THE ABUNDANCE AND DISTRIBUTION OF PRESOLAR MATERIALS IN CLUSTER IDPS. Scott Messenger[1], Lindsay Keller[1], Keiko Nakamura-Messenger[1,2], and Motoo Ito[1], [1]Robert M. Walker Laboratory for Space Science, ARES, NASA JSC, 2101 NASA parkway, Houston TX 77573, USA [1]ESCG, Johnson Space Center, Houston TX 77058. (scott.r.messenger@nasa.gov)

Introduction: Presolar grains and remnants of interstellar organic compounds occur in a wide range of primitive solar system materials, including meteorites, interplanetary dust particles (IDPs), and comet Wild-2 samples [1-3]. Among the most abundant presolar phases are silicate stardust grains and molecular cloud material. However, these materials have also been susceptible to destruction and alteration during parent body and nebular processing. In addition to their importance as direct samples of remote and ancient astrophysical environments, presolar materials thus provide a measure of how well different primitive bodies have preserved the original solar system starting materials.

The matrix normalized abundances of presolar silicate grains in meteorites range from 20 ppm in Semarkona and Bishunpur to 170 ppm for Acfer 094 [4-5]. The lower abundances of presolar silicates in Bishunpur and Semarkona has been ascribed to the destruction of presolar silicates during aqueous processes. Presolar silicates appear to be significantly more abundant in anhydrous IDPs, possibly because these materials did not experience parent body hydrothermal alteration. Among IDPs the estimated abundances of presolar silicates vary by more than an order of magnitude, from 480 to 5500 ppm [2, 6]. The wide disparity in the abundances of presolar silicates of IDPs may be a consequence of the relatively small total area analyzed in those studies and the fine grain sizes of the IDPs. Alternatively, there may be a wide range in presolar silicate abundances between different IDPs. This view is supported by the observation that ^{15}N-rich IDPs have higher presolar silicate abundances than those with isotopically normal N [6].

Here we report the initial results of a new study aimed at (1) determining the abundances of presolar grains in IDPs with improved accuracy and (2) evaluating whether presolar molecular cloud material (with H and/or N isotopic anomalies) is preferentially associated with presolar dust grains. We focus on cluster IDPs previously found to contain silicate stardust.

Experimental: Fragments of cluster IDPs L2036 AA7 (Cl #4) and L2009 O1 (Cl #13) were embedded and vacuum impregnated with low viscosity resin for ultramicrotomy. The particles were sliced into 70 nm sections and series of 3 sections were alternately deposited onto C-coated TEM grids and directly onto Au substrates for SIMS analysis. Quantitative X-ray maps were obtained from the thin sections using a JEOL 2500SE field-emission STEM. The Au-mounted sections were coated with a 50 Å layer of Au to mitigate charging during isotopic measurements. This sample preparation approach is a compromise that is intended to optimize conditions for isotopic measurements while providing an opportunity for subsequent mineralogical study by TEM in adjacent (TEM-mounted) sections.

Isotopic measurements of Au-mounted sections of the IDPs were performed with the JSC NanoSIMS 50L ion microprobe. O and N isotopic images were taken simultaneously, acquiring images of $^{16}O^-$, $^{17}O^-$, $^{18}O^-$, $^{12}C^{14}N^-$, $^{12}C^{15}N^-$, $^{28}Si^-$, and $^{24}Mg^{16}O^-$ in multidetection with electron multipliers. The images were obtained by rastering a 1 pA, <100 nm Cs^+ beam over 10 - 15 μm fields of view. These images were repeatedly acquired for each sample, for a total of 10 – 20 image layers acquired during each analysis. Sample charging was minimized with the use of an electron flood gun. Oxygen and Nitrogen isotopic images were acquired from 10 μm grains of San Carlos olivine and 1-hydroxybenzotriazole hydrate (respectively) placed near each sample as external isotopic standards.

Results and discussion: Investigation of several sections of these particles by TEM showed them to be highly porous, very fine grained, and dominated by anhydrous minerals including enstatite, forsterite, Fe-Ni sulfides, GEMS grains, and carbonaceous material. The identified minor phases include diopside, anorthite, and spinel. Fragment L2006AA7 has been strongly heated during atmospheric entry which resulted in the formation of magnetite rims on all of the sulfide grains and many of the GEMS grains in the sections. We did not observe solar flare particle tracks in AA7.

O and N isotopic images were evaluated by generating direct isotopic ratio images and by manually defining the outlines of spatially resolved 'subgrains' in each of the image layers. The subgrains ranged in size from 300 nm to 1.5 μm. Most of the subgrains had O isotopic compositions near terrestrial/meteoritic values within error. The average analytical uncertainties of these measurements were $1\sigma\ \delta^{17}O$ = 40 ‰ (ranging from 10 - 100 ‰), and $1\sigma\ \delta^{18}O$ = 20 ‰ (ranging from 6 - 70 ‰).

