P-NUCLIDE ENRICHMENTS IN PRESOLAR GRAPHITE GRAINS.

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Introduction: Presolar graphite grains are classified into two density types: high density (HD) and low density (LD) graphites. Based on light element isotopic evidence, the majority of HD graphites come from Asymptotic Giant Branch (AGB) stars [1,2]. Heavy element isotopic studies on HD grains most commonly indicate *s*-process nucleosynthesis, which point to AGB origins [e.g., 3-5]. A minor fraction of HD graphites contain evidence of other stellar sources: type II supernovae (SN) [1,2] and post-AGB stars [6]. In this study, we report excesses in *p*-nuclides ^{84}Sr and ^{92}Mo in HD graphite grains.

Methods: We measured light and heavy element isotopes on 49 HD graphite grains from the KFB1h fraction of Murchison. Carbon and N isotopes were measured using the NanoSIMS 50 at Washington University in St. Louis, while O isotopes were measured with the CAMECA IMS-1280 at the University of Wisconsin Madison [7]. Sr, Zr, and Mo isotopes were measured using Resonance Ionization Mass Spectrometry at the Laser Ionization of Neutrals lab at Lawrence Livermore National Laboratory (LLNL) [5].

Results: In this study, we found a grain (KFB1h-541) with evidence for both *s*- and *p*-process nucleosynthesis. This grain showed a strong Mo *s*-process signature at the beginning of the analysis. As grain ablation continued, a pronounced ^{92}Mo excess appeared briefly, which subsequently returned to an *s*-process Mo signature. Because presolar graphite grains are known to contain subgrains(s) [8], we believe the ^{92}Mo excess was present in a subgrain(s) within the host grain. As ^{92}Mo is a pure *p*-nuclide, we expect to see a comparable excess in the *p*-rich isotope ^{94}Mo that can also be made by the *s*-process; but we observed no such excess in this grain. KFB1h-541 also did not exhibit excesses in the *p*-nuclide ^{84}Sr. This study also found five grains that have excesses in ^{84}Sr (errors are 1σ): KFB1h-011($\delta^{84}Sr_{86} = 302.18 \pm 123.05$), KFB1h-101 ($\delta^{84}Sr_{86} = 1314.53 \pm 251.90$), KFB1h-241($\delta^{84}Sr_{86} = 1061.46 \pm 332.21$), KFB1h-412 ($\delta^{84}Sr_{86} = 1052.47 \pm 398.98$), and KFB1h-552 (670.45 ± 290.34). These ^{84}Sr excesses were not uniformly distributed throughout the individual grains. All five grains have solar Zr and Mo isotopic values within 2σ. The light and other heavy isotopes that were measured in these grains do not provide any additional clues to constrain the stellar sources of the grains, except for KFB1h-541 that has a clear *s*-process signature.

Discussion: Astrophysical models predict that *p*-nuclei are formed by photodisintegration of existing, heavier nuclides at very high temperatures, commonly achieved in core-collapse supernovae. Other astrophysical sites have also been suggested for *p*-nuclide production, including, explosions in white dwarf stars, surface burning in neutron stars, accretion disks, and neutron wind outflows [10]. The detection of excesses in pure *p*-nuclides, ^{84}Sr and ^{92}Mo, in HD graphite grains that do not show any other SN isotopic signature is puzzling, as is the *s*-process signature in the parent grain KFB1h–541and *p*-process in its sub-grain(s). A similar enrichment of the *p*-only ^{92}Mo isotope has been previously reported in mainstream (AGB origins) SiC grains by [11]; but, to the extent of our knowledge, no Sr *p*-nuclide enrichments have been found in presolar SiCs to date [e.g., 9,12]. However, ^{84}Sr excesses have been observed in Ca-Al-rich inclusions [e.g., 13]. Such detections of *p*-isotope enrichments in presolar and solar materials will provide important clues to the yet ambiguous astrophysical sites that produce *p*-nuclides [e.g., 10,13]. More heavy element isotopic measurements on presolar and solar materials and further investigations into *p*-nuclide nucleosynthesis are required to answer these questions.

References: [1] Jadhav M. et al. (2013) *Geochimica et Cosmochimica Acta* 113:193–224 [2] Amari S. et al. (2014) *Geochimica et Cosmochimica Acta* 133:479–522 [3] Cristallo S. et al. (2020) *Astronomy & Astrophysics* 644:A8 [4] Jadhav M. et al. (2012) *Meteoritics and Planetary Science* 47: A5183 [5] Pal I. et al. (2022) *LPS LII*, Abstract #1262 [6] Jadhav M. et al. (2013) *The Astrophysical Journal Letters* 777: L27 [7] Amari S. et al. (2018) *LPS XLIX*, Abstract #1818 [8] Croat T. et al. (2005) *The Astrophysical Journal* 631: 976–987 [9] Lugaro M. et al. (2003) *The Astrophysical Journal* 593:486–508 [10] Rauscher T. et al. (2013) *Reports on Progress in Physics* 76:066201 [11] Savina M. et al. (1998) *LPS XXXIV*, Abstract #2079 [12] Liu N. et al. (2015) *The Astrophysical Journal* 803:12-34 [13] Charlier B. et al. (2021) *Science Advances* 7:eabf6222

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