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PPS21-P14 Room:Convention Hall Time:May 20 18:15-19:30

Early thermal evolution of planetesimals considering low thermal conductivity of powdered materials

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Dust materials in protoplanetary disk accumulated into planetesimals. Protoplanets and asteroids have been considered to be formed by the collisions between the planetesimals. Efficiency of the collisional growth depends on physical properties and internal structure of the bodies. Therefore, it is important to consider the evolution of the physical properties and internal structure of the planetesimals due to thermal metamorphism. In previous studies, the thermal evolution of meteorites parent bodies were calculated in combination with metamorphic temperature or cooling rate estimated from the meteoritic analysis. However, most of these studies used the physical properties, such as thermal conductivity and density, of the meteorites as initial parameters of the parent body. Since the planetesimals accumulated from the dusts are considered to be porous bodies consisted of powdered materials, the above assumption would be improper. The initial properties of the planetesimals are important parameters controlling the thermal evolution and the resultant change of the internal structure. Among these initial properties, we focused on the thermal conductivity.

It is known that the powdered materials have low thermal conductivity compared with rocks having the same composition. Especially under vacuum environment, silicate powders have extremely low thermal conductivity about 0.001 W/mK. Therefore, if assuming the porous body consisted of powdered materials as the initial structure of the planetesimal, the subsequent thermal evolution would be different significantly from the previous models that assumed the physical properties of the meteorites. In this study, we aimed at investigating the effect of the powdered materials of low thermal conductivity on the thermal evolution of the planetesimals.

We numerically solved the equation of one-dimensional and spherically symmetric heat conduction, with the thermal conductivity, porosity, and formation time and size of the planetesimal as variable parameters. For the thermal conductivity of the powdered materials, which is the most interesting parameter in this study, we used experimental values we measured for glass beads (porosity of 40%) under vacuum. Since the thermal conductivity of the powdered materials depends on the cube of the temperature, it varies significantly during the thermal evolution. The temperature dependence was also included in our model.

We found that even planetesimals as small as 10 km in radius experience the significant heating above 2000 K at the center (see figure). Previously, it has been considered that the radius of the planetesimal about 100 km is required in order to heat up sufficiently to form the thermally metamorphic meteorites. Our calculation indicates that the planetesimals smaller than 10 km can serve as the parent bodies of chondritic and/or differentiated meteorites.

When comparing the temperature evolution between the models including and excluding the temperature dependence of the conductivity, the former had lower peak temperature by about 500 K than latter. While the temperature was maintained around the peak temperature for more than 100 m.y. for the latter case, for the former case the temperature dropped to a half of the peak temperature after 20 m.y. Therefore, the temperature dependence of the thermal conductivity of the powdered materials should be included in the model calculation.

When the temperature increases, the powdered materials will be sintered at a certain temperature. Because the thermal conductivity of the sintered materials will be higher than the not-sintered powdered materials, the sintering affects the subsequent thermal evolution. Furthermore, the change of the physical properties after the sintering would be important for the collisional growth between the planetesimals. In this presentation, we will also present the calculation results that include the effect of the sintering.

Keywords: powdered materials, planetesimal, thermal evolution

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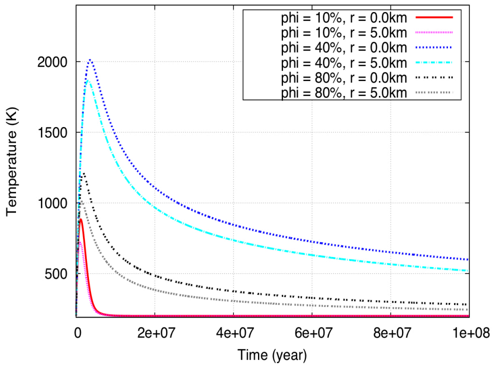

Figure: Thermal evolution of planetesimals of 10 km radius formed at 2 m.y. after CAI formation. "phi" and "r" in the legend refer to the porosity and distance from the center, respectively.