SULFUR-ISOTOPIC SIGNATURE OF PRESOLAR SiC GRAINS OF TYPE X. P. Hoppe[1] and E. Zinner[2], [1]Max Planck Institute for Chemistry, P.O. Box 3060, 55020 Mainz, Germany (peter.hoppe@mpic.de), [2]Laboratory for Space Sciences and Physics Dept., Campus Box 1105, Washington University, St. Louis, MO 63130, USA.

Introduction: Primitive solar system materials contain small quantities of presolar grains that formed in the winds of evolved stars or in the ejecta of stellar explosions [1]. SiC is the best characterized presolar mineral. Most of these grains formed in the winds of 1-3 $M_\odot$ AGB stars. SiC X and U/C grains, which constitute about 1-2% of presolar SiC grains, are from Type II supernovae (SNeII). This is evidenced by specific isotopic fingerprints, e.g., isotopically light (X grains) or heavy (U/C grains) Si and the initial presence of now extinct ^{44}Ti (half life 60 y) [2, 3]. An important signature of U/C grains are large enrichments in ^{32}S [3-5]. Simple ad hoc SNII mixing models cannot account for heavy Si together with light S, as observed in U/C grains. The isotope data suggest preferential trapping of S from the inner Si/S zone over S from other zones [3]. A way to achieve this is by molecule chemistry in SNII ejecta. SiS is predicted to form efficiently in the still unmixed ejecta from the Ni/Si/S zone [6] and it was argued that the S isotope signatures of U/C grains can be explained if SiS is much more efficiently captured by the growing SiC grains than atomic S or other S-bearing molecules from other zones [3].

Here, we report results of S isotope measurements on X grains made in order to gain further insights into the S-isotopic signature of SN dust and the chemical and physical processes taking place in SNII ejecta.

Experimental: The SiC grains of this study were separated from the Murchison CM2 meteorite [7] and deposited from liquid suspension onto a clean Au foil (sample "M7"). Areas suitable for NanoSIMS ion imaging were selected in the Leo 1530 FE-SEM at the MPI for Chemistry. In the WU NanoSIMS ion probe we measured the C- and Si-isotopic compositions (Cs$^+$ primary ions, ~100 nm beam size, ~1 pA) of ~2300 SiC grains found in 464 20 x 20 μm^2-sized areas with an automatic grain mode program [8]. Sulfur-isotopic compositions were measured on 22 X grains by recording high-resolution images of ^{28}Si$^-$, ^{32}Si$^-$, ^{33}Si$^-$, and ^{34}Si$^-$ (1.5-3 x 1.5-3 μm^2, Cs$^+$ primary ions, ~1 pA) with the WU and MPI NanoSIMS ion probes.

Results and Discussion: Twenty-five X grains were found during the automatic search, having δ^{29}Si values between –90 and –570 ‰, δ^{30}Si values between –200 and –700 ‰ (Fig. 1), and ^{12}C/^{13}C ratios from 25 to 1080. These ranges as well as the X grain abundance of ~1% agree with the results of previous studies [4, 9, 10].
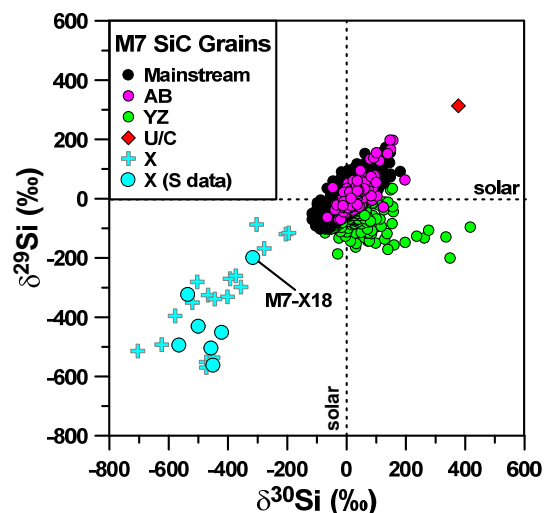

Figure 1. Si-isotopic compositions of different populations of presolar SiC grains from Murchison sample M7. Light-blue circles represent data for the X grains shown in Fig. 3.

Contamination by S on or very close to individual X grains complicated S isotope measurements and the data are likely to be affected by varying contributions of terrestrial S. For six X grains the S signal was clearly dominated by contamination, as evidenced from the spatial distribution of S and Si in the ion images. For the remaining 16 X grains the problem was less severe, though still present (Fig. 2). Although S hotspots were excluded before calculating S-isotopic ratios, intrinsic S-isotopic signatures are likely significantly more extreme than measured. Despite these problems, in one case (M7-X18) a clear excess in ^{32}S was seen and also most of the remaining grains tend to have isotopically light S (Fig. 3). Even if grain M7-X18 (δ^{33}S = –356 ± 114 ‰, δ^{33}S = –209 ± 53 ‰, ~1 wt‰ S) is excluded, mass-weighted averages of δ^{33}S (–70 ± 33 ‰) and δ^{34}S (–32 ± 14 ‰) in the remaining 15 grains are anomalous >2σ.

