A TEM and FE-SEM Study of Two Stardust Cometary Particles Extracted From Tracks T111 and T112. M. Komatsu[1], T. Mikouchi[2], T. J. Fagan[1], M. Miyamoto[2], M. E. Zolensky[3], and K. Ohsumi[4]. [1]Department of Earth and Planetary Science Waseda University, [2]Department of Earth and Planetary Science, University of Tokyo, [3]KT, NASA Johnson Space Center, [4]Japan Synchrotron Research Institute.

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]. The shape of tracks and the presence of individual components dispersed along the tracks indicate that most Wild 2 dust consisted of loose aggregates [2], or large mineral grains that fragmented along the tracks [3].

Here we describe the mineralogy of five particles extracted from two Stardust tracks in cell C2067 and compare our results with other particles [4-7].

Methods:

We examined 16 Transmission electron microscope (TEM) grids of the C2067,1,111 and two grids from C2067,2,112,1. These grains originate from five terminal particles from two tracks 111 and 112 extracted from aerogel tile C2067 (Fig.1). 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 University of Tokyo. Grains of cometary origin were identified in all grids except for C2067,1,111,1 and C2067,1,111,3 (Table 1). TEM images and EDS spectra for particle C2067,1,111,2 and C2067,2,112 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 and Discussion:

Track 111

C2067,1,111,2 is 15 μm in size, mainly composed of Si-aerogel with submicron-sized Fe sulfide grains. Most of Mg-silicates are contaminated with Si-aerogel; only one grain of Mg-pyroxene (approx. En_{99}) is observed.

C2067,1,111,4 is dominated by fragmented olivine crystals up to 10×10 μm in size. This particle is observed in all three consecutive grids. It is composed of FeO-rich olivine, and an Al-Fe-bearing phase (possibly pyroxene?). These grains are surrounded by compressed aerogel. SEM EDS spectra suggest a small range in olivine compositions near Fo_{70} (Fig. 2). Variations in olivine from individual Stardust tracks were also identified by [9]. The olivine compositions in this study are within the range of other Wild 2 olivine [10], but more Fe-rich than most Wild 2 olivine.

Track 112

C2067,2,112,1 is a terminal particle recovered from Track 112. It is dominantly composed of 4 ×4 μm -sized forsteritic olivine (Fo_{97}). Submicron sized chromite is associated with the olivine (Fig. 3). From EDS analysis, the chromite has high Cr_2O_3 content (up to 65 wt. %).

Chromite is a minor phase in Wild 2 particles. Nakamura et al [4] reported the presence of Cr-spinel in a chondrule-like particle. However, chromite in their study contains lower Cr_2O_3 (35 wt.%) and higher Al_2O_3, suggesting different formation conditions. The chromite in this study is similar in composition to Mg-rich chromite associated with amorphous silica and Fe-Ni-S [11], and Cr-rich spinel associated with Coki-B Kool fragments (T141 [13]).

Three possibilities for the formation of chromite can be considered: (i) condensation from a gas; (ii) crystallization from chondrule melt; (iii) secondary product of thermal metamorphism. (i) The condensation of chromite is predicted with olivine and other phases in dust enriched systems [14]. Analysis of one olivine from Track 112 shows a ^{16}O-rich composition similar to CAIs and AOAs [5,7]. At least some CAIs and AOAs formed by condensation. Grains from Track 112 might have a similar origin, but in a higher $f(O_2)$ setting. (ii) Thermodynamic modeling shows that chromite is stable with silicate liquid at high dust enrichment [13], but textures of Track 112 do not appear to be typical of chondrules. (iii) Compositionally similar chromite from the Coki-B Kool fragments is interpreted as a product of metamorphism [12]. Chromite is a sensitive indicator of metamorphic grade in some type 3 chondrites [14]. At this point, a metamorphic origin appears most likely for the Track 112 chromite.

References: [1] Brownlee D.E. et al. 2006. *Science* 314:1711-1716. [2] Zolensky M. et al. 2006. *Science* 314:1735-1739. [3] Burchell M. J. et al. 2008. *MaPS* 43:23-40. [4] Nakamura T. et al. 2008. *Science* 321:1664-1667. [5] Messenger S. et al. *MaPS* 43 suppl:5308. [6] Ohsumi K. et al. 2008. *LPS* XXXIX: #1808. [7] Nakamura-Messenger K. et al. 2011. *MaPS* 46:1033-1051. [8] Cappellen E. V. (1990) *Microsc. Microanal. Microstruct.* 1: 1-22. [9] Tomeoka K.et al. 2008. MaPS 43:273-284. [10] Zolensky M.E. et al. 2008. *MaPS* 43:261-272. [11] Mikouchi et al., 2007. *LPS* XXXVIII: #1946. [12] Joswiak D. J. et al., 2009. *MaPS* 44: 1561-1588. [13] Ebel D. 2006. *In Meteori. & Early Solar Sys. II*: 253-277. [14] Grossman J. N. and Brearley A. J. 2005. *MaPS* 40:87-122.

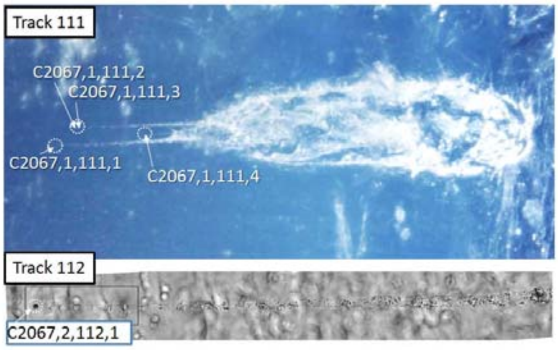

Fig.1. Optical photomicrograph of Tracks 111 and 112. Track 111 is 10741μm long bulbous type track (data from Stardust catalog. http://curator.jsc.nasa.gov/stardust/sample_catalog/index.cfm). Track 112 is 1947 μm long carrot type track (data from [7]).

