Indarch SiC by TIMS, RIMS, and NanoSIMS. C. L. Jennings1, M. R. Savina2, S. Messenger3, S. Amari3, R. H. Nichols, Jr.1, M. J. Pellin2, and F. A. Podosek1, 1Department of Earth and Planetary Sciences, Washington University, St. Louis, MO, 63130, 2Materials Science Division, Argonne National Laboratory, Argonne, IL 60439, 3McDonnell Center for Space Sciences, Washington University, St. Louis, MO, 63130.

Introduction: Silicon carbide is among the most abundant types of presolar grains in meteorites, reaching, for example, 5.8 ppm in Indarch (EH4) [1]. Isotopic studies have shown that these grains are from a variety of stellar sources. Mainstream grains (~95% of presolar SiC) exhibit enhancements in s-process isotopes and there is abundant evidence that they formed around low mass AGB stars [2]. The less well known A and B type grains (~3-4%) are defined as having $^{12}$C/$^{13}$C < 10, with B grains in particular having $^{12}$C/$^{13}$C > 3.5 [3]. Here we report isotopic measurements of SiC grains from Indarch by mass spectrometry: thermal ionization (TIMS), resonant ionization (RIMS), and secondary ion (SIMS) mass spectrometry.

Experimental: The samples were prepared following the method used to produce the KJ series from Murchison [4], with the exceptions that CS$_2$ was used instead of NaOH to dissolve sulfur, and sulfuric acid was not used to dissolve spinel because of its low abundance. The residue was separated by centrifugation into five grain-size fractions. The largest grain-size fraction was examined by SEM and found to be about half SiC and half Si$_3$N$_4$ by grain counting. Si$_3$N$_4$ is much more abundant in these Indarch separates than in the Murchison KJ series because Indarch is rich in Si$_3$N$_4$ of solar system origin. However, a small fraction of Indarch Si$_3$N$_4$ grains have been shown to be presolar [5].

For TIMS measurements, aliquots of each grain-size fraction were direct-loaded with 1/2 $\mu$L boric acid on V-shaped Re filaments. No corrections were made for instrumental discrimination, since this requires a known ratio and all of the measured values were highly anomalous. Uncertainties due to lack of discrimination correction are much lower than the anomalies seen in the grain aggregates.

Eighteen single ~1-5 $\mu$m grains were handpicked from the largest grain-size fraction and pressed into a gold substrate for RIMS and SIMS analyses. The Ba isotopic compositions were determined by RIMS on the CHARISMA instrument, which is described in detail elsewhere [6]. The C and N isotopic compositions of eight grains that remained after RIMS analysis were subsequently measured on the new Washington University NanoSIMS in multicollection mode using procedures similar to those previously described [7].

Results and discussion: The results are comparable to the previous measurements of SiC aggregates [2,8,9]. The Ba isotopic composition of the Indarch grain-size fractions were consistent with s-process nucleosynthesis. The isotopes made only by p-process, $^{130}$Ba and $^{132}$Ba, were depleted relative to normal composition while the others were enhanced to varying degrees. This is to be expected for SiC separates dominated by mainstream SiC grains, which are believed to originate in AGB stars [2,10].

The s-process composition was calculated by the same method as in [9]. In brief, a three-isotope plot of $^{132}$Ba/$^{136}$Ba vs. $^{138}$Ba/$^{136}$Ba ratios was used to find the composition of $^{135}$Ba/$^{136}$Ba when $^{132}$Ba/$^{136}$Ba is forced to zero. This yields the composition of $^{138}$Ba/$^{136}$Ba ratio when the p-only isotope $^{136}$Ba is removed from the mixture. This composition was used to calculate all the other s-process compositions by the same method. The results (Table 1) are in agreement with the previous work, especially for the most fine-grained sample, which is expected to be the most pure separate of Indarch SiC, and also the most enhanced in s-process isotopes [3,9].

