The high abundances of presolar grains found in the most primitive CM meteorite, Asuka 12169

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Introduction

CM chondrites are usually reported to experience varying degrees of aqueous alterations. On the basis of progressive amounts of alteration phases, they are accordingly classified into the petrologic type from 3.0 to 2.0, with subtype from 2.9 to 2.1 (e.g., Rubin et al., 2007). There are also a number of members have experienced the secondary heating to show the thermal effects (e.g., Tonui et al., 2014). These secondary processes in parent body would destroy the presolar grains, which are originated from various stars and survived interstellar and solar nebular processing.

The abundances of presolar SiC reported in CM chondrites are similar to those seen in the most primitive chondrites, but the abundances of presolar O-rich grains. Asuka 12236, classified as CM2.9 chondrite, is reported to have a higher presolar O-rich abundance of 63^{+18}_{-15} ppm from the matrix study (Nittler et al., 2020), but still lower than that in the least-altered chondites. Asuka 12169 has been classified as CM3.0 on the basis of the petrologic and geochemical observations (Kimura et al., 2019; Kimura et al., 2020; Noguchi et al., 2020). In order to demonstrate the primitive property, we performed a survey of presolar grains in Asuka 12169.

Methods

We obtained a polished thin section of Asuka 12169 from National Institute of Polar Research. It was surveyed with an optical microscope and a scanning electron microscope. The fine-grained areas are selected for presolar grain searches. The NanoSIMS imaging was carried out using a CAMECA NanoSIMS 50L ion microprobe at the Institute of Geology and Geophysics, Chinese Academy of Science (IGGCAS). $^{12}C^-$, $^{13}C^-$, $^{16}O^-$, $^{17}O^-$, $^{18}O^-$, and $^{28}Si^-$ were acquired simultaneously. Subsequently, the C-anomalous grains with size >350 nm were taken for silicon isotopes mapping.

Results and discussion

The fine-grained matrix and accreted rims on chondrules and Ca-Al-rich inclusions were mapped for isotopes of C, O and Si in order to search for presolar grains in Asuka 12169. The matrix-normalized abundances of presolar SiC grains and O-rich grains in Asuka 12169 are 73 ± 12 ppm and 208 ± 19 ppm, respectively. These are the most abundant presolar grains ever found in CM chondrites (Leitner et al., 2020), and comparable to those reported in other most primitive chondrites (Davidson et al., 2014; Alexander et al., 2017). The observations of presolar grains provide the robust evidence that Asuka 12169 is the pristine CM carbonaceous chondrite, preserved most records of the nebular processes and events in the region where CM-like planetesimals accreted.

CM chondrites are typical of water-rich, and hence were commonly suffered from severe aqueous alteration that has erased lots of the solar nebular records. In order to assess the degree of alteration, the petrographic type of CM chondrites was also classified from 2.0 to 3.0 with decreasing of the water-contents. CM3.0 was referred to as the most pristine samples, following the categories of ordinary chondrites with type 3.0 as the most primitive chondrites (Sears et al., 1980). However, this category introduces conflict between thermal metamorphism and aqueous alteration. Although CM2.9-3.0 chondrites have low abundances of aqueous alteration products, they could have experienced more severe thermal metamorphism because of their higher petrographic types. The correlation between the petrographic type and the water-contents of CM chondrites could be attributed to degassing during thermal metamorphism in the interior of the CM asteroid. If it is this case, it may not be suitable to refer type 2.9-3.0 as the most primitive CM chondrites. Presolar grains are predominantly submicron-sized. Their abundances are very sensitive to temperature, hence served as a good indicator for the degree of thermal metamorphism. Furthermore, presolar silicates are also readily destroyed by aqueous alteration. The abundance of presolar silicates, presolar silicate/SiC ratio, and/or presolar silicate/oxide ratio can be used to classify the degree of aqueous alteration.

Conclusions

The observations of presolar grains in Asuka 12169 demonstrate that it is highly primitive, experienced little thermal metamorphism neither aqueous alteration. The study of Asuka 12169 will be highly valuable for addressing the nebular records

in the CM planetesimal forming region in the protoplanetary disk, and shed light on the origins and evolutions of Ryugu and Bennu asteroids.

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