MINERALOGY OF STARDUST TRACK 112 PARTICLE: RELATION TO AMOEBOID OLIVINE AGGREGATES.
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Introduction:

The successful analysis of comet 81P/Wild 2 particles returned by the Stardust mission has revealed that the Wild 2 dust contains abundant silicate grains that are much larger than interstellar grains and appear to have formed in the inner regions of the solar nebula [1]. Wild 2 particles include minerals which are isotopically and mineralogically similar to CAIs [e.g., 2, 3] and chondrules [e.g., 4] in chondrites. In addition, particles similar to amoeboid olivine aggregates (AOAs) also have been discovered [5, 6,7].

C2067,2,112,1 is a terminal particle recovered from track #112 (T112). Nakamura-Messenger et al. [7] showed that the forsterite grain in T112 has ^{16}O-enrichment of approximately 40‰ (vs. SMOW) and possibly formed together with AOAs. In this study, we have examined the mineralogy of the T112 particle and compared the possible relationships between T112 and AOAs in primitive meteorites.

Methods: We examined two transmission electron microscope (TEM) grids from C2067,2,112,1 (T112). These grids are from the terminal particle from track 112 extracted from aerogel tile C2067. The ultramicrotomed samples were prepared at NASA JSC (see [7] for details). Grains were examined in secondary electrons and back-scattered electrons and compositions were estimated using a Hitachi-S4500 FE-SEM equipped with a Kevex EDX spectrometer at the University of Tokyo. TEM images and EDS spectra were collected using a Hitachi-8100A STEM equipped with GENESIS EDX system at Waseda University. TEM EDX data were collected using calibrated *k*-factors and thin-film matrix correction procedures [8].

Results: Our two TEM grids from T112 are dominated by one 4×4 μm -sized forsteritic olivine (Fig. 1). Submicron sized chromite is associated with the olivine (Figs. 1b,c). From EDS analysis, the chromite has high Cr_2O_3 content (up to 65 wt. %).

Olivine compositions

The olivine from T112 is near end-member forsterite, but shows a slight enrichment of Fe toward the grain rim (Figs. 2a,b). The Fe content of olivine in AOAs is a sensitive indicator of thermal metamorphism [9,10,11]. In the least metamorphosed chondrites, most AOAs consist of forsterite (Fa<2; Fig. 2c,d). Enrichment of olivine in fayalite component is correlated with petrologic subtype of a host meteorite (Fig. 2d). In CV chondrites, Fe-enrichment is distinct in Allende (petrologic type >3.6 from [12]). The low Fa content of olivine in CVoxB (Fig. 2g) suggests a weaker metamorphic effect in these rocks, although they have been subjected to some aqueous alteration [11]. The Fe enrichment on the rim of T112 olivine may have been caused by a minor degree of thermal processing after the condensation of forsterite.

Chromite compositions

EDS analyses of T112 chromite grains yield Al-absent compositions with intermediate Mg# (Fig. 3); however, it is likely that some Mg detected by EDS is from neighboring olivine and that the grains are closer to pure chromite in composition (Figs. 1c,d). Chromite is a minor phase in Wild 2 particles. Cr-rich spinels have been identified in the chondrule-like particle *Torajiro* [4] and associated with *Coki-B* Kool fragments (T141 [14]); however, these spinels have significant Al_2O_3 (Fig. 3). Mikouchi et al [13] identified chromite with amorphous silica and Fe-Ni-S, but did not report quantitative EDS.

Three possibilities for the formation of chromite can be considered: (i) direct condensation from a gas; (ii) crystallization from chondrule melt; (iii) metamorphism/aqueous alteration. (i) Modeling by [15] predicts that Cr-rich spinel crystallizes in mixed vapor + silicate liquid + refractory solid reactions at high temperatures in dust enriched systems, but always with significant Al_2O_3. (ii) This modeling also shows that chromite is stable with silicate liquid at high dust enrichment [15], but textures of T112 particle do not appear to be typical of chondrules. Furthermore, the ^{16}O-rich composition of olivine in the potted butt sample from (T112) is more consistent with AOAs than chondrules [5,7]. (iii) Tiny Cr-rich grains surrounding olivine in type 3 ordinary chondrites were identified by [16] as products of incipient metamorphism. The T112 chromite might have a similar origin. Cr-rich spinel from Coki-B Kool fragments is also interpreted as a product of metamorphism or crystallization from melts [14].

No chromites have been described so far from AOAs in carbonaceous chondrites. Instead, only Mg-spinel has been found. However, the T112 chromite is a sub-micron grain, and similar crystals might have been overlooked in metamorphosed AOAs. Tiny chromite-like grains of metamorphic origin adjacent to olivines were identified by [16]. Chromite-spinel solid solutions occur in LL chondrites, and become more homogeneous with increasing petrologic type [17]; however, the LL spinels are distinct in composition from T112 chromite (Fig. 3).

The forsteritic, ^{16}O-rich composition of T112 olivine suggests a condensation origin. Slight enrichment in Fa-content along the olivine rim suggests some metamorphism. At this point, we consider metamorphism the most likely origin of T112 chromite.

