A NANOSIMS STUDY OF IRON-ISOTOPIC COMPOSITIONS IN PRESOLAR SILICON CARBIDE GRAINS. K. K. Marhas[1], P. Hoppe[1], and A. Besmehn[1,2], [1]Max-Planck-Institute for Chemistry, Cosmochemistry Department, D-55020 Mainz, Germany (kkmarhas/hoppe@mpch-mainz.mpg.de), [2]Research Centre Jülich, Central Department of Analytical Chemistry, D-52425 Jülich, Germany (a.besmehn@fz-juelich.de).

Introduction: Silicon carbide (SiC) is the best studied presolar mineral phase [1-3]. It is now well established that most of the presolar SiC (mainstream grains and the minor type Z and Y grains) originate from low-mass (1-3 $M_{\odot}$) asymptotic giant branch (AGB) stars. Also type II supernovae (SN) are believed to have contributed to the population of presolar SiC (X grains). Although low in abundance (about 1% of the SiC) the study of X grains has provided important insights into SN nucleosynthesis [e.g., 4, 5].

Only little isotopic information is available for the astrophysically diagnostic element Fe. To date Fe-isotopic compositions were measured for 4 mainstream grains, 9 unclassified grains, and 3 X grains by RIMS [6, 7]. These studies led to surprising results as $^{54}Fe/^{56}Fe$ ratios in mainstream (and unclassified) grains are distinctly lower than solar, having an average $\delta^{54}Fe$ of -130 ‰. Also $^{57}Fe/^{56}Fe$ ratios are mostly lower than solar, although the depletions in ^{57}Fe are less pronounced than those in ^{54}Fe. $^{58}Fe/^{56}Fe$ ratios, on the other hand, show a large scatter around the solar ratio. The lower than solar $^{54}Fe/^{56}Fe$ has been interpreted to be the imprint of Galactic chemical evolution (GCE) [6]. While two of the X grains have $^{54}Fe/^{56}Fe$ ratios in the range of mainstream grains, one X grain is enriched in ^{54}Fe by about 200 ‰. Excesses of several 100 ‰ (with large analytical uncertainties) are seen for ^{57}Fe and ^{58}Fe in all X grains [6].

In order to get additional information on the Fe-isotopic composition of presolar SiC we have measured Fe-isotopic ratios in 8 grains with the NanoSIMS 50 ion microprobe at MPI for Chemistry, Mainz.

Experimental: SiC grains separated from the Sahara 97166 enstatite chondrite [8] were dispersed on gold foils. Prior to the NanoSIMS measurements the sample was screened by low-mass resolution ion imaging for $^{30}Si/^{28}Si$ ratios with our Cameca IMS3f ion microprobe in order to locate the rare X grains. Four X grains identified by ion imaging were subsequently relocated in the NanoSIMS and measured together with 8 additional grains for C, N, and Si-isotopic compositions. Negative secondary ions of ^{12}C, ^{13}C, $^{12}C^{14}N$, $^{12}C^{15}N$, ^{28}Si, ^{29}Si, and ^{30}Si were measured in a combined multi-detection/peak-jumping mode using a defocussed (1-2 µm) Cs^+ primary ion beam of <1 pA.

Fe-isotopic ratios were measured in two of the X grains and in 6 grains of other types. Positive secondary ions of ^{28}Si, ^{52}Cr, ^{54}Fe, ^{56}Fe, and ^{57}Fe were analyzed in a combined multi-detection/peak-jumping mode with a defocussed (~2 µm) primary O^- beam of ~10 pA. ^{58}Fe was not included in the measurements because of its low isotopic abundance (0.31 %). High-resolution ion images, acquired with a focussed O^- primary ion beam (~300 nm), were taken in order to check for possible contributions of Fe contamination to the grains's intrinsic Fe.

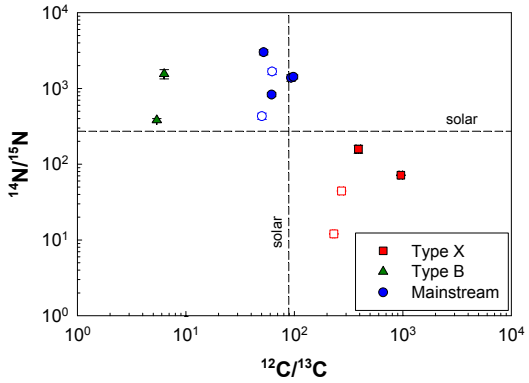

Figure 1. C- and N-isotopic compositions of presolar SiC grains from the Sahara 97166 enstatite chondrite. Errors are 1σ. Filled symbols: Measured for Fe-isotopic composition; open symbols: not measured for Fe-isotopic composition.

