HE-4 AND NE-22 IN INDIVIDUAL HIGH-DENSITY PRESOLAR GRAPHITE GRAINS FROM THE MURCHISON METEORITE.

M. M. M. Meier[1] P. R. Heck[2], S. Amari[3], H. Baur[1], R. Wieler[1], [1]Departement of Earth Sciences, ETH Zurich, Clausiusstrasse 25, CH-8092 Zurich, Switzerland (meier@erdw.ethz.ch). [2]Chicago Center for Cosmochemistry and Dept. Geophysical Sciences, University of Chicago, 5734 South Ellis Avenue, Chicago, IL 60637, USA. [3]Laboratory for Space Sciences and the Physics Department, Washington University in St. Louis, Campus Box 1105, One Brookings Drive, St. Louis, MO 63130, USA.

Introduction: We have analyzed the light noble gas content of 18 individual presolar graphite grains from the Murchison KFC1 high-density (2.15-2.20 g/cm^3) fraction, as part of our ongoing investigation of the noble gas content of individual presolar SiC and graphite grains. The major goal of this work is to identify the stellar sources of these grains (possible sources include Asymptotic giant branch (AGB) stars, born-again AGB stars, J-type carbon stars, novae and supernovae). We analyze presolar graphite grains for which the C and Si isotopic composition is known. Noble gases in graphite from the KFC1 fraction have been analyzed before by [1]. They found significant amounts of nucleosynthetic and radiogenic ^{22}Ne, Ne-G and Ne-R respectively, above their detection limit in only 3 out of 46 (7%) of the analyzed grains. This is a surprisingly small fraction, since other density-separates of Murchison graphite yielded a higher percentage of gas-rich grains. In lower-density KFB1, 22% (11 out of 51) [2] to 28% (14 out of 49) [3] of all presolar grains are gas-rich.

Samples and Methods: The presolar graphite of the KFC1 density fraction used in this work was prepared and mounted on an ultra-clean Au foil. The presolar grains were imaged in a scanning electron microscope (SEM) and subsequently analyzed for their C and Si isotopic composition with the NanoSIMS ion microprobe in St. Louis to help with the identification of stellar sources. Eighteen KFC1 graphite grains have so far been analyzed for He and Ne isotopes at ETH Zurich. The noble gases were extracted using a Nd-YAG infrared laser (λ = 1024 nm) that was fired onto the grain for about 20 seconds (only grains with >50 µm distance to their neighbors were selected to avoid cross-heating). Using a video camera, a successful extraction manifests itself as a short light-pulse. Because of the very small noble gas amounts expected from the individual graphite grains, we used a low-blank extraction line and an ultra-high-sensitivity mass spectrometer that concentrates the sample gases almost quantitatively into the ion source of the mass spectrometer [4]. Presolar grain measurements were bracketed with blank measurements. Interfering species (H_2O, ^{40}Ar, CO_2) were monitored and were found to have a negligible contribution to the neon isotope signals. Our detection limits (defined by two standard deviations of the mean of all 32 blank measurements, see [5]) for ^{4}He, ^{20}Ne, ^{21}Ne and ^{22}Ne, in units of 10^{-15} ccSTP were 580, 31, 0.71 and 4.9 respectively (see Figs. 1 and 2).

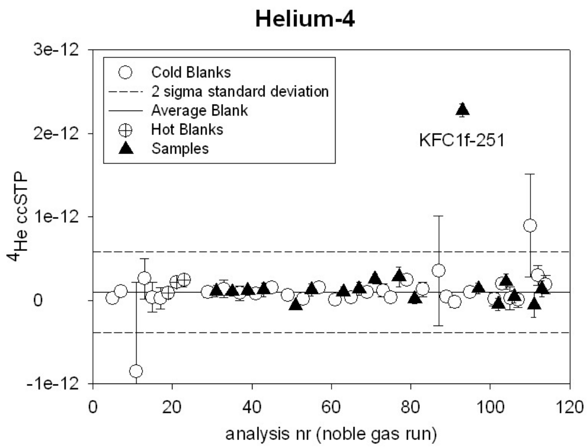

Figure 1: *^{4}He amounts in 32 cold blanks, 3 hot blanks and 18 KFC1 graphite samples. Error bars are 1 sigma and are based on counting statistics. The dashed line represents the detection limit for ^{4}He at ~5.8 × 10^{-13} ccSTP.*

Results: We have detected He or Ne in two out of 18 presolar graphite grains. We report the first detection of ^{4}He in a single graphite grain of the KFC1 density fraction (grain KFC1f-251, d=3.06 µm, ^{12}C/^{13}C=699.2±6.2, δ^{29}Si = -6±15, δ^{30}Si = -7±18). The measured ^{4}He amount is 2.27(±0.8) × 10^{-12} ccSTP (Fig. 1), corresponding to a concentration of 6.96 × 10^{-2} ccSTP/g. The grain showed no significant amounts of any Ne-isotope within 2 sigma, although the ^{20}Ne and ^{21}Ne amounts for this grain (2.8 × 10^{-14} ccSTP and 5.1 × 10^{-16}, respectively) are significant on the one sigma level. If we were to accept this ^{20}Ne amount as real, a ^{20}Ne/^{22}Ne-ratio of >7.2 would result. A lower limit of the ^{4}He/^{22}Ne-ratio is ~595. A second gas-rich grain was identified (KFC1f-302, d=3.47 µm, ^{12}C/^{13}C=103.5±0.6, δ^{29}Si = -4±17, δ^{30}Si = -25±20), showing a clear ^{22}Ne-excess (Fig. 2) of 3.1(±0.3) × 10^{-14} ccSTP (6.63 × 10^{-3} ccSTP/g). Neither ^{4}He nor any other Ne isotope was detected for this grain. The ^{20}Ne/^{22}Ne-ratio from detection limits for this grain is <0.15, the ^{4}He/^{22}Ne-ratio is <5.4.

