ALUMINUM-26 IN SUBMICROMETER-SIZED PRESOLAR SiC GRAINS. P. Hoppe[1], K. K. Marhas[1], R. Gallino[2], O. Straniero[3], S. Amari[4], and R. S. Lewis[5], [1]Max-Planck-Institute for Chemistry, Cosmochemistry Department, D-55020 Mainz, Germany (hoppe@mpch-mainz.mpg.de), [2]Dipartimento di Fisica Generale, Università di Torino, I-10125 Torino, Italy, [3]Osservatorio Astronomico di Collurania, I-64100 Teramo, Italy, [4]Laboratory for Space Sciences and Department of Physics, Washington University, St. Louis, MO 63130, USA, [5]Enrico Fermi Institute, University of Chicago, Chicago, IL 60637, USA.

Introduction: Among the presolar minerals identified to date, silicon carbide (SiC) is best studied [1-3]. A wealth of information on isotopic compositions of the major and many trace elements was obtained on individual grains > 0.5 µm in size. The new generation NanoSIMS ion microprobe makes it now possible to extend isotopic studies to smaller grains. First attempts in this respect were conducted by E. Zinner and co-workers [4, 5] who measured C-, N-, and Si-isotopic compositions of 0.25-0.65 µm-sized SiC grains from the Murchison (CM2) and Indarch (EH4) meteorites. We have extended the isotopic characterization of SiC in this size range to Mg-Al. Here, we report the results obtained for 23 grains from the Murchison separate KJB [6].

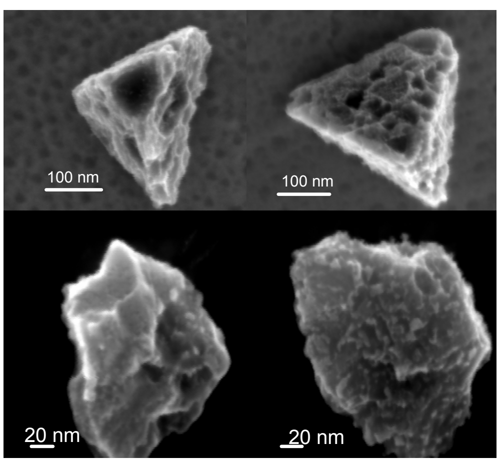

Figure 1. SiC grains from Murchison KJB.

Experimental: SiC grains from Murchison KJB were dispersed on gold foil. Typical grain sizes range from 150 to 350 nm (Fig. 1). Positive secondary ions of the Mg-Al isotopes were measured together with ^{28}Si in multi-detection with the NanoSIMS 50 ion microprobe at the Max-Planck-Institute for Chemistry. Individual SiC grains were identified in $^{28}Si^+$ ion images (20x20 µm^2), produced by rastering a focused O^- primary ion beam (~200 nm, ~10 pA) over three selected areas. Mg-Al-isotopic analyses were made by rastering the primary ion beam over areas of 0.8x0.8 µm^2 around the grains. Subsequently, we performed C-, N-, and Si-isotopic measurements in order to classify the SiC grains of this study. Twenty one of the grains which were measured for Mg-Al could be relocated. Data for 8 additional grains were also collected. 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 defocused (0.5-1 µm) or focused, but rastered (0.8x0.8 µm^2) Cs^+ primary ion beam (<1 pA). Because much of the grains was consumed during Mg-Al-isotopic analyses, analytical uncertainties are sometimes large, but still sufficient to do a classification.

