Si, C AND N ISOTOPES IN SiC FROM ORGUEIL AND MURCHISON: H- AND He-BURNING COMPONENTS IN PRESOLAR GRAINS

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We previously reported the discovery of a suite of morphologically-distinctive SiC grains from Orgueil and Murchison containing isotopically anomalous Si with well-correlated $^{29}Si/^{28}Si$ and $^{30}Si/^{28}Si$ ratios (Fig. 1) [1]. The characteristic "platy" morphology and simple Si isotope systematics set these grains apart from other types of SiC in primitive meteorites [2-5], and we concluded that the grains represent a family formed as condensates of a single, isotopically heterogeneous stellar source. This is in contrast to the view that SiC is a mixture of many (>6) stellar sources [3]. We have now measured C and N isotopic compositions of the same grains analyzed for Si, to investigate further mixing process responsible for the correlated Si isotopic ratios and better constrain the nature of the stellar source.

SiC grains measured for Si isotopes [1] were relocated and analyzed for C and N isotopes with the PANURGE IMS-3F ion probe using an ~ 0.1nA Cs^+ primary beam defocussed to ~ 15 μm diameter. An 8μm field aperture suppressed background contributions to the secondary ion signals. C isotopes were measured as C^- ions at a mass resolving power (MRP) of ~ 3500. N isotopes were measured subsequently as CN^- ions at MRP ~ 6500; molecular interferences were fully resolved. Data are expressed as permil deviations relative to ratios measured in synthetic SiC standard grains for C isotopes and 1-hydroxybenzotriazole hydrate for N isotopes. The isotopic effects in the meteoritic SiC are so extreme that uncertainty regarding the isotopic compositions of our standards relative to the PDB C and air N standards does not affect the conclusions. Of the original 17 grains, 15 were relocated for C analyses, and 9 survived the C isotope runs and yielded CN^- signals adequate for N measurements.

All of the platy SiC grains are highly enriched in ^{13}C. $\delta^{13}C$ values range from 150‰ to 5200‰ (Fig. 2), though the majority of grains possess $\delta^{13}C$ values < 1600‰. All of the platy SiC grains are enriched in ^{14}N, with isotopic compositions ranging from $\delta^{15}N$ = -390‰ to almost pure ^{14}N, $\delta^{15}N$ = - 960‰ (Fig. 3). For all but two grains, Si^-/C^- ratios coincide with values measured on SiC standards, indicating that the data are unaffected by other C-bearing phases. N contents of the grains cannot be determined from their CN^-/C^- ratios due to lack of a N-bearing SiC standard. However, CN^-/C^- ratios proved highly variable (0.05 < CN^- < 1.6) and fluctuated during analyses, suggesting sub-micron heterogeneity of N concentrations within some SiC. Neither C nor N isotopic compositions correlate with Si isotopic variations (Figs. 2 and 3), precluding extension of the binary mixing relationship observed for Si [1] to these elements. C and N isotopic compositions are also decoupled, though the greatest enrichments in ^{13}C and ^{14}N occur in the same grain (Fig. 4). The extreme isotopic compositions and absence of correlated effects between C and Si or N and Si isotopes has been interpreted in terms of multiple stellar sources for the SiC [2-4]. We regard this possibility as unlikely for the platy SiC grains due to the strongly correlated Si isotope compositions (Fig 1). We are therefore left with the problem of identifying a stellar source for ^{13}C and ^{14}N as well as the Si components, capable of mixing these in varying proportions and condensing SiC.

Two possibilities are a red giant on the asymptotic giant branch (AGB) and the precursor to a type II supernova. Gallino *et al.* [6] have predicted that the He cores of AGB stars should produce ^{29}Si, as well as ^{22}Ne and heavy s-process isotopes characteristic of meteoritic SiC. The Si isotope array (Fig. 1) could result from mixing of He-shell material with unprocessed Si from both the H-burning layer and the circumstellar shell. The C and N isotopic compositions suggest mixing may have occurred over several dredge-up cycles, combining H-burning matter at varying stages of ^{13}C and ^{14}N enrichment with ^{12}C-rich He-shell material and isotopically-normal circumstellar gas. The $^{29}Si/^{30}Si$ production ratio estimated from the Fig. 1 array (~2.1) is somewhat higher than the prediction of Gallino *et al.* [6]. The discrepancy may be due to the model parameters chosen by Gallino *et al.* to fit the Kr isotopic compositions of a different class of SiC grains, or to uncertainties in the (n,γ) and (n, σ) cross-sections for reactions

