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Effect of particle size distribution on thermal conductivity of powdered materials

SAKATANI, Naoya[1*] ; OGAWA, Kazunori[2] ; HONDA, Rie[3] ; ARAKAWA, Masahiko[4] ; TANAKA, Satoshi[2]

[1]The Graduate University for Advanced Studies, [2]Institute of Space and Astronautical Science, [3]Kochi University, [4]Kobe University

Understanding about heat transport mechanism of powdered materials, such as lunar surface regolith, is important issue in order to estimate planetary thermal evolution and present thermal state. Thermal conductivity of powdered materials depends on various parameters (particle size and its distribution, temperature, compressional stress, etc.). Depending on these parameters, thermal conductivity can vary by one order of magnitude. Due to insufficiency of the experimental studies, heat transfer mechanism is not understood enough, and it is difficult to constrain in-situ thermal conductivity on planetary surface.

Our purpose is to understand the heat transfer mechanism of powdered materials under vacuum conditions by means of systematic survey of parameter dependences of the thermal conductivity. This will enable us to model the thermal conductivity, which can apply the estimation of thermal conductivity structure on planetary surface. Most of previous studies focus on the powdered samples with uniform particle size. However, actual planetary regolith has wide range of particle size from sub-μm to mm. Moreover, parent bodies of chondritic meteorites would be composed of mixture of meteoritic matrix and chondrule. In this presentation, we will report the effect of particle size distribution on the thermal conductivity under vacuum.

Glass beads mixtures of 100 μm and 200 μm in diameters were used. Prepared samples had volume mixing ratio of 1:0, 2:1, 1:1, 1:2, and 0:1. Porosity of each sample was 0.38, 0.35, 0.32, 0.35, and 0.38, respectively. The thermal conductivity of these samples was measured by line heat source method.

As a result, 100 and 200 μm glass beads of uniform sizes had 0.0023 and 0.0035 W/mK, respectively. This difference in the conductivity would be caused by the difference of radiative heat transfer. On the other hand, mixing samples had thermal conductivity of 0.0039, 0.0029, and 0.0039 W/mK for mixing ratio of 2:1, 1:1, and 1:2, respectively. These conductivities related well to porosity. There were no linear relation between thermal conductivity and mixing ratio. We found M-shaped correlation between them.

The measured thermal conductivity can be represented by the sum of solid conductivity, which is conductive contribution through contact area between the particles, and radiative conductivity, which is radiative contribution through the pore between the particle surfaces. Our results will be explained by the variation of these conductivities with particle size distribution. Therefore, it is necessary to separate the measured values into solid and radiative conductivities for explanation of our experimental results. This can be accomplished by investigation of temperature dependence of the conductivity. In this presentation, we will report dependence of solid and radiative conductivities on the particle size distribution.