With SNII ad hoc mixing, using the 15 $M_\odot$ model of [11], it is possible to reproduce the Si- and C-isotopic compositions of grain M7-X18 (δ^{29}Si = –199 ± 5 ‰, δ^{30}Si = –317 ± 6 ‰, and ^{12}C/^{13}C = 131 ± 2). Mixing matter from the Si/S : O/Si : O/Ne : O/C : He/C : He/N : H zones in the proportions 0.0047 : 0.0026 : 0.0125 : 0 : 0.228 : 0.134 : 0.618 results in

$\delta^{29}Si$ = –198 ‰, $\delta^{30}Si$ = –313 ‰, and $^{12}C/^{13}C$ = 131. For S it results in $\delta^{33}S$ = –459 ‰ and $\delta^{34}S$ = –413 ‰, the fingerprint of the Si/S zone (Fig. 4). There is clear indication for S contamination around M7-X18 (Fig. 2) and some of the S in the grain might be contamination as well. If assuming about 40% contaminating S it is possible to reproduce the S-isotopic composition of X18.
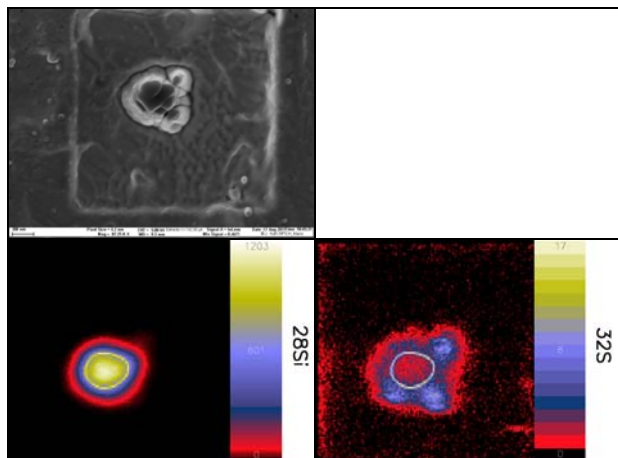

Figure 2. SEM picture, and $^{28}Si^-$ and $^{32}Si^-$ ion images (2 x 2 μm^2) of X grain M7-X18.

It has been argued that S from the Si/S zone must be more efficiently trapped than S from other zones to account for the Si and S isotope data of U/C grains [3]. If we consider a fractionation factor of 50 between S from the Si/S zone and S from the other zones we obtain $\delta^{33}S$ = –792 ‰ and $\delta^{34}S$ = –865 ‰ in the mixture considered above. In this scenario, about 70% of contaminating S would be required to account for the observed S-isotopic composition of M7-X18.

Higher relative contributions from the Si/S zone imply larger ^{32}S enrichments in X than in U/C grains, which has not been seen. However, as we have pointed out, S contamination is a serious and unavoidable problem that might have lowered intrinsic S isotope anomalies to varying degrees. It is possible that in X grains the invoked S fractionation for U/C grains is smaller and intrinsic S concentrations lower. Anyhow, the finding of ^{32}S enrichments in X grains confirms SN model predictions of light S in the Si/S zone. This lends support to the conclusion that U/C grains have preserved a record of S molecule chemistry in their parent SNII ejecta [3].
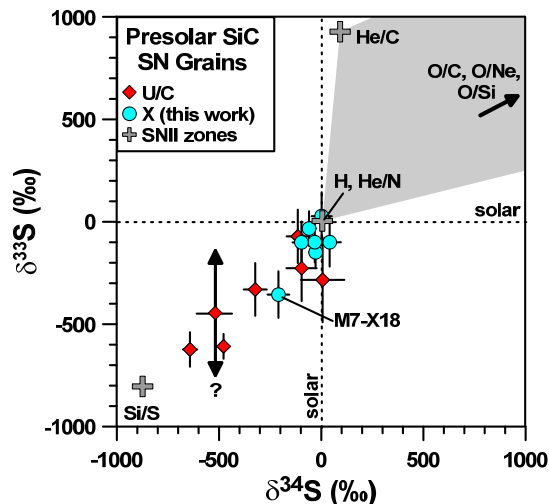
Figure 3. S-isotopic compositions of SiC SN grains and of the different zones in a 15 M$_\odot$ SNII [11]. X grain data are only shown if the error in $\delta^{33}S$ is less than 150 ‰.
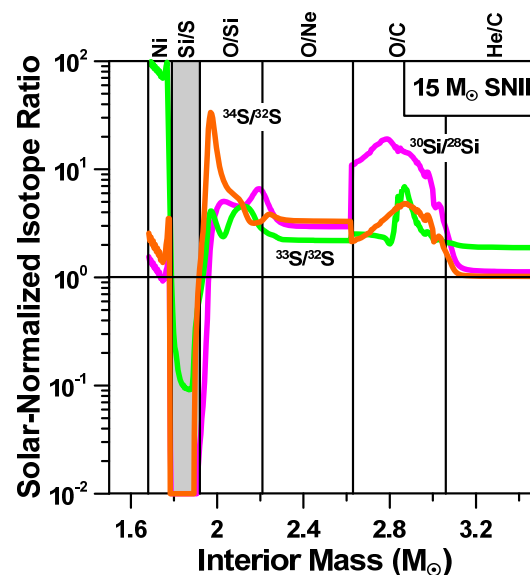

Figure 4. Model predictions of solar-normalized $^{30}Si/^{28}Si$, $^{33}S/^{32}S$, and $^{34}S/^{32}S$ ratios in a 15 M$_\odot$ SNII [11].

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