Spectral and mineralogical properties of dehydrated carbonaceous chondrites

M. Matsuoka[1], T. Nakamura[1], N. Miyajima[2], N. Imae[3], A. Yamaguchi[3], H. Kojima[3]
[1]*Tohoku University, Sendai, Miyagi 980-8578, Japan,*
[2]*Bayerisches Geoinstitut, University of Bayreuth, Bayreuth 95440, Germany,*
[3]*National Institute of Polar Research, Tachikawa, Tokyo 190-8518, Japan*

Introduction: Carbonaceous chondrites are thought to have derived from C-type asteroids based on the similarity of visible (Vis) – infrared (IR) reflectance spectra [e.g., 1-5], and assumed not to have been heated severely on their parent bodies. However, since 1990's many carbonaceous chondrites have found at Antarctica that experienced heating and dehydration after aqueous alteration and before they fell on Earth. The C-type asteroid Ryugu, which is the target asteroid of JAXA Hayabusa2 mission, showed the similar spectra to Murchison meteorite which was heated at 550-900 °C [6]. For estimating the heating and dehydration process on C-type asteroids, it is essential to clarify the spectral, chemical, and mineralogical changes due to heating based on analyses using heated and dehydrated carbonaceous chondrites. The linkage of Vis-IR spectra and mineralogy of naturally-heated carbonaceous chondrites should be helpful for spectral data analyses of ongoing sample return missions (e.g., JAXA Hayabusa2, NASA OSIRIS-REx).

Samples: We used 9 carbonaceous chondrite samples (seven CMs, one CI, and one CV) which classified into heating stages (HS) from I to IV based on X-ray diffraction results [7, 8]: Murchison and Murray are samples of HS-I (<300 °C), Yamato (Y-) 793321, Jbilet Winselwan, Y 982086, and Y 980115 (CI) are HS-II (300-500 °C), Y-86720 and Belgica (B-) 7904 are HS-IV (>750 °C), and Allende (CV3) is an anhydrous sample. For TEM analyses, we observed several samples, LEW87022 CM (HS-I), Jbilet Winselwan (HS-II), and Dhofar 735 CM and laboratory heated Murchison (HS-IV).

Analyses: We measured the Vis-IR reflectance spectra of powdered carbonaceous chondrites using Fourier transform infrared spectrometer (FT-IR: Bruker VERTEX70v) over the wavelength range of 0.4-15 μm at every ~5 nm at Tohoku University. The incident and emission angles were 30° and 0°. Then we performed microscopic analyses using transmission electron microscope (TEM: FEI Titan G2 80-200 S/TEM) equipped with energy dispersive X-ray (EDX) spectrometer at Bayerisches Geoinstitut, University of Bayreuth.

Results and Discussion: Reflectance spectra of HS-I samples show the positive slope in Vis-IR range and the 0.7- and 3-μm absorption bands. The 0.7-μm band due to charge transfer between Fe^{3+} and Fe^{2+} appears in spectra of only HS-I samples. With increasing heating degree, (1) the spectral slope in Vis-IR range decreases (thus bluer), (2) the 3-μm band, which arises from O-H stretching mode in hydrous minerals, becomes shallower and more rounded, and (3) Christiansen feature as the reflectance minimum around 9 μm and Reststrahlen bands shift toward longer wavelength. As the results of the TEM/EDX analyses, the matrix of HS-I LEW87022 is dominated by Fe-rich serpentine and tochilinite. In contrast, matrix of HS-IV samples, Murchison experimentally heated at 900 °C and Dhofar 735, consists of tiny olivine, pyroxene, and FeNi metallic particles mostly smaller than 100 nm in diameter. Therefore, it is indicated that the spectral slope decreasing and the 3-μm band weakening proceed with progress of dehydration of hydrous minerals such as serpentines and tochilinite and formation of submicron-size secondary anhydrous silicates and metals. There seem no hydrous phases survived in the HS-IV samples, which is inconsistent with the presence of the large 3-μm band in the reflectance spectra of these HS-IV samples. This is probably due to the effects of adsorbed and rehydrated terrestrial water on the dehydrated materials in the HS-IV samples, which was shown by the heating experiments of Murchison samples without any effects of adsorbed and rehydrated water [9]. For interpretation of asteroidal spectra observed by remote sensing, Vis-IR spectra are useful to clarify the mineralogical properties. In order to compare spectra of asteroids with those of meteorites directly, especially for around the 3-μm band, we have to remove the effects from terrestrial water such as absorbed and rehydrated water from meteorite spectra. For this reason, the spectral measurements with keeping sample heated under vacuum are in progress.

Acknowledgements: This study was supported by the JSPS Japanese-German Graduate Externship, Japan Society for the Promotion of Science (JSPS) Core-to-Core Program "International Network of Planetary Sciences", and Grant-in-Aid for JSPS Fellows.

References: [1] Hiroi, T. et al. (1993) Science, 261, 1016-1018. [2] Hiroi, T. et al. (1996) M&PS, 31, 321–327. [3] Burbine, T. et al. (2002) Asteroids III, 1, 653-667. [4] Lantz, C. et al. (2013) A&A, 554, 1-7. [5] Takir, D. (2013) M&PS, 48, 1618-1637. [6] Sugita, S. et al. (2013) LPS LXXV Abstract #2591. [7] Nakamura, T. (2005) J. Miner. Petrol. Sci., 100, 260-272. [8] Matsuoka, M. et al. (2017) EPS, 69, 120. [9] Mogi, K. et al. (2017) MetSoc 2017 Abstract #6225.