CONTINUED CHARACTERIZATION OF PRESOLAR SILICATE GRAINS FROM THE ACFER 094 CARBONACEOUS CHONDRITE.
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Introduction: Among circumstellar grains produced around O-rich evolved stars, silicate grains are the most abundant [1]. Until recently, the identification of presolar silicate grains in extraterrestrial materials proved difficult due in part to their destruction by parent body processes, requiring analysis of very primitive samples, and to the experimental challenge presented by their submicron diameters and the predominance of grains of solar-system origin. Presolar silicate grains were first identified in anhydrous interplanetary dust particles (IDPs) [2, 3], and subsequently in meteorites. By far the largest number of presolar silicates in meteorites has been found in the very primitive carbonaceous chondrite Acfer 094 [4-7]. Six additional grains have been found in Semarkona and Bishunpur [8, 9], and NWA 530 [5].

We previously reported the discovery of 9 presolar silicate grains among Acfer 094 matrix grains 0.1-0.5 µm in diameter [4]. This was achieved by isotopic raster ion imaging of dense grain areas in the NanoSIMS ion microprobe. The chemical composition of six grains was determined by X-ray analysis. In addition, the Mg isotopic composition of one grain revealed a high $(^{26}Al/^{27}Al)_o$ ratio of 0.12, explained by cool bottom processing (CBP) in a low-mass thermally pulsing asymptotic giant branch (AGB) star. Here we report additional analyses made on a coarser grain size separate and on a thin section of Acfer 094.

Experimental: A grain size separate of Acfer 094 containing matrix grains 0.5-1 µm in diameter was produced in the same manner described previously [4]. Dense grain areas on a gold substrate were chosen for isotopic analysis in the NanoSIMS. While grain size separates allow us to focus on silicate grains of a specific size range, *in situ* measurements on a polished thin section afford analysis of all matrix grains. For both samples, a ~100 nm Cs^+ primary ion beam was rastered over 30x30 µm^2 (grain separate) or 20x20 µm^2 (thin section) areas. In addition to the three O isotopes, $^{24}Mg^{16}O$ and ^{28}Si were measured simultaneously as negative secondary ions to produce integrated 256x256 pixel ion images. Oxygen isotopic ratio images were calculated and used to identify anomalous grains. A grain had to have an O isotopic composition distinct from that of the surrounding matrix material, most of which is isotopically normal, to be considered presolar. The $^{24}Mg^{16}O$ and ^{28}Si signals could then be correlated with a grain of interest to deduce its silicate nature.

We also measured the three Si isotopes as negative secondary ions for 10 anomalous silicate grains. For these measurements, a Cs^+ primary beam was rastered over 10x10 µm^2 areas around an anomalous grain and 128x128 pixel images were acquired. In addition, we succeeded in producing a focused ion beam (FIB) lift-out section of one presolar silicate identified from a grain dispersion mount. This resulted in the first transmission electron microscopy (TEM) study of a presolar silicate grain from a meteorite. Details of this technique are given in [10].

Results and Discussion: We have identified 11 new presolar silicate grains and 8 presolar oxide grains with diameters between 100 and 600 nm. According to the $^{24}Mg^{16}O^-/^{16}O^-$ ratio of the presolar oxides, 3 appear to be spinel and 5 appear to be corundum. The O isotopic ratios of these grains along with our previously discovered grains from Acfer 094, and those from [6] are shown in Fig. 1. All four of the previously defined presolar oxide groups [11] are represented among these grains. Most are group 1 grains, believed to have formed in the atmospheres of low-mass red giant branch (RGB) and AGB stars.