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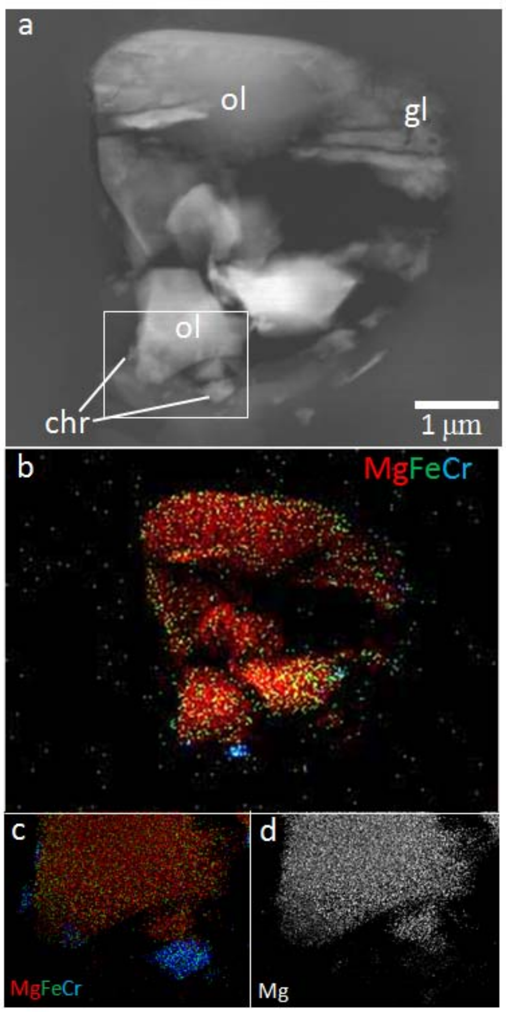

Fig.1. (a) HAADF-STEM image of microtome slice of C2067,2,112,1. Chromite grain at lower right is highlighted by elemental maps (b,c,d; c and d showing area outlined in a). Grain at left is less obvious, but EDS analysis confirms that it is chromite. (b and c) Combined X-ray elemental maps with R=Mg, G=Fe, B=Cr. (b) and outlined area (c). (d) Mg Kα X-ray elemental map.

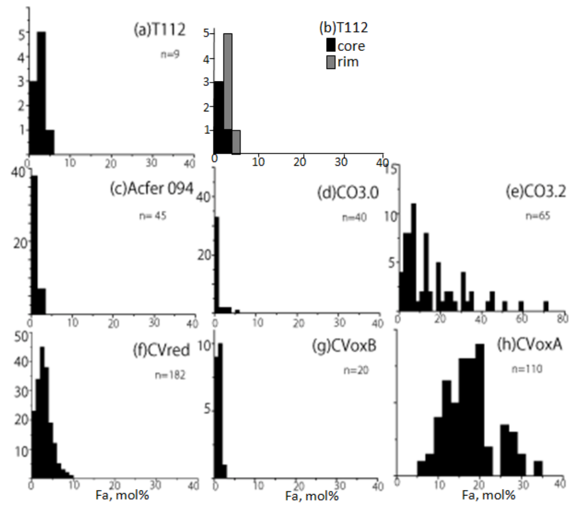

Fig. 2. Compositions of olivine in T112 obtained with SEM-EDS (a, b). AOA olivines from (c) Acfer 094 [11], (d) Y-81020 (CO3.0), (e) Y-82050 and Rainbow (CO3.2) [10], (f) Efremovka, Leoville, and Vigarano (CVred) [9], (g) Kaba (CVoxB) [11], and (h) Allende (CVoxA).

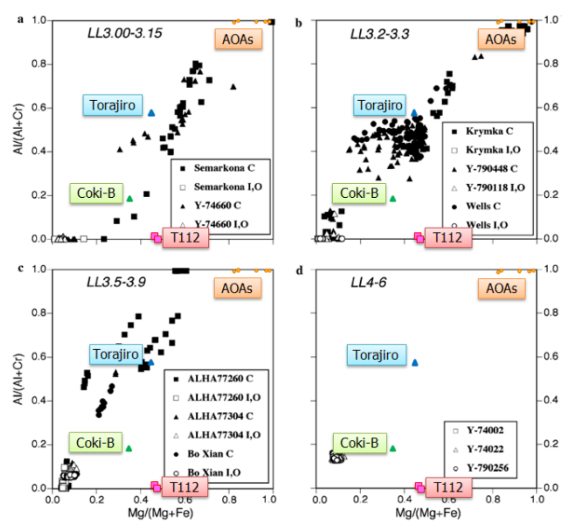

Fig.3. Spinel solid solution compositions of T112, *Coki-B* [14], and *Torajiro* [4] plotted on atomic Mg/(Mg+Fe) vs. Al/(Al+Cr) ratios of spinel group minerals [17] together with spinels in AOAs from reduced CV chondrites Leoville and Vigarano [9], and Allende [18].