CRYSTALLOGRAPHY OF REFRACTORY METAL NUGGETS IDENTIFIED WITHIN CA-AL-RICH INCLUSIONS, CHONDRULES AND MATRIX OF CARBONACEOUS CHONDRITES.

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Introduction: Refractory metal nuggets (RMNs) as described by [1,2] are predicted to be some of the first Nebular condensates [3]. Previous work assumes these grains occur exclusively within Ca-Al-rich Inclusions (CAIs) [4]. Initial results utilising the Australian Synchrotron (AS) suggest this is not the case [5]. Here we present the combination of X-Ray Fluorescence (XRF) and scanning electron microscopy (SEM) techniques that positively identify RMNs within chondrules and matrix, as well as CAIs. We show for the first time the application of transmission Kikuchi diffraction (TKD) to a meteorite, defining nanometer-scale crystallographic and compositional variations of RMNs.

Method: Carbonaceous chondrites Vigarano and Allende were analysed with the AS XRF beamline and Maia detector. GeoPIXE software generated element maps, [6] identifying pixel-sized (2µm) hotspots of platinum group elements (PGEs). Analyses using electron back scatter diffraction (EBSD), and energy dispersive spectroscopy confirmed the presence of PGE alloys at the surface of the sample in the location of the hotspots. TKD analyses on focused ion beam generated sections of PGE alloys, using a 25nm step size, provided high spatial resolution data on the crystallography, orientation, and chemistry of RMNs *in situ*.

Results and Discussion: This approach has identified several RMNs in CAI material, and 6 RMNs within non-CAI material: 4 from Vigarano (3 within chondrules, and 1 within matrix), and 2 from chondrules in Allende. EBSD analysis of RMNs within Allende's chondrules indicate that the RMNs are single crystal cubic alloys with random crystal orientations. TKD analyses of 7 RMNs, between 80-500nm, in CAIs from Vigarano are also cubic alloys with random orientations, but in several cases exhibit polysynthetic twins with 20-130nm spacing. TKD Analysis of 3 PGE alloys, between 0.7-1.1µm, found within sulphide nodules enclosed within a chondrule of Allende reveal they are also single crystal cubic alloys; however the orientations of these grains are nearly identical. This heavily implies that these grains formed through parent body processes rather than condensation in the Nebula. However their similarity in appearance to RMNs highlights the importance of analysing these grains *in situ*.

Identifying RMNs enclosed within matrix and chondrules as well as CAIs has significant implications for how we interpret their formation. It is our aim with further research and analyses of RMNs *in situ* to develop a unifying theory of RMN formation.

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