Results: According to C-, N-, and Si-isotopic compositions, 2 of the SiC grains analyzed for Fe are of type B, 4 of the mainstream type, and 2 of type X (Table 1, Fig. 1). Fe/Si ratios are between $4.7x10^{-4}$ and 0.016 in the type B and mainstream grains, and around 0.01 in the X grains. In the mainstream grain SiC#13 there is a clear indication of Fe contamination as evidenced from a pronounced difference in the Si and Fe ion images (Fig. 2). Without this grain, Fe/Si ratios range up to 0.002 in B and mainstream grains, consistent with what was observed in previous studies [9]. The Fe/Si ratios in the X grains are higher by a factor >10 than those previously studied [10]. However, at least for grain SiC#422-1 this seems to be an intrinsic feature because Fe is homogeneously distributed within the grain (Fig. 2).

The $^{54}Fe/^{56}Fe$ and $^{57}Fe/^{56}Fe$ ratios of the B and mainstream grains as well as of X grain SiC#294-3 are normal within 2σ (Fig. 3). The mass-weighted average of $\delta^{54}Fe$ in the B and mainstream grains (w/o SiC#13) is $\delta^{54}Fe = -34 \pm 31$ ‰ and $\delta^{57}Fe = 9 \pm 24$ ‰. The only resolvable anomalies are seen for $^{54}Fe/^{56}Fe$ and $^{57}Fe/^{56}Fe$ in X grain SiC#422-1 (Fig. 3). But even here,

the anomalies are relatively small with excesses in ^{54}Fe and ^{57}Fe of only 30-40 ‰.

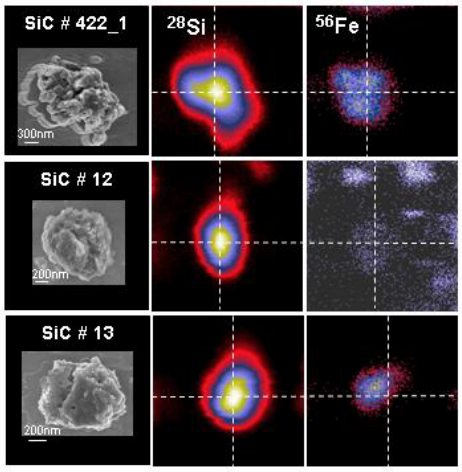

Figure 2. SEM and ^{28}Si and ^{56}Fe ion images of X grain SiC#422-1, and mainstream grains SiC#12 and SiC#13. Field of view is 5 x 5μm^2.

Discussion: The ^{54}Fe/^{56}Fe data of our B and mainstream grains fall at the upper end of the ratios measured by [6, 7] for mainstream grains. In AGB stars ^{54}Fe and ^{56}Fe are consumed by n-captures in the He intershell and the envelope abundances of these two isotopes change only marginally during the third dredge-up events. Contrary, large amounts of ^{57}Fe are produced by n-capture in the He intershell and the third dredge-up will increase the envelope ^{57}Fe/^{56}Fe ratio significantly [6]. The average δ^{54}Fe and δ^{57}Fe values of our B and mainstream grains are roughly compatible with model predictions (δ^{54}Fe ~0, δ^{54}Fe = 50-150 ‰) for 1.5-5 $M_\odot$ AGB stars of solar metallicity and initially solar Fe-isotopic composition [6]. A better match, however, is achieved for $\delta^{54}Fe_{ini}$ ~ -25 ‰ and $\delta^{57}Fe_{ini}$ ~ -90 ‰. In terms of GCE this would mean that ^{54}Fe and ^{57}Fe were depleted relative to solar isotopic abundances at the time the SiC grains formed.

