Petrographic study of a compact type A CAIs with partial melting process

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Refractory inclusions (Ca-Al-rich inclusions (CAIs)) in chondritic meteorites are the oldest substances formed in the Solar System (Connelly et al., 2012). Coarse-grained CAIs are classified into three subtypes, type A, B and C, according to their petrologic features (e.g., Grossman 1975). Compact type A CAIs (CTAs) are expected to be formed in the earliest stage of solar nebula and experienced a partial melting at least once (e.g., Simon et al., 1999). However, there are only a few studies that referring to the formation processes of CTAs from the perspective of crystal growth in partial melting states (Ito et al., 2004, Park et al., 2012, Kawasaki et al., 2017). Generally, spinel in CTAs are poikilitically enclosed by melilite or fassaite, and estimated to be first crystallized mineral from CAI melt (Stolper, 1982). Namely, spinel in CTAs is expected to preserve valuable information of the thermal histories such as partial melting processes. Therefore, we focus on the petrological and mineralogical feature of spinel grains in CTAs. The studied CTA (KU-N) is included in a polished thin section of North West Africa 7865 reduced CV3 carbonaceous chondrite. Yoneyama et al. (2016) had studied the same CTA, and concluded that they experienced multiple partial melting. We have undertaken petrographic and mineralogical investigations of the CTA (KU-N-02) focusing on micro-textures resulting from partial melting (local compositional zoning, grain morphology and relationships of crystallographic orientation), using a polarizing microscope, scanning electron microscope (SEM) and electron back scatter diffraction (EBSD).

In the KU-N-02 CTA, spinel crystals are enclosed by melilite or fassaite. The former (up to 50 µm in size) is substantially euhedral but the edges are rounded, while the latter (about 10 - 100 µm in size) are almost euhedral with sharp edges. On the surfaces of both type of spinel grains, small perovskite particles with sizes of several µm are ubiquitously present. (Fig. 1) By EBSD analyses, a certain crystallographic orientation relationship between spinel and perovskite is observed only in the former type, but no relationship is found in the latter type.

In interior KU-N-02 CAI, one melilite with spinel inclusions showed a remarkable compositional zoning; the bulk of the melilite is Al-rich ($Åk_{15\text{-}25}$), but the area of about 10 µm wide around the spinel surfaces has Al-poor compositions ($Åk_{\sim 30}$) in comparison. (Fig. 2) This texture indicates that the boundary area between spinel and melilite had eutectically melted at high temperature by some heating process, and then Mg/Al contents had been redistributed to melilite and spinel during rapid cooling. Accordingly, this partial melting probably resulted in the unique morphology and the crystallographic orientation relationship of the spinel (and perovskite) enclosed by melilite.

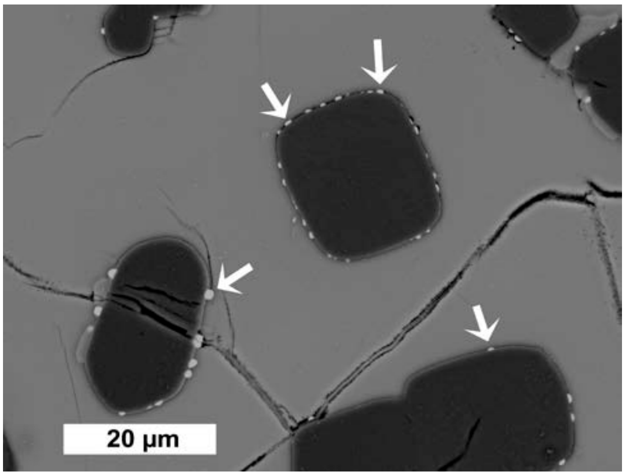

Fig. 1. BSE image indicates the representative texture of spinel crystals enclosed by melilite. The arrays denote perovskite particles.

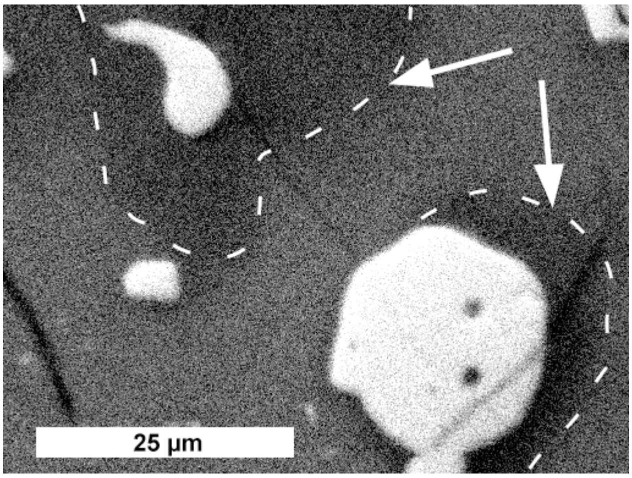

Fig. 2. Al-Xray mapping in a melitlite crystal. The arrays and dashed line denote the Al-poor ($Åk_{\sim 30}$) area.

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