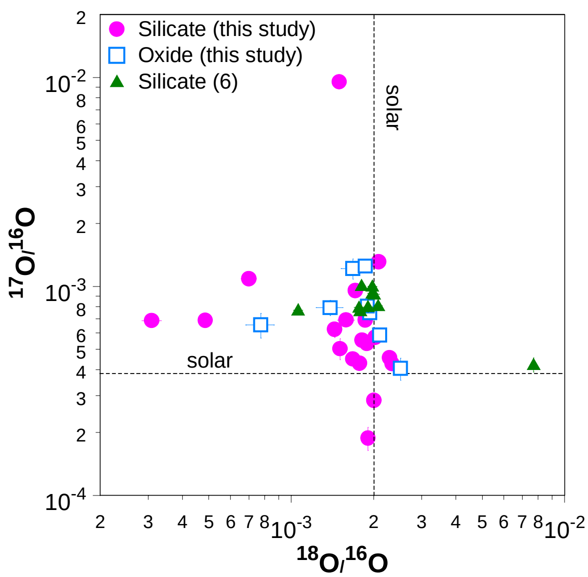

Figure 1. Oxygen isotopic ratios of anomalous silicate and oxide grains from Acfer 094 identified in this study and by [6]. Error bars are 1σ.

The calculated presolar silicate abundance in Acfer 094 of 176 ppm is much higher than that of other presolar phases found in meteorites, with the possible exception of nanodiamonds. This abundance is also higher than those in meteorites that have experienced more parent body processing [5, 8, 9]. However, it is much lower than that of presolar silicates in IDPs (~890 ppm) [2, 3]. We calculate a presolar oxide abundance in Acfer 094 of 108 ppm. This is starkly greater than the presolar oxide abundance in any other meteorite studied to date [11-13]. While silicate grains are subject to destruction by physical processing, oxide grains are expected to be more resilient and thus to survive also in more processed meteorites. This difference in presolar oxide abundance could indicate inhomogeneous distribution of presolar grains in the solar nebula.

The Si isotopic ratios for presolar silicate grains are plotted in Fig. 2 along with the SiC mainstream correlation line. This correlation is believed to result from the initial composition of the parent stars and neutron capture reactions in the He-shell followed by 3rd dredge-up. The latter effect produces small Si isotopic shifts along a slope ~0.1-0.5 line [14, 15]. The silicate data points primarily fall on the mainstream line, though many are shifted slightly to the left. We would not expect to see isotopic shifts due to n-capture nucleosynthesis because the 3rd dredge-up, which brings the products of these reactions to the stellar surface, occurs mainly after the star has become C-rich and O-rich grains no longer condense. Thus, the main factor influencing the Si isotopic ratios of a given silicate grain is the initial composition of the parent star. We might therefore expect a positive correlation between the metallicity (Z) of the parent stars, inferred from the O isotopic ratios, and δ^{29}Si. Although the data by [6] seem to indicate such a correlation, our data do not show a similar trend (Fig. 3). Because of the small size of our grains, however, the Si isotopic ratios may have been diluted by signal from the surrounding normal grains.

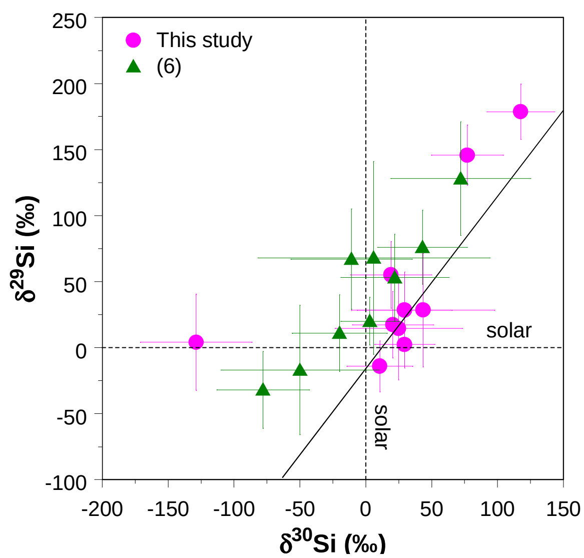

Figure 2. Silicon isotopic ratios given as δ-values for presolar silicate grains from Acfer 094. Also shown is the SiC mainstream correlation line.

