Chondrule-cored aggregates (ChCAs): A new rock-type in CV chondrites with implications for timing of high-T crystallization events in the solar nebula

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Introduction: Ca-Al-rich inclusions (CAIs) and amoeboid olivine aggregates (AOAs) formed by high-temperature reactions between gas and solids, and in some cases liquids, in a hot (ambient temperature > 1400K) region of the protoplanetary disk during initial stages of its evolution [1]. CAIs and AOAs in chondrites of petrologic types $\leq$3.0 tend to be ^{16}O-rich (Δ^{17}O -20‰). In contrast, chondrules formed at lower ambient temperatures (<900K) and tend to be ^{16}O-poor compared to CAIs (Δ^{17}O -10‰). Most chondrules appear to have postdated formation of CAIs and AOAs, though initial stages of chondrule formation might have overlapped with CAIs and AOAs [2,3]. Because of the later formation age of many chondrules, relict CAIs may be found included within chondrules [4], but chondrule fragments included in CAIs are very rare [5].

In this project, we describe minerals, textures and oxygen isotopes of three unusual objects from the CV3 chondrites Allende and Vigarano in which relict chondrule phenocrysts are partially enclosed by granular olivine texturally similar to AOAs. We refer to these objects as chondrule-cored aggregates (ChCAs). They are significant because their textures suggest the opposite of the conventionally accepted timing; namely, in ChCAs, an early stage of chondrule formation was apparently followed by a later stage of olivine condensation.

Methods: Two ChCAs (called NE-27 and SW-7) were identified in Allende, and one (NW-30) was found in Vigarano. Minerals and textures were characterized using petrographic microscopes, a scanning electron microscope (Hitachi S-3400N) and a JEOL JXA 8900 electron probe micro-analyzer (EPMA) at Waseda University. Oxygen isotopic compositions of olivine in the Allende ChCAs were collected using the Cameca ims-1280 SIMS at University of Hawai ‘i using conditions similar to those described in [6]. Typical uncertainty including internal and external errors is ~0.6‰ in both d^{17}O and d^{18}O.

Results: In Allende ChCA NE-27, a large (>200 μm across), low-Ca pyroxene ($En_{98}Wo_1$) similar to a chondrule phenocryst occurs in the core. The relict phenocryst is rimmed by granular olivine grains approximately < 20 μm across. The olivine grains are zoned with cores as Mg-rich as Fo_{95} and rims of approximately Fo_{60}. Olivines with compositions near Fo_{60} also occur in veins that cut across relict pyroxene. ChCA SW-7 has similar low-Ca pyroxene, granular olivine and vein olivine, but is composed of several nodules and has a more diffuse boundary with the Allende matrix. Vigarano ChCA NW-30 also has a core of low-Ca pyroxene. The granular olivine layer is not as complete as in the Allende ChCAs, but granular olivine does appear to replace low-Ca pyroxene near margins of ChCA NW-30.

SIMS oxygen isotope analyses of granular olivine from the Allende ChCAs fall near the Carbonaceous Chondrite Anhydrous Mineral and Primary Chondrule Mineral reference lines (see [7]) and form a spread of Δ^{17}O values from -8 to -3‰. All measurements are from MgO-rich cores and avoid FeO-rich olivine rims. The ^{16}O-poor isotopic composition indicates that the olivine rims of ChCAs did not form in a typical AOA-like setting. Regardless of O-isotopic setting, the ChCAs indicate (1) an early episode of chondrule formation, followed subsequently by (2) fragmentation or some process that released pyroxene phenocrysts from their host chondrules, (3) crystallization of granular olivine grains on the margins of relict phenocrysts, and (4) formation of Fe-rich olivine on rims of grains and in veins during metamorphism.

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