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Thermal conductivity measurements of sintered powder under vacuum condition

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In the planetary formation process, powder like dusts would have formed into planetesimals that have grown into proto-planets or asteroids through collisions between each other. Although efficiency of collisional accretion depends on physical properties (such as density and strength), their change due to thermal metamorphism has not been fully understood. Some planetesimals might have served as parent bodies of meteorites, and evidence of their thermal metamorphisms could give us information of size and formation time of the planetesimals. Therefore, it is important to investigate their thermal evolution and resultant change in the physical properties.

Thermal conductivity of the planetesimal constituents is one of the important parameters for examination of the thermal evolution. While the thermal conductivity of typical rocks is about 1 W/mK, that of powder is in the order of 0.001 W/mK under vacuum, which is lower than the value of rocks by three orders of magnitude. Because of thermal insulation by the powdered materials, even small planetesimals with the radius as small as 10km might have experienced temperature more than 1000 K (Ogawa, 2013), so that sinter bonding might have formed between powder particles that could have caused a significant change of the thermal conductivity.

Henke et al. (2012) calculated the thermal evolution of primitive porous planetesimals consisted of powdered materials as a model of parent bodies of chondrites. They assumed that sintering occured as the internal temperature increased, which process made planetesimals thermal conductivity higher by one to two orders of magnitude. Measured data of thermal conductivity of some kind of powders under vacuum is available (e.g. Sakatani et al., 2012), but there are few reports, in which the thermal conductivity of sintered material is measured. In their study, they used thermal conductivity derived as a function of porosity based on the measured value of silicate powder and chondrites.

However, based on our measurements of the thermal conductivity of glass beads (Sakatani et al., 2012), a positive correlation between the thermal conductivity and the pressure (thus, the inter-particle contact area) was observed. Therefore, the thermal conductivity should be re-examined as a function of the contact area instead of porosity.

In this study, we aims at investigating thermal conductivity of the sintered materials under vacuum condition, in order to provide constraints on the thermal conductivity of the sintered materials in planetesimals. Glass beads of several particle sizes were used as pre-sintered powder samples.

For sample preparation, we examined neck radius variation due to the heating temperature and the heating duration using a theoretical expression (Sirono, 1999; Poppe, 2003). The results indicated that, in order to make the neck radius 10 times larger than that is formed by heating for 0.1 hours, increasing heating time to 1000 hours are equivalent with increasing heating temperature by 100 K. Thus we adopted change the heating temperature instead of heating duration to control the sintering contact area.

Currently we are plannig to measures the thermal conductivity of sintered samples by so-called line heat source method. Two methods are considered for installation of a heat system in the samples: (1) puting the system in the glass beads and then heating both samples and the system to induce sintering of glass beads and (2) putting the system between two separate sintered samples created under the same condition. In the former case, heating during sintering may induce the change of electric resistance of the heating wire by oxidation and melting of a resin used between the wire and the thermocouple. The latter case is free from these problems, thus we adopted the latter method for installation of the line heat source system. We present detailed explanation of the measuring method and results of these experiments in the presentation.

Keywords: sintering, powdered materials, thermal conductivity