FIRST PRESOLAR SILICATE DISCOVERED IN AN ANTARCTIC MICROMETEORITE.

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Introduction: The study of presolar grains has given important information about the isotopic compositions of stellar matter which has become a building block of our solar system. Recently, presolar silicates have been discovered in interplanetary dust particles (IDPs) [1, 2] and meteorites [3, 4]. Micrometeorites, which are the most dominant extraterrestrial materials on Earth [5-7], have previously been searched for presolar grains [8-10], but no presolar grains have been discovered yet. Here, we report a newly discovered presolar silicate phase from an Antarctic micrometeorite (AMM).

Samples and Methods: AMMs analyzed in this study were collected at Cap-Prudhomme, west Antarctica in 1988 [11]. Seven AMMs, AWU01-3, 9, 11, 14, 16, 24, and 25, were crushed and fragments were pressed into Au foil for study with the ims3f ion microprobe [12]. Other fragments of the same AMMs were analyzed for Ne isotopes by noble gas mass spectrometry [13]. NanoSIMS, a newly developed ion microprobe for investigating sub-µm isotopic distribution, is now available, and we re-analyzed the samples that were left after the ims3f measurements. For the NanoSIMS analysis, a ~1pA Cs^+ primary ion beam was accelerated to 16kV and rastered over the samples. The primary beam diameter was ~200nm. Negatively-charged secondary ions were extracted with 8kV to go through a double focusing mass spectrometer and be detected by a multi-collector system. Mass resolution power was set around 6,000. $^{12}C^-$, $^{13}C^-$, $^{16}O^-$, $^{17}O^-$, and $^{18}O^-$ were simultaneously detected by five electron multipliers. The AMMs were analyzed in isotopic imaging mode with repeated scans over a 20x20µm area for each analysis.

Results: In total, a 8000µm^2 area of the pressed surfaces of seven AMMs was analyzed with the NanoSIMS in 38 individual imaging measurements. Almost all analyzed areas were isotopically normal in C and O on a 200nm scale. The only exception was found in AWU01-16, which contains an isotopically anomalous area of ~5x3µm (Fig. 1). Its isotopic ratio is $1.41 \pm 0.05 \times 10^{-3}$ in $^{17}O/^{16}O$ and $2.42 \pm 0.03 \times 10^{-3}$ in $^{18}O/^{16}O$ (Fig. 2). The observed +2700‰ enrichment of ^{17}O indicates a presolar origin of this phase. After the isotopic analysis of this presolar phase, the area was investigated by SEM-EDS and FE-SEM. The presolar phase was identified as silicate, but was chemically indistinguishable from the surrounding isotopically normal material (Fig. 3, 4). This phase was also analyzed for Mg isotopes with the NanoSIMS, but no ^{26}Mg excess was observed.

Discussion: As seen in Figure 2, the presolar silicate phase has an oxygen isotopic composition similar to that of group 1 presolar oxides. The lack of a ^{26}Mg excess in group 1 grains indicates that it formed in the early stage of an asymptotic giant branch (AGB) star [14]. The most striking feature of this presolar silicate phase is its size. It is larger than any presolar silicates found in IDPs and meteorites, which range in size from 200-940nm [1-4]. A secondary electron image (Fig. 3) of the isotopically anomalous area shows that it is not a single grain but an aggregate of 10-20 grains. These grains may originally have formed a single larger grain in the AMM which was then crushed during sample preparation. The pressing into the Au foil may have led to a flattening of the fragmented presolar phase, which may have increased its apparent size. Based on a simple calculation, its original size may have been 1-2µm.

The Ne isotopic composition of AWU01-16 is distinctly different from that of other AMMs in this study. AWU01-16 is enriched in the solar wind (SW) component, whereas the solar energetic particle (SEP) component is dominant in other AWU01 AMMs (Fig. 5). The SW component penetrates only several tens of nm near the surface of material exposed to interplanetary space [15], whereas SEP is penetrating to a few tens of µm from the surface because of its higher energy than normal solar wind [16]. Thus, the high SW concentration in AWU01-16 indicates that this particle experienced significantly less heating during its atmospheric entry and/or that it had a highly porous structure before atmospheric entry.

Based on the possibly inflated two-dimensional size of this presolar phase, the abundance of presolar material in AMMs from this study is calculated to be ~1300ppm. Although the statistics is limited, this value is higher than that of meteorites (~40ppm) [3,4], but comparable to that of IDPs (~800ppm) [2]. Further studies of presolar grains in AMMs are necessary for a better understanding of their characteristics.

