CHARACTERIZATION OF PRESOLAR SILICATE AND OXIDE GRAINS USING NANOSIMS AND AUGER SPECTROSCOPY.
A. N. Nguyen[1], F. J. Stadermann[2], L. R. Nittler[1], and C. M. O'D. Alexander[1]. [1]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road NW, Washington DC 20015, USA (nguyen@dtm.ciw.edu), [2]Laboratory for Space Sciences, Washington University, One Brookings Dr., St. Louis, MO 63130, USA.

Introduction: Presolar silicates condensed in the outflows of red giant stars and supernovae. In studying the isotopic compositions of these grains, the nucleosynthetic processes that occur in the parent stellar sources can be investigated. The chemical compositions and mineralogies of the grains reflect the physical conditions and compositions of the stellar atmospheres during grain condensation.

Presolar silicates are typically less than 500 nm in diameter [1], making their analysis experimentally challenging. The NanoSIMS ion microprobe has become a powerful tool for analyzing the isotopic compositions of presolar silicates. The Auger nanoprobe is a good complementary technique for obtaining chemical information because it achieves a high spatial resolution (10s nm) and is non-destructive [2]. Nine presolar silicates identified in the ALHA 77307 carbonaceous chondrite have previously been analyzed using Auger spectroscopy [1]. Here we describe new presolar silicates and oxides identified in this meteorite, and the Auger results of select grains.

Experimental: A polished thin section of the carbonaceous chondrite ALHA 77307 was analyzed by raster ion imaging in the Carnegie NanoSIMS 50L ion microprobe. A focused Cs^+ primary ion beam was rastered over 20×20 μm^2 areas. Typically, negative secondary ions of the three O isotopes, the three Si isotopes, and MgO were collected simultaneously with secondary electrons. The $^{28}Si^-/^{16}O^-$ and $^{24}Mg^{16}O^-/^{16}O^-$ ratios of an anomalous grain give a first estimate of its mineralogy.

The chemical make-up of anomalous grains were then investigated using the Washington University PHI 700 Auger spectrometer. Complete elemental spectra were obtained by spot measurements for grains that were well defined in secondary electron images. Major element distribution maps were acquired for grains that could not be discerned in the secondary electron images. These maps not only help to distinguish grains from the surrounding matrix, but inhomogeneous elemental distributions or rims can also be recognized. Currently, we report qualitative spectral interpretation, but future work will allow for quantitative results.

Isotopic Analysis: We have identified 91 presolar silicate grains and 11 presolar oxide grains. Combined with previously reported data [1,3], the abundance of presolar silicates and oxides in ALHA 77307 is 140 ppm and 20 ppm, respectively. The O isotopic ratios of grains from this study are plotted in Fig. 1. It should be noted that due to isotopic dilution, the actual compositions of these grains are likely to be more extreme [1]. All four presolar oxide groups [4] are represented in these grains, with most belonging to Group 1. Grains in this group are enriched in ^{17}O, relative to normal, and have $^{18}O/^{16}O$ ratios close to solar. They condensed in the atmospheres of low mass red giant branch and asymptotic giant branch stars. The O isotopic compositions of the identified oxide grains are not systematically different from the silicate grains.

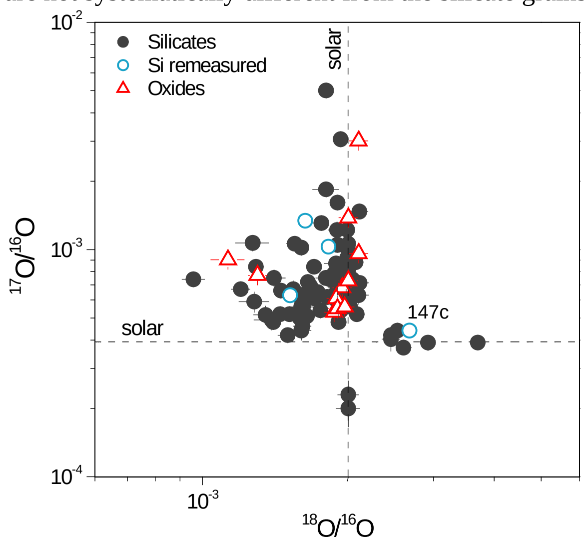

Figure 1. Oxygen isotopic ratios of presolar silicate and oxides from ALHA 77307. Error bars are 1σ.

