Crystalline and amorphous forsterite grain formation

Katsuya Kamitsuji[1]; Takeshi Sato[1]; Mami Kurumada[1]; Yuki Kimura[1]; Chihiro Kaito[1]

[1] Ritsumeikan Univ.

IR spectra taken by the Infrared Space observation (ISO) for Red Super Giant (RSG), Asymptotic Giant Branch (AGB) stars, post-AGB stars and planetary nebula (PNe), indicated a mixture of amorphous and crystalline silicates [1]. The observation of crystalline phase were changed our view of the silicates. It is important to study the formation of crystalline and amorphous Mg-bearing silicate grains. The direct formation of forsterite (Mg2SiO4) and enstatite (MgSiO3) grains did not occur in condensation experiments in laboratory [2, 3]. In a previous paper we demonstrated the crystalline Mg2SiO4 (forsterite) grain formation due to coalescence growth of Mg and SiO smoke grains (Mg-SiO system) in the case of SiO grain riches atmosphere in Mg-SiO system [4]. Most of the Mg2SiO4 grains were contained silicon crystallites. On the formation of oxide grains in laboratory, the same component grains on the refractory material can not be obtained for the decomposition during the evaporation. In a previous paper, we succeeded to produce TiO2 grains by evaporating Ti in an atmosphere contained oxygen of 10 Torr in the mixture gas Ar using tantalum (Ta) boat [5].

In the present study, we studied that the formation of Mg-bearing silicate grains in atmosphere contained oxygen using this technique. We succeeded to produce crystalline and amorphous Mg-bearing silicate spherical particles in the two gas evaporation methods i.e., Mg and SiO mixture powder evaporation in oxygen atmosphere and the coalescence between MgO and SiO2 smokes. Single, poly and amorphous spherical particles with the size of 50-300 nm were produced. All the crystalline Mg-bearing silicates were forsterite. Enstatite was not observed. The cooling velocity can be altered one order higher by pumping of the mixture gas at the top of the chamber. It was found that one order higher cooling velocity produced the selective growth of amorphous particles. Since the cooling velocity is different at the site of the smoke by general gas evaporations, the single and poly crystals formations of forsterite are due to the crystallization from the amorphous spherical particles, i.e., the first produced particles were amorphous.

In order to see the crystallization process of amorphous spherical particles, the direct observation was done in transmission electron microscope using the special heating holder. It was found that the amorphous particles showed the characteristic contrast of the surface layer 30 nm by heating at 650C. By heating 800C, the particles were crystallized to forsterite spontaneously from the particle surface. Before the crystallization, the microcrystallite formation took place on the surface of amorphous particles. The density change due to the microcrystallization, the special rim contrasts may be appeared. In the previous paper, the amorphous Mg-bearing silicate crystallizes into forsterite by heating to 1000C in vacuum, but enstatite was not produced [6].This crystallization temperature was lower than previous report. The lower crystallization temperature is one of the characteristic natures of the ultrafine particles. In the case of forsterite material, the lower the crystallization was clearly observed. The result of in-situ observation on the crystallization process will be presented.

[1] C. Walkens et al., Astronomy and Astrophysics 315 (1996) L245-248.
[2] J. A. Nuth et al., In Experiments on cosmic dust analogues, edited by Bussoletti et al. Dordrecht: Kluwer (1988) p.191.
[3] N. Suzuki et al., Meteoritics and Planetary Science 35 (2000) 1269-1273.
[4] C. Kaito et al., Meteoritics and Planetary Science 38 (2003) Nr 1, 49-57.
[5] Y. Atou et al., Physica E 16/2 (2003) 179.
[6] K. L. Day and B. Donn, The Astrophysical Journal 222 (1978) L45-48.