ARTIFICIAL COSMIC SPHERULES PRODUCED BY MELTING EXPERIMENTS OF THE POWDERED ALLENDE METEORITE. T. Gondo¹ and H. Isobe¹, ¹Dept. Earth Envi. Sci., Grad. Sch. Sci. Tech., Kumamoto Univ., Kurokami, Kumamoto, 860-8555, Japan, e-mail: isobe@sci.kumamoto-u.ac.jp

Introduction: Micrometeorites (MMs) are extra-terrestrial fine particles derived from asteroids and comets and continuously falling to the Earth. Depending on their velocity, mass and entry angle, micrometeorites have undergone various degrees of heating during the atmospheric entry within a few seconds. This heating lead to significant textural, mineralogical and chemical modifications to MMs.

Micrometeorites are steady accumulation flow of planetary materials to the Earth. The annual mass is estimated at approximately 30,000 tons. The MM sample can be collected from Antarctica, ocean floor sediments and suspended particles in the stratosphere. Some MMs show remarkable similarity on mineralogy and chemical compositions to carbonaceous chondrite [1,2].

MMs can be classified into two groups based on their size and textures: (1) fine-grained MMs (FgMMs), which are dominated by a fine-grained porous groundmass of micron-sized minerals, and (2) coarse-grained MMs (CgMMs), which are dominated by anhydrous silicates with larger than several microns meters, generary with glassy mesostasis [3].

The MMs larger then 70 μm in diameter show various melted textures. In particular, completely melted micrometeorites are known as cosmic spherules. Cosmic spherules have experienced large degrees of melting of primary phases during atmospheric entry, and form molten droplets [3,4].

In this study, we carried out rapid heating and quenching experiments on fine particles of the Allende meteorite to reproduce cosmic spherules by atmospheric entry.

Experimental: We used powdered Allende meteorite (typical CV3 chondrite) with approximately 100 μm in diameter as the starting material. The rapid heating and quenching within a few seconds are implemented by free fall of starting material particles through a high temperature vertical furnace with regulated gas flow of H₃, CO₂ and Ar to control oxygen fugacity and total gas flow [5]. Upward gas flow in the furnace tube can reduce falling velocity of the particles to reproduce thermal history of the cosmic spherules. The maximum temperature of the particles in this study is approximately 1520 °C. In the furnace, fO₂ is controlled to oxygen partial pressure of the upper atmosphere at approximately altitude of 86 km where MMs heated. Run products are retrieved from the bottom of the furnace tube and observed with a field-emission scanning electron microscope (FE-SEM, JEOL JSM-7001F) and analyzed with an energy dispersive X-ray spectroscopy (EDS, Oxford INCA system).

Results and Discussion: The run products show quite analogous textures to micrometeorites including scoriaceous, porphyritic olivine and barred olivine. Almost molten particles show spherical shape due to surface tension of the silicate melt. The outside shape of the particles is various depending on melt fraction of the particle.

Fe-rich rim in olivine crystals found in the porphyritic olivine spherules, can be considered to be formed when it is quenched (Fig. 1). Olivine phenocrysts in porphyritic spherules are characterized by hexagonal shape with sharp edge. The sharp edged olivine phenocrysts are quite rare in chondrules. It occurs, however,
in molten micrometeorites, known as cosmic spherules. Internal texture of the artificial cosmic spherule produced in this work shown in Fig. 1(b) is remarkably similar to that of the natural porphyritic spherules shown in Figs. 1(A) and (B) of Cordier C. et al. (2011) [6].

Spherules with low pyramid structure on the surface also occur (Fig. 2a). Petal-like iron oxide crystals also characterize the surface of the spherule. In this particle, barred-olivine texture was observed. The barred-olivine texture with a uniform orientation is limited within domains in the spherule. Ultra fast cooling rate may prohibit uniform alignment of barred-olivine crystals in the whole spherule. Barred-olivine texture with domain structure is quite similar to the barrd-olivine spherules reported in Fig. 2 of Cordier, C. et al. (2011) [6]. Petal-like iron oxide crystals do not occur in the spherule. Occurrence and texture of iron oxide crystals may attribute to segregation of iron oxide from silicate due to surficial oxidation and curvature of the spherule surface.

On the surface of molten spherules, Fe sulfide also occur (Fig. 3). Immiscibility between sulfide melt and silicate melt may induce sulfide melt discharge from silicate melt. The surface deposition of iron sulfide on cosmic spherule has not been reported. Sulfide on micrometeorites may be removed by abrashion in the upper atmosphere. This process may be constant source of sulfur species to the upper atmosphere other than terrestrial volcanic activity.

In this study, we successfully reproduced artificial cosmic spherules with remarkably analogous textures to natural ones. Analogy of the run products to micrometeorites can be discussed on textural, mineralogical and chemical modifications during atmospheric entry of inter planetary materials.