Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.15328

A New Coordinated NanoSIMS, Transmission Electron Microscopy and Atom Probe Tomography Approach for the Characterization of Primitive Astromaterials

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Presolar grains are remnants of evolved stellar systems preserved within primitive extraterrestrial materials. They are important for studying physical and chemical processing, and formation mechanisms occurring within the interstellar medium, Solar Nebula and their parent stellar environments [1]. Our recent work has shown coordinated nano-scale Secondary Ion Mass Spectrometry (NanoSIMS) and Atom Probe Tomography (APT) can show isotopic and chemical signatures at major to trace levels, morphological signatures, and regional contextual relationships [2,3]. Previous studies have shown Transmission Electron Microscopy (TEM) of Focus Ion Beam (FIB) TEM lamella, can provide localized contextual relationships, crystallographic information and chemical information [1]. Coordinating NanoSIMS, TEM, and APT could gain access to almost all contextual, structural and geochemical signatures within each presolar grain. However, this has proved challenging owing to the preparation requirements for TEM and APT. For example, studying specimen prepared as APT needles in TEM removes the local context, the higher degree of surface exposure can alter the chemistry of beam sensitive materials, and the shank angle of the needle can impact the quality of TEM diffraction images.

We designed a new FIB method which takes a 100 nm thick FIB-TEM lamella and sandwiches it between two indium slices (5 µm x ~300 nm x 3 µm). The indium is melted onto the lamella surface using the electron beam (Fig 1). This process adds bulk to the lamella, making it more amenable to APT needle formation (Fig 2). Consequently, samples can be prepared per the optimal requirements for each technique improving data quality, acquisition stability, and access to the signatures and relationships summarised earlier. This technique can be used for measuring multiple phases across a TEM lamella and targeting an individual phase. For example, a presolar grain identified using NanoSIMS could be targeted, studied in TEM and then indium sandwiched with its precise location in the TEM lamella marked using a Pt button for preparation of an APT needle and 3D atomic scale acquisition.

[1] A. M. Davis (2014) Meteorites and cosmochemical processes, 1. [2] Nevill N. et al. (2023) LPSC, 54, #1707. [3] Nevill N. et al. (2023) LPSC, 54, #1714.