TI ISOTOPIC COMPOSITIONS OF MURCHISON SIC;

TI ISOTOPIC COMPOSITIONS OF MURCHISON SIC;   T. R. Ireland[1], E. K. Zinner[2], and S. Amari[3], [1]Research School of Earth Sciences, The Australian National University, Canberra ACT 2601, Australia. [2]Physics Dept. and McDonnell Center for the Space Sciences, Washington University, St Louis, MO 63130, U.S.A, [3]Enrico Fermi Institute and Dept. of Chemistry, University of Chicago, Chicago, IL 60637, U.S.A.

We have analyzed eight large (8-20 µm) individual SiC grains from separate LU of the Murchison CM2 meteorite [1] for their Ti isotopic compositions with the SHRIMP ion microprobe at the ANU. The concentration of Ti in these grains is generally low, <100 ppm, but some grains have Ti concentrations up to several thousand ppm (see Table 1 which also lists the results of previous Washington University ion microprobe measurements of the C, N, and Si isotopic compositions of the grains). The Ti does not always appear to be homogeneously distributed through the grains with the Ti^+ signal showing large temporal variations. Hence a low sputter rate was used with a primary O_2^- beam of around 0.2-0.4 nA. For the grains with the highest Ti concentrations, sufficient Ti^+ signal was produced to enable automatic peak centering on all peaks, for grains with low Ti, centering was only possible on $^{48}Ti^+$. For these analyses peak positions were checked by analyzing neighboring hibonite grains. Isobaric interferences were monitored at ^{44}Ca, ^{51}V, and ^{52}Cr. With the exception of the terrestrial (synthetic) SiC these corrections are small compared to the uncertainties of the measurements.

The results are listed in Tables 2 and 3. Each analysis is the result of 10 scans through the mass sequence which represents about 20 minutes analytical time. In Table 2, the data for terrestrial standards and LU hibonite grains are presented as permil deviations from terrestrial ratios [2] with ^{48}Ti as the primary reference isotope and ^{46}Ti as the secondary. The terrestrial kaersutite standard is normal within error with mass fractionation of around 15 ‰/amu, typical of instrumental fractionation produced in the ion microprobe. Three of the Murchison hibonite grains analyzed on the LU mount appear normal but the third is characterized by a large depletion in ^{50}Ti. A synthetic SiC crystal was analyzed and found to have low Ti but high Cr signals. It is normal at the 2σ level after a large (709 ‰) correction for ^{50}Cr.

In Table 3 the Murchison LU SiC data are presented as deviations of the ratios from the terrestrial values corrected for an instrumental mass fractionation of 15 ‰/amu, as indicated by the terrestrial kaersutite. The errors associated with this correction are small compared with the uncertainties of the Ti isotopic ratios in the SiC analyses, as well as the size of the anomalies.

With the exception of the first three grains which have normal C, N, and Si (Table 1), large anomalies are seen in all four Ti isotopic ratios, in contrast to meteoritic hibonite that exhibits anomalies mostly in the $^{49}Ti/^{48}Ti$ and $^{50}Ti/^{48}Ti$ ratios (Fig. 1). These features qualitatively agree with model predictions for the He-burning shell of AGB-stars [3] that are successful in explaining the observed Kr-isotopic compositions of Murchison SiC [4]. However, there is some disagreement in the details. Figure 1 also shows the predicted He-shell ratios (scaled down by a factor of 150) for different metallicities Z (ranging from 5×10^{-3} to 2×10^{-2}) and overlap factors r (0.6 to 0.8) [3, 5]. In the 3-isotope plots of Figs. 2-4, the He-shell components AGB(He) lie in the directions of the arrows. The SiC grains with anomalies in C, N, and Si plot above the mixing lines solar - AGB(He) indicating larger $\delta^i Ti/\delta^{50}Ti$ ratios, especially for ^{46}Ti and ^{47}Ti (5-5-1). If the observed compositions do represent mixing between Ti from the He shell of AGB stars and Ti in the envelope (assumed to have solar composition), the fraction of the AGB(He) component is on the order of 0.5-4 %.

