PETROLOGICAL CHARACTERISTICS OF THE FINE-GRAINED CAIS FROM THE REDUCED CV CHONDRITES THIEL MOUNTAINS 07003 AND 07007, AND ORIGIN OF ANORTHITE.

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Fine-grained Ca-Al-rich inclusions (FGIs) from the reduced CV (CV_{Red}) chondrites are believed to be aggregates of direct gas-solid condensates in the early solar nebula [e.g. 1] and to have been free from severe alkali- and Fe-rich secondary mineralization which, in contrast, is common in Allende FGIs [e.g. 2, 3]. In order to better understand the origin of these pristine FGIs and the condensation sequences in the nebula, we performed detail petrological studies of FGIs in two CV_{Red} chondrites Thiel Mountains (TIL) 07003 and 07007. The meteorites are petrographically similar to the other CV_{Red} chondrite Leoville, including elongated chondrules and CAIs with a preferential orientation and widespread microfaults that suggest they experienced high degree of compaction and deformation [4-6].

Eight polished thin sections (3 from TIL 07003 and 5 from TIL 07007) were carefully examined to search for the CAIs. Scanning electron microscope (JEOL JSM-6380A at SNU) and field-emission electron microprobe (JEOL JXA-8530F at KOPRI) were used for petrological observations, acquisitions of backscattered electron (BSE) images and X-ray elemental maps and measurements of major element compositions. Modal abundances of some FGIs were acquired with BSE images and X-ray elemental maps.

Based on the grain sizes and appearances as aggregates of nodules, we identified 68 FGIs. Individual FGIs are aggregates of spherically or irregularly shaped nodules having size of a few to near 100 μm. Matrix materials are often found along the boundaries of the nodules indicating that the FGIs were porous in the nebula. Each nodule is concentrically zoned with a spinel (± hibonite ± perovskite) core, surrounded by a middle layer of melilite and/or anorthite and then by an Al-diopside layer. There are three different types of nodules; in the middle layers, melilite-bearing without anorthite (M), anorthite-bearing without melilite (A), and both melilite- and anorthite-bearing (MA). The M- and A-type nodules are dominant while MA is relatively rare.

Among 68 FGIs, 26 inclusions are composed of entirely one type of nodule (hereafter single-nodule-type FGIs), while 42 FGIs consisting with more than two types (multi-nodule-type FGIs). The single-nodule-type FGIs consist either only of M-type (n=21) or A-type (n=5) nodules; there is no FGI having only MA-type. The multi-nodule-type FGIs are either composed of (i) mostly M-type with minor amounts of MA-type or (ii) mostly A-type with minor MA- and M-types. There are a few FGIs having more or less equal amounts of M- and A-types, however there is no MA-dominant multi-nodule-type. Six FGIs show macro-scale zonation having A-type nodules in the core surrounded by M- (± MA-) types, similar to previous observation [1]. The reverse texture was found in only 1 inclusion.

In the MA-type nodules, while grain boundaries between anorthite and Al-diopside are more or less sharp and flat, those between anorthite and melilite are irregular and wedge-shaped, possibly indicating the anorthite grew from the boundaries between melilite and Al-diopide by replacing melilite. Near the boundaries between melilite and anorthite, small melilite grains are often enclosed by anorthite. The modal abundances of anorthite decrease with those of melilite but show no obvious correlations with those of spinel or Al-diopside. These observations also suggest the replacements of melilite by anorthite. Nepheline, known as products of parent body alteration [3], is rare but found in some FGIs without any preferential correlation with anorthite abundances. We also notice that with increasing modal abundances of anorthite, i) the sizes of FGIs increase, ii) the boundaries between nodules become less clear, iii) matrix materials in FGIs are less common, and iv) abundances of perovskite (and probably hibonite, grossite and Al-Ti-diopside) decrease. The compositions of melilite ($Åk_{1.9\text{-}33.8}$, averaging $Åk_{12.3}$) and anorthite ($An_{95.2\text{-}100}$, averaging $An_{98.9}$) do now show any systematic variation along with the abundances of anorthite.

A current view on a nebular origin of anorthite by a replacement of melilite in CV_{Red} FGIs [e.g. 1] is strengthened by this study. Our observation of bimodal distribution in melilite/anorthite abundances show that degree of replacement was not continuous, i.e., some escaped from the replacement, while the other experienced almost complete replacement. If all FGIs formed at the same place, M-type nodules were condensation products at higher temperature than A-type. In this case, initial abundances of perovskite in FGIs might have controlled the anorthite-forming reactions. Alternatively, M-type and A-type nodules might have formed at distinct reservoirs that separated temporally and/or spatially. However the reservoirs must have been close enough to form multi-nodule-type FGIs.

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