NANOSIMS STUDIES OF SMALL PRESOLAR SiC GRAINS: C- AND Si-ISOTOPIC COMPOSITIONS AND TRACE ELEMENT ABUNDANCES.

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Introduction: Silicon carbide is the best studied presolar mineral phase in meteorites. A wealth of information exists on the isotopic compositions of many elements and on trace element abundances [1]. Most data, however, are for micrometer-sized grains. Since previous studies had indicated grain-size dependencies of isotopic compositions and trace element concentrations, a comprehensive characterization of submicrometer-sized SiC grains is important to get a complete picture of presolar SiC formation. To date, isotope data for individual, submicrometer-sized grains exist for C, N, and Mg-Al in SiC from Murchison [2, 3], and for C, N, Si, Mg-Al, and Ti in SiC from Indarch [2]. Trace element abundances of submicrometer-sized grains have been measured in SiC bulk samples [4]. Regardless of size, trace element data on individual Y and Z grains are rare because these grains are found mostly among the smaller grains.

Here, we report on extended isotope and trace element studies on individual SiC grains from Murchison separate KJB (typical size 0.25-0.45 μm) [5]. Important questions are: (i) How do C- and Si-isotopic ratios compare with those of the larger Murchison SiC grains? (ii) What are the abundances of the different SiC populations? (iii) What are trace element (Zr, Mo, Ba, Nd) abundances in the rare Y and Z grains?

Experimental: Thousands of KJB grains were dispersed on an ultra-clean Au foil. The C- and Si-isotopic measurements were done by automated ion imaging with the NanoSIMS at MPI for Chemistry [6]. The ion imaging consists of three steps: (i) Acquisition of simultaneous ion images of $^{12}C^-$, $^{13}C^-$, $^{28}Si^-$, $^{29}Si^-$, and $^{30}Si^-$ by rastering a focused Cs^+ ion beam (~1 pA, 100 nm) over areas 30 x 30 μm^2 in size (integration time of ~15 min). (ii) Automated particle recognition and isotope measurements in square areas with a lateral length of 2x the grain diameter (defined at 10% of the maximum ^{28}Si intensity) around each grain, with integration times of 60 s. (iii) Moving the sample stage to the adjacent analysis area and continuation with step (i). Application to 1 μm-sized synthetic SiC grains gave grain-to-grain repoducibilities (1σ) of 6 ‰ for $^{13}C/^{12}C$ and of 7 ‰ for $^{29}Si/^{28}Si$ and $^{30}Si/^{28}Si$.

Selected grains were subsequently measured for Zr, Mo, Ba, and Nd concentrations. For this purpose a focussed O^- ion beam (~10-15 pA, 300 nm) was rastered over the grains (2 x 2 μm^2) and positive secondary ions of ^{28}Si, ^{90}Zr, ^{98}Mo, ^{138}Ba, and ^{144}Nd were measured in multi-collection. Relative sensitivity factors were measured on fine-grained NBS611 glass fragments dispersed on Au foil. Grain-to-grain reproducibility was 5 % for $^{90}Zr/^{28}Si$, 15 % for $^{98}Mo/^{28}Si$, 40 % for $^{138}Ba/^{28}Si$, and 31 % for $^{144}Nd/^{28}Si$.

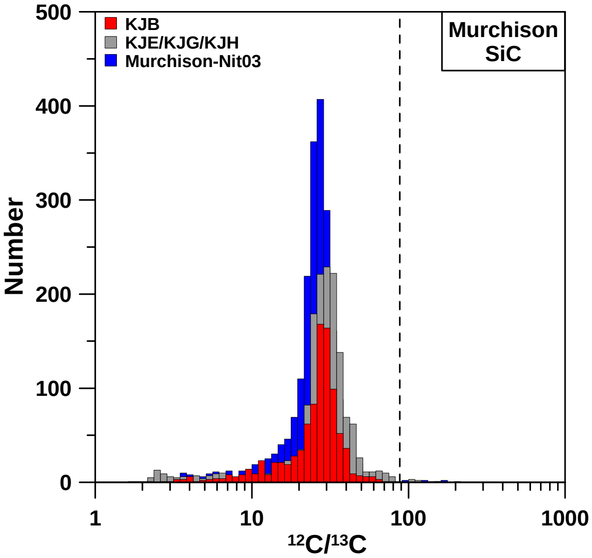

Figure 1. Histograms of $^{12}C/^{13}C$ ratios in presolar SiC from Murchison. Data sources: [8, 9] (KJE/KJG/KJH), [10] (Murchison-Nit03), and this work (KJB).

Results and Discussion: The automated particle recognition identified some 925 presolar SiC grains on the KJB mount. Among these grains are 88 % mainstream grains, 3.1 % A&B grains, 0.9 % X grains, 2.4 % Y grains, and 5.5 % Z grains. This is compatible with what is observed for larger Murchison grains, except that the Z grain abundance is much higher among the KJB grains; a similarly high Z grain abundance was inferred for submicrometer-sized grains from Indarch [2]. Mass-weighted averages of C- and Si-isotopic compositions are 37.8±1.2 ($^{12}C/^{13}C$), 25.9±1.5 ‰ (δ^{29}Si), and 36.9±2.4 ‰ (δ^{30}Si), in agreement with data for KJB bulk samples [7]. The distributions of $^{12}C/^{13}C$ (Fig. 1) and Si-isotopic ratios (Fig. 2) are compatible with what is observed for the larger Murchison SiC grains. An exception is grain 11-17-1 which has an unusual Si-isotopic composition, possibly the signature of a supernova source. Back-projection of Si-isotopic ratios on the MS line along an

AGB evolution line with slope 0.2 results in a negative correlation between Δ^{30}Si and δ^{29}Si$_{ini}$ (for a definition see [11]), which includes not only the Y and Z grains but also the majority of the A&B and mainstream grains. The correlation between Δ^{30}Si and δ^{29}Si$_{ini}$ has been observed before, specifically for Z grains [10, 11]. It has been suggested that the lack of low Δ^{30}Si for low δ^{29}Si$_{ini}$ (metallicity) may be the result of extensive cool bottom processing which prevents SiC formation during early thermal pulses on the AGB [10].

