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Thermal conductivity model for powdered materials under vacuum

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Powdered materials have been ubiquitously existed in the solar system from the past to the present. For example, in early solar nebula, km-sized bodies so-called planetesimals are considered to have formed by accretion of dust particles. At present, surface of the Moon and asteroids are covered with crushed rock powders, called regolith. It is known that the powdered materials have lower thermal conductivity than intact materials by more than two orders of magnitude under vacuum condition. Therefore, even if the regolith covers a planetary body with thin thickness, it strongly affects the thermal evolution. The thermal conductivity of powdered materials under vacuum depends on several parameters (temperature, particle size, porosity, compressional stress, etc.), and varies by an order of magnitude, depending on the parameters. Since powdered materials on planetary bodies have various physical parameters, construction of an integrative thermal conductivity model describing these parameter dependences is of importance to address thermal problem of the planetary bodies.

Until now, we have experimentally investigated the parameter dependences of the thermal conductivity of powdered materials under vacuum, mainly using glass beads as analogous samples. Heat transfer mechanism in the powdered media has been studied based on the experimental results. In this presentation, we introduce a theoretical model of the thermal conductivity.

Previous studies for the thermal conductivity of powdered materials suggested several models. Some researchers modeled sphere beds with regular packing structures such as simple cubic packing, others suggested empirical models determined from experimental data. However, these models were not completely based on the physical mechanism. Moreover, they were incapable of reproducing the experimental results accumulated from previous experimental studies, and thermal conductivity values estimated from the models sometimes differed by one order of magnitude. Thus, it had been hard to estimate the thermal conductivity of powdered materials on planetary bodies accurately.

We first constructed the first quantitative model of the thermal conductivity of powdered materials in accordance with physical and heat transfer mechanisms successfully, by assuming random packing of mono-sized spheres. Our model integratively describes the parameter dependences, such as temperature, particle size, porosity, compressional stress, etc. By giving values of these parameters, we can estimate the thermal conductivity of powdered materials with various physical conditions. By comparing the model with experimental data for glass beads we obtained, it was found that our model could predict maximum values, and that the relative differences were less than factor of three.

Keywords: thermal conductivity, powdered material