TEM ANALYSIS OF A PRESOLAR SILICATE GRAIN IN THE DOMINION RANGE 08006, CO CHONDRITE. L. B. Seifert[1], P. Haenecour[1], T. J. Zega[1,2], and C. Floss[3] [1]Lunar and Planetary Laboratory, University of Arizona, 1629 E University Blvd. Tucson, AZ, 85721-0092, lseifert@lpl.arizona.edu. [2]Materials Science and Engineering, University of Arizona. [3]Laboratory for Space Sciences and Physics Department, Washington University, One Brookings Drive, Campus Box 1105, St, Louis, MO 63130.

Introduction: Presolar grains are dust particles that condensed in ancient circumstellar environments and survived transport through the interstellar medium and the formation of our own solar system. They can offer insights into stellar nucleaosynthesis, circumstellar thermodynamics, and parent body processing [1-2]. Here we report on the chemistry and structure of a Mg-silicate presolar grain from the type 3.0 CO chondrite Dominion Range (DOM) 08006.

Methods: A petrographic thin section of DOM 08006 was obtained from the meteorite curatorial facility at NASA Johnson Space Center, Houston TX, USA. Grains were identified via raster-ion-imaging using NanoSIMS at Washington Univeersity in St. Louis. Fifty-five oxygen-anomalous grains were identified and initial phase identification was made based on Auger spectroscopy [3]. We chose one of these, DOM-59 for detailed analysis using transmission electron microscopy (TEM).

The grain was prepared for TEM using previously described focused ion beam scanning electron microscope (FIB-SEM) methods [4] with an FEI Helios G3 FIB located at the Lunar and Planetary Laboratory (LPL). Prior to lifting out a section of this grain, a carbon strap was deposited to protect the grain from Ga^+ implantation. However, in an attempt to make the section very thin, part of the capping layer was milled through, damaging a small part of the grain, but leaving the majority of the grain undamaged and still preserved by a capping layer (Fig. 2).

The FIB section was analyzed with LPL's newly installed 200 keV aberration-corrected Hitachi HF5000 TEM, equipped with scanning TEM (STEM)-based bright-field (BF) and dark-field (DF) imaging detectors as well as a large solid-angle (2 sr) Oxford Instruments energy-dispersive X-ray spectrometer (EDS) and a post-column Gatan Quantum imaging filter for electron energy-loss spectroscopy (EELS). DOM-59 was measured at 200 keV for its detailed structure and composition.

Results: NanoSIMS analysis shows enrichment in ^{17}O and depletion in ^{18}O (Fig. 1B-C) with $^{17}O/^{16}O$ = 11.6E-4 ±0.5 and $^{18}O/^{16}O$ = 0.69E-4 ±0.03 [3], placing it in the Group-2 field as previously defined by [2]. While the O-anomaly has a crescent shape (Fig. 1B-C), TEM data shows that DOM-59 has a roughly round morphology measuring 310×390nm (Fig. 1A).

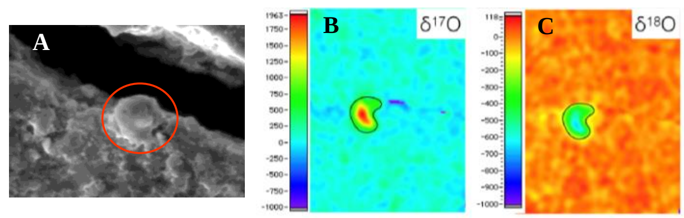

Figure 1: (a) Red circle indicates location of grain within matrix, (b)NanoSIMS isotopic map showing crescent shaped hotspot and enrichment in ^{17}O (c) NanoSIMS isotopic map showing depletion in ^{18}O.

TEM-EDS mapping of DOM-59 reveals that it is composed of a polyphasic Mg-silicate with a core-shell structure. The center of the grain is composed of a high-Ca pyroxene such as pigeonite or augite. A mantle composed of Mg-silicate is likely a low-Ca pyroxene such as an orthopyroxene, surrounding the Ca-rich core. This structure is not physically visible in the Bright Field (BF) and High Angle Annular Dark Field (HAADF) images (Fig. 2A-B), however there is a distinct difference in the EDS maps between the core, mantle, and rim (Fig. 3). An iron rim surrounds the Mg-silicate mantle.

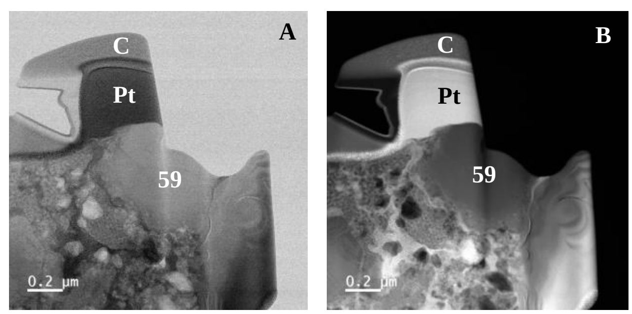

Figure 2: (a) Bright Field image of DOM-59, (b) Dark Field image of DOM-59.

