MAGNESIUM ISOTOPE MEASUREMENTS ON PRESOLAR SILICATE GRAINS FROM AGB STARS.

János Kodolányi[1] and Peter Hoppe[1], [1]Max Planck Institute for Chemistry, Johann Joachim Becher Weg 27, Mainz, D-55128, Germany (E-mail: j.kodolanyi@mpic.de)

Introduction: Silicates are among the most abundant presolar grains found in primitive meteorites [e.g., 1]. The Mg isotope composition of presolar silicate grains can provide information about the Galactic chemical evolution (GCE) of Mg isotopes and about nucleosynthetic processes influencing the Mg isotope composition of evolved stars [2,3]. Magnesium isotope data on presolar silicates are scarce, largely due to the analytical challenge posed by the extreme small size (longest dimension rarely exceeding ~300 nm) of presolar silicate grains [2].

Although the vast majority (> 80 %; [4,5]) of presolar silicate grains belong to the oxygen isotope Group 1 defined by [6], which suggests $1.2 < M < 2.2$ M_{solar} AGB stars as most likely sources for these grains [7], most of the available Mg isotope data were obtained on the far less abundant Group 4 grains of most likely supernova origin [2]. Considering the fact that much of the Mg found in our solar system must have derived from presolar silicate and spinel grains, the Mg isotope composition of Group 1 silicates is central to the understanding of the relative contributions of different stellar sources to the Mg inventory of our solar system. Here we report on our new Mg isotope measurements on Group 1 presolar silicate grains together with our previously obtained data [8] in order to expand our knowledge on the Mg isotopes in presolar materials.

Experimental: Presolar silicate grains were found in a petrographic thin section of the ungrouped carbonaceous chondrite Acfer 094 [9] by ion imaging with the NanoSIMS at the Max Planck Institute for Chemistry. Negative secondary ions of $^{16,17,18}O$, ^{28}Si, and $^{27}Al^{16}O$, produced by rastering a Cs^+ primary ion beam (~100 nm, ~1 pA) over fifty 10 x 10 μm^2-sized areas, were measured in multi-collection and presolar silicates were identified based on their anomalous O-isotopic compositions. For Mg isotope analysis of our presolar silicates we adopted the sample preparation technique of [2], originally developed for dense grain separates. This technique minimises dilution effects imposed by isotopically "normal" (~terrestrial) matrix material on the Mg isotope measurements of presolar silicates by removing matrix material in the presolar silicate grains' vicinity with a focussed ion beam prior to Mg isotope analysis (Fig. 1a-d).

The details of this preparation method are discussed by [8]. Five Group 1 silicate grains (with shortest and longest diameters of 90-230 and 200-300 nm, respectively) have been selected so far for the measurement of their Mg isotope compositions, but two of the grains were lost during sample preparation. The relative sensitivity factor ($\varepsilon(Al)/\varepsilon(Mg) = 0.84$) used to calculate the Al/Mg and the initial $^{26}Al/^{27}Al$ ratio in one of our presolar silicate grains was measured on an in-house Burma spinel standard [10].

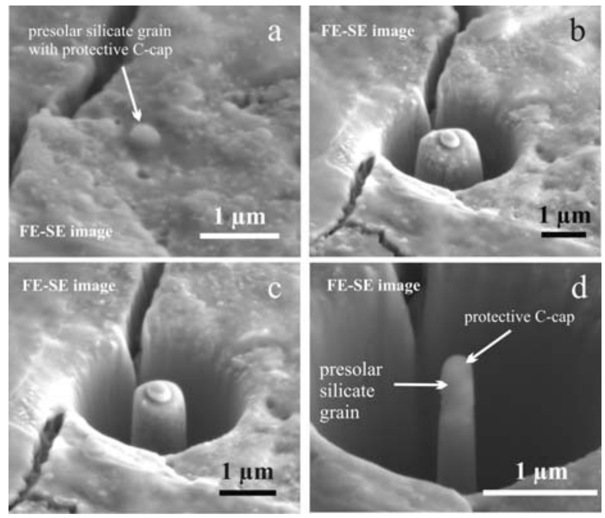

Figure 1: FIB-preparation of a presolar silicate for Mg isotope measurements [8].

