

### IRON AND NICKEL ISOTOPE MEASUREMENTS IN HIBONITE USING CHILI

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**Introduction:** Hibonite-rich CAIs from CM chondrites have the largest nucleosynthetic anomalies of all materials believed to have formed inside the Solar System. In particular, these anomalies are found in the most neutron-rich isotopes of calcium and titanium, i.e., <sup>48</sup>Ca and <sup>50</sup>Ti (e.g.,  $\delta^{50}\text{Ti}$  range is >300‰; [1–4]). These anomalies are believed to be the result of a heterogeneous distribution of material, originating from a rare type Ia supernova, in the early Solar System [1]. In these types of supernovae, neutron-rich isotopes of iron-peak elements are predicted to be efficiently produced alongside <sup>48</sup>Ca and <sup>50</sup>Ti, for example, <sup>54</sup>Cr, <sup>58</sup>Fe, <sup>62</sup>Ni, and <sup>64</sup>Ni [5]. This suggests that large isotopic heterogeneities may have also existed in iron, chromium, and nickel when the Solar System formed, and traces of these may be preserved in hibonite-rich CAIs. This prediction has yet to be tested as the abundances of iron-peak elements in hibonite-rich CAIs are low, and abundant isobaric interferences exist that complicate analysis of these elements with conventional mass spectrometry.

**Methods:** We are in the process of addressing this problem with CHILI, a new resonance ionization mass spectrometry (RIMS) instrument at the University of Chicago [6,7], taking advantage of both the larger useful yield and the element-specific ionization process. We have developed resonance ionization schemes that allow us to measure all stable isotopes of iron and nickel whilst avoiding isobaric interferences at mass 58 u by applying a special laser timing scheme [8].

**Samples:** The first meteoritic hibonite we have analyzed is CAI 2-5-1, a large (>200  $\mu\text{m}$ ) single hibonite grain with large mass-dependent fractionation effects in oxygen, calcium, and titanium, and a  $\delta^{48}\text{Ca}$  value of approximately +43‰ [9]. This CAI is classified as a FUN (fractionated and unidentified nuclear effects) CAI, a group of CAIs believed to have formed by melt distillation in the solar nebula. No mass-dependent fractionation effects were found in magnesium, suggesting that isotopically normal magnesium was introduced after the melting event [9]. We have also analyzed a terrestrial hibonite standard (Madagascar hibonite) and a NIST 611 glass. The CAI and standards are mounted in a one-inch epoxy round coated with gold for conductivity.

**Results and discussion:** Our measurements show that CAI 2-5-1 has no anomalies in iron isotopes that are resolvable beyond the analytical uncertainty of a few tens of permil. Nickel isotope measurements were inconclusive due to its low abundance and nonresonantly ionized molecular interferences. Our measurements suggest that the grain is zoned in its iron abundance, with the edge of the grain being more iron-rich than the center by a factor of ~6. Based on volume estimates by post-CHILI SEM images, we estimate that the average iron concentration is on the order of 10–50 ppm. Fe/Ni ratios are varying between ~60 at the edge of the grain and ~40 in the center.

The lack of large iron isotope anomalies in this CAI could be the result of full evaporation of iron during melt distillation, followed by introduction of isotopically normal iron after the evaporation event, similar inferences apply to magnesium [9]. CAI 2-5-1 shows zoning both in iron and magnesium abundances, which may support a scenario in which both of these elements entered the hibonite lattice by diffusion.

**Outlook:** We are planning to optimize the analytical protocol for hibonite-rich CAIs and to shift the focus of our measurements to highly anomalous hibonite-rich CAIs (i.e., platy hibonite crystals). The precision of our iron isotope measurements is sufficient to resolve the large anomalies that are expected to accompany those in <sup>48</sup>Ca and <sup>50</sup>Ti.

**References:** [1] Hinton R. W. et al. (1987) *The Astrophysical Journal* 312:420–428. [2] Ireland T. (1990) *Geochimica et Cosmochimica Acta* 54:3219–3237. [3] Liu M.-C. et al. (2009) *Geochimica et Cosmochimica Acta* 73:5051–5079. [4] Kööp et al. (in press) *Geochimica et Cosmochimica Acta*. [5] Clayton D. D. (2003) *Cambridge University Press*. [6] Stephan T. et al. 2013. *Lunar & Planetary Science* 44:#2536. [7] Stephan T. et al. 2014. *Lunar & Planetary Science* 45:#2242. [8] Stephan T. et al. 2016. *Lunar & Planetary Science* 47:#2793. [9] Kööp et al. (2015) *Lunar & Planetary Science* 46:#2750.