Selected Area Electron Diffraction (SAED) patterns were acquired across the grain. Patterns from across the assemblage show the grain is crystalline and indexing is consistent with a pyroxene.

Discussion: Comparison of the O-isotopic composition of DOM-59 with nucleosynthetic models [5] suggest an origin in low mass asymptotic giant branch (AGB) stars (< 2 M☉) [5-6]. These types of grains experienced an extra deep mixing mechanism, called cool bottom processing, which brings up material from the bottom of the stellar envelope and destroys ^{18}O. Alternatively, new calculations by Lugaro et al. suggest these grains could have condensed in intermediate mass (4-8 $M_\odot$) AGB stars [7].

DOM-59 is dominated by the silicate mineral phase. This grain displays a core-shell structure with a Ca-rich core, which is likely to have condensed first and provided a nucleation site for the surrounding Mg-rich material. A core like this has not been previously documented in DOM 08006. This anti-correlation between Ca and Mg is shown in the EDS maps in addition to an Fe-rich rim surrounding the lower edge of the grain (Fig. 3).

Most circumstellar grains form through condensation in the gaseous envelopes that surround their progenitor star. Equilibrium thermodynamic calculations aim to predict the solids which condense out of a solar-composition gas at different temperatures which we can compare to DOM-59, assuming a similar metallicity (solar) in the progenitor star's envelope and condensation via equilibrium predictions [8]. Enstatite and diopside phases, Mg-rich and Ca-rich pyroxenes respectively, condense at temperatures of about 1300-1350K at a pressure of 10^{-4} bars [8].

The origin of the Fe rim surrounding the lower edge of the grain (Fig. 3) is not well constrained. One possibility is thermal metamorphism, which could have driven Fe to diffuse from the matrix to the grain, similar to previous observations in the Adelaide meteorite [9]. However, the DOM 08006 CO3.0 chondrite is thought to be one of the least altered meteorites available for study [6,10-11] and so parent-body metamorphism seems unlikely. Analysis of additional grains could help test this hypothesis.

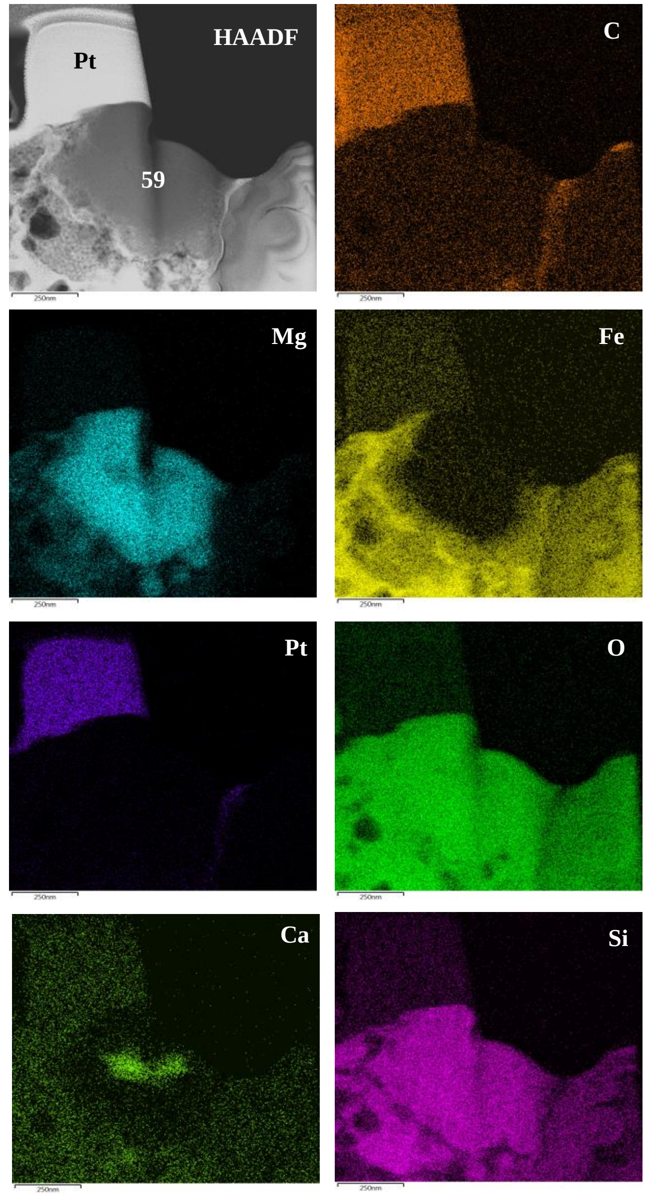

Figure 3: EDS maps of grain region with HAADF image for comparison. Maps show abundance of Mg, Si, O, and a Ca core.

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