The TEM study of a presolar silicate (Fig. 4), whose Mg-isotopic composition indicates that its parent star underwent extensive CBP, revealed an amorphous structure with no rims or sub-grains. The X-ray analysis indicates a nonstoichiometric composition containing Si, Mg, Fe, Al, and Ca. Although astronomical observations predict that circumstellar silicates are Mg-rich [1], we find that many of the presolar silicate grains contain substantial amounts of Fe.

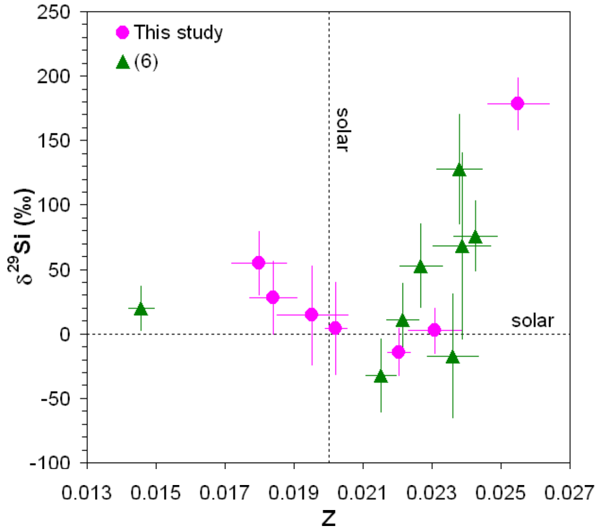

Figure 3. δ^{29}Si vs. Z for presolar silicate grains belonging to group 1.

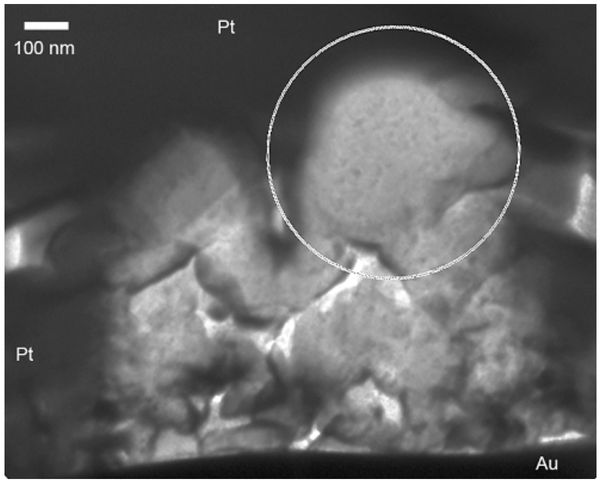

Figure 4. Bright-field TEM image of FIB lift-out section. The 500 nm presolar silicate grain is circled. The Pt is from the production of the section, and the Au is the gold foil substrate.

References: [1] Waters, L. B. F. M. *et al.* (1996) *A&A 315*, L361-L364. [2] Messenger, S. *et al.* (2003) *Science 300*, 105-108. [3] Floss, C. and Stadermann, F. J. (2004) *LPS XXXV*, Abstract #1281. [4] Nguyen, A. N. and Zinner, E. (2004) *Science 303*, 1496-1499. [5] Nagashima, K. *et al.* (2004) *Nature 428*, 921-924. [6] Mostefaoui, S. and Hoppe, P. (2004) *ApJ 613*, L149-L152. [7] Stadermann, F. J. *et al.* (2005) this conference. [8] Mostefaoui, S. *et al.* (2003) *M&PS 38*, A99. [9] Mostefaoui, S. *et al.* (2004) *LPS XXXV*, Abstract #1593. [10] Stroud, R. M. *et al.* (2002) *M&PS 37*, A137. [11] Nittler, L. R. *et al.* (1997) *ApJ 483*, 4715-495. [12] Choi, B.-G. *et al.* (1998) *Science 282*, 1284-1289. [13] Zinner, E. *et al.* (2003) *GCA 67*, 5083-5095. [14] Lugaro, M. *et al.* (1999) *ApJ 527*, 369-394. [15] Guber, K. H. *et al.* (2003) *Phys. Rev. C 67*, 062802-1 – 062802-4.