Accepted Manuscript

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PII: S0016-7037(16)30672-X
DOI: http://dx.doi.org/10.1016/j.gca.2016.11.030
Reference: GCA 10038

To appear in: Geochimica et Cosmochimica Acta

Accepted Date: 17 November 2016


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In situ analysis of Refractory Metal Nuggets in carbonaceous chondrites

Luke Daly\textsuperscript{a,*}, Phil A. Bland\textsuperscript{a}, Kathryn A. Dyl\textsuperscript{a}, Lucy V. Forman\textsuperscript{a}, Katy A. Evans\textsuperscript{a}, Patrick W. Trimby\textsuperscript{b}, Steve Moody\textsuperscript{b}, Limei Yang\textsuperscript{b}, Hongwei Liu\textsuperscript{b}, Simon P. Ringer\textsuperscript{c}, Christopher G. Ryan\textsuperscript{d}, and Martin Saunders\textsuperscript{e}

\textsuperscript{a}Department of Applied Geology, Curtin University, GPO Box U1987, Perth, WA 6845, Australia.
\textsuperscript{b}Australian Centre for Microscopy and Microanalysis and ARC Centre of Excellence for Design in Light Metals, The University of Sydney, NSW 2006, Australia.
\textsuperscript{c}Australian Institute for Nanoscale Science and Technology, and School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney, NSW, 2006, Australia.
\textsuperscript{d}CSIRO Earth Sciences and Resource Engineering, 26 Dick Perry Avenue, Kensington, Perth, WA 6151, Australia.
\textsuperscript{e}Centre for Microscopy, Characterisation and Analysis, The University of Western Australia, WA 6009, Australia.

Abstract

Micrometre to sub-micrometre-scale alloys of platinum group elements (PGEs) known as refractory metal nuggets (RMNs) have been observed in primitive meteorites. The Australian Synchrotron X-ray Fluorescence (XRF) beamline, in tandem with the Maia detector, allows rapid detection of PGEs in concentrations as low as 50-100 ppm at 2 µm resolution. Corroborating these analyses with traditional electron microscopy techniques, RMNs can be rapidly identified \textit{in situ} within carbonaceous chondrites. These results dispute the assumption of most previous studies: that RMNs are unique to Ca-Al-rich inclusions (CAIs). We find that RMNs are, in fact, observed within all components of carbonaceous chondrites, such as the matrix, chondrules (consistent with observations from Schwander et al. (2015b) and Wang et al. (2007)), and sulphides; though the majority of RMNs are still found in CAIs. The chemistry of RMNs reveals a complex diversity of compositions, which nevertheless averages to CI chondrite abundance ratios. This implies that RMNs are the dominant, if not sole host phase for PGEs. One hundred and thirteen RMNs from this study are combined with reported compositions in the literature, and compared to condensation model compositions similar to Berg et al. (2009), RMNs derived experimentally by precipitation (Schwander et al., 2015a), host phase and host meteorite. Comparisons reveal only weak correlations between parent body processes (sulphidation) and nebular processes (condensation and precipitation) with RMN compositions. It appears that none of these processes acting in isolation or in tandem can explain the diversity observed in the RMN population. Our interpretation is that the Solar Nebula inherited an initially compositionally diverse population of RMNs from the Giant Molecular Cloud; that a variety of Solar System processes have acted on that population; but none have completely homogenised it. Most RMNs have experienced disk and asteroidal processing, but some may have retained a primordial composition. RMNs have been identified in pre-solar graphite grains (Croat et al., 2013). We anticipate that pre-solar RMNs will be present elsewhere in primitive meteorites.

Keywords: Refractory Metal Nuggets, Solar Nebula, Solar System, Origin, Meteorites, carbonaceous chondrites

*Corresponding author: Luke Daly, Email: luke.daly@postgrad.curtin.edu.au, telephone: +61497840194
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