AUTOMATED SEARCH FOR RARE PRESOLAR SILICON CARBIDE FROM NOVAE AND OF TYPE A/B: A COMBINED ISOTOPIC STUDY OF SINGLE GRAINS WITH NANOSIMS AND NOBLE GAS MASS SPECTROMETRY.

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Introduction: Presolar silicon carbide (SiC) grains from novae are very rare. It is estimated that novae contribute only about 3 ‰ to the interstellar dust inventory [1]. So far, for only 8 presolar SiC grains a nova origin has been suggested [2,3]. Nova grains are characterized by low $^{12}C/^{13}C$ (<10) and $^{14}N/^{15}N$ (<20) ratios, higher than solar $^{30}Si/^{28}Si$ (most grains) and close to solar or lower than solar $^{29}Si/^{28}Si$. These signatures are qualitatively consistent with model predictions for ONe novae [4]. However, a recent investigation revealed supernova-produced isotopes in some of these samples, excluding a nova origin [3]. It is desirable to investigate whether this applies in general to grains to be considered nova grains. In addition to the nova grains, other grains with low $^{12}C/^{13}C$ ratios (< 10) are the A/B type SiC which comprise about 5% of all presolar SiC [5,6]. Most A/B type grains are thought to have originated from J-type carbon stars [5,6] or born-again AGB stars [7].

Here we report the first results of an automated search for single presolar SiC grains with low $^{12}C/^{13}C$ ratios with the NanoSIMS ion microprobe and new results of our first combined NanoSIMS and noble gas study [8]. Our major goal is to constrain the origins of the grains by measuring C-, N-, and Ne-isotopes and subsequently also radiogenic supernova isotopes (e.g. ^{26}Mg, ^{44}Ca). Noble gases are prominent nucleosynthetic products of all stellar sources considered for A/B type and nova grains, and serve as diagnostic isotopes in conjunction with the other isotopes measured.

Samples and Experimental: The SiC grains for the automated search were extracted from the carbonaceous chondrite Murchison using a standard procedure [9]. We have analyzed 643 presolar SiC grains in automatic mode with the Cameca NanoSIMS 50 ion microprobe at the MPI for Chemistry, Mainz. 110 additional grains from Murchison and Murray have been analyzed manually in the NanoSIMS and with IR laser noble gas extraction coupled to an ultra-high sensitivity mass spectrometer equipped with a compressor ion-source at ETH Zurich [10]. Manual analyses are described in [8].

The recently developed automated MPI ion imaging system for the NanoSIMS [11] has been customized for the search of A/B type and nova grains. Using a Leo 1530 SEM we mapped densely occupied areas on the sample mount, which was then transferred to the NanoSIMS. Synthetic SiC doped with N was used as a standard. The entire area selected for further analysis was presputtered in the NanoSIMS using a focused Cs^+ primary ion beam (~160 pA) in raster mode to remove surface contamination. The area of interest was divided into 50 µm square fields, where raster images (256 x 256 pixels) of negative secondary ions of ^{12}C, ^{13}C, $^{12}C^{14}N$, $^{12}C^{15}N$ and ^{28}Si, produced by a ~100 nm-sized Cs^+ beam (< 1 pA), were acquired simultaneously. Individual grains were automatically identified in the ion images using a particle recognition algorithm. The ion beam was rastered over an area twice the diameter of the grain to analyze each identified particle individually. Due to planned subsequent analyses of noble gases and radiogenic isotopes, integration time was minimized to 60 s per grain to reduce sample consumption. After all grains in one 50 µm square area have been analyzed, the sample stage was moved to start investigation of neighboring fields.

We consider grains with $^{28}Si^-/^{12}C^-$ ratios of 0.75 ± 0.5 to be SiC, taking into account surface contamination. Using a SEM-manipulator we will transfer grains of interest individually from the densely populated sample mount to an empty mount to achieve sufficient sample spacing as required for IR laser noble gas extraction of single grains.

Results: From more than 800 automatically analyzed particles we identified 643 SiC grains. The $^{12}C/^{13}C$ ratios range from 3.7 to 420, the $^{14}N/^{15}N$ ratio varies from 26 to 1400 (Fig. 1). As measurement times were kept short, both C- and particularly N-isotopic ratios may be affected by contributions from terrestrial contamination. Seven grains have $^{12}C/^{13}C$ ratios < 10 and classify univocally as type A/B. We also consider additional 10 grains with $^{12}C/^{13}C$ ratios

< 15 likely to be of type A/B, considering surface contamination with terrestrial carbon. The fraction of A/B type grains found is 2.6 %.

