NEON-22, OXYGEN-18, AND ALUMINUM-26 EXCESSES IN SINGLE PRESOLAR GRAPHITE GRAINS FROM MURCHISON: A COMBINED RARE GAS AND NANOSIMS STUDY.

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Introduction: A Ne component, highly enriched in ^{22}Ne, named Ne-E(L), was discovered by [1]. Its carrier was later found to be presolar graphite [2]. Noble gas studies of presolar graphite from Murchison [3] revealed that Ne-E(L) consists of radiogenic ^{22}Ne (from the decay of ^{22}Na: Ne-R) and of a minor contribution of AGB star He-shell Ne (G component) (see, e.g., [4]). Helium and Ne analyses in single graphite grains from Murchison were pioneered by [5]. They discovered that in the density fraction KFB1 from Murchison 30% of the graphite grains contained measurable amounts of ^{22}Ne, while none of them contained ^{20}Ne, ^{21}Ne or ^{4}He above detection limit.

Here we investigate He and Ne isotopes in individual graphite grains from KFB1 using a recently developed procedure for noble gas analysis of single presolar SiC grains [6]. One of our major goals was to determine the fraction of grains containing measurable amounts of ^{22}Ne, and to investigate whether ^{4}He can be detected. Together with isotopic data of C, O, and Mg-Al we can constrain the stellar sources of the grains.

Samples and Experimental: Graphite was extracted from Murchison using acid dissolution [3]. Graphite grains from KFB1 (2.10–2.15 g/cm^{2}) were mounted on Au-foil and imaged in the SEM. ^{12}C^{-}, ^{13}C^{-}, ^{16,18}O^{-}, ^{28}Si^{-} ions from 134 selected grains were analyzed in the St. Louis NanoSIMS using a primary Cs^{+} beam. 29 of these presolar graphite grains (1.5 to 7.1 µm) were measured for He and Ne in Zürich according to the procedure developed for single presolar SiC grains [6] using a pump to compress the gas into the ion-source [7]. Due to high spectrometer memory the first measurement session had detection limits comparable to [5]. The second session yielded ~2x better detection thresholds (Fig. 1).

After noble gas analysis, we investigated the samples in the SEM in Mainz to observe whether they had been completely melted and to control whether neighboring graphite grains remained unaffected by the laser beam. On 13 melt residues we performed analyses of ^{24,25,26}Mg^{+} and ^{27}Al^{+} with the Mainz NanoSIMS in multicollection mode using a primary O^{-} beam.

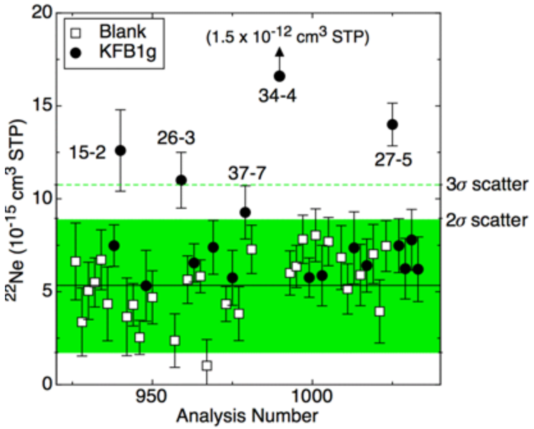

Figure 1. ^{22}Ne gas amounts of blanks and presolar KFB1g graphite grains of measurement session 2 after memory and background correction. 2σ blank scatter is indicated by the shaded region and is defined as the detection limit (3.6 x 10^{-15} cm^{3} STP), the solid line represents the average blank value. ^{22}Ne-rich grains are labeled. Errors are 1σ (applies to all figures).

Results: In the two sessions we found 1 out of 9, and 5 out of 20 grains, respectively, with detectable amounts of ^{22}Ne (Fig. 1). No grain had ^{4}He above detection limit. The fraction of ^{22}Ne-rich grains found is similar to that reported by [5]. Inspection by SEM revealed that in all but one case neighboring grains were unaffected by laser-heating. The gas amounts detected in grain 34-4 of (1.5±0.3 x 10^{-12} cm^{3} STP ^{22}Ne) were far higher than in any other grains but might contain gas from neighboring grain 34-3 which shows signs of melting. This grain was so gas-rich that even ^{20}Ne was above detection limit and allowed us to determine a ^{20}Ne/^{22}Ne ratio (0.052±0.014). For the other ^{22}Ne-rich grains in session 2 we determined upper limits of ^{20}Ne/^{22}Ne ranging from 0.3 to 0.7, and for ^{4}He/^{22}Ne from 0.2 to 40. We find a correlation of decreasing ^{22}Ne-concentration with increasing grain size. ^{12}C/^{13}C ratios range from ~10 to 1300, ^{16}O/^{18}O ratio range from ~300 to 550 (Fig. 2). We find clear evidence for ^{26}Mg excesses >3σ in 3 of 13 melt residues, which can be attributed to the decay of ^{26}Al. Inferred ^{26}Al/^{27}Al ratios are between 0.12 and 6.8 x 10^{-3} (Fig. 3) For 6 other melt residues we calculated upper limits on ^{26}Al/^{27}Al ratios (up to 5.9 x 10^{-3}).

