The effects of porosity of surface materials on the reflectance spectra of C-type asteroids

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C-type asteroids are classified into several subtypes based on their reflectance spectra. Compositional and physical properties (e.g., mineral composition, surface roughness, and alteration and weathering degrees) are responsible for the diversity of the reflectance spectra of C-type asteroids. Some previous studies (e.g., Cloutis et al. 2018) have investigated how these properties impact the reflectance spectra of carbonaceous chondrites (CCs) whose parent bodies are C-type asteroids. In this study, we have carried out compaction experiments of Murchison CM chondrite powder (< 155 μm) in order to understand quantitively the porosity dependence on the reflectance spectra.

The Murchison powder sample was put in a sample holder, compacted by manual tapping of the holder, and further compressed by a SUS plate to make six different porosity levels of the sample. The initial, uncompacted sample was prepared by leveling the surface (and designated as tap-0 sample). To reduce the surface porosity, the sample holder was tapped 10 times (tap-10 sample), 20 times (tap-20 sample) and 40 times (tap-40 sample). After the sample holder were tapped 40 times, the sample holder was pressed with the SUS plate by hand (hand-press sample) and by 500 kg (500kg-press sample). The reflectance spectra and the porosity of all samples were then measured by FT-IR and micro-tomography CT, respectively, at Tohoku University.

The porosity of the sample powder decreases as the sample were compacted from the tap-0 to 500kg-press sample. In addition, we found that the porosity decreases from the surface to the bottom of the sample powder and thus it is essential to obtain the surface porosity (not bulk porosity) to understand the porosity dependence on the spectra. We define the surface porosity as the porosity between the surface to the depth to which light comes in from vertical direction: light can penetrate through spaces between small grains and stop at a depth at which it is absorbed.

The measurement of the reflectance spectra showed that decreasing the surface porosity of the powder sample with tapping 0 to 40 times results in an increase in reflectance at 550nm wavelength with a small change of the slope of spectra. On the other hand, decreasing the surface porosity by pressing (hand-press and 500kg-press samples) results in brightening at shorter wavelengths and bluer-sloped spectra. The bluing of the spectra is probably due to an increase of the surface flatness by pressing using the flat surface of the SUS plate.

Our results indicate that the surface porosity and the spectral features are correlated: as the surface porosity decreases, the reflectance increases with a slight reddening of the slope of spectra. Small changes of the slope indicate small changes of the roughness of the surface by tapping. On the other hand, pressing with the flat SUS plate changed the roughness of the surface making it flatter surface, which results in bluing of the spectra. Therefore, the changes of spectral properties of the hand-press and 500kg-press samples are resulting from mixed effects of decreasing surface porosity and flattening of the surface. Our results provide a quantitative relationship between grain-size, porosity, and spectral features of C-type asteroids. Further studies with the same experimental procedures using different grain size of the powder sample are required to distinguish between porosity and grain-size effects and to isolate only porosity effect on the spectra of C-type asteroids.

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