

ALUMINUM-26 IN SUBMICROMETER-SIZED PRESOLAR SiC GRAINS. P. Hoppe¹, K. K. Marhas¹, R. Gallino², O. Straniero³, S. Amari⁴, and R. S. Lewis⁵, ¹Max-Planck-Institute for Chemistry, Cosmochemistry Department, D-55020 Mainz, Germany (hoppe@mpch-mainz.mpg.de), ²Dipartimento di Fisica Generale, Università di Torino, I-10125 Torino, Italy, ³Osservatorio Astronomico di Collurania, I-64100 Teramo, Italy, ⁴Laboratory for Space Sciences and Department of Physics, Washington University, St. Louis, MO 63130, USA, ⁵Enrico 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 $> 0.5 \mu\text{m}$ 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].

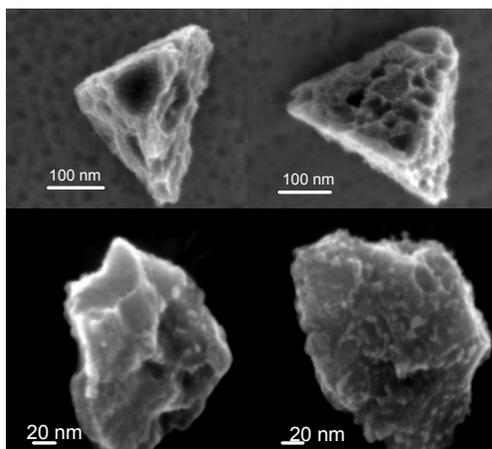


Figure 1. SiC grains from Murchison KJB.

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 $^{28}\text{Si}^+$ ion images ($20 \times 20 \mu\text{m}^2$), produced by rastering a focused O^+ primary ion beam ($\sim 200 \text{ nm}$, $\sim 10 \text{ pA}$) over three selected areas. Mg-Al-isotopic analyses were made by rastering the primary ion beam over areas of $0.8 \times 0.8 \mu\text{m}^2$ around the grains. Subsequently, we performed C-, N-, and Si-isotopic measurements in order to clas-

sify 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 , $^{12}\text{C}^{14}\text{N}$, $^{12}\text{C}^{15}\text{N}$, ^{28}Si , ^{29}Si , and ^{30}Si were measured in a combined multi-detection/peak-jumping mode using a defocused ($0.5\text{-}1 \mu\text{m}$) or focused, but rastered ($0.8 \times 0.8 \mu\text{m}^2$) Cs^+ primary ion beam ($< 1 \text{ pA}$). Because much of the grains was consumed during Mg-Al-isotopic analyses, analytical uncertainties are sometimes large, but still sufficient to do a classification.

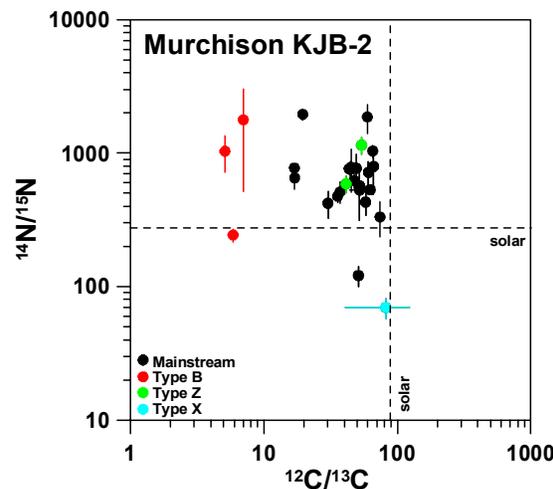


Figure 2. C- and N-isotopic compositions of presolar SiC grains from Murchison separate KJB.

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 $^{25}\text{Mg}/^{24}\text{Mg}$ ratios of the KJB grains are normal within $\sim 2\sigma$. The mass-weighted average of $\delta^{25}\text{Mg}$ is $-9 \pm 20 \%$. 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 $\sim 0.7 \text{ Ma}$). Aluminum concentrations range from about 1 wt% in the X grain to about 14 wt% in one of the B

grains. Inferred $^{26}\text{Al}/^{27}\text{Al}$ ratios are between 0.0007 and 0.38 (Fig. 4). KJB mainstream and B grains have $^{26}\text{Al}/^{27}\text{Al}$ 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 $^{26}\text{Al}/^{27}\text{Al}$ ratios are found in the B grains. The Z grains have $^{26}\text{Al}/^{27}\text{Al}$ ratios at the lower end of the observed range. A rough negative correlation between $^{26}\text{Al}/^{27}\text{Al}$ and $^{12}\text{C}/^{13}\text{C}$ ratios is seen for the mainstream, Z, and B grains. The mass-weighted average $^{26}\text{Al}/^{27}\text{Al}$ ratio of 0.0036 is compatible with that measured in KJA/KJB bulk samples [10].

