NITROGEN AND CARBON ISOTOPIC COMPOSITION OF SILICON CARBIDE IN THE CO3.0 METEORITE ALHA77307, A NANOSIMS STUDY.

J. B. Smith[1], P. K. Weber[1], G.R. Huss[2] and I. D. Hutcheon[1], [1]Lawrence Livermore National Laboratory, PO Box 808, L-231, Livermore, CA 94550, [2]Arizona State University, Tempe, AZ 85287-1404; smith371@llnl.gov.

Introduction: Presolar grains have been identified in primitive members of all chondrite classes [1, 2]. The study of the isotopic compositions of presolar grains provides information on galactic evolution and nucleosynthesis in stars [3, 4], while the abundances and characteristics of presolar grains contain a record of thermal processing in the solar system [2, 5]. Much of the detailed work on presolar silicon carbide grains has focused on Murchison [e.g., 2] and Orgueil [4], but several other carbonaceous [6, 7], ordinary, and enstatite chondrites [8-11] have also been studied. This study investigates the isotopic composition of silicon carbide from the CO3.0 carbonaceous chondrites ALHA77307 and Colony. SiC is present in ALHA77307 at a matrix normalized abundance of ~8.8 ppm [5], which is approximately twice the abundance of Colony [5], but less than in CI chondrites and the matrices of CM and primitive ordinary and enstatite chondrites [3]. The abundances of SiC and other presolar grains in ALHA77307 seem to correlate with the degree of chemical processing that produced CO3 chondrites [2, 5]. This implies that the same nebular processing that produced the bulk composition of the CO3 chondrite class also modified the assemblage of known presolar grains [5]. To test whether all chondrite classes originated from the same reservoir of presolar dust it is necessary to look for primary differences, not related to thermal processing, between SiC in CO3 chondrites and other chondritic meteorites.

Method: An ALHA77307 sample of ~1.5 grams was processed using the methodology developed by [2]. The SiC-spinel residue was dispersed onto gold foils and SiC grains identified using an automated grain-identification program provided by IXRF® running on a JEOL-845 SEM equipped with an energy-dispersive X-ray system at Arizona State University. Six presolar SiC grains, all with diameters of ~0.8 microns, were analyzed on the Cameca NanoSIMS 50 at Lawrence Livermore National Laboratory. The isotopic compositions of carbon and nitrogen were determined by simultaneous multi-collection of ^{12}C, ^{13}C, $^{12}C^{14}N$, $^{12}C^{15}N$, and ^{28}Si. A mass resolving power of ~6500 was used to resolve $^{13}C_2$ from $^{12}C^{14}N$, and $^{12}C^{15}N$ from $^{13}C^{14}N$. A ~2 pA, $^{133}Cs^+$ primary ion beam focused into a ~100 nm spot was rastered across a 4 x 4 micron area. Measurements consist of 40 scans summed to create a single image for each isotope. Isotope ratios are reported relative to the NIST 8541 and 8558 standards.

Results: The SiC have homogeneous C isotopic ratios within each grain. The $^{12}C/^{13}C$ ratio of three of the grains is approximately 50. One grain has a ratio of ~75, while two have $^{12}C/^{13}C$ ratios greater than solar, ~115 and ~135 (Fig. 1). Presolar SiC with such high ratios are relatively rare and it is surprising to find two such grains in this small dataset. Murchison (CM2) and Orgueil (CI) both contain SiC having $^{12}C/^{13}C$ ratios of >100 with an abundance of about 1%.