Results and discussion: We identified 14 presolar silicate and 1 presolar oxide grains in the analysed 5000 μm^2 of the meteorite matrix. Based on their O-isotopic signatures all analysed silicate grains belong to O isotope Group 1 (Table1; Fig. 2; [6]). Two of the grains analysed successfully for Mg isotopes have solar system $^{25}Mg/^{24}Mg$ ratios within analytical uncertainty (1 σ) whereas a third grain shows a slight enrichment in ^{25}Mg ($\delta^{25}Mg = 32 \pm 20$ ‰; $\delta^{x}Mg = [((^{x}Mg/^{24}Mg)_{grain}/\ [(^{x}Mg/^{24}Mg)_{meteoritematrix})-1]\times1000$, where ^{x} = 25 or 26; Table 1; Fig. 3). $^{26}Mg/^{24}Mg$ ratios exceed solar system values for two of the grains analysed ($\delta^{26}Mg = 35 \pm 16$ ‰ and 39 ± 20 ‰) whereas a third grain has a $^{26}Mg/^{24}Mg$ indistinguishable from that of solar system materials (Fig. 3).

Silicate and spinel data seem to follow a trend with a slope roughly corresponding to the slope of the GCE model of [15] for stars with ~solar metallicities (Fig. 1). Departures from the predicted GCE [15] trend towards higher $^{26}Mg/^{24}Mg$ (as seen for some spinel grains) are likely to be related to the (in-situ) decay of the short-lived ($t_{1/2} \approx 0.7$ million years) ^{26}Al.

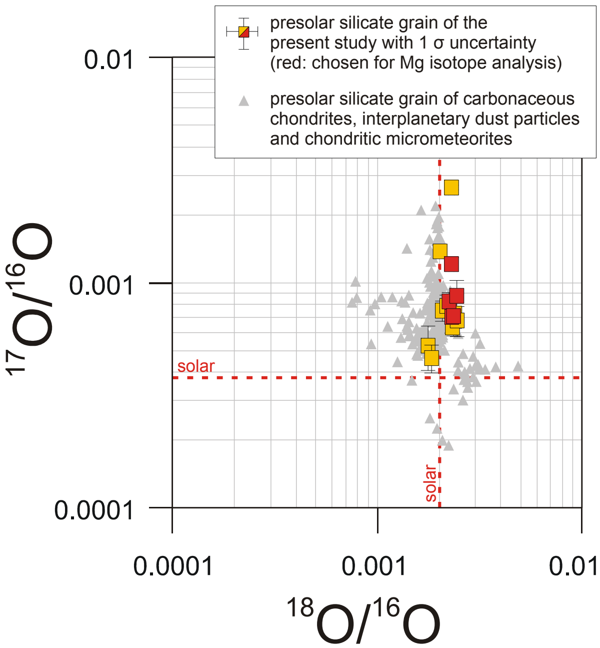

Figure 2. Oxygen isotope composition of presolar silicate grains. Literature data are from [4,5,11 and 12].

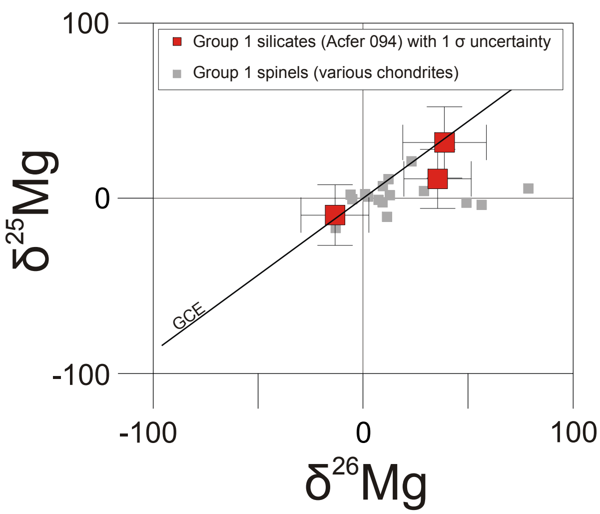

Figure 3. Magnesium isotope composition of Group 1 presolar silicate and spinel grains. Spinel data are from [3] and [14]. The slope of the GCE line is from the model of [15] for -0.1 < [Fe/H] < 0.1 stars ([Fe/H] = log[$(Fe/H)_{star}/(Fe/H)_{solar}$]).

