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Reproduction of cosmic dust particles in laboratory plasma

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Growth processes of nanometer sized solid particles are essential to understand the evolutional history of materials accompanying with stellar life, because cosmic dust with nanometer size is smallest building blocks of planetary system bodies and is used as a substrate to make larger molecules. Nevertheless, formation processes of individual cosmic dust founding in meteorites are less to understand even more than 100 years investigation. I believe one crucial reason is a lacking of significant phenomena of nanoparticles. Since the diameter of cosmic dust is on the order of couple nanometers to ~100 nm, even in their growth process is drastically different from their bulk material, i.e., coalescence growth becomes dominant growth mode. Then, plasma environments strongly affect to the formation of nanoparticles.
We performed a series of condensation experiments which involved exposing a vapor phase to plasma to form nanoparticles as cosmic dust analogues, a situation that exists ubiquitously in space. Several cosmic dust analogues were only reproduced in plasma, e.g., organic globules with hollow center [1], silicates with non-mass dependent oxygen isotopic fractionation [2] and enstatite via direct homogeneous condensation [3]. Here, I would like to introduce first two results particularly, because those two results include interdisciplinary subjects.
Organic hollow globules were discovered in a carbonaceous chondrite [4] and recognized the abundance in the solar system [5-7]. The organic globules are a construction of shells with a cavity in their center and show via isotopic anomalies of nitrogen and hydrogen, that they are extraterrestrial products [5]. Then, a question "where and how were the primitive organic materials produced?" is fundamental to understand the evolutional history of carbon in space. Globules were synthesized using benzene or aromatic molecules, introduced into He RF plasma. After the experiments, brownish to yellowish or white deposits were visible on electrodes for plasma generation. Organic hollow globules were found in the deposit. To form hollow center, singular phenomena of nanoparticles and plasma particles and/or electrons are important.
Oxygen isotopic compositions formed by mass independent fractionation (MIF) processes have been widely observed in cosmic dust particles in the early solar nebula. Only photodissociation has been known to produce MIF of oxygen before our experiments. Therefore, the reason for the oxygen isotopic compositions of CAIs and chondrules has been discussed based on an ultraviolet photodissociation process of carbon monoxide in solar nebula [8]. Recently, we found that electrical discharge can produce MIF of oxygen in refractory oxide grains [2]. Presolar silicate materials, which are an important reservoir of oxygen in the early solar nebula, are believed to have been produced in high-temperature regions prior to the formation of the solar nebula. Our results may provide another possible path, caused by the processing of presolar silicate materials and leading to the MIF of oxygen of cosmic dust.
Actually, since some cosmic dust can reproduce only in plasma fields, I believe formation of nanoparticles in a plasma field has a great potential to understand the evolutional process of solar materials.

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