Reproduction of GEMS-like materials in the induction thermal plasma system

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Amorphous silicates are considered to be one of the most primitive materials of the solar system and some of them came from pre-solar environments. Chondritic porous interplanetary dust particles (CP IDPs) contain abundant amorphous silicate grains of ~100 nm in size with Fe-Ni and FeS nanoparticles known as GEMS (glass with embedded metal and sulfides) [1,2]. Solar and interstellar origins of GEMS have been proposed [1, 2]. Experimental study on non-equilibrium condensation of GEMS-like materials is crucial for determination of the GEMS origin.

The ITP system (induction thermal plasma) offers rapid vaporization condition by a discharged high temperature flame (~10,000 K) and rapid cooling rate (10^4~10^5 K/s). Amorphous silicates with metallic iron nanoparticles inside, which are similar to the characteristics of GEMS, were experimentally reproduced using an ITP system [3]. In order to constrain the formation condition of GEMS, we systematically changed ITP operation conditions and performed evaporation and condensation experiments with a new ITP system [4].

The ITP system used in the present study was JEOL TP-40020NPS with 6 kW RF plasma torch. We carried out the vaporization and condensation experiments with a mixed Ar-He plasma flame in the system of Si-Mg-Fe-Na-Al-Ca-Ni-O with the averaged chemical composition of GEMS [1] without sulfur. The plasma generating condition was controlled by selection of a plasma forming gas injecting direction (tangential and radial flame patterns) and reactor pressure (30 and 70 kPa). The tangential flame of the thermal plasma provides more higher cooling rate than the radial flame, and higher reactor pressure enhances the vaporization degree of the starting material [4].

All run products show presence of amorphous silicate, metallic iron, and FeNi in X-ray diffraction spectra and peaks of amorphous silicate at ~10 μm in the FTIR spectra. TEM observation shows that the run products have a variety of textures; amorphous silicate grains from <a few nm to >100 nm with or without aggregation and with or without embedded metallic iron or iron nickel nanoparticles. Among them, the most similar nanomaterial with GEMS was reproduced in a tangential flame condition at 70 kPa (Fig. 1). Although the condensation condition was not quantitatively investigated yet, the present result shows that GEMS-like nanomaterial can form in a limited parameter range of the ITP system, which indicates that the formation conditions and environments of actual GEMS might also be limited.

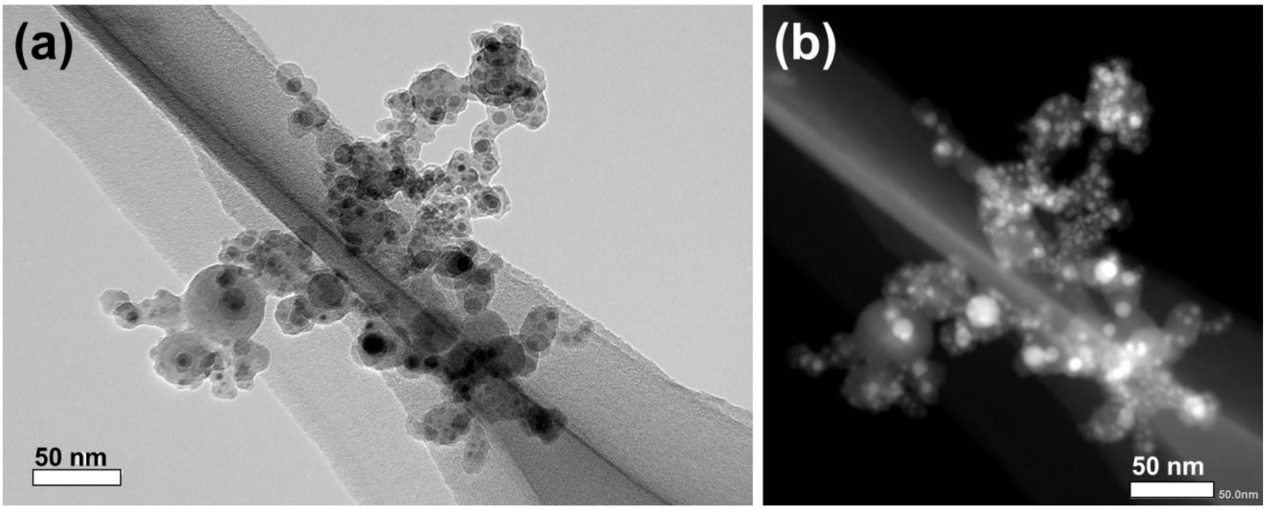

Figure 1. (a) TEM image and (b) STEM-HADDF image of metal embedded amorphous silicate grains produced in tangential plasma flame condition at 70 kPa.

References

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