PRESOLAR SILICATES WITH UNUSUAL MAGNESIUM-ISOTOPIC COMPOSITIONS. J. Leitner, P. Hoppe and J. Kodolányi, Max Planck Institute for Chemistry, Hahn-Meitner-Weg 1, 55128 Mainz, Germany (jan.leitner@mpic.de).

Introduction: Primitive solar system materials contain small amounts of isotopically anomalous stardust that formed in the outflows of evolved stars [1]. The most abundant type of this "presolar" dust available for single grain analyses are silicates [2], with typical sizes of ~150 nm [3]. Other than refractory oxides, presolar silicates cannot be chemically extracted from their meteoritic hosts, but have to be identified in situ by secondary ion mass spectrometry (SIMS) at high lateral resolutions. Based on their O isotopes, most (>99%) of the silicates and oxides are divided into four distinct groups [4,5]. Group 1 grains (~70%) come from low-mass (1.2–2.2M$_{\odot}$) asymptotic giant branch (AGB) stars of ~solar metallicity, with higher than solar $^{17}O/^{16}O$ ratios and $^{18}O/^{16}O$ ratios ranging from about solar down to ~1×10^{-3}. The isotopic compositions of other rock-forming elements, like Mg and Si, are not expected to be modified significantly by nucleosynthesis in low-mass AGB stars when O-rich dust forms [6–8]. Thus, they largely represent the initial isotopic compositions of their parent stars, mainly reflecting Galactic chemical evolution (GCE). However, recently, several Group 1 silicates were found to have ^{25}Mg-excesses incompatible with a low-mass AGB origin and favoring stellar explosions as their sources [9]. Group 2 grains also have enhanced $^{17}O/^{16}O$ ratios, but significantly lower $^{18}O/^{16}O$ (<1×10^{-3}). Their O-isotopic signatures can be explained by additional mixing processes like cool bottom processing in red giant/AGB stars of M <1.5 M$_{\odot}$ and Z <Z$_{\odot}$ [e.g., 10]. Alternatively, some of the grains could come from intermediate-mass (4–8 M$_{\odot}$) AGB stars that experienced hot bottom burning (HBB) [11]. HBB can strongly affect the $^{25,26}Mg/^{24}Mg$ ratios, resulting in larger excesses than for the Group 1 grains [e.g., 11,12]. Here, we report two Group 1 silicate grains with light Mg-isotopic compositions that cannot be explained by standard low-mass AGB star models.

Samples & Experimental: The new Hyperion RF plasma O primary ion source, which was recently installed on the Cameca NanoSIMS 50 at the MPI for Chemistry, allows measurements of Mg-isotopes with a spatial resolution of <100 nm [8]. A focused O$^-$ ion beam (~0.5 pA) was rastered over 2×2 μm^2-sized areas around the presolar silicate grains and positive secondary ion images of ^{24}Mg, ^{25}Mg, ^{26}Mg, ^{27}Al, and ^{28}Si were acquired in multi-collection mode. Sixteen Group 1 silicates from the CR chondrite Meteorite Hills (MET) 00426 (d ~180–380 nm), previously identified by their O-isotopic compositions, were selected for analysis. Mg-isotopic ratios were normalized to those of the surrounding matrix of presumed Solar System composition (Fig. 1).

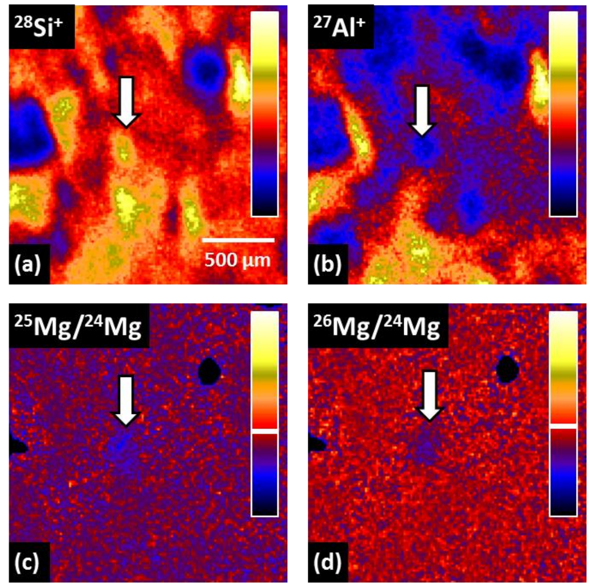

Figure 1. *Secondary ion (SI) images of (a) $^{28}Si^+$ and (b) $^{27}Al^+$, together with (c) $^{25}Mg/^{24}Mg$- and (d) $^{26}Mg/^{24}Mg$-ratio images for the ^{24}Mg-rich grain MET_01B_53_1. It is clearly identified as a silicate from the SI images. (Intensities and ratios increase from black/blue to yellow/white.) Terrestrial isotope ratios are marked by the white bars in the color scale bars.*

