PRESOLAR NEON AND HELIUM EXPOSURE AGES OF JUMBO PRESOLAR SIC GRAINS (LS+LU) FROM MURCHISON.
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Introduction: The time between formation of presolar grains around stars and their incorporation into planetesimals in the early solar system is poorly constrained. Neon-21 exposure-ages of µm-sized presolar SiC bulk samples [1–2] have been invalidated due to recoil loss of cosmogenic ^{21}Ne (revised ^{21}Ne recoil length ~2 µm, [3]). Its shorter recoil length makes Xe more suitable for exposure age determinations of small grains [4]. Ott et al. [4] thus suggested average Xe exposure ages of presolar SiC bulk separates to be a few 10 Myr or less, much lower than expected lifetimes of interstellar dust of ~500 Myr [5]. A large fraction of "young" grains was suggested [4] to be in line with a starburst origin of the parent stars of SiC mainstream grains ~1-2 Gyr before solar system formation [6]. Recently, presolar exposure ages of 24 to ~1200 Myr for very large single grains from the Murchison LS+LU fraction have been estimated from ^{6}Li excesses measured in the NanoSIMS [7,8]. In these very large grains, Ne recoil loss is of minor importance. Here, we thus determine presolar Ne and He exposure ages in single SiC grains from the LS+LU fraction.

Samples and Experimental: Very large "Jumbo" SiC grains (ø < ~50 µm; ρ = ~3.2 g/cm^3) were extracted from the meteorite Murchison by acid-dissolution and density separation [9] in Chicago. The grains were deposited on a Au-foil mount with a micromanipulator and pressed into the Au with a quartz disk. The grains were imaged in the SEM and identified as SiC with EDX. The C and Si isotopic compositions were analyzed with the St. Louis NanoSIMS by multicollection of ^{12,13}C$^-$, ^{28,29,30}Si$^-$ secondary ions. Noble gases from 22 grains (ø mostly ~10–50 µm) were measured in Zurich using a slightly modified procedure developed for single µm-sized presolar SiC grains [10]. Grains were melted with an IR laser. He and Ne isotopes were detected in an ultra-high sensitivity mass spectrometer [11]. Detection limits were comparable to those of previous studies (^{21}Ne = 2.26 x 10^{-16} cm^3; ^{3}He = 2.75 x 10^{-16} cm^3 STP). Grain volumes were estimated from SEM images. The resulting mass uncertainty is estimated to be a factor of 2. Interstellar production rates of ^{21}Ne and ^{3}He in SiC were taken from Reedy [12] and are estimated to be uncertain by at least a factor of 1.6. Considering also ^{21}Ne recoil losses of up to ~20% (see below), absolute ^{21}Ne exposure ages may thus be uncertain by a factor of 3, but production ratios ^{3}He/^{21}Ne should be much better constrained.

Results and Discussion: 19 out of 22 large SiC grains contained detectable amounts of either cosmogenic ^{21}Ne or ^{3}He, or both. The cosmogenic ^{21}Ne has been corrected for a nucleosynthetic ^{21}Ne contribution of <20% according to nucleosynthetic ^{22}Ne determined from Fig. 1 (see below). ^{21}Ne cosmic ray exposure ages (T_{21}) for 10 grains range from ~13 to 106 Myrs, whereas the largest grain (~50 µm) has a high ^{21}Ne age of ~480 Myr. Upper limits of T_{21} for 6 further grains range from ~3 to 150 Myrs. Ages are not recoil corrected. From [3] we estimate the ^{21}Ne$_{cos}$ recoil loss to be <20% for our samples, smaller than other uncertainties. The T_{21} age range is broadly in agreement with ^{6}Li ages [8] of other grains from the LS+LU separates, (also not recoil-corrected), although Ne-ages tend to be lower than Li-ages. We thus conclude that some of the large SiC grains have exposure ages as low as suggested by Ott et al. [4], whereas others approach estimates of interstellar grain lifetimes.

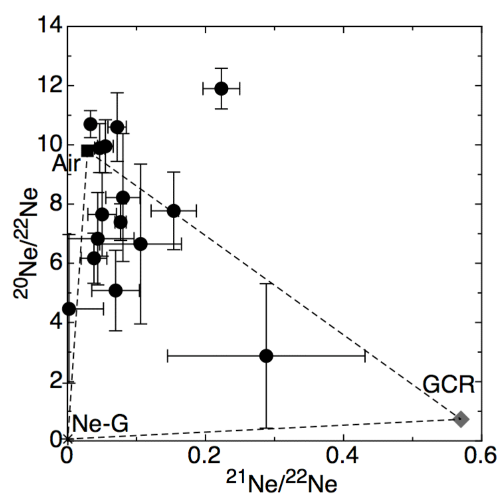

Figure 1. Three isotope diagram showing the measured Ne isotopic compositions of Jumbo presolar SiC grains. The gas consists of a large Ne blank from the Au foil ("Air"), intrinsic AGB star He-shell Ne-G [10] and interstellar cosmogenic Ne ("GCR" [12]). Despite the large air-Ne contribution, nucleosynthetic ^{22}Ne and cosmogenic ^{21}Ne can be derived from the measured data.