One subgrain exhibited an anomalous O isotopic composition: $\delta^{17}O = +182 \pm 52$ ‰, and $\delta^{18}O = +108 \pm 21$ ‰ (1σ). The Si/O and Mg/O ratios of this grain determined from the isotopic images are consistent with this grain being a silicate, although it is not yet known whether it is crystalline or amorphous. Given the size of the grain (300 nm) and the total area imaged so far (48 μm^2), this IDP is found to have a *very preliminary* presolar silicate abundance near 3000 ppm. Though still highly uncertain, this value is within the previously determined range for IDPs.

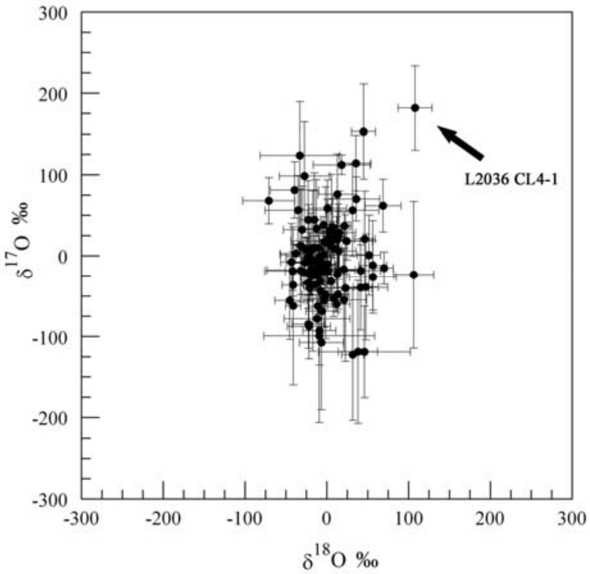

Fig. 1: O isotopic ratios of 125 submicrometer regions (subgrains) identified in O isotopic images of both IDPs. The arrow indicates the presolar grain candidate discussed in the text.

Many submicrometer organic regions in the samples were clearly visible in the N isotopic images, despite a strong N background originating from the epoxy. The N-rich regions associated with the IDP exhibited large and highly variable enrichments in $^{15}N/^{14}N$ ratios, with most values falling between $\delta^{15}N$ = +100 to +400 ‰ [Fig. 2]. Several $\delta^{15}N$-rich hotspots were also observed, with $\delta^{15}N$ values ranging from +800 to +1400 ‰. The sizes and range in N isotopic compositions of the ^{15}N-rich hotspots are similar to those recently reported in meteorites and IDPs [7-9].

Interestingly, the presolar silicate candidate grain is adjacent to ^{15}N-rich material and is about 1 μm from the most ^{15}N-rich material observed in this sample. The direct association of a presolar olivine grain with molecular cloud material was recently reported [10]. It will be important to establish whether organic matter associated with presolar grains shares common chemical characteristics.

Although this project is still at an early stage, the results show that it is feasible to accurately determine presolar silicate abundances within a single IDP. This is made possible by the very fine grain sizes of these materials. A single IDP fragment may contain several thousand grains analyzable by NanoSIMS (>250 nm). Subdividing IDPs by ultramicrotomy thus provides dozens of independent samples of that material for presolar grain searches. On the other hand, approximately half of this IDP is so fine grained that it is not possible to distinguish whether those (<250 nm) grains have presolar versus solar system grains, even with the NanoSIMS. Astronomical observations have shown that interstellar dust grains are predominantly < 200 nm in diameter [11]. The silicate stardust abundances reported in meteorites and IDPs should thus be considered lower limits, and substantially greater abundances may be encountered when it is feasible to analyze their smallest constituents.

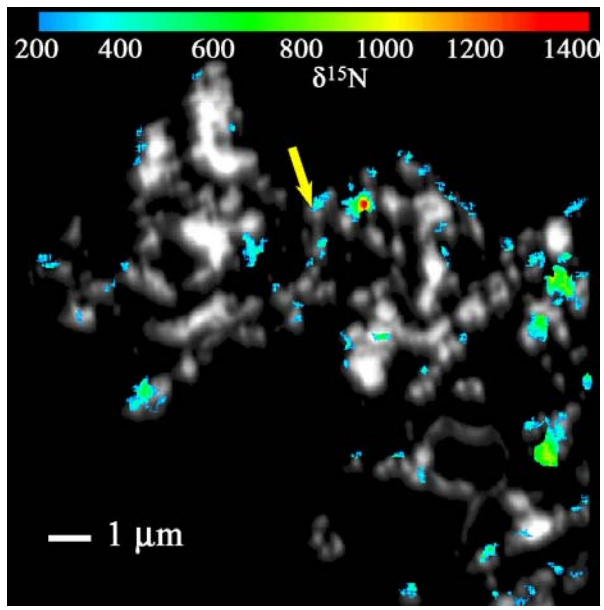

Fig. 2: This image shows regions of IDP L2036 AA7 with $\delta^{15}N$ values larger than +200 ‰ overlain on the ^{16}O image of the sample. The location of the presolar silicate candidate grain is indicated by the arrow.

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