Results & Discussion: Two grains among the 16 Group 1 silicates show a significant ^{25}Mg-depletion compared to solar of δ^{25}Mg ~ –190 ‰ (Figs. 1&2). One of the grains (MET_01B_53_1) displays a similar depletion in ^{26}Mg (–179±15 ‰), while the other has a small excess (δ^{26}Mg = 97±12 ‰). Similar ^{25}Mg-depletions have been reported for seven Al-oxide grains (4 Group 1, 3 Group 2) [5,13], with ^{26}Mg-excesses ranging from 200 to ~11,000 ‰ (Fig. 2). The large scatter in the δ^{26}Mg-values for the oxides can be explained by the decay of ^{26}Al ($t_{1/2}$ = 717,000 a). Both silicate grains contain only low levels of Al (Al/Mg = 0.06 for MET_01B_53_1 and 0.14 for MET_01B_20_1), thus, their Mg-isotopic ratios are unlikely to be significantly affected by ^{26}Al-decay. In principle, a light Mg-isotopic composition as observed for MET_01B_53_1 could be indicative of a parent star with low metallicity, but this is not reflected in its O isotopes ($^{17}O/^{16}O = 9.37\pm0.84\times10^{-4}$, $^{18}O/^{16}O = 1.81\pm0.11\times10^{-3}$). The same is true for MET_01B_20_1 ($^{17}O/^{16}O = 7.72\pm0.76\times10^{-4}$, $^{18}O/^{16}O = 1.74\pm0.11\times10^{-3}$), as well as the seven ^{25}Mg-poor Al-oxides [5,13].

To circumvent this problem, Nittler et al. [5] proposed an anomalous Mg starting composition for the parent star of KH14, due to "local heterogeneities in the interstellar medium arising from incomplete mixing of supernova ejecta" [5,14]. We note that several silicate and oxide grains of likely core-collapse supernova (CCSN) origin also display ^{25}Mg-depletions ranging from –177 ‰ to –320 ‰ [5,13,15] (Fig. 2). Exploring the CCSN-models from [16] and [17], we find that comparable ^{25}Mg-depletions (δ^{25}Mg ~ –170 ‰ to –340 ‰) can be produced in 15–25 $M_{\odot}$ stars of solar metallicity, when material from the He/N and He/C shells and the outer envelope is mixed. These ^{25}Mg-depletions predicted to be accompanied by ^{26}Mg-excesses (150 ‰ to 420 ‰), as observed for some of the ^{25}Mg-poor Group 4 SN grains (Fig. 2) (very large ^{26}Mg-excesses in some oxide grains with high Al/Mg, as observed for KH2 [5], may be primarily due to ^{26}Al-decay after grain formation). Thus, the low-^{25}Mg-high-^{26}Mg-compositions *could* indeed be a signature of AGB stars with starting compositions influenced by incompletely mixed SN ejecta; on a first-order estimate, this might also have led to comparatively high initial $^{18}O/^{16}O$ ratios. However, this hypothesis cannot explain the Mg-isotopic composition of grain MET_01B_53_1, since ^{26}Mg-*depletions* are not produced this way. This grain plots, within error limits, on a slope-1-line (Fig. 2), and also corresponds largely with the 2σ-upper-limit fit line of the category A Group 1 silicates from [8]. Its Mg isotopes also comply with the GCE-model from Timmes et al. [18], corresponding to a parent star of ~0.4 $Z_{\odot}$ [7,18]. As mentioned before, this is not supported by the O-isotopic composition, which indicates about solar metallicity. A possible way to explain this discrepancy could be mixing of the aforementioned SN-processed material with a ^{24}Mg-rich (low-Z) reservoir to serve as the starting composition, or material dominated by SN-ejecta from a star with initial depletions in the heavier Mg isotopes. This hypothesis could also explain the isotopic compositions of the other Group 1 silicate, as well as the ^{25}Mg-poor AGB grains; their respective $^{26}Mg/^{24}Mg$-ratios would have been modified according to various amounts of ^{26}Al incorporated in the grains. Investigation of the Si-isotopic ratios of the two MET-silicates is in progress and might allow to further constrain the origin of their peculiar Mg-isotopic compositions.

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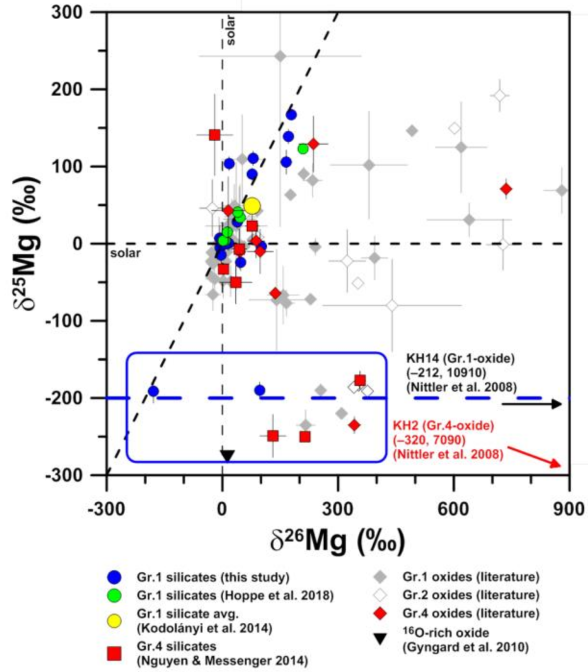

Figure 2. *Mg-isotopic compositions of the presolar silicates from this study, together with silicates from [8], and the average of Group 1 silicates from [7]. Literature data for grains from Group 1, 2 and 4 are shown for comparison [13,15,19]. Only grains with δ^{26}Mg <900 ‰ are displayed here. The blue dash-line and rectangle highlight the ^{25}Mg-poor grain population. The dashed slope-1-line represents roughly the GCE trend. All error bars are 1σ.*

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