【Grant-in-Aid for Specially Promoted Research】

Science and Engineering (Mathematics/Physics)

Title of Project : A model for formation and evolution of solid materials in space based on 3D structures of solar primitive materials

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Research Project Number : 15H05695 Researcher Number : 90180017
Research Area : Earth and Planetary Science, Petrology, Mineralogy and Economic Geology
Keyword : Earth and Planetary Materials, Condensation, Space Weathering, Hayabusa2

【Purpose and Background of the Research】

According to an astronomical model, dust particles formed by condensation from high temperature gas around evolved stars. They then metamorphosed under particle-beam irradiation (space weathering) in interstellar space, and eventually accumulated to give birth to the solar system (Figure 1). However, this model has not been verified in terms of material science. Examination of particles preceding the formation of the solar system found in cosmic dust and primitive meteorites can reveal solid formation and evolution not only in the solar system but also in the pre-solar environments. In particular, 3D structures of extraterrestrial samples (Figure 2) are expected to give new insights. The purpose of this research is to construct a robust model for solid formation and evolution in space by analyzing the 3D structures together with their reproduction experiments.

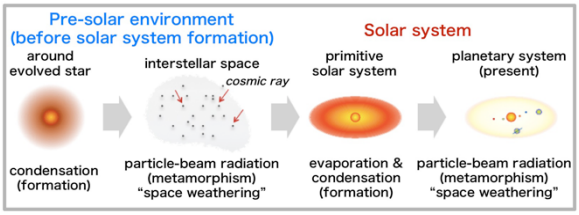

Figure 1. Solid formation and evolution in space.

【Research Methods】

(1) Dust formation: amorphous silicate particles with metallic iron and iron sulfide nanoparticles (GEMS), which might be source materials for the solar system, are present in cometary dust (Figure 3). Their formation conditions and origins are revealed by combining 3D structure analysis of GEMS with condensation experiments. (2) Dust evolution: conditions of space weathering and its role in interstellar space are elucidated by combining 3D structure analysis of space-weathered samples with ion-beam irradiation experiments. (3) 3D structures of cosmic dust and meteorites, which contain organic materials and water as well as minerals, are obtained in order to reveal their formation and evolution processes. (4) Techniques for multiscale 3D structure analysis are established.

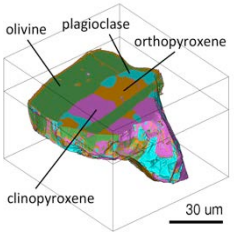

Figure 2. 3D structure of a Hayabusa particle.

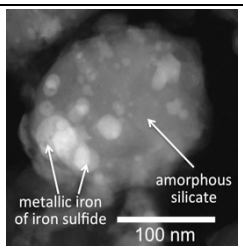

Figure 3. 2D TEM image of GEMS.

【Expected Research Achievements and Scientific Significance】

This research will give a deep understanding of the formation and evolution processes of solid materials from pre-solar to solar systems, in particular the formation environment of solids in space and the space weathering in interstellar space, which cannot be revealed by astronomical observation alone. This will allow us to expand our understanding of the history of the solar system back to the pre-solar stage; moreover, the initial conditions of the formation of the Earth and the other planets can be obtained as the source materials of the solar system. The expected results of this research are of paramount importance for the analysis of the samples returned from asteroids in JAXA Hayabusa2 mission in 2020 and NASA OSIRIS-REx mission in 2023.

【Publications Relevant to the Project】

・A. Tsuchiyama, M. Uesugi, T. Matsushima, et al., Three-Dimensional Structure of Hayabusa Samples: Origin and Evolution of Itokawa Regolith. *Science*, 333, 1125-1128 (2011)
・A. Tsuchiyama, Asteroid Itokawa: A source of ordinary chondrites and a laboratory for surface processes. *Elements*, 10, 45-50 (2014)

【Term of Project】 FY2015-2019

【Budget Allocation】 394,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.kueps.kyoto-u.ac.jp/~web-min/