

Isotopic and Elemental Analyses of Meteorites and Mars Analogues by Hyperion-NanoSIMS.

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Introduction: NanoSIMS isotope imaging has been demonstrated to be especially powerful in characterizing meteoritic components, interplanetary dust particles, and cometary particles with high sensitivity and high spatial resolution. While NanoSIMS can achieve a primary beam spot size of ~50–100 nm with the primary Cs⁺ ion source, the spatial resolution is compromised in the negative mode (by a factor of several) when using the Duoplasmatron (DP) ion source, which limits our ability to investigate certain isotope systems requiring positive secondary ions at very high spatial resolution. This problem has been recently addressed by the development of a new radio-frequency plasma oxygen ion source (Hyperion-II), which produces a much higher primary beam current (~150 nA) with <~1% variation over the course of one day and with reduced spot size. Here we present some recent studies on presolar grains, meteoritic carbonates, and Mars analogues with the Hyperion-II source on the NanoSIMS.

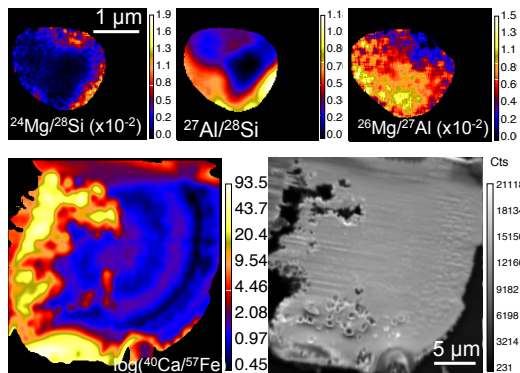


Fig. 1. Upper panel: Ratio images of a presolar mainstream SiC grain 1.5 μm in size. Lower panel: $\log_{10}(\text{Ca}/\text{Fe})$ atomic ratio (left) and SE (right) images of a hematite spherule of 25 μm in size from Mauna Kea volcano, Hawaii (RSF is not corrected).

Presolar SiC: Mainstream (MS) SiC grains originated from low-mass asymptotic giant branch (AGB) stars. AGB stars produce ^{26}Al ($t_{1/2}=0.72$ Myr) during shell H- and He-burning and by neutron capture, and determining $^{26}\text{Al}/^{27}\text{Al}$ ratios in MS grains can thus yield valuable information on nucleosynthesis in AGB stars. However, the literature $^{26}\text{Al}/^{27}\text{Al}$ data might have suffered from Al contamination due to the poor spatial resolution of the DP source and mainly represent lower limits [1]. We re-investigated the Mg-Al isotope ratios of 30 MS grains with the Hyperion-NanoSIMS 50L at Carnegie. The improved spatial resolution reveals heterogeneous distributions of ^{24}Mg , ^{26}Mg , and ^{27}Al within a single SiC grain. Figure 1 shows that the upper right part of this grain has lowered $^{26}\text{Mg}/^{27}\text{Al}$ ratios that are accompanied by increased Mg contents, likely pointing to Mg, Al-contamination. We reduced the data by carefully examining the isotope images, and the inferred initial $^{26}\text{Mg}/^{27}\text{Al}$ ratios range from 5×10^{-4} to 2×10^{-3} with a mean of 9×10^{-4} , which are higher than the literature data [2] by about a factor of two on average and are more consistent with recent AGB models [3].

Meteoritic Carbonates: ^{53}Mn - ^{53}Cr ($t_{1/2}=3.7$ Myr) radiometric dating has been widely applied to constraining the timing of aqueous processes in the early solar system, e.g., [4, 5]. Most of previous analyses were carried out on Cameca IMS ion probes with a primary beam size of ~5 μm in spot-analysis mode, which limited our capability of studying smaller samples or sampling variable Mn/Cr ratios. We recently developed an analytical protocol to measure Mn-Cr isotopes with the Hyperion-NanoSIMS 50 instrument at WashU with a primary beam of ~150 nm in size (10 pA). Our first results for carbonates from Renazzo CR2 meteorite were reported in [6]. We found large variations in the Mn/Cr ratio within single carbonate grains of 10–100 μm in size. We collected isotope data in imaging mode in order to better sample the large variations in Mn/Cr seen across a single grain. As a result, we were able to reproduce the isochron slope and uncertainty for Renazzo reported in [4] by analyzing only one of their seven dolomites. This greatly reduces the required amount of samples for ^{53}Mn - ^{53}Cr dating and is essential for analyzing micrometeorites and mission-returned samples in the future.

Mars Analogue: Hematite spherules from Mauna Kea volcano, Hawaii, which are formed by aqueous precipitation under acid-sulfate conditions, show mineralogical and morphological similarities with hematite spherules (blueberries) observed in sulfate-rich outcrops at Meridiani Planum on Mars [7]. To understand the formation process of hematite spherules, we imaged three MK spherules of 10–30 μm in size for their C, Mg, Al, S, Cl, K, Ca, V, Mn, Ni elemental abundances with the NanoSIMS 50 at WashU. We, for the first time, observed oscillatory zonings in many of the elements within each spherule, likely reflecting cyclic variations in the fluid composition during the growth of the spherules. These measurements have important implications to the formation of Martian blueberries.

References: [1] Groopman E. et al. (2015) *The Astrophysical Journal* 90:1151–1154. [2] Zinner E. (2014) *Presolar Grains in Treatise on Geochemistry* 1:181–210. [3] Liu N. et al. (2018) *The Astrophysical Journal* 865: 112 (14pp). [4] Jilly-Rehak C.E. (2018) *Geochimica et Cosmochimica Acta* 222, 230–252. [5] Matzel J.E.P. *LPS XLV*, Abstract #1645. [6] Ogliore R. C. et al. (2019) *LPS L*, Abstract #2778. [7] Morris R. V. et al. (2005) *Earth and Planetary Science Letters* 240: 168–178.