A COMPLEX PRESOLAR GRAIN IN ACFER 094 – FINGERPRINTS OF A CIRCUMSTELLAR CONDENSATION SEQUENCE? C. Vollmer[1], P. Hoppe[1], F. E. Brenker[2] and H. Palme[3], [1]Max-Planck-Institute for Chemistry, Particle Chemistry Department, P.O. Box 3060, 55020 Mainz, Germany (cvollmer@mpch-mainz.mpg.de), [2]JWG – University, Institute for Mineralogy, Senckenberganlage 28, 60054 Frankfurt/Main, Germany, [3]University of Cologne, Institute for Geology&Mineralogy, Zülpicher Str. 49b, 50674 Cologne, Germany.

Introduction: Presolar silicates in primitive meteorites and interplanetary dust particles (IDPs) preserve chemical and isotopic information about O-rich evolved stars [e.g. 1] or supernovae [2]. Spectroscopically, circumstellar silicate grains have been detected more than a decade ago [3], but only new developments in high resolution mass spectrometry and above all the invention of the NanoSIMS ion microprobe made the in-situ identification of presolar silicates inside primitive solar system materials possible. Previous studies have shown that the matrix of the carbonaceous chondrite Acfer 094 contains up to 180 ppm presolar silicates [1, 4, 5]. Here we report on new results from a combined NanoSIMS/SEM/EDX study of presolar silicates in Acfer 094.

Experimental: We chose suitable fine-grained matrix areas in a polished thin section of Acfer 094 for isotopic mapping with the NanoSIMS at MPI for Chemistry. A focused Cs^+ ion beam (<100 nm, ~0.6 pA) was rastered over these areas, 10x10 μm^2 in size, and negative secondary ions of ^{16}O, ^{17}O, ^{18}O, ^{28}Si and $^{27}Al^{16}O$ were simultaneously detected and converted to 256x256 pixel ion images. Total integration time for each ion image was ~1 hour. All grains with O-isotopic anomalies > 4σ were relocated in the SEM for high-resolution imaging and EDX spectra (5-10 kV) for selected grains were acquired. In a particularly interesting grain (7_04) EDX spectra were taken for two points (acquisition time 300 s) at the centre and the rim. Subsequently this grain was measured again in the NanoSIMS for ^{16}O, ^{28}Si, $^{24}Mg^{16}O$, $^{27}Al^{16}O$ and $^{56}Fe^{16}O$ (1st image sequence) and ^{16}O, ^{28}Si, ^{32}S, $^{44}Ca^{16}O$ and $^{56}Fe^{16}O$ (2nd image sequence). For these investigations a Cs^+ beam of ~50 nm and <0.1 pA was rastered over an area around grain 7_04 (3x3 μm^2, 128x128 pixel) with an integration time of ~11 minutes per image sequence.

Results and discussion: *Detection of presolar silicates.* Fourteen presolar silicates and six presolar oxides have been identified in the matrix of Acfer 094, ranging in size from 0.1 to 1 µm. One 0.8 µm large grain (8_10) seems to consist of heterogeneously coagulated particles of smaller size. The presolar silicate grains represent a matrix-normalized abundance of ~140 ppm: $\delta^{17}O$ values vary from 100 to 11800 ‰ and $\delta^{18}O$ from -600 to 410 ‰, which is within previously reported ranges [1, 4, 5]. These silicates formed in the winds of low mass (1-2.5 $M_\odot$) O-rich RGB- and AGB-stars with close-to-solar metallicities [6]. However, two grains with a strong enrichment in ^{18}O might come from a high metallicity AGB star or a type II supernova [2].

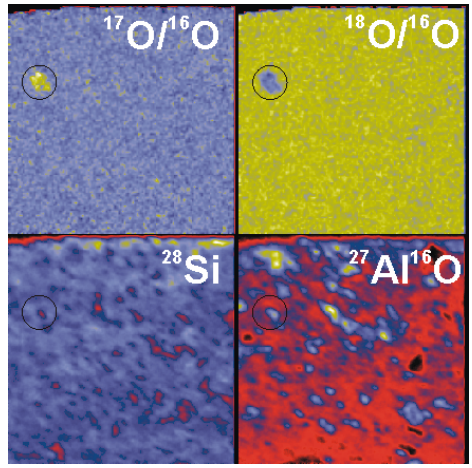

Figure 1. ^{17}O, ^{18}O, ^{28}Si and $^{27}Al^{16}O$ ion images of the area, where the complex grain 7_04 has been detected (encircled). Field of view is 10x10 μm^2 (256x256 pixel).

The complex presolar grain 7_04. Isotopic mapping revealed an unusually large (~1 x 0.6 µm) and complex presolar grain consisting of an Al-rich core and a Si-rich rim (Fig. 1).

