Identification of Silicate and Carbonaceous Presolar Grains in the type 3 Enstatite Chondrites

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Abstract. We surveyed presolar grains in primitive enstatite chondrites by isotopography using the HokuDai isotope microscope system. The mineral identification has been conducted by X-ray analysis with scanning electron microscopy. The chemical compositions are determined for eight silicate and ten carbonaceous presolar grains. Presolar grains of pyroxene compositions are dominant in the enstatite chondrites. This suggests that presolar silicates of enstatite composition were selectively survived in the enstatite chondrite parent body or the enstatite chondrite formation area in the solar nebula.

Keywords: presolar grain, silicate, carbon, meteorites, SIMS, isotope imaging
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INTRODUCTION

Primitive meteorites, interplanetary dust particles (IDPs) and Antarctic micro meteorites (AMMs) contain presolar silicate grains that predate the formation of our solar system [1-7]. The silicate grains have been found by O-isotope ion imaging with a NanoSIMS [e.g. 1-3,7] and with an isotope microscope (Cameca ims-1270 + SCAPS [8]) [e.g. 4-6]. Although about 200 presolar silicates were discovered, the chemical compositions of only 27 presolar silicate grains have been studied in carbonaceous chondrites (CCs) [e.g. 2-4], IDPs [e.g. 1] and AMMs [e.g. 7]. The spatial resolution and the quantitative analysis capability of the conventional ion imaging technique have been difficult to determine the mineral species of sub-micron presolar silicate grains because of the small size and abundant silicate grains formed in the solar system. Among the 27 presolar silicate grains identified so far, eight have compositions similar to olivine, eleven are pyroxene-like, and seven are GEMS (glass with embedded metal and sulfides)-like compositions. The sizes of presolar silicates seem to be between 100 and 1000 nm with most grains less than 300 nm.

Ebata et al. [9] have discovered silicate and carbonaceous presolar grains from three type 3 enstatite chondrites (ECs) by in-situ measurements. However, grain characterizations were limited to about 17 % of all presolar grains found and the characterized mineral species were only pyroxene compositions. It seems that presolar silicate species of ECs may be different from those of CCs, IDPs and AMMs. Here we report further in situ studies of silicate and carbonaceous

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presolar grains in three primitive EH3 chondrites, Yamato-691, ALHA81189 and Sahara 97072.

EXPERIMENTAL

We surveyed presolar grains by isotopography using the HokuDai isotope microscope system (Cameca ims-1270 + SCAPS [8]). We applied two homogeneous irradiation conditions of primary beam for about 70 μm across field; the rastered ion beam of small size and the static broad ion beam. Total integration time for each field was ~1 hour for rastered beam condition and ~1.5 hours for static beam condition. We used a 50 μm contrast aperture (CA) except for C isotopes. A 150 μm CA was used for C isotopes. The primary beam intensity was adjusted to ~0.5 nA for both irradiation conditions. The sputtering depth was less than 100 nm for the sequence. The digital image processing methods, the selection criterion for distinguishing presolar grains and estimation of the analytical errors are the same as [4].

For mineral identification of presolar grains, mineralogical and petrographical characterization of matrix areas containing isotopic anomalous grains has been conducted using a field emission type scanning electron microscope (JEOL JSM-7000F) equipped with energy dispersive X-ray spectrometer (Oxford INCA).

RESULTS AND DISCUSSION

Presolar silicates were identified by oxygen isotopographies: 3 grains from areas of about 61,000 μm^2 for Y-691 (the volume abundance: 4 ppm); 19 from about 99,000 μm^2 for ALHA81189 (17 ppm), whereas no presolar silicate grains were identified grains from areas of about 30,000 μm^2 for SAH 97072 (<3 ppm). Presolar carbonaceous grains were also identified by carbon isotopographies: 14 grains from areas of about 63,000 μm^2 for Y-691 (20 ppm); 13 from about 96,600 μm^2 for ALHA81189 (12 ppm); and 3 from about 32,000 μm^2 for SAH 97072 (8 ppm). The abundance of presolar silicates is much smaller in these EH3 chondrites than in primitive CCs and IDPs [e.g. 1, 5].

The oxygen isotopic compositions of presolar silicates in the EH3 chondrites are shown in Figure 1. The most grains (~ 90 %) have excesses in ^{17}O with nearly normal $^{18}O/^{16}O$ ratios. These grains are categorized into the so-called group 1, which likely formed around O-rich red giant or asymptotic giant branch (AGB) stars [10]. The rest belongs to the group 4, which has nearly normal $^{17}O/^{16}O$ ratios and excesses in ^{18}O. The origin of group 4 grains is considered as AGB stars or super novae.

The sizes of presolar silicates are 0.2-1.1 μm (average: 0.49 μm) and carbonaceous grains are 0.1-1.2 μm (average: 0.40 μm). The average size of presolar silicate grains of the ECs is larger than those of CCs and IDPs [e.g. 1, 2, 3]. In the case of presolar carbonaceous grains, the average size is smaller than those from CCs [11].

The chemical compositions are determined for eight presolar silicate grains (e.g. Figure 2 (a, c)); Enstatite: 3, Fe-rich hypersthene pyroxene (En_{50}): 1, Fe-rich olivine (Fo_{30}): 1, SiO_2: 1, aggregates of pyroxene-like compositions: 2. The SiO_2 grain and aggregates may be amorphous. In the case of carbonaceous grains, the chemical compositions are determined for ten grains (e.g. Figure 2 (b,d)); graphite: 4, SiC: 6. Presolar grains of pyroxene compositions are more dominant than other presolar silicate species in the ECs, whereas olivine, pyroxene and GEMS are equally distributed CCs [e.g. 2-4], IDPs [e.g. 1] and AMMs [7]. This suggests that presolar silicates of enstatite composition were selectively survived in the ECs parent body or the enstatite chondrite formation area in the solar nebula.

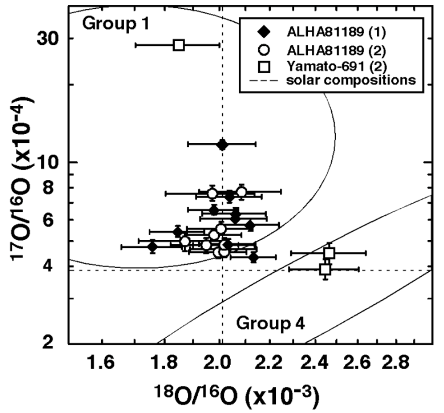

FIGURE 1. O-isotopic ratios of presolar silicate grains from Y-691 and ALHA 81189. Error bars are 2σ. Ten grains belong to Group 1 and two grains belong to Group 4 defined by [11]. (1) and (2) in the legend correspond to the primary beam conditions of static and rastered beam, respectively.

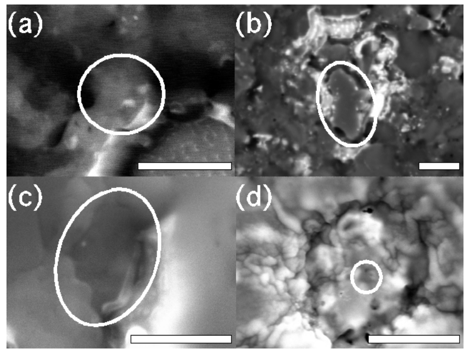

FIGURE 2. Examples of identified presolar grains in this study (indicated by circles). (a) enstatite grain from ALHA81189. (b) SiC grain from ALHA81189. This grain is surrounded by FeS. (c) enstatite grain from Y-691. (d) Graphite grain form Y-691. This grain is surrounded by Fe metal. Scale bars are 1 μm.

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