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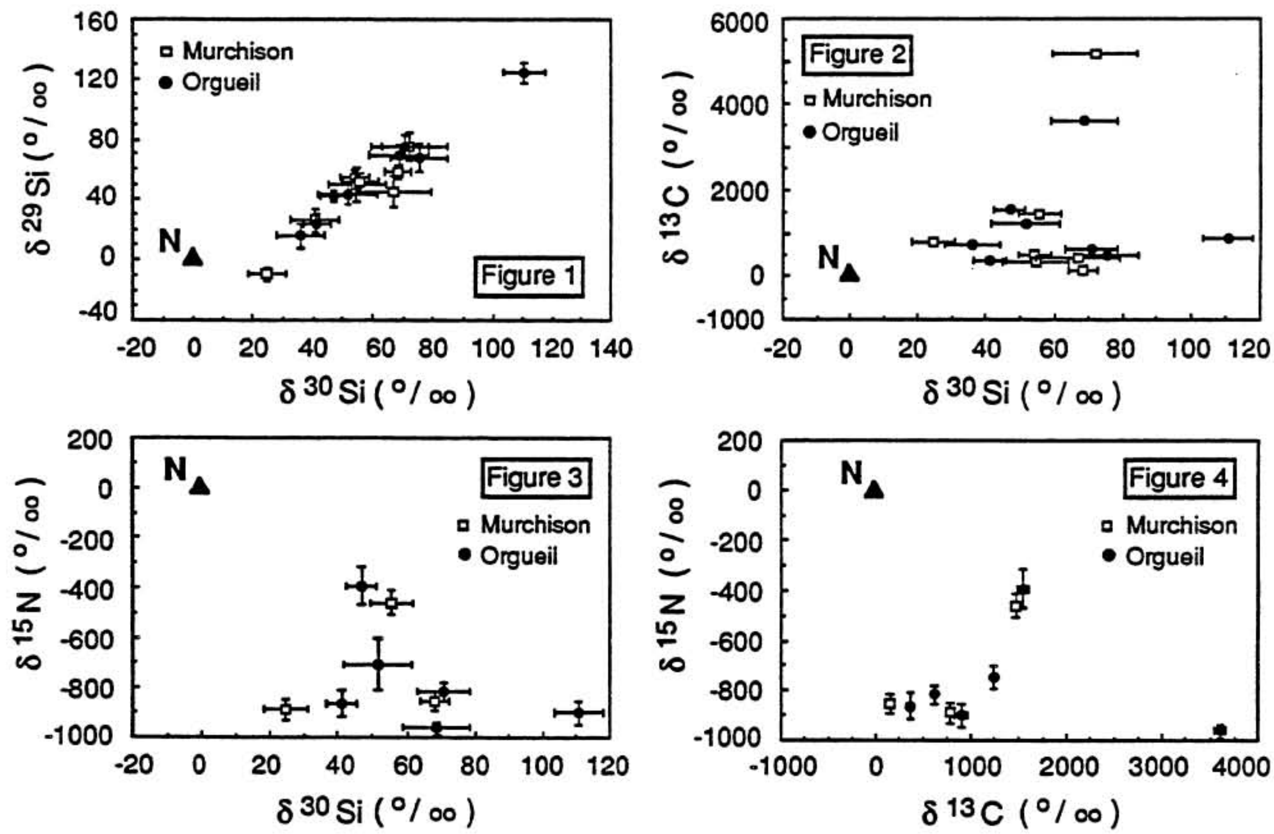
involving the Si isotopes. An alternative source is a pre-supernova star. The convective He-burning layer of the progenitor of a type II supernova [8] has a C/O ratio > 1, required for SiC condensation, while producing ^{29}Si and ^{30}Si in proportions compatible with the Fig. 1 array. This layer also contains significant excess ^{22}Ne and may produce s-process isotopes by (σ,γ) reactions on ^{14}N seed nuclei [7, 8]. The ^{13}C and ^{14}N excesses found in the SiC would require addition of these isotopes in varying proportions from the overlying H-burning shell prior to condensation.

We consider that the family of platy SiC grains are condensates of material ejected from a single star. Contributions from different nuclear burning zones during mass loss create an isotopically heterogeneous circumstellar shell. The stellar outflow will, in general be variable in time and space. Mixing ratios of different zones will also vary and SiC will record the prevailing mix of isotopes during condensation. Very fine-grained material must also condense in this circumstellar shell. A basic question that remains is the origin of the very fine grained SiC aggregates (which often contain extreme C and N isotopic compositions and uncorrelated Si isotopes). This SiC may also come from a single star or may represent a broader ensemble of interstellar material from many different sources. The isotopic patterns of the fine SiC may thus reflect the scale of dust mixing in dense molecular clouds containing rapidly evolving stars undergoing substantial mass loss.

References: [1] Stone J. *et al.* (1990) LPSC XXI, 1212-1213. [2] Zinner E. *et al.* (1987) Nature 330, 730-732. [3] Zinner E. *et al.* (1989) GCA 53, 3273-3290. [4] Tang M. *et al.* (1989) Nature 339, 351-354. [5] Alexander C.M.O'D. *et al.* (1990) LPSC XXI, 9-10. [6] Gallino R. *et al.* (1990) Nature 348, 298-302. [7] Hashimoto M. *et al.* (1989) Astron. Astrophys. 210, L5-L8. [8] Prantzos N. *et al.* (1988) Astrophys. J. 331, L15-L19.

Figs 1-4: Si, C and N isotopic compositions of "platy" SiC from Orgueil and Murchison. Uncertainties are 2σ. Points marked "N" denote normal Si, C and N isotopic compositions.



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