The ^{3}He cosmic ray exposure ages (T_3) for 18 grains range from ~3 to 92 Myrs, and a few grains display essentially identical T_3 and T_{21} (Fig. 2). This is surprising, since the expected recoil length of even the lowest-energy (~7 MeV) $^3He_{cos}$ nuclei [13] should be almost 40 µm [14], larger than the longest dimension of almost all grains (while recoil lengths of the ^{3}H precursor are even considerably larger). Therefore, almost all grains should show much lower ^{3}He ages than ^{21}Ne ages, whereas such a discrepancy is actually observed just for the largest grain, for which it might be least expected. A rough trend of increasing T_3/T_{21} with grain size (apart from the largest grain) probably indeed reflects preferential recoil loss of ^{3}He. However, unless actual recoil lengths of ^{3}H and ^{3}He are much lower than reported values [14,15], the high ^{3}He concentrations of most grains require another explanation. A non-cosmogenic origin of the ^{3}He is very unlikely since i) almost all data points fall within uncertainty on the left of the 1:1 line in Fig. 2 and ii) in Fig. 2 we only consider grains with $^3He/^4He$ ratios considerably higher than any conceivable trapped He composition. Recoiled cosmogenic ^{3}He from Murchison matrix acquired during the meteoroid stage is also negligible. A possible explanation is that during their presolar life the grains were considerably larger than what we observe today. The morphology of some grains appears not to be consistent with them being fragments of even larger grains, however. We thus speculate that grains might have been coated with icy or organic mantles during much of their interstellar journey. Although mantles seem to grow rather slowly and remain thin even in dense molecular clouds [16], they might help in the formation of grain agglomerates [5] large enough (>100 µm) to retain a sizeable fraction of the $^3He_{cos}$.

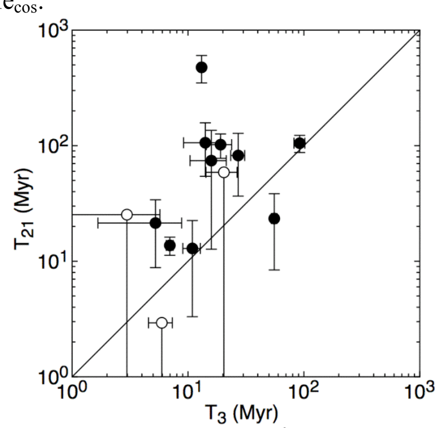

Figure 2. Ne-21 ages (T_{21}) vs. ^{3}He ages (T_3) of 13 presolar SiC grains in which cosmogenic ^{21}Ne and ^{3}He were detected (open symbols = upper limits). T_{21} have been corrected for contributions of AGB star He-shell material (<20%). Error bars are 1σ. They include analytical uncertainties and uncertainties for He-shell corrections. Ages have not been corrected for recoil loss (<20% for T_{21}).

In contrast to previous studies of µm-sized grains [10] we detected no pure nucleosynthetic isotopic signatures (e.g., Ne-G; Fig. 1). This is due to the relatively high Au foil blank with terrestrial atmospheric composition. Nevertheless, nucleosynthetic ^{22}Ne amounts in the grains can be estimated from Fig. 1.

The LS+LU grains contain similar amounts of He- and Ne-G per grain as the much smaller SiC grains measured earlier [10]. This is surprising since one would expect the amounts of He-shell material implanted during the post-AGB phase to be surface correlated [10].

The C- and Si-isotopic ratios ($^{12}C/^{13}C = 3 – 90$; $\delta^{30}Si = -21 – 116$; $\delta^{29}Si = -48 – 156$) classify most grains as mainstream SiCs originating from different low- to intermediate mass AGB stars with solar or close to solar metallicities. Most grains have $^{12}C/^{13}C$ ratios between 40 and 60, while four grains for which exposure ages have been determined have $^{12}C/^{13}C < 12$ and a few have close to solar C isotopic composition. The C- and Si-isotopic composition of our sample set confirms that SiC from the LS+LU fraction is isotopically distinct from smaller SiC grains. Their surface morphology also distinguishes them from smaller grains. This indicates that these samples constitute at least partly a distinct population of presolar SiC [8,17].

Summary and Conclusions: We determined ^{21}Ne and ^{3}He exposure ages of 19 single presolar LS+LU SiC grains and obtain ~3 to 480 Myr, which essentially overlaps with the ^{6}Li age range of ~24 to 1200 Myr [8]. Some grains thus have presolar ages close to estimates of interstellar lifetimes but many others are considerably younger. ^{3}He ages often approach ^{21}Ne ages, although recoil should have led to an almost complete loss of $^3He_{cos}$ We hypothesize that some grains were held together by mantles to form large agglomerates in interstellar space, while others may be fragments of larger grains.

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References: [1] Tang M. & Anders E. (1988) *ApJ* 335, L32–34. [2] Lewis R. S. et al. (1994) *GCA* 58, 471–494. [3] Ott U. & Begemann F. (2000) *MAPS* 35, 53–63. [4] Ott U. et al. (2005) *MAPS* 40, 1635–1652. [5] Jones A.P. et al. (1997) in: Bernatowicz T. J. & Zinner E. (eds.) *AIPC* 402, 595J. [6] Clayton D.D. (2003) *ApJ* 598, 313–324. [7] Gyngard F. et al. (2007) *LPS XXXVIII*, #1963. [8] Gyngard F. et al. (2007) *MAPS 70,* #5068. [9] Amari S. et al. (1994) *GCA* 58, 459–470. [10] Heck P.R. et al. (2007) *ApJ* 656, 1208–1222. [11] Baur H. (1999) *EOS Trans. AGU*, 46, F1118. [12] Reedy R.C. (1989) *LPS XX*, 888–889. [13] Currie L.A. et al. (1956) *Phys. Rev.* 101, 1557–1568. [14] Ziegler J.F. et al. (1985) The Stopping and Ranges of Ions in Matter, Vol. 1. [15] Farley K.A. et al. (2006) *EPSL* 248, 451–461. [16] Cuppen H.M. & Herbst E. (2006) ApJ 668, 295–309. [17] Virag A. et al. (1992) *GCA* 56, 1715–1733.