Table 1. Mineralogy of Wild 2 particles

grain	grid	mineralogy
C2067,1,111,1	#4	no grains observed
	#5	no grains observed
	#6	no grains observed
	#7	no grains observed
C2067,1,111,2	#3	glass
	#4	glass, FeS
	#5	glass, FeS
	#6	glass, FeS
	#2A	Fe-ol, px, glass, FeS
C2067,1,111,3	#6	no grains observed
	#7	no grains observed
	#8	no grains observed
	#9	no grains observed
C2067,1,111,4	#3	ol, glass
	#4	ol, px, glass
	#5	ol,px, glass
C2067,2,112,1	#1	ol, chr, glass
	#4	ol, chr, glass

ol; olivine, px; pyroxne, chr; chromite, glass; SiO_2-rich glass

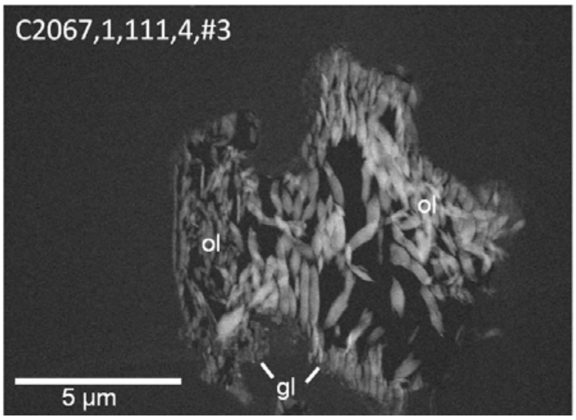

Fig. 2. Secondary electron image of the grain in C2067,1,111,4,#3. C2067,1,114,#3 is composed of Fe-rich olivine. Olivine grains are surrounded by compressed aerogel (SiO_2-rich glass).

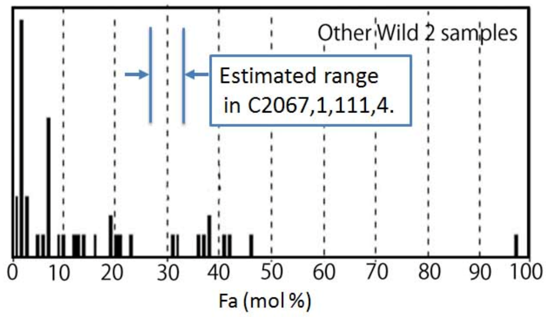

Fig.3. Compositional ranges of olivines in C2067,1,111,4 (a) and other Wild 2 samples (data from [11]).

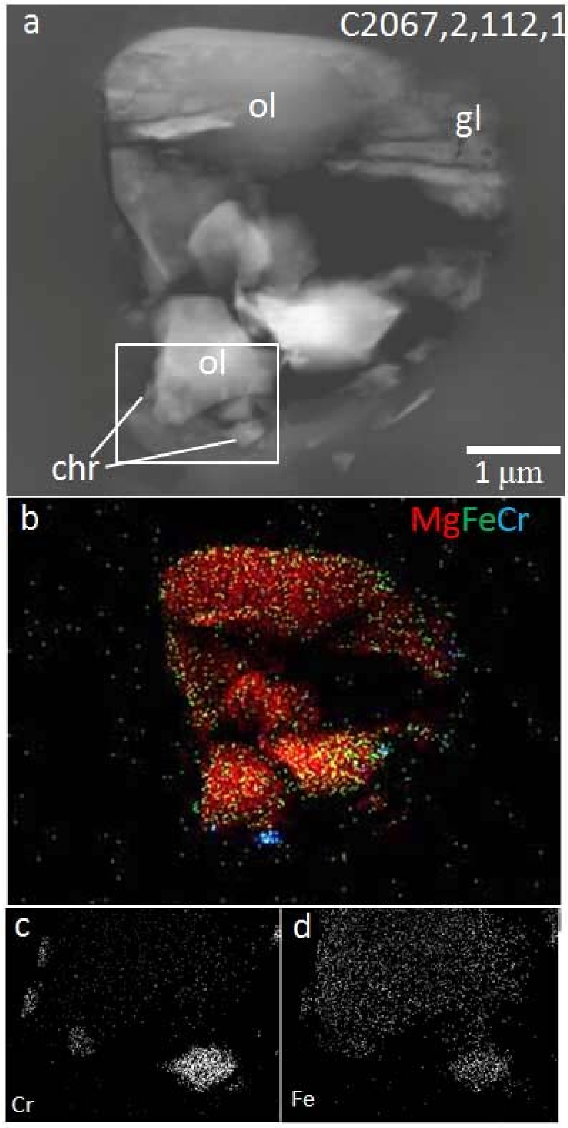

Fig.4. (a) HAADF-STEM image of microtome slice of C2067,2,112,1. Chromite grain at lower right is highlighted by elemental maps. Grain at left is less obvious, but EDS analysis confirms that it is chromite. (b) Combined X-ray elemental map. R;Mg, G;Fe, B;Cr. (c-d) K-line X-ray elemental maps of Cr and Fe of the outlined area of (a).