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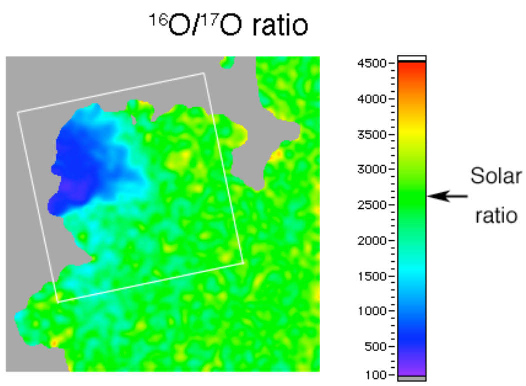

Fig. 1. $^{16}O/^{17}O$ ratio image of presolar silicate phase discovered in AWU01-16. The isotopically anomalous area is ~5x3μm. The size of the image is 20x20μm. The white square indicates the area shown in Fig. 3.

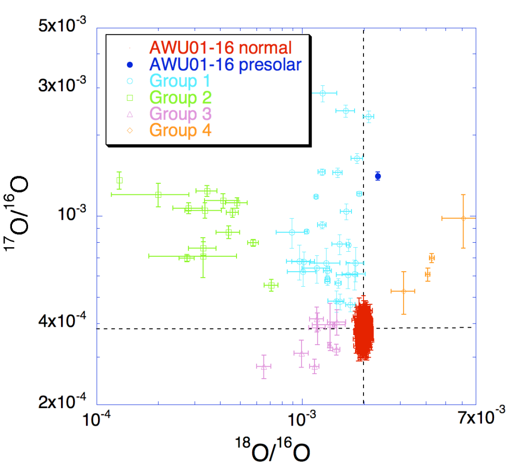

Fig. 2. Oxygen three isotope plot of presolar oxides. Data of group 1-4 presolar oxides are from [14]. The presolar phase discovered in this study is similar to group 1 presolar oxides. Dashed lines express solar isotopic ratios. Errors are 1σ.

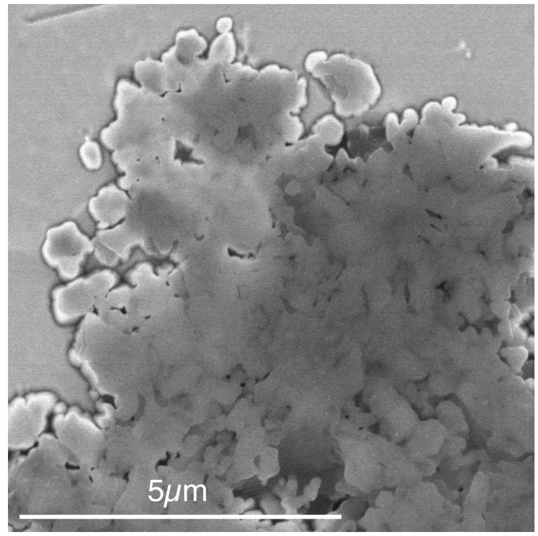

Fig. 3. FE-SEM image of the presolar silicate phase.

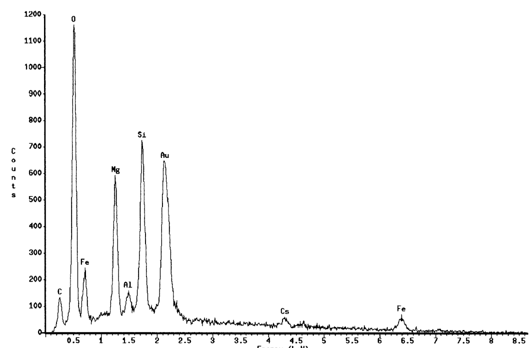

Fig. 4. EDS spectrum of the presolar silicate phase. Its pattern is similar to that of low-Ca pyroxene.

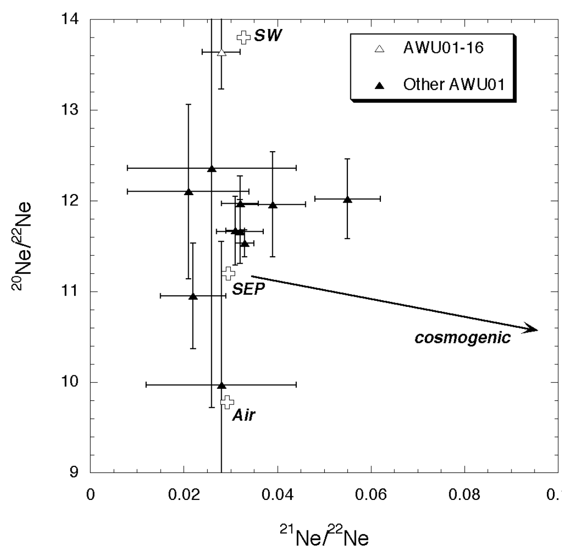

Fig. 5. Neon three isotope plot of AWU01 AMMs. Data are from [13]. AWU01-16 is more enriched in the SW component than other AWU01 AMMs.