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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The planets in the solar system formed approximately 4.6 billion years ago. In the solar nebula, km-sized small bodies are thought to form via accretion of small dust grains as a first step of the planet formation. The evolution of dust grains in the protoplanetary disks is the key to understanding the first step of the planet formation. Submicron-sized interstellar dust grains are incorporated into the gaseous solar nebula and grow into km-sized planetesimals. The pathways of dust growth from submicron-sized grains to km-sized planetesimals are not yet fully understood, however. In this thesis, we discussed what the building blocks of planetesimals are and how planetesimals formed in the solar nebula, from the thermal history of small bodies. In the inner region of the solar nebula, chondrules, mm-sized spherical igneous grains, would be formed in the first a few million years of the solar nebula, although the heating and cooling processes of the igneous spherules are still under debate. Some chondrules are composed of two or more chondrules fused, called compound chondrules. We can interpret the presence of compound chondrules as the result of collisions between crystallized chondrules and supercooled precursors. We focused on the shock-wave heating within the solar nebula, which is one of the leading candidates for the source of chondrule-forming events. In Chapters 2 and 3, we evaluated whether compound chondrules can form via the collision of supercooled chondrule precursors in the framework of the shock-wave heating model. We found that chondrule precursors immediately turn into supercooled droplets when the shock waves are optically thin, and they can maintain supercooling until the condensation of evaporated fine dust grains. Owing to the large viscosity of supercooled melts, supercooled chondrule precursors can survive high-speed collisions on the order of 1 km s^{-1}. We also showed that optically thin shock waves with a spatial scale of ~ 10^4 km could reproduce the fraction, size ratio, and textural feature of compound chondrules observed in ordinary chondrites. The thermal and mechanical properties of dust aggregates depend on their internal structure. In Chapters 4 and 5, we numerically calculated the thermal conductivity of dust aggregates. We found that the thermal conductivity of dust aggregates through the solid network follows a power-law function of the filling factor and the coordination number of dust aggregates. We also give a theoretical explanation for why a power-law gives it from the fractal structure of dust aggregates in Chapter 6. The Rosetta mission to comet 67P/Churyumov−Gerasimenko has provided plenty of data to understand what comets are made of. The thermal and mechanical properties of dust aggregates depend on their internal structure, i.e., whether homogeneous or hierarchical. In Chapter 7, we calculated the thermal inertia, tensile strength, and compressive strength of dust aggregates using formulae derived in Chapters 4−6. We found that we cannot explain the tensile strength of the comet if it is a homogeneous aggregate of μm-sized dust grains. On the other hand, the thermal inertia, tensile strength, and compressive strength of the comet are consistent with those of hierarchical aggregates of cm- or dm-sized constituent aggregates. Our findings indicate that the icy planetesimals may form via accretion of cm- or dm-sized compressed dust aggregates in the solar nebula. Recent observational studies have revealed that all 1000 km-sized large trans-Neptunian objects form satellite systems. However, their origins are still under debate. The largest Plutonian satellite, Charon, is thought to be an intact fragment of an impactor directly formed via a giant impact, although whether giant impacts can explain the characteristics of other satellite systems, e.g., the secondary-to-primary mass ratios, the spin/orbital periods, and their small eccentricities, remains to be determined. In Chapter 8, we found that hydrodynamic simulations of giant impacts can reproduce the secondary-to-primary mass ratio of the satellite systems of large trans-Neptunian objects when the impact velocity is approximately the same as the escape velocity. We also revealed that the satellite systems' current distribution of spin/orbital periods and small eccentricity could be explained when their spins and orbits tidally evolve, initially as fluid-like bodies, and finally as rigid bodies. These results suggest that all satellites of large trans-Neptunian objects were formed via giant impacts before the outward migration of Neptune and that they were fully or partially molten during the giant impact era. Recent studies proposed that accretion of cm-sized dust aggregates onto pre-existing planetesimals can form 100−1000 km-sized large trans-Neptunian objects within a few million years. Thus, we concluded that rapid accretion of cm-sized dust aggregates is a strong candidate for the origin of small icy bodies including comets and trans-Neptunian objects. This planet formation scenario is recently featured, and we revealed that the thermal histories of small icy bodies are also consistent with the hypothesis. The rapid formation of icy planetesimals in the gaseous solar nebula might support our scenario for chondrule formation in shock waves caused by pre-existing eccentric planetesimals. Although understanding of the physical properties of hierarchical dust aggregates is still limited, we will reveal the nature of hierarchical dust aggregates in future experiments and simulations.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).