Spectral and mineralogical properties of naturally-heated carbonaceous chondrites; implication to heating processes on the surface of hydrous asteroids

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The parent bodies of carbonaceous chondrites are thought to be C-type asteroids based on the similarity of visible (Vis) -infrared (IR) spectra between carbonaceous chondrites and C-type asteroids [e.g., 1-5]. Several C-type asteroids are thought to have been heated and dehydrated judging from their spectra which are similar to the spectra of experimentally-heated chondrites [1,6]. The Hayabusa2 spacecraft of the Japan Aerospace Exploration Agency (JAXA) was arrived at the target C-type asteroid 162173 Ryugu in June 2018. Ryugu spectra exhibit a weak 2.72-μm OH absorption band that is present across the surface of the asteroid, and nearly always darker than values typical for carbonaceous chondrites [7,8]. The meteorites whose spectral features are most similar to Ryugu are shocked or moderately-heated carbonaceous chondrites. In this study, we performed spectral analysis in Vis-NIR range and mineralogical analysis in micro scale using carbonaceous chondrites that heated dehydrated on their parent bodies.

Spectral and mineralogical analyses were performed using nine naturally-heated and dehydrated carbonaceous chondrite samples (seven CM, one CI, and one CV chondrites), which classified into heating stages (HS) from I to IV based on X-ray diffraction results [9]. In-situ heating of samples at 120–400 ˚C was performed during spectral measurements and successfully removed absorption water and part of rehydrated water from chondrite samples. Lewis Cliff (LEW) 87022 (unheated CM), Jbilet Winselwan, and Dhofar 735 (heated at 600–900 ˚C [10]) were used for transmission electron microscope (TEM) analysis.

Reflectance spectra of HS-I samples show the positive slope in Vis- IR range and the significant 0.7- and 3-μm absorption bands. The 0.7-μm band appears in only HS-I sample spectra. With increasing heating degree, (1) Vis-IR slope decreases, (2) the 0.7- and 3-μm bands decrease, and (3) Mid-IR spectral feature (i.e. Christiansen feature (CF) and Reststrahlen bands (RB)) shifts toward longer wavelength. TEM/EDX analyses showed that the matrix of severely-heated chondrites consists of tiny olivine, low-Ca pyroxene, and fine Fe- and Ni-rich metal grains (<1 μm). It is indicated that in proportion to the heating degree, amorphization and dehydration of serpentine and tochilinite from HS-I to HS-II might cause the 0.7- and 3-μm band weakening, and spectral slope and albedo decreasing of spectra. Then, formation of secondary olivine and pyroxene, and FeNi-rich metal grains at HS-IV would be responsible for the 3-μm band depth decreasing, spectral slope and albedo increasing, CF peak shift, and RB changes of chondrite spectra.

We plan to compare other IR reflectance spectra of asteroids, such as those acquired by AKARI [11], to better interpret remotely sensed data of Bennu (NASA’s OSIRIS-REx mission target) and Ryugu. Future NIRS3 observations before/after the Small Carry-on Impactor (SCI) crater experiment and lab analyses of returned samples will reveal additional compositional properties of Ryugu.

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