The higher-than-terrestrial $^{25}Mg/^{24}Mg$ and $^{26}Mg/^{24}Mg$ ratios in one of our Group 1 presolar silicate grains may indicate $Z > Z_{solar}$ for the parent star, although they could also be the (partial) result of AGB nucleosynthesis (α-capture on ^{22}Ne and n capture reactions in the He burning shell and He intershell and p-capture in the H-burning shell) in a $Z \approx Z_{solar}$ star with $M = 1.5\text{-}3\ M_{\odot}$ [3].

Table 1. Oxygen- and Mg-isotope compositions of presolar silicate grains from this study and [9].

Grain #	$^{17}O/^{16}O$ (10^{-4})	$^{18}O/^{16}O$ (10^{-4})	$\delta^{25}Mg$ (‰)	$\delta^{26}Mg$ (‰)
1	7.32 ± 0.49	19.24 ± 0.79	11 ± 17	35 ± 16
2	10.19 ± 0.63	19.51 ± 0.87	-9 ± 17	13 ± 16
3	6.58 ± 0.77	19.88 ± 1.30	32 ± 20	39 ± 20

#1: acfer094_03a_04_01, #2: acfer094_03a_addim02_02, #3: acfer094_04a_08_01

Increased $^{26}Mg/^{24}Mg$ in combination with ~terrestrial $^{25}Mg/^{24}Mg$ may indicate in situ ^{26}Al decay, although our isotope data are not conclusive because of measurement uncertainties. Nevertheless, if we take the data for grain acfer094_03a_04_01, which has normal $^{25}Mg/^{24}Mg$ within 1σ and a >2σ excess in ^{26}Mg and assume that all the ^{26}Mg excess is from ^{26}Al decay then an initial $^{26}Al/^{27}Al$ ratio of 0.016 ±0.006 can be calculated for this grain. This ratio is at the upper end of what is found for Group 1 oxide grains [3,14] but lower than the value inferred for a Group 2 silicate grain [13] and in many Group 2 oxide grains [3,14].

Although our results are novel, they are nevertheless preliminary. Analyses of more Group 1 silicate grains is planned to better constrain the Mg isotope composition of Group 1 silicate grains. Future work will also focus on improving analytical precision so that the possible effect of ^{26}Al decay on $^{26}Mg/^{24}Mg$ ratios can be better resolved, which could help improve models estimating $^{26}Al/^{27}Al$ of evolved AGB stars.

References: [1] Hoppe P (2008) *Space Sci Rev, 138*, 43-57. [2] Nguyen A. N. et al. (2010) *LPS XLI*, Abstract #2413. [3] Zinner E. et al. (2005) *GCA, 69*, 4149–4165. [4] Floss C. and Stadermann F. J. (2009) *GCA, 73*, 2415–2440. [5] Vollmer C. et al. (2009) *GCA, 73*, 7127-7149. [6] Nittler L. R. et al. (1997) *ApJ, 483*, 475-495. [7] Nittler L. R. (2009) *Publ Astronom Soc Australia, 26*, 271-277. [8] Kodolányi J. and Hoppe P. (2011) *PoS*, in review. [9] Newton J. et al. (1995) *Meteoritics*, *30*, 47-56. [10] Fahey A. J. (1988) *PhD Thesis*. Washington University, St. Louis, U.S.A. [11] Floss C. et al. (2006) *GCA*, *70*, 2371-2399. [12] Yada T. et al. (2008) *Meteoritics and Planet. Sci.*, *43*, 1287-1298. [13] Nguyen A. N. and Zinner E. (2004) *Science, 303*, 1496-1499. [14] Nittler L. R. et al. (2008) *ApJ, 682*, 1450-1478. [15] Fenner Y. et al. (2003) *Publ Astronom Soc Australia, 20,* 340-344.