# COMPOSITIONAL AND MICROSTRUCTURAL ANALYSIS OF METAL ASSEMBLAGES HOSTED IN A REFRACTORY INCLUSION.

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**Introduction:** Calcium-aluminum-rich inclusions (CAIs) hosted in primitive meteorites, are the oldest solids in the Solar System [e.g., 1]. Some of these inclusions contain metal nuggets that are complex assemblages of Fe-Ni alloys [e.g., 2,3]. Presolar origin, condensation from the solar nebula, and crystallization from immiscible metal-silicate melt are the mechanisms hypothesized for their origins, however, secondary alteration has also affected some of these assemblages [e.g., 4]. Similar metal assemblages observed in chondrules and chondritic matrix indicate that these assemblages might share common high-temperature origins [5]. These metal assemblages record a diversity of early Solar System conditions, (e.g., variable temperatures, and oxygen fugacity etc.), that are reflected in their contradistinctive chemical composition, mineralogy and microstructures. Here we report detailed mineralogical and microstructural study of these metal assemblages hosted in a CAI. This work is part of a broader effort focused on using CAI microstructures to understand the thermal landscape in which they formed.

**Samples and Methods:** The metal assemblages studied here occur within a compact type-A inclusion from the NWA 5028 CR2 chondrite. The CAI defines an Al-Mg isochron with an initial $^{26}Al/^{27}Al$ ratio of $(6.0 \pm 1.1) \times 10^{-5}$ [6]. We investigated the metal assemblages using a CAMECA SX-100 electron microprobe at the Lunar and Planetary Laboratory to obtain backscattered electron (BSE) images, wavelegnth dispersive x-ray spectrometry (WDS) spot analyses, and elemental maps of selected regions. We further investigated these regions using the FEI Helios NanoLAB 660 focused-ion beam scanning-electron microscope (FIB-SEM), equipped with an EDAX energy dispersive x-ray spectrometer (EDS) and electron back scatter diffraction (EBSD) detector, located at the Lunar and Planetary Laboratory, University of Arizona.

**Results:** The metal assemblages are composed of an Fe-Ni-Co alloy. The Fe content varies from 45 to 90 wt%, whereas the Ni content varies from 6 to 48 wt%. Co occurs as a minor element (up to 3 wt%). No refractory PGEs were detected in the metal phases. EBSD analysis shows the individual metal grains are euhedral, suggesting crystallization in a fluid or gaseous environment. The metal nuggets show subsolidus exsolution into kamacite and taenite (Figure 1), where the high-Ni and low-Ni phases occur as lamellae arranged in preferred orientation. Most metal grains contain Fe-oxide inclusions, with abundant V (up to 17 wt %) and Cr (up to 8 wt%). The metal assemblages are surrounded by Fe-oxides, phosphate, and minor sulfides. The surrounding CAI does not show the effects of alteration, suggesting that the alteration of metal assemblages occurred before their incorporation into the host inclusion. Moreover, Wark-Lovering rims surrounding the host CAI show a canonical initial $^{26}Al/^{27}Al$ ratio, suggesting that if alteration occurred, it did so early (<640,00 years after CAI formation) [6]. These metal assemblages record complex processes in the early solar nebula, therefore further isotopic and microstructural study will be essential for understanding their origins.

**References:** [1] Connelly J. N. et al . (2012) *Science* 338:651-655. [2] El Goresy A. et al. (1997) *Meteoritics* 12:215-216. [3] Wark D. A. and Lovering J. F. (1976) *7th Lunar and Planetary Science* 912-914. [4] Armstrong, John T. et al. (1987) *Geochimica et Cosmochimica Acta* 51: 3155-3173. [5] Daly L. et al. (2017) *Geochimica et Cosmochimica Acta*. [6] Mane P. et al. (2016) *Meteoritics & Planetary Science* 51S1:300.

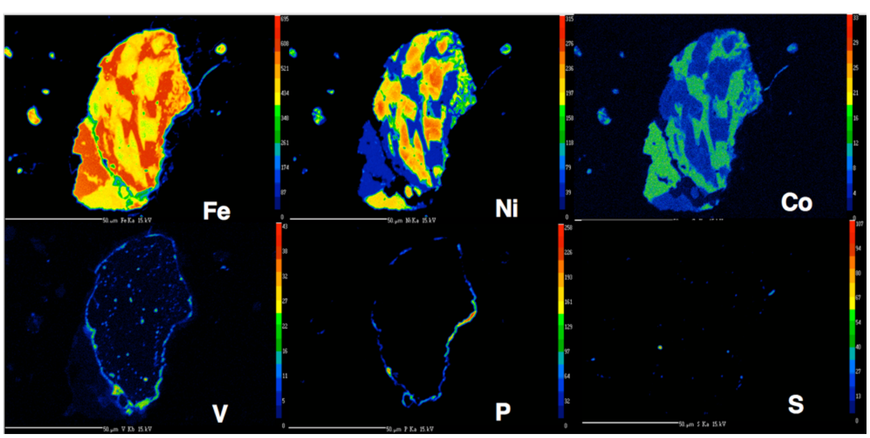


Figure 1: WDS elemental maps of a metal assemblage from a compact type-A CAI from NWA 5028 CR2 chondrite.