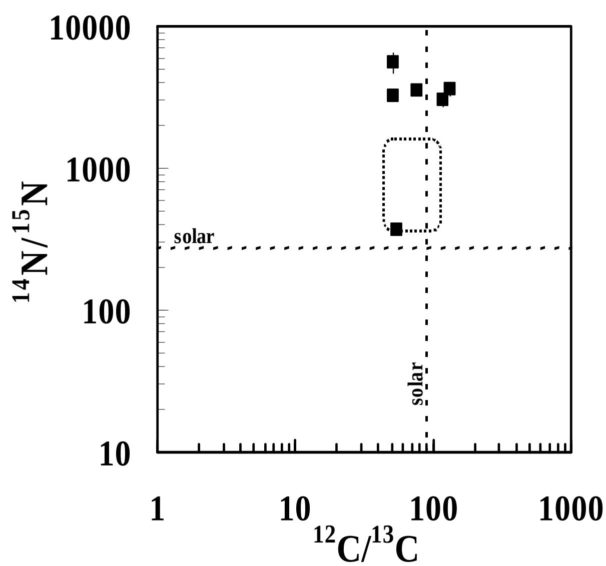

Figure 1: Nitrogen versus carbon in ALHA77307 SiC. Note log scales. Outlined region shows the distribution of Colony SiC grains [6, 7]. Dashed lines represent solar values. Errors are 2σ.

All of the SiC are ^{14}N-rich relative to solar. Five of the grains have $^{14}N/^{15}N$ ratios greater than 2000, while the other has a ratio of ~375 (Fig. 1). The ALHA77307 SiC grains have generally higher $^{14}N/^{15}N$ ratios than similar-sized Colony SiC grains [6]. The SiC grains have relatively homogeneous nitrogen isotopic compositions. However, one grain shows two distinct areas with nitrogen abundances differing by ~2X (Fig. 2). The $^{14}N/^{15}N$ and $^{12}C/^{13}C$ ratios in both areas are clearly non-solar with respective values of ~6000 and ~51.

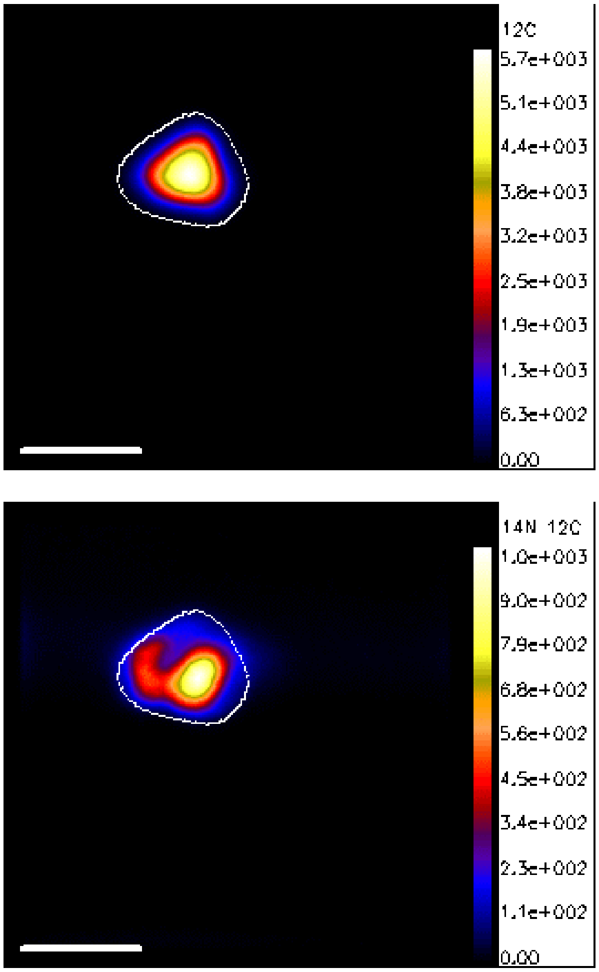

Figure 2: Spatial distribution of ^{12}C (top) and ^{14}N (bottom). See text for discussion on nitrogen distribution. Scale bar is 1 micron. The color bar on the right-hand side represents the number of counts in each pixel. The Region of Interest (white outline) is defined by all pixels with greater than 500 counts of ^{12}C. The ^{12}C background is 2.4 counts per pixel.