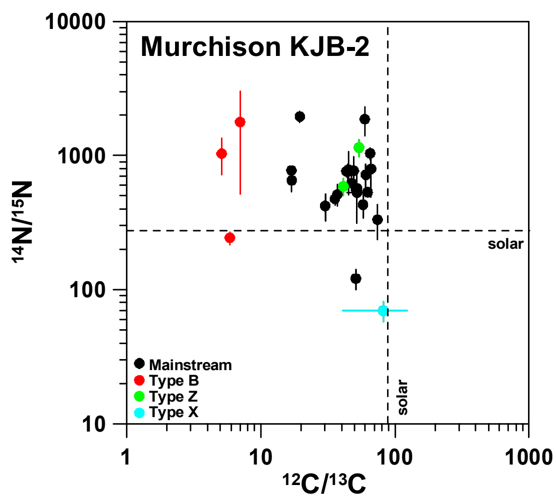

Figure 2. C- and N-isotopic compositions of presolar SiC grains from Murchison separate KJB.

Results: According to C-, N-, and Si-isotopic compositions 3 of the SiC grains analyzed for Mg-Al are of type B, 15 of the mainstream type, 1 of type X, and 2 of type Z (Figs. 2 and 3; for a classification of presolar SiC grains see [7]). Observed ranges of C-, N-, and Si-isotopic compositions fall within those previously observed for SiC grains of similar size [4, 5] as well as in the micrometer-size range [e.g., 8, 9].

The $^{25}Mg/^{24}Mg$ ratios of the KJB grains are normal within ~2σ. The mass-weighted average of $\delta^{25}Mg$ is -9±20 ‰. All grains exhibit large excesses in ^{26}Mg compared to its solar isotopic abundance which can be attributed to the decay of radioactive ^{26}Al (half life ~0.7 Ma). Aluminum concentrations range from about 1 wt% in the X grain to about 14 wt% in one of the B grains. Inferred $^{26}Al/^{27}Al$ ratios are between 0.0007 and 0.38 (Fig. 4). KJB mainstream and B grains have $^{26}Al/^{27}Al$ ratios that are higher by about a factor of 2 than those of typical micron-sized SiC grains [8]. Except the X grain and a two mainstream grain agglomerate, the highest $^{26}Al/^{27}Al$ ratios are found in the B grains. The Z grains have $^{26}Al/^{27}Al$ ratios at the lower end of the observed range. A rough negative correlation between $^{26}Al/^{27}Al$ and $^{12}C/^{13}C$ ratios is seen for the mainstream, Z, and B grains. The mass-weighted average $^{26}Al/^{27}Al$ ratio of 0.0036 is compatible with that measured in KJA/KJB bulk samples [10].

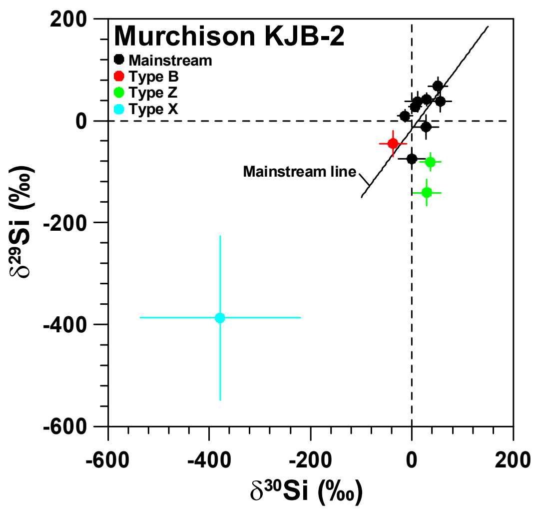

Figure 3. Si-isotopic compositions of presolar SiC grains from Murchison separate KJB. Data are only shown for grains with error < 30 ‰ (except the X grain).

Discussion: Our ^{26}Al data for submicron-sized SiC grains are qualitatively consistent with those of larger grains. A closer look, however, reveals two differences between the two data sets: (i) $^{26}Al/^{27}Al$ ratios of type B and mainstream grains are higher in submicron-sized grains. (ii) The negative correlation between $^{26}Al/^{27}Al$ and $^{12}C/^{13}C$ ratios is more pronounced for the smaller grains. This could be explained either by a contribution of contaminating Al in the study of larger grains or by different parent stars.

