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Morphology of presolar corundum grains from unequilibrated ordinary chondrites

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Corundum (Al_2O_3) is one of the first refractory minerals that condense directly from gas of the solar composition. Presolar corundum grains, which have highly unusual oxygen isotopic compositions compared to solar-system materials, are condensates in outflows from oxygen-rich AGB stars and/or su-pernovae. It is therefore important to understand the formation conditions of corundum grains in order to understand the first stage of dust formation around evolved stars. The morphological and crystal-lographic features of presolar corundum grains should reflect the formation conditions and subsequent thermal his-tory of the grains. In order to understand morphology and crystallographic orientation of presolar corun-dum grains, we first made detailed observations of morphology and crystallography of corundum grains from residues unequlibrated ordinary chondrites using field-emission scanning electron microscopy (FE-SEM) and electron back-scattered diffraction (EBSD) and the oxygen isotopic compositions of the grains were then measured to identify the circumstellar condensates.

The acid-residues of ordinary chondrites, Semarkona (LL3.0), Bishunpur (LL3.1), and Roosevelt County (RC) 075 (LL3.2) were used for this study. Corundum candidate grains were found with cathodo-luminescence imaging, and 198 corundum grains were confirmed by EDS equipped to a FE-SEM. For individual grains, secondary electron images were taken from four different directions and crystal-lographical information was obtained by EBSD. Oxygen isotopic compositions of 111 grains were meas-ured with UH Cameca ims-1280 ion microprobe. The details of analytical technique are described in Makide et al. (2009). After the isotopic measurements, the presolar corundum grains were reexamined by FE-SEM and EBSD.

The 198 corundum grains discovered were classified into three types according to their morphology. Type A grains have smooth surfaces (73 grains), type B grains are irregularly shaped and have rough sur-faces with 10-nm-sized fine structures with-out crystal faces (62 grains). Intermediate grains that cannot easily be classified into either type A or B are type C (73 grains). The 111 corundum grains, of which oxygen isotopic compositions were measured. Nine presolar corundum grains were found: seven grains have oxygen isotopic compositions with positive ^{17}O excesses and small ^{18}O depletions; two grains show 17O depletions. The presolar grains consist of 6 type B, 2 type A, and 1 type C grains.

The observed presolar/solar corundum ratio of 8% is higher than that of 1% reported by Makide et al. (2009). This difference could be attributed to the difference in size of grains analyzed. The size of grains measured in our study is about 1 micron on average, but only larger grains (1-5 micron) were measured by Makide et al. (2009). Because larger grains have a higher pos-sibility of survival during thermal events in the early solar system, these observations may imply that circumstellar corundum grains are dominantly <~1 miicron in size. Hoefner (2008) showed that corundum dust grown to ~1 micron could be easily ejected by mass-loss winds due to radiation pressure, indicating that further growth could be suppressed by rapid cooling, which may support our observation.

Choi et al. (1998) argued that presolar grains have irregular surfaces or are aggregates of smaller grains. This is consistent with the dominance of type B presolar corundum grains in this study. We ob-tained 10 EBSD patterns for different spots on the type B presolar grain. The EBSD patterns of all spots were the same, which are also the same as that taken prior to isotopic analysis, suggesting that the grain is not an aggregate of small grains but is a single alpha-corundum crystal. The present results may suggest common formation of fluffy and fine-structured corundum grains around various evolved stars.

Keywords: presolar grain, circumstellar dust, evolved star, oxygen isotope