A PRE SOLAR SILICON CARBIDE GRAIN OF TYPE C WITH EXTREMELY LOW $^{12}$C/$^{13}$C RATIO. P. Hoppe$^1$, J. Schofield$^2$, M. Pignatari$^{3,4,5}$, and S. Amari$^6$.

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Introduction: Primitive Solar System materials contain small quantities of presolar grains that formed in the winds of evolved stars and in the ejecta of stellar explosions [1]. Silicon carbide (SiC) is the best studied presolar mineral. Based on C-, N-, and Si-isotopic compositions it is divided into distinct populations. While most SiC grains formed in the winds of low-mass asymptotic giant branch (AGB) stars, supernovae (SNe) made an important contribution to the population of presolar SiC grains as well [1]. Of particular interest are presolar SiC grains with low $^{12}$C/$^{13}$C ratios ($^{12}$C/$^{13}$C < ~20). Among them are the Type AB and putative nova grains, some of which may have formed in the ejecta of SN explosions [e.g., 2, 3]. Low $^{12}$C/$^{13}$C ratios have also been observed in a significant fraction of the SN Type C grains.

Here, we report on a search for new SiC grains with low $^{12}$C/$^{13}$C ratios by NanoSIMS ion imaging, in order to get a better understanding on their origins and on the nucleosynthetic and mixing processes in their parent stars. In this search we identified a Type C grain with extremely low $^{12}$C/$^{13}$C ratio. We present the B-, C-, N-, Al-, Si-, and Ti-isotopic compositions of this particularly interesting grain which we discuss in the context of an H ingestion SN model of [4].

Experimental: SiC grains from the Murchison separate KJE (median size: 1.14 μm) [6], dispersed on a clean Au foil, were screened for grains with low $^{12}$C/$^{13}$C ratios by C and Si ion imaging with the NanoSIMS at MPI for Chemistry. For this purpose a focused Cs+ ion beam (~1 pA, 100 nm) was rastered over 149 30 x 30 μm2-sized areas on the Au foil and negative secondary ion images of $^{12}$C, $^{13}$C, $^{28}$Si, $^{29}$Si, and $^{30}$Si were recorded in multi-collection. Subsequently, 13 identified AB grains and one C grain were measured for C-, N-, Li-, B-isotopic compositions, and the C grain in addition for Mg-Al and Ca-Ti-isotopic compositions. We recorded in multi-collection negative secondary ions of $^{12}$C, $^{13}$C, $^{14}$N, $^{12}$C$^{13}$N, $^{28}$Si (Cs+ ion source, ~1 pA, 100 nm), and positive secondary ions of $^6$Li, $^7$Li, $^{10}$B, $^{11}$B, and $^{28}$Si, of $^{24}$Mg, $^{25}$Mg, $^{26}$Mg, $^{27}$Al, and $^{28}$Si, and of $^{28}$Si, $^{46}$Ca, $^{48}$Ca, $^{46}$Ti, and $^{50}$Ti (Hyperion O source, ~3 pA, 100 nm).

Results and Discussion: The C-, N-, and Si-isotopic ratios of the AB grains from this study are in line with those from the literature [5, and references therein] (Figs. 1, 2). Boron-isotopic ratios are normal, albeit within large experimental uncertainties of ~30%. Type C grain KJE3-110 has a very low $^{12}$C/$^{13}$C ratio of 1.03 ± 0.01, very similar to C grain G240-1 from the study of

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Figure 1. C- and N-isotopic compositions of 13 AB grains and of C grain KJE3-110 from this study in comparison to literature data of presolar SiC grains [5].

Figure 2. Si-isotopic compositions of 13 AB grains and of C grain KJE3-110 from this study in comparison to literature data of presolar SiC grains [5].
[7, 8] which has $^{12}\text{C}/^{13}\text{C} = 1.04 \pm 0.01$ (Fig. 1). Grain KJE3-110 is heavily enriched in $^{15}\text{N}$, $^{26}\text{Al}$, and the heavy Si isotopes, with $^{14}\text{N}/^{15}\text{N} = 11.0 \pm 0.03$, $^{26}\text{Al}/^{27}\text{Al} = 0.041 \pm 0.002$, $\delta^{28}\text{Si} = 1825 \pm 35$‰, and $\delta^{30}\text{Si} = 1484 \pm 40$‰ (Figs. 1-3). No excess $^{44}\text{Ca}$ was observed, which constrains $^{44}\text{Ti}/^{48}\text{Ti}$ to $< 4.2 \times 10^{-3}$. The $^{50}\text{Ti}/^{48}\text{Ti}$ ratio is about solar. The B concentration is low ($^{11}\text{B}/^{28}\text{Si} = 3 \times 10^{-5}$), which did not allow to get a meaningful $^{11}\text{B}/^{28}\text{B}$ ratio.

Profiles of selected isotopic ratios predicted by model 25T-H are shown in Fig. 4 (solid lines), together with the isotopic ratios measured in KJE3-110 (dotted lines). In a thin layer around $M = 6.98 \, \text{M}_\odot$ (thick light-blue line in Fig. 4) isotopic ratios of grain KJE3-110 are relatively well matched, except for $^{26}\text{Al}/^{27}\text{Al}$ and $^{28}\text{Si}/^{26}\text{Si}$ (not shown), which are off by factors of $\sim 10$. However, the C/O ratio is only $\sim 10^{-2}$ which makes formation of SiC very unlikely. Following the approach in [3], considering heterogeneous mixing over larger scales (from 6.82 to 11 M$\odot$) and adjustment of predicted $^{12}\text{C}/^{13}\text{C}$ and $^{26}\text{Al}/^{27}\text{Al}$ ratios by factors of 3 and 5, respectively, it is possible to find a good fit to measured ratios along with C/O $>1$. The isotopic ratios of KJE3-110 can be reproduced within factors of $<1.7$; exceptions are the $^{44}\text{Ti}/^{48}\text{Ti}$ and $^{11}\text{B}/^{28}\text{Si}$ ratios which are too high by factors of 7 and $\sim 10$, respectively. We note that the production of $^{44}\text{Ti}$ and $^{11}\text{B}$ is very sensitive to model parameters and that the B/Si ratio may be affected by fractionation during grain condensation.

While the C-, N-, and Al-isotopic ratios of grains KJE3-110 and G240-1 are very similar, grain KJE3-110 has a much higher enrichment of the heavy Si isotopes. This suggests heterogeneous mixing of matter that experienced explosive H burning (high $^{13}\text{C}$, $^{15}\text{N}$, $^{26}\text{Al}$) with matter that experienced neutron-capture nucleosynthesis (enhanced $^{29,30}\text{Si}$) in SNe and supports similar conclusions previously drawn by [8, 10, 11].

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