STARDUST IN FINE-GRAINED CHONDRULE RIMS AND MATRIX IN LAPAZ 031117: INSIGHTS INTO THE CONDITIONS OF DUST ACCRETION IN THE SOLAR NEBULA.

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Introduction: The relationship between chondrules and fine-grained materials in primitive chondritic meteorites has been investigated for years, but remains obscure. In particular, the origin of the fined-grained rims surrounding chrondrules in many carbonaceous chondrites is still uncertain. Two main hypotheses have been proposed: formation by accretion in the solar nebula before incorporation of the chondrules into planetesimals [1–3], or formation by compression-alteration of matrix material around chondrules on the parent body asteroids [4].

Presolar grains (e.g. silicates, oxides and SiC) have been found with varying abundances in different primitive solar system materials and can be used to better understand conditions in the early solar nebula [e.g., 5]. Presolar silicate grains, in particular, are susceptible to secondary alteration processes [6] and can therefore provide constraints on accretion processes in the solar nebula and the effects of parent body processing.

LAP 031117 is a newly discovered CO3.0 chondrite [7]; our initial investigation showed that its matrix material contains high abundances of presolar silicate grains [8]. The presence of large fine-grained rims around some of the chondrules in this meteorite led us to carry out a search for presolar grains in these areas. Here we report on the results of this investigation and discuss the genetic relationship between the matrix and fine-grained chondrule rims in LAP 031117.

Methods: We carried out NanoSIMS 50 raster ion imaging using a focused Cs^+ primary beam of ~1 pA (~100 nm in diameter) that was rastered over areas of 10x10 µm^2 (256^2 pixels). Secondary ions of $^{12}C^-$, $^{13}C^-$, $^{16}O^-$, $^{17}O^-$ and $^{18}O^-$, as well as secondary electrons, were simultaneously acquired in multicollection mode. The total areas mapped are 14,050 µm^2 and 11,000 µm^2 in the matrix and chondrule rim, respectively. Subsequently, high-resolution secondary electron images, elemental spectra (from 30 to 1730 eV) and elemental maps were acquired for most of the grains using the PHI 700 Auger Nanoprobe at Washington University in St. Louis.

Isotopic compositions: To date we have identified 50 O-anomalous grains in LAP 031117 (34 in the matrix and 16 in the rim). Based on the classification proposed by [9], 44 grains belong to group 1, with excesses in ^{17}O and sub-solar to solar $^{18}O/^{16}O$ ratios, five grains exhibit enrichments in ^{18}O relative to solar and belong to group 4, and one grain with an excess in ^{17}O and a depletion in ^{18}O belongs to group 2 (Fig. 1).

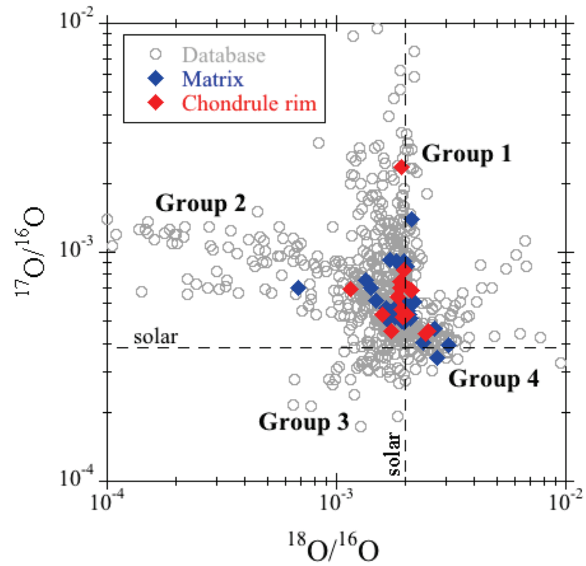

Figure 1. Oxygen three-isotope plot showing the O-anomalous grains identified in matrix areas (blue) and fine-grained chondrule rim (red) in LAP 031117. Other data (grey) are from the presolar grain database (http://presolar.wustl.edu/~pgd/).

We also found fifteen C-anomalous grains in LAP 031117 (six in the matrix and nine in the rim). Thirteen grains are ^{13}C-rich ($^{12}C/^{13}C$ between 52 and 72) and are probably mainstream SiC; this was confirmed by Auger analyses for the grains that could be relocated. The other two grains are ^{12}C-rich ($^{12}C/^{13}C$ = 138 ± 5 and 101 ± 2); we have not yet determined the compositions of these grains.

