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Experimental investigation of parameter dependence for thermal conductivity of regolith

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Moon, Mercury, or asteroids' surface is covered with regolith. Thermal conductivity of powder material as regolith under vacuum environment depends on several parameters such as particle size, porosity, temperature, and stress. Although lunar thermal conductivity was measured in Apollo Heat Flow Experiments, the measured thermal conductivity seems to differ from the original one due to change in the regolith condition during drilling (Langseth et al., 1976). For correction of the measured thermal conductivity and for in-situ heat flow measurements in future, it is required to quantify the thermal conductivity variation as a result from the change of the regolith condition. Furthermore, powder materials have extremely low thermal conductivity of an order of 0.001 W/mK under vacuum condition. Therefore regolith layer on small bodies behaves as a heat-insulating layer, which affects their thermal evolution (Akridge et al., 1998). Since regolith condition on the small bodies which are under low gravity has uncertainty, it will be required that the thermal conductivity is modeled and its range is restricted. The purpose of this study is that the parameter dependencies of powders' thermal conductivity are investigated experimentally under vacuum condition and the heat transfer mechanism is understood.

The powders' thermal conductivity under vacuum is represented as sum of two contributions; thermal conduction through the particle contact region (solid conductivity) and thermal radiation between adjacent particle surfaces (radiative conductivity). One of the methods for separation of measured conductivity into these two conductivities is to investigate temperature dependence of the thermal conductivity assuming the temperature dependence of the radiative conductivity (Watson, 1964). Merrill (1969) studied the particle size dependence of the solid and radiative conductivities using some sizes of glass beads according to the Watson's method. The solid conductivity decreased with increasing the particle size, which was explained by the number of contact points of thermal resistances per unit volume. The radiative conductivity increased with the particle size, which was interpreted as making the effective length between particles longer. However, the glass beads he used had large porosity variation among the sample sizes, and therefore, his result might not reflect only the particle size effect, which will cause misunderstanding of the heat transfer mechanism. In this presentation, we re-investigated the particle size effect on the solid and radiative conductivity using several sizes of glass beads with porosity being almost constant among the sizes.

We used five sizes of glass beads, which have almost constant porosity. The thermal conductivity was measured by the line heat source method. The system's temperature was controlled by a thermostatic chamber from -25 to 50 degC. The thermal conductivity was separated into solid and radiative conductivities according to the Watson's method.

The results were the followings. The radiative conductivity increased linearly with increasing the particle size, consistent with the Merrill's result. On the other hand, the particle size dependence of the solid conductivity was different from Merrill's, which would reflect the effect of the porosity control; the solid conductivity slightly increased with increasing the particle size. Our results can be interpreted as not only (1) the effect of the number of contact points per unit volume but also (2) the effect of the particle size on thermal conductance per unit contact region. In theoretical model including these two effects (Halajian and Reichman, 1969), the solid conductivity is independent of the particle size, and it was found that the theoretical model derives comparable value with the solid conductivity obtained in this study.

Keywords: regolith, thermal conductivity