Development of a new analytical scheme for micrometeorites and discovery of micrometeorites with intriguing mineralogy

Introduction: Combined mineralogical and isotopic studies of individual Wild 2 cometary particles revealed that the materials formed in the inner solar system had been transported to the outer solar system before the formation of the Wild 2 comet [e.g., 1, 2, 3, 4]. We sought another analytical scheme for MM (micrometeorite) studies. In this new analytical scheme, we have two objectives: identification of nonchondritic MMs and identification of asteroidal MMs with mineralogy indistinguishable from CP IDPs, which are regarded as cometary grains [5].

Samples and methods: MMs used in this study were found in the surface snow collected near the Dome Fuji Station, Antarctica in 2003 and 2010. The surface snow was melted and filtered in a clear room. After identification of MMs, we performed SR-XRD, FIB section preparation, TEM, micro-Raman, SEM, EPMA, INAA, and/or noble gas mass spectroscopy for each MM.

Results and discussion: We investigated twelve MMs and could classify them into five types based on their mineralogy: refractory MMs, chondrule-like MMs, fine-grained polycrystalline MMs, coarse-grained crystalline MMs, and phyllosilicate-rich MMs. Here we show the mineralogical results of two MMs with intriguing mineralogy.

Refractory MM A MM is composed mainly of anorthite, diopside, and spinel. A BSE image of the cross section of the MM showed that it has an amoeboid structure, in which small (<5 micrometer) AI-rich and Ti-bearing diopside exists on its surface and its interior and anorthite fills the interstices of diopside. The major minerals are similar to those in type C CAIs [6]. Although its amoeboid structure suggests low degrees of melting during the formation event, the MM has a compact interior, in which diopside and anorthite have triple junctions with ~120° angles suggestive of recrystallization, both olivine and low-Ca pyroxene show almost no compositional zoning. The low-Ca pyroxene crystals elongate near the a-axis direction and are composed of a unit cell-order mixture of ortho and clino low-Ca pyroxene with stacking disorders. Its microstructure indicates rapid cooling (>20-30 K hr⁻¹) form above 1275K [7]. Both olivine and low-Ca pyroxene in this MM contain abundant tracks with ~5 x 10⁻⁴ cm⁻², which corresponds to ~10⁶-year exposure to the solar wind [8]. Tracks in olivine are erased by flash heating above ~600 °C [9]. Because typical cometary IDPs are heated to ~720 °C [10], it is plausible that the MM was derived from an asteroid instead of a comet although any materials similar to this MM have not been found among meteorites.

Fine-grained polycrystalline MM A MM is composed of small (<400 nm) crystals of Fe-bearing olivine, Fe-free low-Ca pyroxene, Fe-Ni metal, Fe sulfide, amorphous silicate, and interstitial carbonaceous material. Although these crystals have often triple junctions with ~120° angles suggestive of recrystallization, both olivine and low-Ca pyroxene show almost no compositional zoning. The low-Ca pyroxene crystals elongate near the a-axis direction and are composed of a unit cell-order mixture of ortho and clino low-Ca pyroxene with stacking disorders. Its microstructure indicates rapid cooling (>20-30 K hr⁻¹) form above 1275K [7]. Both olivine and low-Ca pyroxene in this MM contain abundant tracks with ~5 x 10⁻⁴ cm⁻², which corresponds to ~10⁶-year exposure to the solar wind [8]. Tracks in olivine are erased by flash heating above ~600 °C [9]. Because typical cometary IDPs are heated to ~720 °C [10], it is plausible that the MM was derived from an asteroid instead of a comet although any materials similar to this MM have not been found among meteorites.