THERMAL INERTIA OF FINE-GRAINED POWDER OF THE MURCHISON CM CHONDRITE DETERMINED BY EXPERIMENTAL HEATING.

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Introduction: Thermal inertia, the degree of thermal resistance, strongly depends on grain size and porosity of material. Using this parameter, we can estimate what types of materials are on the surface of asteroids. There are several studies measuring the thermal diffusivity of meteorite bulk samples [1] including carbonaceous chondrites [2]. However, no previous studies have obtained the thermal inertia of powders of carbonaceous chondrite with different grain size. In this study, we conducted heating experiments using a powder of carbonaceous chondrite to determine the thermal inertia. The results will contribute to interpret the thermal inertia distribution of C-type asteroid 162173 *Ryugu* observed with NIRS3 and TIR onboard Hayabusa2 [3] [4].

Experimental methods: We prepared a chip of Murchison CM chondrite and crushed into particle sizes less than 2000μm, and measured its thermal inertia. Then the sample was further crushed into finer grains (<512μm, <155μm and the final size <77μm). A part of the powder was separated from each grain-size fraction and measured for the grain-size distribution and the mean-particle diameter, *d* (μm). For each sample, and we carried out the thermal inertia measurements by applying the following procedures. We packed the meteorite powder into a sample holder (φ10mm x 5mm: Fig. 1). The bulk-porosity of the powder was controlled from 32% to 59% by the number of tapping. In the sample container, 4 thermocouples were inserted horizontally every 1mm depth (Fig. 1). We used CO_2 laser to heat the surface of the sample up to about 450K in a vacuum chamber (~ 10^{-6} torr) for 5 minutes and cooled it rapidly for 30 minutes by turning off the laser. For each experimental condition (grain size and bulk-porosity), we repeated this heating/cooling cycle more than 5 times to improve precision and reliability. During the experiment, we measured temporal variation of the temperatures for each thermocouple inside of the sample powder.

Results and discussion: The obtained temperature profiles were used to calculate thermal diffusivity *K*, thermal conductivity *k*, and thermal inertia Γ. We first determined Δt, a time difference (sec.) of peak temperature between the two neighboring thermocouples, and then, assuming a semi-infinite medium, we simply calculated *K*, *k*, and Γ as follows:

$$K = \frac{\Delta z^2}{2\omega\,\Delta\,t^2}, \qquad k = K\rho' c, \qquad \Gamma = \sqrt{\rho' c k}$$

Here Δz is the depth difference of the thermocouples (m), ω is circular frequency (rad/s), *c* is specific heat [6], and ρ' is apparent density of the sample. Bulk porosity is calculated from $\phi = 1 - \rho'/\rho$ (from 32% to 59%), where ρ is the true density of Murchison (2.27 g/cc, determined in this study using a specific gravity bottle). Since our experimental system did not have ideal geometry (finite size of the sample container and spot heating), we carried out 2-dimensional numerical calculation simulating the geometry of our experiment, and introduced a coefficient in the thermal diffusivity *K* to compensate the difference in geometry between analytical solution and our experiment.

For fine-grained Murchison powder with the grain size less than 155μm ($d = 73 \pm 8$μm) and the porosity of 49%, we obtained a good reproducibility in temperature profiles among 5-time heating/cooling circles and the results show that $K = 1.0 \times 10^{-9}\ \mathrm{m^2s^{-1}}$, $k = 1.0 \times 10^{-3}\ \mathrm{Wm^{-1}K^{-1}}$ and $\Gamma = 30\ \mathrm{Jm^{-2}K^{-1}s^{-1/2}}$. These values are similar to those of silicate powder [5], but much lower than those of a chip of CM carbonaceous chondrite (e. g., $K = 6.02 \times 10^{-7}\ \mathrm{m^2s^{-1}}$ in [2]).

References: [1] Yomogida and Matsui (1983) *Journal of geophysical research*, 88, 9513-9533. [2] Opeil et al. (2010) *Icarus*, 208, 449-454. [3] Sugita et al. (2019) *Science,* 364, 10.1126/science.aaw0422. [4] K. Kitazato et al. (2019) *Science*, 364, 10.1126/science.aav7432. [5] S. Henke et al. (2012) *Astronomy & Astrophysics*, 537, A45. [6] Wada et al. (2018) *Progress in Earth and Planetary Science*, 5:82.

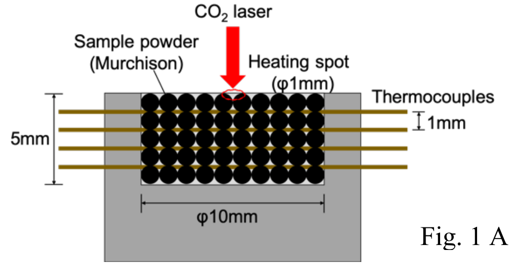

Fig. 1 A cross section of the sample holder