![Fig. 1. Ba isotopic compositions (in permil deviations from normal) in presolar SiC from Indarch: single grains and bulk grain-size fractions.](image-url)
represents an individual star, the range of isotope distributions obtainable by s-process nucleosynthesis in AGB stars is much larger than that indicated by aggregate measurements. Measurements of Ba isotopes in individual SiC grains from the Murchison meteorite are indistinguishable from individual SiC grains from Indarch [11]. It was not possible to extrapolate to a pure s-process component for single grains because the only purely non-s-process isotopes, $^{130}$Ba and $^{132}$Ba, were too scarce to measure in individual grains.

Of the eight individual grains measured by both RIMS and NanoSIMS, seven were mainstream grains and one (grain #6) was a B grain. The Ba isotope distribution for grain #6 was indistinguishable from solar, and one (grain #6) was a B grain. The Ba isotope distribution of the grains studied to date. Additional single-grain analyses are thus required to determine the stellar sources of B-grains.

**References:**

### Table 1. Ba isotopic compositions of Indarch grain-size fractions measured by TIMS and calculated s-process compositions

<table>
<thead>
<tr>
<th>Sample</th>
<th>$^{130}$Ba/$^{136}$Ba dev</th>
<th>$^{132}$Ba/$^{136}$Ba</th>
<th>$^{134}$Ba/$^{136}$Ba dev</th>
<th>$^{135}$Ba/$^{136}$Ba dev</th>
<th>$^{137}$Ba/$^{136}$Ba dev</th>
<th>$^{138}$Ba/$^{136}$Ba dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0.01346</td>
<td>0.01290</td>
<td>-0.15-0.20</td>
<td>-0.15-0.20</td>
<td>-0.15-0.20</td>
<td>-0.15-0.20</td>
</tr>
<tr>
<td>KJ (bulk)</td>
<td>0.02000</td>
<td>0.01900</td>
<td>0.01800</td>
<td>0.01700</td>
<td>0.01600</td>
<td>0.01500</td>
</tr>
<tr>
<td>0.10-0.15 µm</td>
<td>-0.00002</td>
<td>0.037</td>
<td>0.039</td>
<td>0.041</td>
<td>0.042</td>
<td>0.043</td>
</tr>
<tr>
<td>0.15-0.20 µm</td>
<td>0.00202</td>
<td>0.034</td>
<td>0.036</td>
<td>0.038</td>
<td>0.040</td>
<td>0.042</td>
</tr>
<tr>
<td>0.20-0.25 µm</td>
<td>0.00010</td>
<td>0.034</td>
<td>0.036</td>
<td>0.038</td>
<td>0.040</td>
<td>0.042</td>
</tr>
<tr>
<td>0.25-0.30 µm</td>
<td>-0.00229</td>
<td>0.035</td>
<td>0.037</td>
<td>0.039</td>
<td>0.041</td>
<td>0.043</td>
</tr>
<tr>
<td>&gt; 0.3 µm</td>
<td>-0.00240</td>
<td>0.035</td>
<td>0.037</td>
<td>0.039</td>
<td>0.041</td>
<td>0.043</td>
</tr>
</tbody>
</table>

### Table 2. Ba isotopic compositions of individual SiC grains from Indarch measured by RIMS, and C and N isotopic compositions on the same grains measured by NanoSIMS.

<table>
<thead>
<tr>
<th>Grain</th>
<th>$^{12}$C/$^{13}$C</th>
<th>$^{14}$N/$^{15}$N</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>695 ± 251</td>
<td>-666 ± 62</td>
</tr>
<tr>
<td>#2</td>
<td>832 ± 136</td>
<td>-792 ± 34</td>
</tr>
<tr>
<td>#4</td>
<td>96 ± 181</td>
<td>-60 ± 165</td>
</tr>
<tr>
<td>#6</td>
<td>-5 ± 179</td>
<td>-41 ± 136</td>
</tr>
<tr>
<td>#7</td>
<td>-54 ± 136</td>
<td>-795 ± 35</td>
</tr>
<tr>
<td>#10</td>
<td>-128 ± 702</td>
<td>-424 ± 378</td>
</tr>
<tr>
<td>#17</td>
<td>75 ± 188</td>
<td>-744 ± 52</td>
</tr>
</tbody>
</table>

*In permil deviations from measured standard; all reported errors are 2 σ