In the different zones of type II SN Fe-isotopic compositions vary over many order of magnitudes. It was shown that the isotopic compositions of many elements in X grains can be satisfactorily explained if matter from the Si/S-, He/C, and He/N zones is mixed in variable proportions [4]. Small contributions from the interior Ni zone, which probably provides the ^{44}Ti seen in many X grains [4], will have a strong impact on the Fe-isotopic ratios because of very high concentrations of ^{56}Fe and its radioactive progenitors. In view of the large variations expected for Fe-isotopic ratios in different SN zones, the close-to-normal ratios in the X grains of this study are surprising. Nevertheless, the Fe-isotopic signature of X grain SiC#422-1 is qualitatively consistent with that observed by [6] for one of their X grains and can be qualitatively understood in terms of the 15 $M_\odot$ type II SN model of [11] by mixing matter from the Si/S, He/C, and He/N zones, although the observed excess in ^{54}Fe falls short of that expected for mixtures that can reproduce the Si-isotopic signature of SiC#422-1 (see Fig. 10 in [4]).

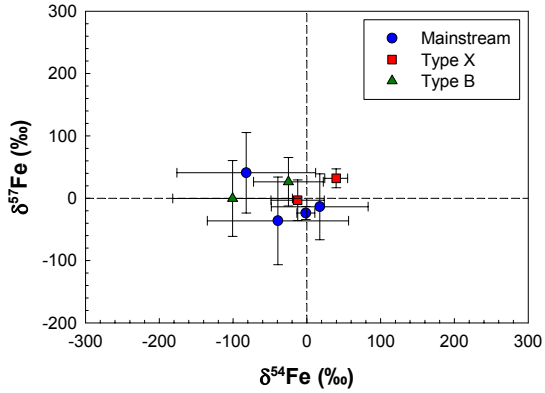

Figure 3. Fe-isotopic compositions of presolar SiC grains from the Sahara 97166 enstatite chondrite. Errors are 1σ.

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References: [1] Zinner E. (1998) *Ann. Rev. Earth Planet. Sci.*, 26, 147. [2] Hoppe P. and Zinner E. (2000) *JGR*, 105, 10371. [3] Nittler L. R. (2003) *EPSL*, 209, 259. [4] Hoppe P. et al. (2000) *MAPS*, 35, 1157. [5] Pellin M. et al. (1999) *LPSC*, 30, abstr. #1969. [6] Davis A. M. et al. (2002) *LPSC*, 33, abstr. #2018. [7] Tripa C. E. et al. (2002) *LPSC*, 33, 1975. [8] Besmehn A. (2001) *PhD. thesis*, Universität Mainz. [9] Amari S. et al. (1995) *Meteoritics*, 30, 679. [10] Hoppe P. et al. (2001) *ApJ*, 551, 478. [11] Woosley S. E. and Weaver T. A. (1995) *ApJS*, 101, 181.

Table 1. C-, N-, Si-, and Fe-isotopic compositions and Fe/Si ratios in presolar SiC grains from Sahara 97166.

Grain	Type	δ^{29}Si (‰)	δ^{30}Si (‰)	^{14}N/^{15}N	^{12}C/^{13}C	δ^{54}Fe (‰)	δ^{57}Fe (‰)	Fe/Si x10^{-3}
SiC#12	Mainstream	-3 ± 4	3 ± 5	3003 ± 232	52.0 ± 0.4	-82 ± 94	41 ± 65	0.47
SiC#13	Mainstream	-16 ± 3	2 ± 3	1380 ± 137	93.1 ± 0.6	-1 ± 12	-24 ± 10	16.0
SiC#17	Mainstream	-12 ± 6	3 ± 7	1423 ± 87	98.1 ± 1.3	18 ± 66	-14 ± 53	4.7
SiC#408-7	Mainstream	48 ± 6	38 ± 8	828 ± 49	61.6 ± 0.7	-39 ± 96	-36 ± 70	1.24
SiC#10	B	34 ± 5	26 ± 6	381 ± 20	5.4 ± 0.02	-101 ± 81	-0 ± 61	1.91
SiC#14	B	-8 ± 5	24 ± 6	1552 ± 216	6.3 ± 0.02	-25 ± 47	26 ± 39	0.65
SiC#294-3	X	-336 ± 10	-491 ±11	158 ± 19	389 ± 19	-13 ± 36	-3 ± 33	14.6
SiC#422-1	X	-313 ± 5	-498 ± 5	71 ± 1	959 ± 36	40 ± 16	32 ± 15	11.5