Discussion: Based on the ^{12}C/^{13}C-ratios of all analyzed grains except for the gas-free grain KFC1f-036, a born-again AGB star, a J-type carbon star and a nova origin can be excluded. The two remaining plausible stellar sources for the analyzed grains are AGB stars and supernovae. In the following we will discuss the origin of the two gas-rich grains.

Ne-22-rich grain KFC1f-302: The fraction of ^{22}Ne-rich KFC1 grains (1 out of 18, or ~6%) observed by us is just as low as the fraction of 7% observed by [1] in KFC1 graphite grains, confirming their finding. The observed ^{22}Ne-concentration in grain KFC1f-302 is also similar to the concentrations they observed (5.1 – 75 × 10^{-4} ccSTP/g). From the upper limit of <0.15 on the ^{20}Ne/^{22}Ne-ratio of the ^{22}Ne-rich grain KFC1f-302 alone, we cannot distinguish between Ne-G and Ne-R, the two components of Ne-E(L). Unfortunately, the C and Si isotope ratios of this grain are inconclusive on the question of an AGB star or supernova origin.

He-4-rich grain KFC1f-251: No ^{4}He has been found in any of the 46 individual graphite grains analyzed in the first single grain KFC1 study [1]. He-4 excess in an individual presolar KFB1 graphite grain has been observed recently by [2], together with ^{20}Ne and ^{22}Ne. Note that helium by itself is usually not considered very diagnostic in presolar grains, as it is thought to be easily lost by diffusion and heating [2].

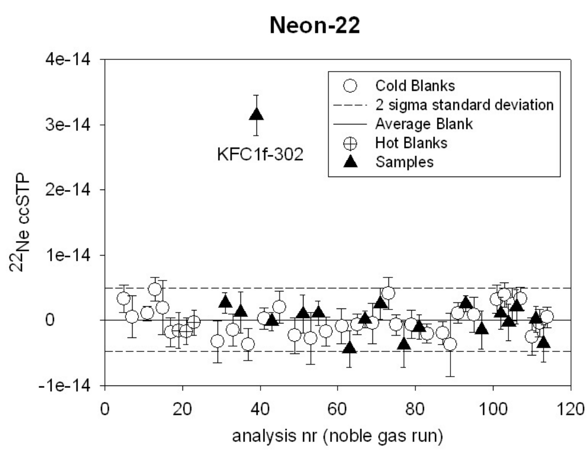

Figure 2: *^{22}Ne amounts in 32 cold blanks, 3 hot blanks and 18 KFC1 graphite samples. Error bars are 1 sigma and are based on counting statistics. The dashed line represents the detection limit for ^{22}Ne at 4.9 × 10^{-15} ccSTP.*

The high ^{4}He/^{22}Ne-ratio of >595 as observed in grain KFC1f-251 is compatible with a He shell origin in a 1/3 solar metallicity, 2-3 solar mass AGB star [5]. In this scenario, the graphite grains form in the cool envelope of the AGB star, inheriting its high ^{12}C/^{13}C-ratio. During the post-AGB phase, He and Ne from the exposed He shell are then implanted by fast stellar winds [7]. As mentioned in the result section, an amount of 2.8 × 10^{-14} ccSTP ^{20}Ne (significant only when using a one – instead of two – sigma detection limit) was detected in this grain. If we assume this amount to be real, the lower limit for the ^{20}Ne/^{22}Ne-ratio is 7.2, which would exclude the He shell of a low-mass AGB star, where ^{20}Ne/^{22}Ne is <0.1 [5]. A high ^{20}Ne/^{22}Ne ratio would be more indicative of the carbon-burning region of a massive star of 8-10 solar masses [8]. But as this region is depleted in He, another source for the observed He is needed.

Comparison with bulk data: From the measured gas amounts, a concentration of ~2.9 × 10^{-5} ccSTP/g Ne-E(L) for bulk KFC1 material can be calculated (total analyzed presolar graphite mass: ~1.1 × 10^{-9} g), a value that agrees within a factor of 2 with the bulk value given in [6] and within a factor of 3 with the value calculated by [1]. If all graphite grains analyzed in this work contained ^{22}Ne just below the detection limit, this would amount to a total of ~7.5 × 10^{-5} ccSTP/g, higher than the bulk values from [6]. We can therefore assume that at least ~60% of all the ^{22}Ne in KFC1 is located in gas rich grains. The ^{4}He concentration for bulk KFC1 is ~2.1 × 10^{-3} ccSTP/g, but unlike ^{22}Ne, this value cannot be compared with [6] or [1] as no ^{4}He bulk concentration of KFC1 residue is given therein. It can be compared with the implied bulk content of KFB1, though, as ^{4}He was found in a single presolar graphite grain from KFB1 by [2]. Using the data given there, we calculate a ^{4}He bulk concentration of ~1.3 × 10^{-4} ccSTP/g for KFB1 (total analyzed presolar graphite mass: ~1.8 × 10^{-9} g), or about 16 times lower than observed by us for KFC1. Additional work is needed to tell whether this difference results from poor statistics or from a fundamental difference in the ^{4}He bulk content of KFC1 and KFB1 graphite grains.

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