Trace element concentrations were measured in 7 Y, 25 Z and 23 mainstream grains. Typical Zr concentrations are higher (factor 1.8) in Y and Z grains than in mainstream grains. This does not hold for Mo and Nd. Ba concentrations are higher (factor 2) in Z grains than in mainstream and Y grains. There are weak positive correlations between Mo, Zr, and Nd abundances (all grain types). More important, there is a good correlation between Ba concentrations and Δ^{30}Si in Y and Z grains (Fig. 4). Trace element concentrations depend not only on abundances in the atmosphere of the parent star but also on how they get incorporated into the SiC grains. The observed correlation between Ba concentrations and Δ^{30}Si in Y and Z grains is compatible with model predictions for 1.5-3 $M_{\odot}$ AGB stars of sub-solar metallicities. This confirms low-metallicity stars as most likely stellar sources for Y and Z grains and suggests unfractionated condensation/implantation of Ba in SiC from low-metallicity parent stars.

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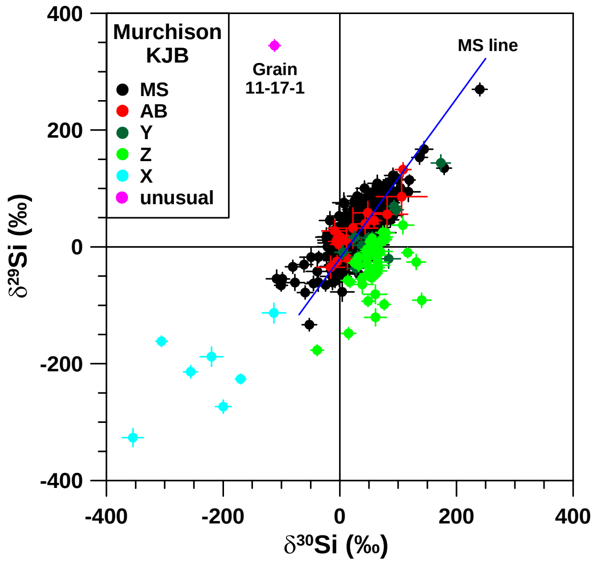

Figure 2. Si-isotopic compositions of presolar SiC grains from the Murchison separate KJB. Mainstream (MS) line: $\delta^{29}\mathrm{Si} = 1.37 \times \delta^{30}\mathrm{Si} - 20$ [2].

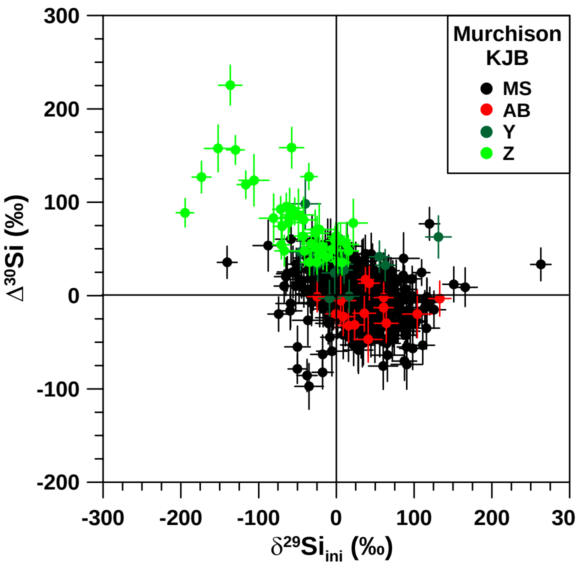

Figure 3. Distance Δ^{30}Si from the MS line as function of the initial δ^{29}Si for Murchison KJB grains. See text for details.

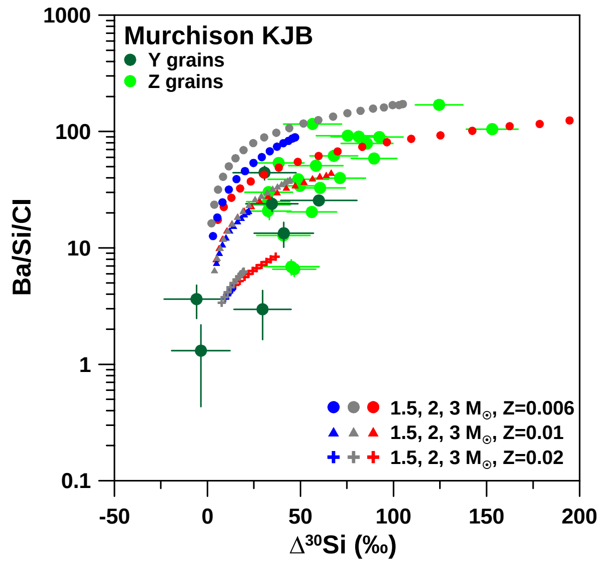

Figure 4. Ba/Si ratios normalized to CI as a function of the distance Δ^{30}Si from the MS line in Y and Z grains and predictions for AGB stars with standard ^{13}C pockets and C/O>1.

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