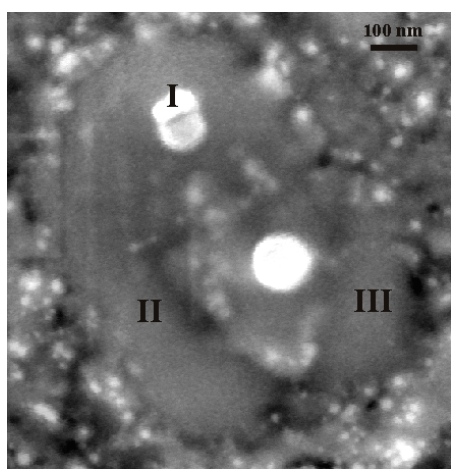

Figure 2. High resolution SEM image of grain 7_04. Numbers mark different areas in the rim (see text for details). The two bright spots are due to C implantation during EDX measurements.

SEM imaging (Fig. 2) showed that the central grain, ~500x350 nm^2 in size, is a single triangular crystal. The Si-rich material accreted on all three sides of this triangulum without any distinct morphology.

Region	$\delta^{17}O$ (‰)	$\delta^{18}O$ (‰)
Al-rich core	357 ± 92	-382 ± 27
Region I	779 ± 115	-508 ± 26
Region II	414 ± 88	-310 ± 27
Region III	460 ± 90	-298 ± 27
Whole grain	500 ± 40	-350 ± 11

Table 1. Oxygen isotope data of different regions in grain 7_04 (see Fig. 2) and the whole grain. All values are matrix normalized, errors are 1σ.

For further characterization, different regions of interest within the grain, each ~230x230 nm^2 in size, have been selected (Table 1). Regions II and III are isotopically comparable to the core within errors, region I stands out by its more extreme values. A possible explanation for the differences in the Si-rich rim might be that the isotope data for the smaller regions II and III are affected by contributions from the surrounding isotopically normal matrix. If this were the case then the silicate rim would have sampled material that was more heavily CNO-processed than that from which the central grain formed. Another possibility is the existence of a distinct particle with a different isotopic composition within region I, which might shift the overall isotopic signature.

If we compare the average O-isotopic data of grain 7_04 with model predictions for RGB/AGB stars [6], then the parent star is similar to the sun in mass and metallicity (~1.2 $M_\odot$, Z~0.02).

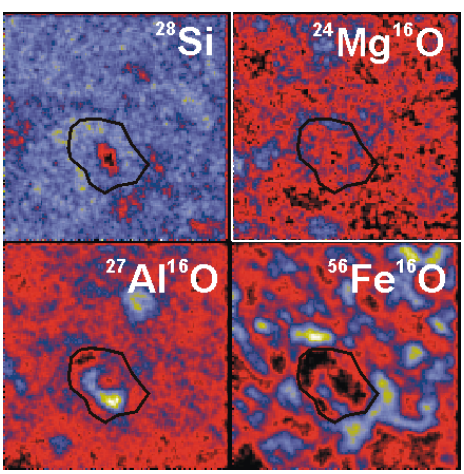

Figure 3. ^{28}Si, $^{24}Mg^{16}O$, $^{27}Al^{16}O$ and $^{56}Fe^{16}O$ ion images of 7_04 with the approximate outline of the grain. Field of view is 3x3 μm^2 (128x128 pixel).

EDX-spectra of the central grain (5 kV) showed dominant peaks of Al, Mg, Fe and Si, on the rim (10 kV) of Si, Mg, Fe, Al, S and Ca (in descending intensity). This led to the hypothesis that the central grain consists of a Fe-rich spinel, the rim of a low Ca-orthopyroxene. However, it can not be excluded that these EDX signatures are affected by the surrounding material. In a subsequent NanoSIMS re-examination count rates for Ca and Mg have been too low for accurate statistics. The central grain itself displays low Mg count rates pointing to a corundum rather than spinel (Fig. 3). The first phase to condense in a star with O/C > 1 is indeed corundum [7], which could have served as a condensation nucleus for the silicate mantle of grain 7_04.

An overall depletion of Fe as seen in Fig. 3 points to a Mg-rich silicate in the rim. This composition contrasts other presolar grain studies [e. g. 4], but supports astronomical observations of crystalline silicates with low iron content [3]. A small band of iron overlying the Al-rich core indicates the presence of iron rich minerals that might have condensed in the same event.

Model calculations show that condensation of crystalline silicates onto preexisting nuclei is sensitive to the mass loss rate of the parent star [8]. If the mass loss rate is $>3x10^{-5}$ $M_\odot$/yr, silicates in heterogeneous grains are expected to be crystalline, but grain-grain collisions and particle bombardment can amorphize them. Further investigation of the silicate material could therefore give testimony of these processes and the condensation history of the grain. Lift out of the grain with the FIB technique, detailed structural examination in the TEM and synchrotron radiation based trace element mapping are planned.

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