PRESOLAR GRAINS FROM HIGHER-MASS AGB STARS?

J. Leitner¹, P. Hoppe¹, and J. Kodolányi¹
¹Max-Planck-Institut für Chemie, Hahn-Meitner-Weg 1, 55128 Mainz, Germany, jan.leitner@mpic.de

Introduction: Isotopically anomalous dust that formed in the outflows of evolved stars or in the ejecta of stellar explosions [1] is a minor, but important component of primitive solar system materials. Silicates are the most abundant type of “presolar” dust available for single grain analyses [2], with characteristic sizes of ~150 nm [3]. Based on their O isotopes, most (>99%) presolar silicates and oxides are divided into four distinct groups [4]. Group 1 grains (~70%) are believed to come from low-mass (~1.2–2.2Ms) asymptotic giant branch (AGB) stars of ~solar metallicity, with higher than solar 17O/16O ratios and 18O/16O ratios ranging from about solar down to ~1×10⁻³. However, recent studies of Mg-isotopes in Group 1 silicates showed that not all of these grains come from low-mass AGB stars; instead, a fraction of them displays large ²⁵Mg-excesses incompatible with a low-mass AGB origin, indicating stellar explosions as their sources [5]. Group 2 grains also have enhanced ¹⁸O/¹⁶O ratios, but significantly lower ¹⁶O/¹⁸O (<1.1×10⁻⁴). Likely sources are red giant/AGB stars of M < 1.5 Ms, and Z < Zₗₑₜₜ experiencing additional mixing processes like cool bottom processing [e.g., 6]. Alternatively, some of the grains could stem from high-mass (4–8 Ms) AGB stars undergoing hot bottom burning (HBB) [7]; and finally, a few of the Group 2 grains might have formed in the winds of post-AGB stars [e.g., 8]. Here, we report on two Group 2 silicates with Mg-isotopic compositions indicative of an origin in ~6 Ms AGB stars, and on several Group 1 silicates possibly coming from ~4.5 Ms AGB stars with higher-than-solar metallicities.

Methods: Mg isotope studies were conducted with the new Hyperion RF plasma O primary ion source installed on the MPIC Cameca NanoSIMS 50 on presolar silicates previously identified during standard O-isotopic mapping of Meteorite Hills 00426, Elephant Moraine 92161, and Acfer 094. A focused O beam (~100 nm, ~0.5 pA) was rastered over 2×2 μm²-sized areas around the presolar silicate grains, and secondary ion images of ²⁴Mg⁺, ²⁷Al⁺, and ²⁶Si⁺ were acquired simultaneously. Subsequently, ²⁴Mg/²⁶Mg and ²⁶Mg/²⁸Mg were measured for selected grains.

Results and Discussion: The two Group 2 silicates display ²⁵Mg-enrichments of 165 ‰ and 1050 ‰, respectively, and ³⁰Mg-values of 200–300 ‰; five Group 1 silicates have ²⁵Mg-enrichments of 104 ‰–280 ‰, with ³⁰Mg between 18 and 65 ‰ (all errors ≤13 ‰). For low-mass AGB stars, no major modifications of the Mg isotopes are expected, and their compositions mainly reflect Galactic chemical evolution (GCE) [e.g., 9]. HBB, however, can strongly affect the ²⁵Mg/²⁶Mg ratios, resulting in larger excesses for the Group 2 grains [7,10]. Comparison of these models with the grain data indicates an origin from 6–7 Ms AGB stars of ~solar metallicity for the two Group 2 silicates, as similarly inferred previously for two Group 2 spinel grains [7]. The ²⁵Mg-enrichments of the five Group 1 silicates are not accompanied by similarly high ²⁵Mg-excesses; thus, a GCE-related origin can be excluded. One possible explanation for their isotopic signatures is the occurrence of explosive H-burning in supernova explosions [5], but given the only moderate ²⁵Mg enrichments another potential source is intermediate-mass AGB stars of supersolar metallicity [10]. In the latter case, we find a good match between the 3.75–4.75 Ms models with Z = 0.03 and the grain data, especially when adopting a less effective ²⁶Mg-production via ²²Ne(α,γ)²⁶Mg than typically assumed [11]. The Group 2 silicate grain with the largest ²⁵Mg-excess also shows small enrichments in ²⁶Si and ³⁰Si, while the three Group 1 grains measured so far show no significant deviations from the Solar System Si-isotopic composition. In summary, we find that, by taking the latest AGB star models and reaction rate updates into account [7,10], the two Group 2 silicates discussed here originate from higher-mass AGB stars (M ~ 6 Ms). Several Group 1 silicates with moderate ²⁵Mg-enrichments could have formed around AGB stars with masses of 3.75–4.75 Ms and Z > Zₗₑₜₜ, although an alternative source of this sub-population could be core-collapse supernovae with H-ingestion [5]. AGB stars with M > 4 Ms are expected to have contributed a significant fraction of silicate and oxide dust to the presolar grain inventory of the nascent Solar System [12]; however, evidence for such grains has been exceptionally rare so far [7], and was restricted to presolar grains of Group 2. Our results show that high-resolution Mg isotope studies are a suitable tool for the identification of HBB signatures, and that the Group 1 grains might contain a sub-population of dust from intermediate-mass AGB stars with supersolar metallicity.