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Formation of Cosmic Spherules: Relationships among Shapes, Compositions, and Textures

Masao Doi[1], Taishi Nakamoto[1*], Tomoki Nakamura[2], Yuji Yamauchi[3]

[1]Tokyo Institute of Technology, [2]Tohoku University, [3]Kyushu University

Cosmic spherules are extraterrestrial origin, spherical silicate grains; they are collected from polar ice, ocean floor sediments, and stratosphere. In this study, we focus on cosmic spherules that are once molten completely.

Compositions, sizes, and textures of cosmic spherules have been measured. And some works suggest that compositions and textures are related to each other. On the contrary, quantitative measurement on the shape of cosmic spherules and a relationship among shape, composition, and texture have not been done. Those should be investigated to reveal the nature of cosmic spherules and their formation process. In addition, the formation process of cosmic spherules may have an implication for the formation of chondrules. Thus, in this study, we attempt to reveal the relationships based on a new measurement of the shape, compositions, and textures, using a theoretical model.

We use samples collected from Antarctic ice. From ice in the blue ice field at the Cape Tottuki, 903 micrometeorites of sizes in a diameter range from 0.100 mm to 0.238 mm were identified based on the surface element abundance. The micrometeorites include fully, partially, and no melted particles. Among them, we only use the fully melted particles. The number of such cosmic spherules is 525.

In addition, we select cosmic spherules that have a smooth surface, because the smooth surface suggests that they are once molten completely. We analyze 50 cosmic spherules with smooth surface. After the measurement of the shape, each sample is polished to have a flat surface and analyzed for major element concentrations by an EPMA. In the analysis, we exclude samples which have cavities or unmelted parts in them. Then, the final number of samples becomes 27.

The shape of cosmic spherules are approximated by three-axial ellipsoids. After the measurement of shape, bulk composition of each cosmic spherule is analyzed by EPMA. Observing the polished section, we can see the texture of each sample.

Measured compositions and textures show that barred olivine and cryptocrystalline particles have lower SiO2 and olivine-like compositions, while glassy particles have higher SiO2 content and pyroxene-like compositions. Compositions and textures are tightly correlated.

A motion of dust particles entering the Earth atmosphere from the space is modeled. The equation of motion takes into account the frictional gas drag and the gas density distribution in the atmosphere. To evaluate the deformation, the ram pressure is calculated. The degree of deformation is evaluated using a theoretical model.

The melting temperature of the dust particle is given by the composition of the particle. The compositional change of the dust particle due to the evaporation is also taken into consideration.

Numerical results of our theoretical model show that the final composition would depend on the entry parameters such as the entry angle, velocity, the size, and the initial composition. Since Fe is likely to evaporate, as the evaporation proceeds, the composition becomes Fe-poor. A comparison of the measured composition with the numerical results suggests that observed cosmic spherules have not experienced a heavy evaporation. Initial composition of cosmic spherules seems to determine the final composition and structure.

Measured shapes of cosmic spherules show that shapes of most of samples are consistent with our model. However, some samples have smaller deformation than the theoretical model. This suggests that those samples re-solidified under the ram pressure that is lower than our model estimates. This may happen if the grain does not re-solidify even under the melting temperature and experiences the super cooling. We have also realized that less deformed spherical cosmic spherules have glassy textures and pyroxene rich compositions. This seems consistent with our theory: the ram pressure drives the deformation.

Keywords: cosmic spherule, shape, composition, texture, formation