In 1-3 $M_{\odot}$ asymptotic giant branch (AGB) stars, the most likely stellar sources of mainstream and Z grains, ^{26}Al is produced in the H burning shell by the nuclear transformation of pre-existing ^{25}Mg and brought to the envelope with the third dredge-up events. Based on the AGB star models of Straniero and co-workers [11, 12], we have calculated $^{26}Al/^{27}Al$ ratios for different values of mass, metallicity, Reimer's parameter η for mass-loss, and amount of ^{13}C in the He intershell (^{13}C pocket). For $Z=Z_{\odot}$ the predictions for $^{26}Al/^{27}Al$ ratios in the envelope are between 0.001 and 0.004 when $^{12}C/^{13}C$ = 20-100, slightly higher than the predictions by [13] and in reasonable good agreement with the data for the KJB mainstream grains and the two Z grains (Fig. 4). $^{26}Al/^{27}Al$ does not vary systematically with metallicity, in agreement with the observation that Z grains have $^{26}Al/^{27}Al$ ratios in the range of the mainstream grains. Also, the ^{13}C pocket has only very little effect on the $^{26}Al/^{27}Al$ ratio. Higher stellar mass and/or lower mass loss result in lower $^{26}Al/^{27}Al$ ratios (Fig. 4).

The origin of type B grains is still a matter of debate [e.g., 14]. The higher $^{26}Al/^{27}Al$ and lower $^{12}C/^{13}C$ ratios compared to those in mainstream grains can be qualitatively understood in terms of a larger contribution of matter that experienced H burning.

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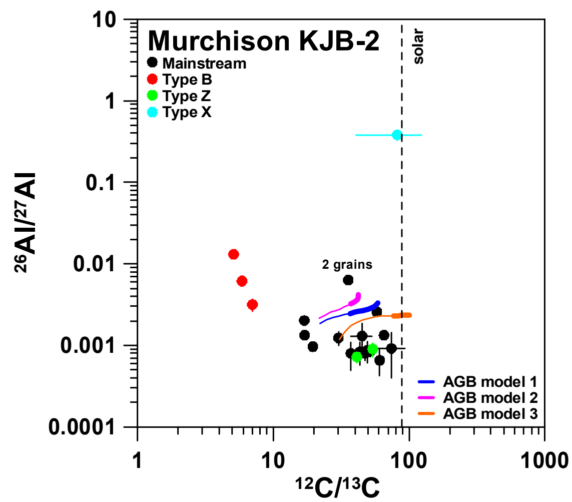

Figure 4. $^{12}C/^{13}C$ and inferred $^{26}Al/^{27}Al$ ratios of presolar SiC grains from Murchison separate KJB. AGB models: (1) $M = 1.5\ M_{\odot}$, $Z = Z_{\odot}$, η = 0.1; (2) as (1) but η = 0.3; (3) $M = 3\ M_{\odot}$, $Z = Z_{\odot}$, η = 1.5. The thick lines indicate C/O>1.

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] Zinner E. et al. (2001) *MAPS*, 36, A231. [5] Zinner E. et al. (2003) *MAPS*, 38, A60. [6] Amari S. et al. (1994) *GCA*, 58, 459. [7] Hoppe P. and Ott U. (1997) In *Astrophysical Implications of the Laboratory Study of Presolar Materials* (ed. T. Bernatowicz and E. Zinner), AIP, 27. [8] Hoppe P. et al. (1994) *ApJ*, 430, 870. [9] Nittler L. R. and Alexander C. M. O'D. (2003) *GCA*, 67, 4961. [10] Amari S. et al. (2000) *MAPS*, 35, 997. [11] Straniero O. et al. (1997) *ApJ*, 478, 332. [12] Straniero et al. (2003) *PASA*, 20, 389. [13] Forestini M. et al. (1991) *A&A*, 252, 597. [14] Amari S. et al. (2001) *ApJ*, 559, 463.