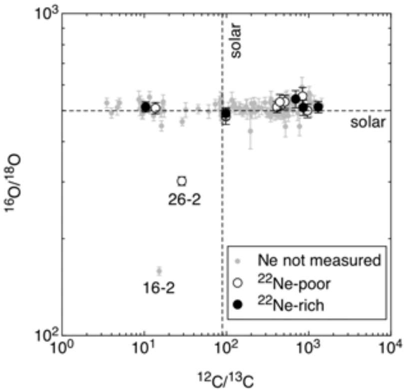

Figure 2. ^{16}O/^{18}O ratios vs. ^{12}C/^{13}C ratios of ^{22}Ne-rich and ^{22}Ne-poor graphite grains together with isotopic data of graphites not analyzed for noble gases.

Discussion and Conclusions: The O-isotopic signature of the graphites agrees with results from previous studies [e.g. 8]. The inferred ^{26}Al/^{27}Al ratios are in the lower range of values observed in a larger number of KFB1 graphites [8]. This might be due to contamination during laser heating by material from the Au-foil, which presumably contains some Al.

Ne-E(L) has first been attributed to have a nova origin [9], since ^{22}Na is a prominent product of novae. The Ne-isotopic composition of our ^{22}Ne-rich graphite grains (^{20}Ne/^{22}Ne << 10) is, however, inconsistent with recent model predictions for ONe novae (^{20}Ne/^{22}Ne = 90 – 2890, [10]) if we invoke Ne implantation. However, considering trapped ^{22}Na without Ne implantation, a nova origin is not contradictory to the Ne grain data.

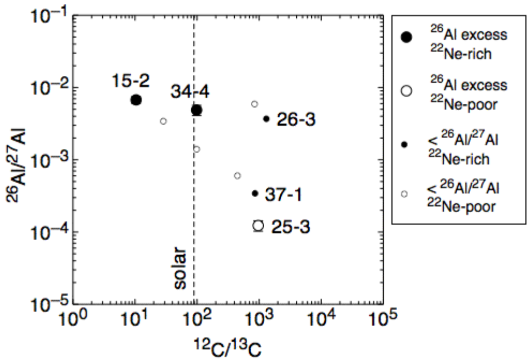

Figure 3. Inferred ^{26}Al/^{27}Al ratios vs. ^{12}C/^{13}C ratios of melt residue of ^{22}Ne-rich and ^{22}Ne-poor KFB1g graphite grains. Upper limits of ^{26}Al/^{27}Al ratios are given if the ^{26}Mg excess was < 3σ.

For the one grain (34-4) with known ^{20}Ne/^{22}Ne ratio and ^{12}C/^{13}C=98.2 we also consider a CO nova origin unlikely (^{12}C/^{13}C=0.3–1.8; [10]). In case the Ne would stem from neighboring grain 34-3 a nova origin would be even more unlikely due to its much higher ^{12}C/^{13}C ratio (546). 34-4 also has ^{26}Al and its origin can be most readily explained by a supernova (SN), since its noble gas composition tends to exclude an AGB star parent. Although the low ^{20}Ne/^{22}Ne is consistent with pure AGB He-shell material [6], the absence of detectable ^{4}He might be an indication that we observe Ne-R. However, we cannot exclude that ^{4}He has been lost more readily than in SiC before analysis in this and other graphite grains. Four other grains have ^{12}C/^{13}C ratios <5 and ^{16}O/^{18}O ratios close to solar (Fig. 3), while another 17 grains have ^{12}C/^{13}C ratios <20 and ^{16}O/^{18}O ratios between ~450 and 550; including ^{22}Ne-rich grain 15-2 with the highest ^{26}Al/^{27}Al ratio, (6.8±0.8) x 10^{-3}, of our samples. This is consistent with model predictions of ^{26}Al/^{27}Al ratios in CO novae (0.006 to 0.6; [10]). The grains with ^{12}C/^{13}C<20 are qualitatively consistent with predictions for some CO nova models [10] considering some reasonable contamination with solar material.

Two samples display prominent enrichment in ^{18}O (Fig. 3): 26-2 (upper limit of ^{20}Ne/^{22}Ne<0.5) and 16-2 (noble gases not measured). Their heavy O is a hint for a possible SN origin. The comparatively low ^{12}C/^{13}C ratios of the two ^{18}O-rich grains can be qualitatively explained by the existence of a ^{13}C-rich layer produced by rotation-induced mixing in some SN precursors [11,12]. The ^{22}Ne, without any accompanying ^{4}He, is most likely radiogenic (Ne-R) from the decay of ^{22}Na which is predicted to be produced in SNe.

Other possible origins of ^{22}Ne-rich presolar grains are stellar winds of post-AGB stars (G component) and Wolf-Rayet (WR) stars [6,13]. Due to the high abundance of He in their winds (^{4}He/^{22}Ne-G=108–591 [6]; WR star ^{4}He/^{22}Ne~165 [13]) one would expect to find coexisting implanted ^{4}He, in contrast to our findings. The upper limits of the ^{4}He/^{22}Ne ratios determined for 18 grains are lower than expected from the modeled G component predictions and they are also lower than ratios measured in most mainstream SiC grains [6]. This makes a post-AGB or WR star origin unlikely. More data needs to be acquired to investigate whether there is a difference in isotopic compositions between gas-rich and gas-poor grains.

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