The Si isotopes were measured along with the O isotopes for 76 presolar silicates. Due to the lower ionization efficiency of Si in these minerals, however, the errors are relatively large. We were able to remeasure the Si isotopes in 4 grains (indicated in Fig. 1) for improved statistics. Measurements of similar precision were also obtained for presolar silicate grains from the interplanetary dust particles (IDPs) L2054 E1 and G4 [5]. The Si isotopic compositions of these grains lie along the mainstream SiC correlation line (Fig. 2), but many fall to the left of the line, indicating parent stellar n-capture reactions did not greatly affect their compositions. The relatively normal Si isotopic composition of grain 147c indicates its ^{18}O enrichment does not reflect a high metallicity source, but rather points to a massive star origin [6]. The parent stellar metallicity (Z) can be deduced from the $^{18}O/^{16}O$ ratios of grains whose compositions are not affected by cool bottom processing, and it is expected that $\delta^{29}Si$ should correlate well with Z (e.g. [1]). Better Si data need to be obtained to investigate this possible relation.

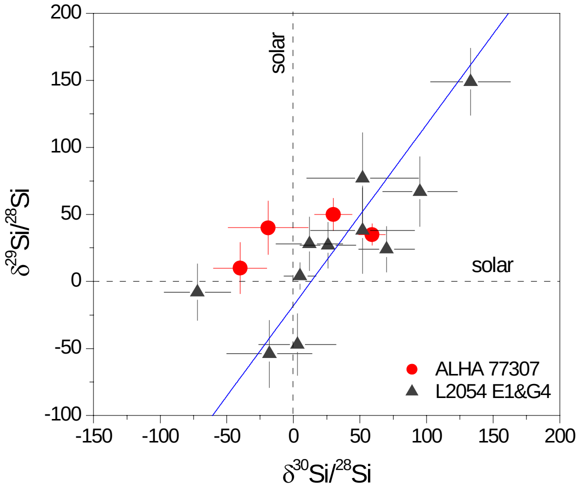

Figure 2. Silicon isotopic ratios of select presolar silicate grains from ALHA 77307 and the IDPs L2054 E1 and G4. δ^{29}Si errors are less than 35‰. The blue line indicates the correlation line for mainstream SiC.

Chemical Analysis: Auger analyses were achieved for 69 presolar silicates, and 4 presolar oxides. The isotopic compositions of 15 of these grains were previously reported [1,3]. Of the oxides, one is an Al oxide (likely Al_2O_3), one is Mg-rich, one contains Fe, Al and Mg, and one is an Fe-rich oxide, though likely not FeO. All of these oxides are Group 1 grains. Floss et al. [7] previously observed a presolar ^{18}O-rich Fe oxide grain similar to wüstite.

The majority of silicate grains have Fe~Mg (54%). 23% are Fe-rich (Mg/Fe<1), and 23% are Mg-rich (Mg/Fe>1). Ca is present in 26% of the silicates, and 19% contain Al. We do not see a correlation between Fe/Mg content, and the presence of Ca or Al. One grain contains substantial amounts of Ca and Al (Ca/Mg ~ 0.7; Ca/Al ~0.7). The elemental composition of this grain, however, is different than the recently observed presolar grain comprised of Ca-Al-rich minerals [8]. Though astronomical spectra point to a majority of Mg-rich silicates [9], Fe seems to be more prominent in the silicates analyzed in this study and others [1,8,10,11]. The Fe content of these grains could be due to nebular or parent body alteration [12], or it could be a consequence of non-equilibrium condensation [10,13].