The situation is similar for Si (Fig. 5). The SiC data points again plot off the mixing line between solar Si and Si predicted for the He shell [5]. For Si, the admixture of AGB(He) to normal Si would represent between 3 and 14 %. There are other possible stellar sources for SiC and it remains to be seen whether AGB models can reproduce the observed Ti and Si isotopic compositions. However, the large grains analyzed here are not representative of most interstellar SiC from meteorites. For example, grain 5-5-1, which has the most extreme Si and Ti isotopic compositions (dashed lines) on all 3-isotope plots, has an unusually large ^{13}C excess. All 5 anomalous grains differ significantly in their Si from bulk fine-grained SiC [6] that carries most of the s-process Kr and Xe [4].

References: [1] Wopenka *et al.* (1989) *Meteoritics* **24**, 342. [2] Ireland (1988) *Geochim. Cosmochim. Acta* **52**, 2827. [3] Gallino *et al.* (1990) *Nature* **348**, 298. [4] Lewis *et al.* (1990) *Nature* **348**, 293. [5] Gallino *et al.*, pers. commun. [6] Amari *et al.* (1991) *Lunar Planet. Sci.* this volume.

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Table 1. C, Si, N isotope data and Ti concentrations of LU SiC

Sample	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{29}Si$ (‰)	$\delta^{30}Si$ (‰)	Si/C	Ti (ppm)
3-6-4	-42±4	10±42	-2.0±2.5	-3.8±3.1	0.97	49
3-6-11	-41±5	-31±34	-4.2±3.0	-7.4±3.2	1.00	66
7-6-2	-23±6	-43±98	1.0±2.5	-1.1±3.1	0.93	n.m.
2-5-1	694±10	-600±38	94.7±2.9	77.0±3.6	0.93	468
7-4-1	716±8	-884±6	90.1±2.8	73.1±3.3	0.96	3128
1-6-1	739±9	-505±47	64.5±2.3	75.2±2.5	1.06	n.m.
4-6-1	794±7	-554±27	34.6±2.1	39.2±2.4	0.91	84
5-5-1	18883±132	-839±8	101.7±3.3	63.8±3.7	1.06	9817

n.m. = not measured. Errors in all Tables and Figures are 1σ.

Table 2. Ti isotopic compositions of standards and LU hibonite†

Sample	$^{48}Ti+$ (kc/s)	$\Delta^{46}Ti$ (‰/amu)	$\delta^{47}Ti$ (‰)	$\delta^{49}Ti$ (‰)	$\delta^{50}Ti$ (‰)
Terrestrial standards					
kst	140	15.7±1.1	-1.1±1.3	-1.9±1.8	-0.3±3.7
Ti metal	260	19.7±0.4	0.4±0.5	-0.4±0.6	0.7±1.0
SiC	0.3	-15±12	42±36	-70±38	117±56
Murchison LU hibonite					
4-7-a	130	15.4±0.4	-2.8±1.2	-3.1±1.6	3.8±1.9
3-7-a	12	8.9±1.2	2.4±2.7	-7.8±3.3	-0.1±4.4
4-7-b	13	11.3±1.4	0.5±3.7	-6.0±5.7	-2.1±9.1
5-5-a	16	8.5±4.7	-3.6±4.7	-14.1±8.7	-52.5±11.0

†Ti isotopic data following mass fractionation correction using $^{46}Ti/^{48}Ti$ as an internal reference and an exponential mass-fractionation law.

Table 3. Ti isotopic compositions of LU SiC‡

Sample	$^{48}Ti+$ (kc/s)	$\delta^{46}Ti$ (‰)	$\delta^{47}Ti$ (‰)	$\delta^{49}Ti$ (‰)	$\delta^{50}Ti$ (‰)
3-6-4	0.06	9±30	32±30	45±38	12±35
3-6-11	0.8	14±9	16±12	8±9	-16±11
7-6-2	4.9	-5±7	8±5	10±8	2±7
2-5-1	0.2	121±18	15±26	118±22	169±22
7-4-1	0.8	146±22	53±17	98±24	126±15
1-6-1	26	19±27	9±13	70±17	122±34
4-6-1	0.5	63±17	2±20	41±25	99±25
5-5-1	1.8	96±7	52±12	82±8	65±13

‡ Ti isotopic ratios relative to terrestrial compositions following a linear 15 ‰/amu mass fractionation correction, i.e. these data are not referenced to an internal ratio.

$$\delta^i Ti = 1000 \times [(^i Ti/^{48}Ti)_{meas}/(^i Ti/^{48}Ti)_{terr} - 1] - [(48-i)\times 15]$$

Data are listed in order of increasing $\delta^{13}C$ as per Table 1.

Figure 2

Figure 3

Figure 4

Figure 1

Figure 5