

MAGNESIUM AND TITANIUM ISOTOPIC COMPOSITIONS OF AN UNUSUAL HIBONITE-PEROVSKITE REFRACTORY INCLUSION FROM ALLENDE: IT IS FUN.

M.-C. Liu¹, L. P. Keller² and K. D. McKeegan¹ ¹Dept. of Earth, Planetary, and Space Sciences, UCLA (mcliu@ucla.edu), ²Robert M. Walker Laboratory for Space Science, ARES, NASA/JSC.

Introduction: Hibonite-rich refractory inclusions are among the first solids that formed in the solar nebula [1], and thus provide constraints on the earliest environment in the Solar System. An unusual hibonite-perovskite inclusion from Allende, SHAL, consists of a large ($\sim 500 \times 200 \mu\text{m}$) single hibonite crystal and coexisting blocky perovskite ($\sim 200 \mu\text{m}$ in size) [2]. The hibonite is characterized by chemical and oxygen isotopic compositions similar to those in the FUN (Fractionated and Unknown Nuclear anomalies) inclusion HAL [3]. However, the rare earth element (REE) patterns measured at different spots of SHAL hibonite are highly variable, ranging from Group II-like (light REEs enriched relative to heavy REEs) to Group III-like (relatively flat with slight Eu depletions) [4], but overall contrast largely with that of HAL [e.g., 2], especially in the Ce and Yb abundances. This implies that SHAL hibonite formed and underwent distillation processes under more reducing conditions [4]. Interestingly, the accompanying perovskite has uniform, unfractionated oxygen isotopic compositions (avg. $\delta^{17}\text{O} = \delta^{18}\text{O} = -7\%$) [2] and REE abundances that are completely different from those of SHAL hibonite [4]. This has been interpreted that perovskite and hibonite may not be co-genetic [3]. Here we performed Al-Mg and Ti isotopic measurements of SHAL hibonite and perovskite to determine if the FUN characteristics are observed in these two isotope systems, and to further constrain the origin and evolution of SHAL.

Results: Isotopic measurements of Al-Mg and Ti in SHAL were performed on the UCLA CAMECA ims-1290 ion microprobe by following the analytical protocols described in [1]. The Al-Mg and Ti data obtained in both terrestrial standards and SHAL hibonite and perovskite are shown below. Both SHAL hibonite and perovskite, despite very high $^{27}\text{Al}/^{24}\text{Mg}$ ratios, are devoid of ^{26}Mg excesses that can be attributed to the decay of ^{26}Al . $\delta^{25}\text{Mg}$ (mass-dependent fractionation) in hibonite is $\sim -5\%$ /amu relative to Madagascar hibonite, but is not well constrained for perovskite due to very large uncertainties owing to extremely low Mg contents. Similar to Mg isotopes, SHAL hibonite and perovskite show essentially the same Ti isotopic compositions, with anomalies in ^{50}Ti of $\sim 14\%$, but the former shows greater Ti isotope fractionation than the latter (2.5%/amu vs. 0%/amu).

Discussion and Conclusions: The Al-Mg and Ti isotopic compositions of SHAL hibonite are consistent with those of HAL, suggesting that SHAL hibonite is a FUN inclusion and likely formed prior to homogenization of ^{26}Al and Ti isotope variations in the solar nebula. However, the formation mechanisms for SHAL and HAL differ, given the differences in the REE patterns and degrees of oxygen mass-dependent fractionation. The Group-II to Group-III like REE patterns, the Yb depletions, and negative $\delta^{25}\text{Mg}$ observed in SHAL hibonite are all consistent with condensation of the hibonite precursor in a reducing environment. The lack of large Ce depletions in SHAL hibonite implies that distillation processes that fractionated hibonite's oxygen isotopes must have taken place under a reducing condition, but the extent to which SHAL hibonite was distilled appears to be less than HAL because of the smaller degree of oxygen mass-dependent fractionation. The perovskite shares essentially the same Ti and Mg isotopic compositions as hibonite and probably formed in the same reservoir. The ultrarefractory REE pattern seen in perovskite likely resulted from gas-solid fractionation which depleted HREEs in this reservoir. This process also explains why SHAL hibonite is generally depleted in HREEs relative to LREEs.

References: [1] Liu M.-C. et al. 2009. *GCA* 58: 5051–5079. [2] Keller L. P. et al. 2012. *MAPS* 75: #5313 (abstr.) [3] Fahey A. J. et al. 1987. *GCA* 51:329–350. [4] Mane P. et al. 2013 *MAPS* 76: #5268 (abstr.).

