

Petrology and mineralogy of a coarse-grained CAI “TTA01” from Allende

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Ca-Al-rich inclusions (CAIs) in meteorites are the oldest objects formed in the Solar System (Connolly et al., 2012) and composed of high-temperature condensate minerals from a solar-composition gas (e.g., Grossman, 1972). Coarse-grained CAIs in CV chondrites are divided into Type A, Type B and Type C CAIs according to their petrography. Fine-grained inclusions and fluffy Type A CAI are suggested to be condensates from the solar nebular gas (e.g., MacPherson and Grossman, 1984), while compact Type A, Type B and Type C CAIs formed by melt crystallization (e.g., MacPherson and Grossman, 1981; Yurimoto et al., 1998). In this study, we conduct petrographic observations of a coarse-grained CAI from Allende, TTA01 (Imai and Yurimoto, 2000), which has two regions with distinct petrographic signatures, using FE-SEM-EDS system (JEOL JSM-7000F; Oxford X-Max 150) installed at Hokkaido University.

TTA01 has an elliptical shape with a size of ~3.5 x 2.5 mm on the polished section of Allende. It is mainly composed of spinel, melilite, anorthite, and fassaite and contains secondary minerals of sodalite, nepheline, grossular, and monticellite. TTA01 can be divided into two regions. “Region A” is enriched in fassaite and anorthite. Subhedral anorthite (~1 mm long) and anhedral melilite and fassaite poikilitically enclose spinel crystals. A bulk chemical composition of region A is Type C CAI-like and plotted on the spinel + anorthite area of the ternary phase diagram of CAIs by Stolper (1982). Åkermanite contents of melilite in region A are ~50-70 mol%.

“Region B” is enriched in melilite. Small melilite and spinel grains (5-50 μm) are poikilitically enclosed in anorthite and fassaite crystals. Melilite also contains finer spinel grains. A bulk chemical composition of region B is Type B CAI-like and plotted on the spinel + melilite area of the Stolper diagram. Åkermanite contents of melilite in region B are ~15-50 mol%. Small melilite crystals often contain Al-rich grains with Åkermanite contents of < 25 mol% and they are surrounded by melilite with > 30 mol%.

According to the petrographic observations, crystallization orders for region A is from spinel, anorthite, to melilite + fassaite, while those for region B is from spinel, melilite to anorthite + fassaite. These crystallization orders are consistent with the bulk chemistry of each region. The bulk chemistry and distinct Åkermanite contents of melilites in regions A and B suggest that the two regions could not have formed from a homogeneous, single melt. Type C CAI-like precursor and Type B CAI-like precursor may have been accreted together and then remelted to form TTA01. A liquids temperature of anorthite in region A is 1340°C while that of melilite in region B is 1430°C (Stolper, 1982). The melting of precursors of TTA01 at 1340-1430°C is consistent with the above observations; spinel and a part of melilite in region B were relict of the melting event.