

## Petrography and oxygen isotopic compositions of a compact Type A Ca-Al-inclusion from NWA 7865 reduced CV3 chondrite

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Ca-Al-rich inclusions (CAIs) are found in chondritic meteorites, and the oldest objects formed in the Solar System (Connelly et al., 2012). Igneous CAIs exhibit unequilibrated oxygen isotopic compositions distributed along CCAM line (e. g., Yurimoto et al, 2008; Krot 2019). The oxygen isotope compositions of CAI minerals are considered to reflect the formation process under the various oxygen isotope compositions. Igneous CAI are divided into Compact Type A CAI (CTA) and Type B on basis of differences in bulk composition and mineralogy. For Type B CAI, it was understood that formation process and oxygen isotope evolution by observation and oxygen isotope analysis (e. g., Kawasaki et al., 2018). On the other hand, it has been demonstrated that the oxygen isotope evolution according to crystal growth of CTA melilite (Yurimoto et al., 1998; Park et al., 2012). However, it is complex that CTA formation process (e. g., Simon et al., 1999; Ito et al., 2004), there are not systematic studies for total formation histories of CTA from melt to solidification. In this study, in order to understand whether the oxygen isotope evolutions were typical during the formation of igneous CAI, we performed petrographic observations and evaluated the crystal growth and crystallization sequence of the constituent minerals until CTA totally have solidified, for KU-N-02 CTA from NWA 7865 CVred 3.1 chondrite. Then, Oxygen isotopic compositions were measured in consideration of the petrographic observations, using SIMS (Hokkaido Univ. Cameca ims-1280HR). Using the sequence of formation, the oxygen isotopic evolution of the CAI melt was established.

KU-N-02 CTA has a type A CAI bulk composition, and spinel grains are poikilitically enclosed by melilite and fassaite, indicating that crystallization sequence of KU-N-02 CTA is spinel-melilite-fassaite. The spinel is uniformly <sup>16</sup>O-rich ( $\Delta^{17}\text{O} \sim -23$ ), and the melilite are uniformly <sup>16</sup>O-poor ( $\Delta^{17}\text{O} \sim -2\%$ ). Single melilite crystal exhibits normal zoning ( $\text{Åk}_{15 \text{ to } 60}$ ), showing concentric crystal growth. But about 2-20  $\mu\text{m}$  around spinel and fassaite enclosed by single melilite crystal has a more  $\text{Åk}$ -rich patch texture. Small fassaite crystals overgrow on the spinel surface enclosed by  $\text{Åk}$ -rich patch texture. If residual melt were trapped during the melilite crystallization,  $\text{Åk}$ -rich melilite and fassaite may be crystallized from residual melt inclusion. This small fassaite are also uniformly <sup>16</sup>O-poor ( $\Delta^{17}\text{O} \sim -2\%$ ) consistent with oxygen isotopic compositions of melilite within the error range. This result consistent with formation process of  $\text{Åk}$ -rich melilite and small fassaite by petrographic observation. The oxygen isotopic disequilibrium between <sup>16</sup>O-rich spinel and <sup>16</sup>O-poor melilite and fassaite was caused by partial melting and oxygen isotope exchange between the melt and the <sup>16</sup>O-poor nebular gas (e. g., Yurimoto et al., 1998). At the melilite crystal boundaries, the fassaite enclosed spinel and are irregular shapes. This fassaite systematically crystallized from the residual melt. In general, the fassaite exhibits growth zoning with decreasing Ti contents from core to rim, and also show continuous variations in  $\Delta^{17}\text{O}$  from <sup>16</sup>O-poor ( $\Delta^{17}\text{O} \sim -4\%$ ) to <sup>16</sup>O-rich ( $\Delta^{17}\text{O} \sim -23\%$ ), along the inferred directions of crystal growth. The correlation of oxygen isotope compositions with Ti content in the fassaite imply that the oxygen isotopic composition of CAI melt evolved from <sup>16</sup>O-poor to <sup>16</sup>O-rich during fassaite crystallization, due to oxygen isotope exchange with a surrounding <sup>16</sup>O-rich nebula gas (Kawasaki et al., 2018).

These results indicate that the disequilibrium oxygen isotope distribution in CTA was caused by the

oxygen isotope evolution of the CTA melt during crystal growth. This oxygen isotope evolution of the CTA is similar to the type B CAI described by Kawasaki et al. (2018), and support that igneous CAI experienced that heating and melting events under the same oxygen isotopic environment, independent of the chemical compositions of precursor.

Keywords: CAI, Oxygen isotope, Petrography