Amorphous silicate dust formed by condensation experiments: a key to GEMS formation process.

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Anhydrous IDPs (interplanetary dust particles), which are considered to have cometary origin, have a large amount of amorphous silicate called GEMS (glass with embedded metal and sulfides). This is typically ~200 nm in diameter and consists of SiO_2-rich silicate glass including small (typically 10-50 nm in size) and rounded grains of Fe, Ni metals and sulfides. There are two formation models proposed for GEMS: (1) inner solar condensates from a high temperature Si-rich gas [1,2], and (2) interstellar silicate dust preserved in the outer solar system [3]. Matsuno et al. [4] succeeded to synthesize ~50 nm sized amorphous silicate grains with metallic iron. However, only a single iron grain is included in contrast to GEMS with multiple iron inclusions. They also showed that if different metal materials are used instead of Fe, their grain textures were changed probably due to the difference of the surface energy. The surface energy depends on the chemical composition. Therefore, in the present study, we performed condensation experiments in the system of Si-Mg-Fe-Al-Na-Ca-Ni-O with the solar abundance and the mean composition of GEMS with various O/Si ratios.

Powders of starting materials were injected into induction thermal plasma (ITP). ITP can provide ultra-high temperature (~10^4 K) to evaporate the starting material immediately, and then, the obtained gas was quenched under an Ar-He atmosphere at atmospheric pressure. We obtained 100-500 mg of condensates in one experimental run and the run products were analyzed by powder X-ray diffraction (XRD), infrared spectroscopy (IR) and scanning transmission electron microscopy (STEM/TEM). At O/Si<2.7 of the starting material, iron and amorphous silicate are identified and at O/Si>2.8, magnetite appeared with amorphous silicate. The amorphous silicate has multiple iron inclusions, which is similar to GEMS in texture. Some run products have broad absorption bands at about 9.8 and 18.5 μm, which is similar feature to the interstellar silicate dust [5]. The present experimental result shows that GEMS can form as the condensate from the high temperature gas.

[1] Keller & Messenger (2011) GCA, 75, 5336 [2] Keller & Messenger (2013) GCA, 107, 341 [3] Bradley (2013) GCA 107, 336 [4] Matsuno et al. (2012) Met. Planet. Sci. 47, #5129 (abstr.) [5] Henning (2010) in Astromineralogy.

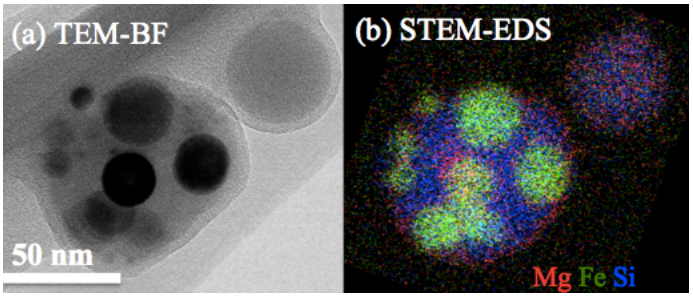

Fig.1 A bright-field TEM image (a) and a elemental map by STEM- EDS (energy dispersive spectrometer) system of the run product (O/Si = 2.3).