The $^{12}C/^{13}C$ and $^{14}N/^{15}N$ ratios of the 110 manually analyzed grains range from 3.4 to 113 and from 45 to 705, respectively. In this subsample we found 5 A/B type grains, 4 from Murchison and 1 from Murray, representing a fraction of 4.5 %. For the first time we measured noble gases in individual A/B type grains. Preliminary results of this subsample have been presented in [8]. Here we reconsider these data based on an improved data reduction. Of the samples from Murchison one SiC grain (SiC070) contains considerable amounts of ^{22}Ne ((11.45 ± 0.27) 10^{-14} cm^3 STP) and ^{4}He ((681.2 ± 2.9) 10^{-14} cm^3 STP), 2 SiC contain ^{4}He with no ^{22}Ne above our detection limit ((2.2 to 7.0) 10^{-15} cm^3 STP). One A/B type grain from Murchison and one from Murray do not contain any noble gases above detection limit.

Discussion and Conclusion: *A/B type grains.* Born-again AGB stars are characterized by low $^{12}C/^{13}C$ ratios and enrichments in s-process elements [7]. One can assume that s-process element enhancements are positively correlated with ^{4}He and ^{22}Ne amounts, hence favoring born-again AGB stars as the stellar sources for the 3 noble gas-rich grains of type A/B. Likewise, the 2 gas-poor grains stem plausibly from J-type C stars, which have low $^{12}C/^{13}C$ ratios in their envelopes [5,6]. For the 17 A/B grains found in the automated search we cannot yet discern between the two sources.

Nova grains. None of our grains with low $^{12}C/^{13}C$ ratios has $^{14}N/^{15}N$ ratios as low as the previously found nova grains [2,3]. However, one grain from Murchison (SiC 070) classified as type A/B, which we found in our initial work, has C-, N-, Si- and Ne-isotopic compositions which are qualitatively consistent with model predictions [4] for a CO nova occurring on a low mass white dwarf (see Table 1). However, as no data on radiogenic isotopes are available for this grain, a supernova origin must be considered an alternative possibility in view of the finding by [3]. Grain MuriVII e6-19 found during the automated search shows C- and N-isotopic compositions, which are qualitatively compatible with the same nova model. Noble gases from this grain have not been measured yet, hence its case as a nova grain needs confirmation. The measurements of Mg, Ca, and the noble gases should allow us to decide whether this grain formed in a nova, a supernova, or in unusual carbon stars.

The automated search and analysis method presented here has proven to be an efficient and reliable approach to find and investigate rare SiC grains out of a large sample. We expect to find more very rare nova grain candidates and eventually will determine whether they are truly from novae or are rather supernova condensates.

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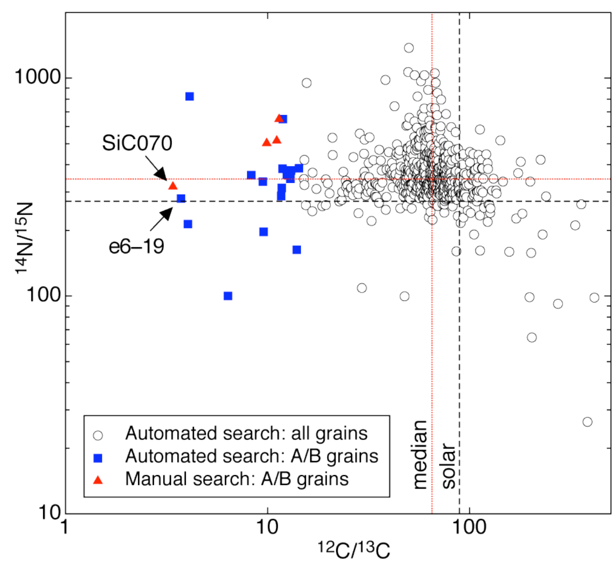

Figure 1. $^{12}C/^{13}C$ and $^{14}N/^{15}N$ ratios for presolar SiC analyzed in this study. A/B type grains: solid symbols. Nova grain candidates: arrowed solid symbols. Analytical errors of $^{12}C/^{13}C$ and $^{14}N/^{15}N$ ratios of A/B type grains are < 1 to 5 %.

Ratio	SiC070	e6-19	Model [4]
$^{12}C/^{13}C$	3.4±0.1	3.7±0.1	0.5 – 2
$^{14}N/^{15}N$	317±18	280±8	100 - 1400
$^{20}Ne/^{22}Ne$	< 0.36	n. a.	0.18 - 0.53

Table 1. Comparison of the two nova grain candidates with model predictions [4] of a nova with a CO white dwarf < 1 M_{solar}. The $^{12}C/^{13}C$ and $^{14}N/^{15}N$ ratios of the samples are possibly shifted towards the terrestrial values due to terrestrial contamination. 1σ analytical errors are shown.