Non-equilibrium condensation process for synthesis of cosmic dust analogues by triple thermal plasma jet

Tae-Hee Kim [1], Jeong-Hwan Oh [1], Minseok Kim [1], Yong Hee Lee [2], Akira Tsuchiyama [3], Junya Matsuno [4], Aki Takigawa [4], and Sooseok Choi [1]

[1]Jeju National University, Korea, Republic of

[2]Jeju National University, Japan

[3]Kyoto University, Korea, Republic of

[4]Kyoto University, Japan

Amorphous silicate is the major component of cosmic dust and considered to be one of the most primitive materials in the solar system. 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). Two different origins of GEMS have been proposed; non-equilibrium condensation in the early solar nebula and amorphization by irradiation in interstellar medium [1,2]. However, they are still in controversy. Experimental study on non-equilibrium condensation of cosmic dust analogues as GEMS-like materials is crucial for determination of the GEMS origin.In previous studies, nanoparticles with very similar structures to GEMS were formed using the ITP (Induction thermal plasma) system at 6 kW in a limited parameter range of [3], which suggested that a high quenching rate is a key condition to reproduce GEMS-like textures. Subsequently, we performed condensation experiments with the single DC non-transferred thermal plasma jet to improve the quenching rate and offer higher temperature. Generally, the highest temperature of the thermal plasma jet discharged by DC non-transferred torch is typically higher (~15,000 K) than that of ITP flame (~10,000 K). Moreover, the quenching rate of thermal plasma is typically more than 10 times higher compared with ITP flame. However, the starting material was not sufficiently vaporized because some of the starting material passed outside the thermal plasma. In order to improve the vaporization and provide higher quenching rates, we carried out the vaporization and condensation experiments in the triple thermal plasma jet system. A mixture of micron-sized metal and oxides powder was used as a starting material; Si, SiO_2, MgO, Fe, Na_2SiO_3, CaO, and Ni under 10 μm. The chemical composition having the averaged composition of GEMS [1] without sulfur was adopted as a starting material. In this study, the thermal plasma was discharged by an input power of 30 kW, which is higher than the previous ITP experiments at 6 kW to improve vaporization efficiency of the starting material. The starting material was injected into the high temperature region of the merged thermal plasma jet and condensed nanoparticles were collected at the chamber wall. The run products were analyzed with SEM-EDS to be nano-sized silicates and metal particles.

References[1] Keller L. P. et al. 2011. Geochimica et Cosmochimica Acta, 75:5336[2] Bradley J. P. et al. 2004. Astrophysical Journal, 17:650[3] Kim T. H. et al. 2017. Proceeding #P2-33-7. ISPC 23 (International Symposium on Plasma Chemistry)