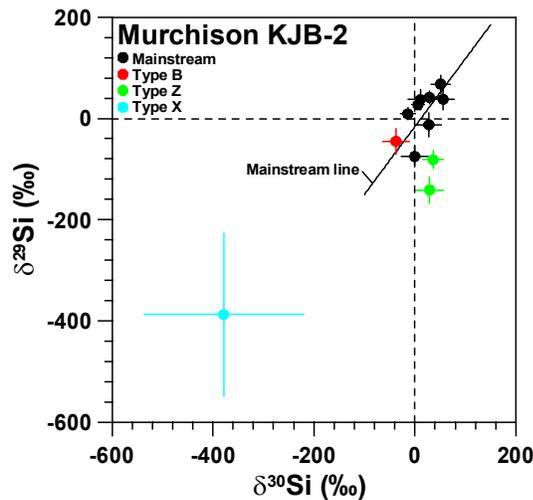


Figure 3. Si-isotopic compositions of presolar SiC grains from Murchison separate KJB. Data are only shown for grains with error $< 30\%$ (except the X grain).

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) $^{26}\text{Al}/^{27}\text{Al}$ ratios of type B and mainstream grains are higher in submicron-sized grains. (ii) The negative correlation between $^{26}\text{Al}/^{27}\text{Al}$ and $^{12}\text{C}/^{13}\text{C}$ 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 $^{26}\text{Al}/^{27}\text{Al}$ 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 $^{26}\text{Al}/^{27}\text{Al}$ ratios in the envelope are between 0.001

and 0.004 when $^{12}\text{C}/^{13}\text{C} = 20-100$, 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). $^{26}\text{Al}/^{27}\text{Al}$ does not vary systematically with metallicity, in agreement with the observation that Z grains have $^{26}\text{Al}/^{27}\text{Al}$ ratios in the range of the mainstream grains. Also, the ^{13}C pocket has only very little effect on the $^{26}\text{Al}/^{27}\text{Al}$ ratio. Higher stellar mass and/or lower mass loss result in lower $^{26}\text{Al}/^{27}\text{Al}$ ratios (Fig. 4).

The origin of type B grains is still a matter of debate [e.g., 14]. The higher $^{26}\text{Al}/^{27}\text{Al}$ and lower $^{12}\text{C}/^{13}\text{C}$ 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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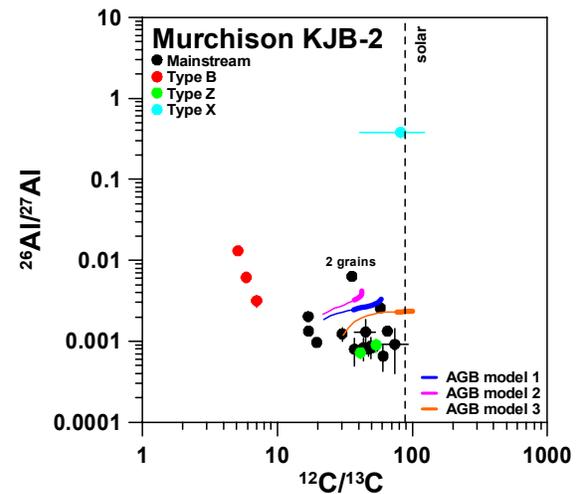


Figure 4. $^{12}\text{C}/^{13}\text{C}$ and inferred $^{26}\text{Al}/^{27}\text{Al}$ ratios of presolar SiC grains from Murchison separate KJB. AGB models: (1) $M = 1.5 M_{\odot}$, $Z = Z_{\odot}$, $\eta = 0.1$; (2) as (1) but $\eta = 0.3$; (3) $M = 3 M_{\odot}$, $Z = Z_{\odot}$, $\eta = 1.5$. The thick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

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