Discussion: Standard models of low-mass AGB stars predict $^{12}C/^{13}C$ ratios of 40–100 as first the ^{13}C-rich pocket at the base of the stellar envelope is brought to the surface during First Dredge-up and then ^{12}C is added from the helium shell during the many Third Dredge-up episodes [12]. Non-standard models that include the Cool Bottom Processing [13] or Hot Bottom Burning (in more-massive stars) [14] can produce lower $^{12}C/^{13}C$ ratios. High $^{12}C/^{13}C$ ratios may also indicate a massive-star source (e.g., type II supernova), due to a larger contribution from helium burning, but such grains should have low $^{14}N/^{15}N$ ratios [e.g. 15].

The nitrogen isotopic ratios measured in ALHA77307 overlap with those of other meteorites [3,4,6]. The high $^{14}N/^{15}N$ ratios of five of the grains imply low-mass stars that have experienced Cool Bottom Processing [e.g., 4]. The production mechanism for the low $^{14}N/^{15}N$ grain is currently not understood [e.g., 4, 15]. Nitrogen isotopes may also record the irradiation history of the host meteorite and of the precursor material [4, 6, 7]. Cosmic ray exposure lowers the $^{14}N/^{15}N$ ratio of ^{14}N-rich grains because ^{14}N and ^{15}N are produced in approximately the same abundance. The exposure ages of ALHA77307 and Colony are estimated to be ~24.7 Ma and ~11.7 Ma, respectively [16]. Thus, one would expect the average $^{14}N/^{15}N$ ratio of ALHA77307 SiC to be lower than that of Colony. Our current limited data show the opposite tendency, but further data will be required to rigorously evaluate this expectation.

The heterogeneous distribution of the nitrogen in one grain raises the question of the siting of N in SiC. This N heterogeneity has not been observed before, although SiC subregions enriched in ^{44}Ca and ^{48}Ti isotopes have been observed [17].

We plan to analyze additional SiC in ALHA77307 to determine whether grains with high $^{12}C/^{13}C$ ratios are as common as suggested by these data. Si isotopic data will also be collected to help constrain the possible origins of the grains. Excesses of ^{30}Si relative to ^{29}Si will show whether or not the high $^{12}C/^{13}C$ grains are type Y, which should make up ~1% of the SiC.

References: [1] Huss G.R. (1990) *Nature, 347*, 159-162. [2] Huss G.R. and Lewis R.S. (1995) *GCA, 59*, 115-160. [3] Hoppe P. et al. (1994) *Ap. J., 430*, 870-890. [4] Huss G.R. et al. (1997) *GCA, 23*, 5117-5148. [5] Huss G.R. et al. (2003) *GCA, 67*, 4823-4848. [6] Smith J.B. and Huss G.R. (2003) *LPS XXXIV*, #1729. [7] Smith J.B. and Huss G.R. (2003) *Meteoritics, 38, (7)* A118. [8] Huss et al. (1994) *LPS XXV*, 585-586. [9] Smith J.B. and Huss G.R. (2002) *LPS XXXIII*, #1789. [10] Huss G.R. et al. (1995) *LPS XXVI*, 645-646. [11] Jennings C.L. et al. (2002) *LPS LPS XXXIII*, #1833. [12] Busso M. et al. (1999) *Ann.Rev. Astron. Astrophys., 37*, 239-309. [13] Wasserburg G.J. et al. (1995) *Ap. J., 447*, L37-L40. [14] Boothroyd A.I. et al. (1995) *Ap. J., 422*, L21-L24. [15] Hoppe P. and Ott U. (1997) In *Astrophysical Implications of the Laboratory Study of Presolar Materials.* (Bernatowicz and Zinner, eds.) 27-58. [16] Scherer P. and Schultz L. (2000) *MAPS, 35*, 145-153. [17] Besmehn A. and Hoppe P. (2002) *Meteoritics, 37 (7),* A17.

Acknowledgments: Supported by NASA W-19,894 (IDH) and NAG5-11543 (GRH) and performed under the auspices of the Dept. of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.. The Antarctic Meteorite Curatorial Facility is thanked for providing the sample.