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Oxygen isotopic distribution of a porous Type A CAI from Ningqiang chondrite

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Ca-Al-rich Inclusions (CAIs) have been reported oldest age in the solar system and large mass-independent fractionation for oxygen isotopic compositions. Fine grained CAIs, which are thought to be condensed from gas, often contain micron-sized voids (Lin and Kimura, 2003; Wasson et al., 2000). However, coarse-grained compact CAIs are usually unporous. We found a porous CAI having many micron-sized voids from Ningqiang C3-ungrouped chondrite. We studied petrology and oxygen isotopic distribution of the CAI in order to reveal the formation process of micron-sized voids.

Petrographic observation and chemical analysis were performed by FESEM-EDS (JEOL JSM-7000F + Oxford INCA Energy). Crystal orientation analysis was performed by EBSD (HKL Cannel 5). Oxygen isotopic composition was analyzed by SIMS (CAMECA, ims-1270).

A coarse grained CAI analyzed in this study has about 2x2 mm in size with rounded shape but with irregular potion in part. The CAI is mainly composed of melilite, diopside, spinel and perovskite. The CAI has a porous structure with voids occupying nearly 30% in volume. The CAI is rimed by Wark-Lovering rim composed of melilite, spinel, anorthite and diopside layers. The CAI is classified into type A CAI with high perovskite abundance by the bulk composition and mineralogy.

Two types of void are observed in the CAI. We categorized small void and large void by their size and shapes. The small voids are three micrometers or smaller in size. The voids distributed in regions near the Wark-Lovering rim and in 50-100 micron sized regions consist of 5 micron sized melilite crystals with few micron sized perovskite crystals. Melilite crystals in the regions show reverse zoning, i.e., Mg-rich interior and Al-rich rim. The oxygen isotopic compositions of the melilite varies from delta-^{18}O = -40 permil to delta-^{18}O = 0 permil. Reversely zoned melilites in type A CAIs are believed to be condensed from gas (MacPherson and Grossman, 1984). Therefore, it is suggested that melilite in the regions did not experience melting, and small void was formed during the process of condensation and accumulation of melilite and perovskite.

The large voids have roundish irregular shape and distributed inside of 300 micron sized melilite crystals. In a single crystal of melilite crystals void-rich areas are gehlenitic (ak2-5) and void-free areas are akermanitic (ak15-24). Oxygen isotopic compositions of the melilite crystals at the void-rich areas were delta-^{18}O = -5 permil and the void-free areas were delta-^{18}O = -20 ~ -10 permil. Nepheline was sometimes observed at the area with voids. The mineral layer of diopside and anorthite exists at walls of some voids. Fine grained porous CAIs in Ningqiang are thought to be formed by an aqueous alteration on its parent body (Sugita et al., 2009). If the large voids in the CAI were formed by the aqueous alteration, it is required that voids were preferentially formed at gehlenitic area or that melilite compositions became gehlenitic during the void formation. We will study the relation between chemical zoning and crystals growth of melilite in order to clarify formation processes of the large voids in this CAI.

Keywords: void, CAI, oxygen isotopic composition, Ningqiang, melilite