Elemental compositions: Auger analysis of the 43 O-anomalous grains that could be relocated revealed that 37 are ferromagnesian silicates, five are oxides (two with spinel-like compositions, one with a corundum-like composition and two Fe-Mg oxides) and one has a silica-like composition. Iron contents are between 0–36 at% (median = 20 at%) and 0–23 at% (median = 15 at%) for presolar silicates in the matrix and chondrule rim, respectively.

The calculated abundances of silicate, oxide and SiC grains in the matrix are 137 ± 25 ppm, 10 ± 6 ppm and 94 ± 38 ppm and in the rim are 76 ± 20 ppm, 9 ± 7 ppm and 74 ± 25 ppm (without correcting for detection efficiency; Fig. 2). Based on the number of grains identified, the ratios of presolar silicate to oxide grains in the matrix and chondrule rim are 10 and 7, respectively.

Discussion: The calculated abundances of presolar silicates, oxides and SiC in LAP 031117 (Fig. 2) are comparable to those determined for other primitive carbonaceous chondrites [e.g., 10, 11], indicating that LAP 031117 is a very pristine meteorite that did not undergo significant secondary alteration, such as aqueous alteration or thermal metamorphism.

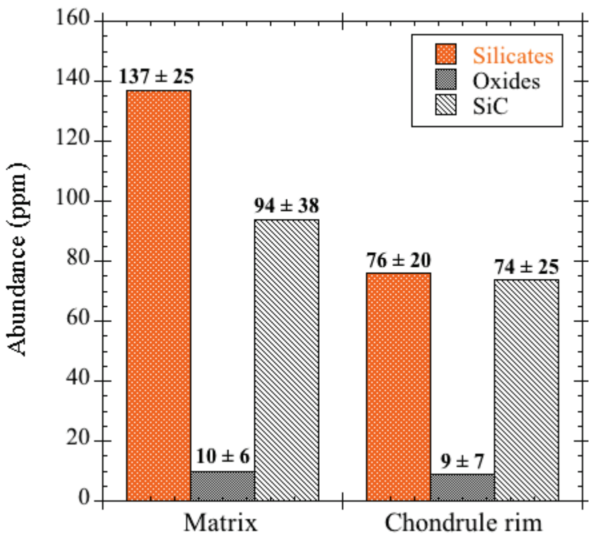

Figure 2. Comparison of the abundances of presolar grains in the matrix and fine-grained chondrule rim of LAP 031117.

Comparison of the presolar grain abundances in LAP 031117 shows that within errors the abundances of presolar oxide and SiC grains are the same in the matrix and chondrule rim (Fig. 2). However the abundance of presolar silicates is significantly higher in the matrix than in the rim. Various hypotheses can be considered to account for this difference. Accretion of the rim and matrix from nebular reservoirs with distinct presolar grain populations seems unlikely since the abundances of oxide and SiC grains are comparable. Moreover, while detailed mineralogical studies of the fine-grained material in LAP 031117 have not been carried out yet, past work has shown that there are no chemical or mineralogical differences between the matrix and fine-grained chondrule rims in another CO3.0 chondrite, ALHA77307 [12].

Presolar silicate grains are, however, known to be more susceptible to heating and alteration than other, more refractory, presolar phases [e.g., 6], suggesting that the fine-grained chondrule rim in LAP 031117 may have experienced more secondary processing than the associated matrix material. Parent body processes are one possible mechanism for this secondary alteration, but this is unlikely, both because LAP 031117 is a very pristine meteorite which did not experience much secondary alteration and because the proximity of the matrix and fine-grained rim of chondrule likely precludes alteration of one component and not the other.

It is more likely that the difference in presolar silicate abundances between the matrix and the fine-grained rim reflects processing in the solar nebula, during the dust accretion around the chondrules, before the incorporation of the chondrules in meteorite parent bodies. Studies [e.g., 13-15] have suggested that accretion of the fine-grained rims around chondrules may have occurred shortly after their formation, when the chondrules were still hot. If this is the case, then the lower presolar silicate abundances that we observe in the chondrule rim in LAP 031117 could be due to destruction of some presolar silicates as the result of heating during accretion of the rim around the chondrule. However, this heating must have been limited because the abundances of presolar oxides and SiC are similar in both matrix and chondrule rim.

Conclusions: Comparison of the presolar grain abundances in the matrix and fine-grained chondrule rim of LAP 031117 suggests formation of the rims by dust accretion onto relatively hot chondrules before their incorporation into planetesimals. Our observations are, therefore, more consistent with a nebular origin for the chondrule rims in LAP 031117 [e.g., 1–3] than with an origin through impact-compaction of fine-grained matrix material around chondrules within a parent body setting [4].

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