Fig. 3 shows an Auger elemental distribution map for an area of the ALHA 77307 thin section containing a presolar silicate, and demonstrates the fine-scale detail that can be obtained. Spot analysis indicates the grain in Fig. 3 is an Fe-rich silicate. The elemental map shows this 100 nm grain has a 60 nm Mg-rim. It is unlikely that this rim was produced during parent body alteration because this would produce an Fe-rich rim. If this rim formed during primary condensation, it suggests the parent stellar atmosphere was either temporally or spatially enriched in Mg during the latter stages of condensation. Further investigations need to be made to determine the source of this feature.

References: [1] Nguyen A. N. et al. (2007) *ApJ*, 656, 1223–1240. [2] Stadermann F. J. et al. (2006) *LPS XXXVII*, #1663. [3] Nguyen et al. (2006) *M&PS*, *41*, A5355. [4] Nittler L. R. et al. (1997) *ApJ*, *483*, 4715-495. [5] Nguyen et al. (2007) *LPS XXXVIII*, #2332. [6] Nittler L. R. et al. (2008) *ApJ*, submitted. [7] Floss C. et al. (2008) *ApJ*, *672*, in press. [8] Vollmer C. et al. (2007) *M&PS*, *42*, A5107. [9] Waters, L. B. F. M. et al. (1996) *A&A*, *315*, L361-L364. [10] Floss C. et al. (2006) *GCA*, *70*, 2371–2399. [11] Bose M. et al. (2007) *M&PS*, *42*, A5063. [12] Nguyen A. N. and Zinner E. (2004) *Science*, *303*, 1496–1499. [13] Gail H.-P. (2003) In *Astromineralogy* (ed. T. Henning) pp. 55-120.

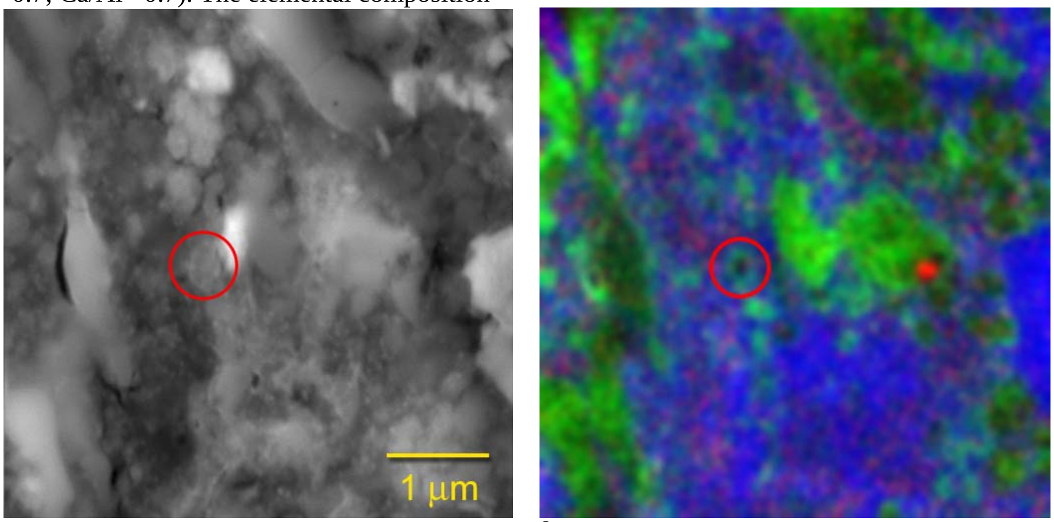

Figure 3. Scanning Auger microprobe images of a 5×5 μm^2 area of a thin section of ALHA 77307. (left) secondary electron image. (right) composite RGB elemental image (red = Ca, green = Mg, blue = Fe). Circled is an Fe-rich presolar silicate grain ($^{17}O/^{16}O = 7.14 \pm 0.39 \times 10^{-4}$; $^{18}O/^{16}O = 1.98 \pm 0.08 \times 10^{-4}$) with a Mg rim.