it does not exhibit evidence of radiation damage attributable to interstellar medium (ISM) processes (e.g. particle tracks or damaged rim). In fact, few crystalline presolar silicates display evidence for radiation damage [2, 9], suggestive of short ISM residence times. Interstellar residence times as short as 3 Ma were estimated for large presolar SiC grains [10]. These grains were proposed to originate from >2 M$_\odot$ stars that formed during a starburst event 1-2 Ga before Solar System formation [10]. However, this scenario is not viable for grain 1_2_2b, whose O isotopic composition indicates formation from a ~1 M$_\odot$ star with expected lifetime of ~10 Gyr. Alternative origins include a fortuitous encounter of the evolved star with the Sun's parent molecular cloud or annealing of the grain prior to its incorporation into the asteroid parent body.

TEM analyses of Group 3 silicates include an amorphous grain similar to high-Ca pyroxene [2] and an amorphous GEMS grain [3]. Unlike 1_2_2b, these grains are likely SN grains with large depletions in ^{17}O. Presolar crystalline Fe-bearing olivine and Mg-rich pyroxene grains have previously been identified (see [2] and references therein). These olivine grains could have formed under oxidizing conditions where FeO was incorporated into the crystal lattice. Grain 1_2_2b has a very low Fe content and thus formed under comparatively reduced conditions or at high temperatures.

References: [1] Nittler L. R. et al. (2008) *Astrophys. J.* 682:1450-1478. [2] Nguyen A. N. et al. (2016) *Astrophys. J.* 818(1):51-67. [3] Keller L. P. and Messenger S. (2011) *GCA* 75:5336-5365. [4] Zinner E. (2014) In *Treatise on Geochemistry (2nd Ed.)*, pp. 181-213. [5] Nguyen A. N. et al. (2010) *Astrophys. J.* 719:166-189. [6] Vollmer C. et al. (2008) *Astrophys. J.* 684:611-617. [7] Nguyen A. N. and Messenger S. (2014) *Astrophys. J.* 784:149. [8] Klöck W. et al. (1989) *Nature* 339(6220):126-128. [9] Vollmer C. et al. (2009) *Astrophys. J.* 700:774-782. [10] Heck P. R. et al. (2009) *Astrophys. J.* 698(2):1155-1164.