Synthesis of cosmic dust analogue particles in the newly developed ITP (induction thermal plasma) system

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Cosmic dust formed by condensation from high temperature gas around young and evolved stars or in the primordial solar nebula [1,2]. Some of them could be building block of our solar system.
The ITP (Induction Thermal Plasma) system enables the formation of nanoparticles from supersaturated vapors by homogeneous nucleation and growth because it offers vaporization of refractory materials at thousands of degree Celsius and very rapid quenching rates [3]. It can also control the evaporation and condensation environments by adjusting the characteristic of the thermal plasma. Moreover, condensation experiments from gases with various chemical compositions can be relatively easily performed in the ITP system because almost any reagents can be introduced into the plasma. For example, GEMS-like materials were reproduced in the different ITP system in the previous study [2].
In order to examine the formation processes of various cosmic dust analogues, a new ITP system (JEOL TP-40020NPS, max. 6 kW) was set up in our laboratory. The objective of the research is examination of the performance of the newly developed ITP system on production of nano-sized condensates simulating cosmic dust formation in circumstellar environments. We have already performed preliminary examinations using starting materials of SiO_2 (quartz), MgO (periclase), and Si-Mg-Fe-Na-Al-Ca-Ni-O in our ITP system [4]. In this study, we performed condensation experiments in the system of MgO-SiO_2 and examined the performance of the ITP system by changing plasma conditions.
We used mixtures of periclase and quartz powders with 1:1 molar ratio as stating materials for all experiments. The various operating parameters were applied to improve the evaporation rate and condensation conditions, such as feeding rates of starting material, reactor pressures, the presence of an additional slit gas, and the injecting direction of plasma forming gas. Plasma input power was fixed at 6 kW. The produced powders were analyzed by XRD, FT-IR, SEM, and TEM. Nano-sized condensates of amorphous silicate, forsterite, and protoenstatite were observed in most of the experimental products. We found that (1) the feeding rate of the starting material and reactor pressure control the vapor density and residence time at the high temperature regions of the plasma flame, (2) the vapor condenses into particles more rapidly by injecting the slit gas into the plasma flame, and (3) the injecting direction of the plasma forming gas changes temperature distribution of the plasma flame, which most influences condensation conditions. The plasma forming gas flows into the plasma generating torch axially (tangential flow) or swirly (radial flow). The radial flow provides a longer and narrower plasma flame that improves the residence time of the starting material at the high temperature region than the tangential flow. The more uniform nanoparticles were produced in the radial flow condition.

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Keywords: Cosmic dust, GEMS, Induction thermal plasma, Condensation experiment, Nanomaterial synthesis, Infrared spectrum

