VIS-IR REFLECTANCE SPECTROSCOPY OF HYDROUS CARBONACEOUS CHONDRITES WITH VARIABLE HEATING AND DEHYDRATION DEGREES. M. Matsuoka[1], T. Nakamura[1], N. Miyajima[2], N. Imae[3], A. Yamaguchi[3], H. Kojima[3], [1]Div. Earth Planet. Mater. Sci., Tohoku University, Sendai, Miyagi 980-8578, Japan (mmatsuoka@dc.tohoku.ac.jp), [2]Bayerisches Geoinstitut, University of Bayreuth, Bayreuth 95440, Germany, [3]Research National Institute of Polar Research, Tachikawa, Tokyo 190-8518, Japan.

Introduction: 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]. The ground observation of C-type asteroid Ryugu showed that its surface material is similar to unheated CM chondrite based on the detection of the 0.7-μm band [6], and/or heated carbonaceous chondrite because its spectral slope of 0.4-1.0 μm corresponds with that of Murchison CM2 chondrite heated at 550-900°C [7]. Thus, it is important to track spectral changes of carbonaceous chondrites due to dehydration for deducing the surface material properties of C-type asteroids, especially for the sample return missions such as JAXA Hayabusa2 and NASA OSIRIS-REx.

In order to relate spectral signatures to chemical and mineralogical characteristics of heated carbonaceous chondrites, we measured the reflectance spectra of powdered hydrous carbonaceous chondrites that experienced heating to various extents on their parent bodies. The reflectance spectra of these powdered chondrites are also measured using the near-infrared spectrometer (NIRS3) flight model that is now onboard Hayabusa2 spacecraft, and the results of the measurement indicate that NIRS3 is able to distinguish heating degrees based on the 3-μm band signatures [8].

Experimental: We used nine samples (seven CM, one CI, and one CV chondrites), whose heating degrees are already determined based on the X-ray diffraction patterns of fine-grained matrix material [8]. The heating degree is classified into heating stages (HS) from I to IV based on the mineralogical characteristics [9]: Murchison and Murray classified as HS-I samples heated at <300°C, Yamato (Y-) 793321, Jbilet Winselwan, Y 982086, and Y 980115 (CI) classified as HS-II samples heated at 300-500°C, Y-86720 and Belgica (B-) 7904 as HS-IV samples heated at >750°C, and anhydrous Allende (CV).

Reflectance spectroscopy. Reflectance spectra of meteorite samples were measured 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, at the incident and emission angles of 30° and 0°, respectively. The grain size of Murray, Y-793321, and B-7904 is changed from <3350, <512, <155, to <77 μm, and at each grain size the spectra were measured. On the other hand, the grain size of the other six chondrites is <155 μm. During measurements, the ambient gases around samples were evacuated down to <2 hPa in order to reduce the effects of atmospheric and adsorbed water.

Results: Reflectance spectra of HS-I samples have positive Vis-IR slope and absorption bands around 0.7 μm (Fig. 1), and 3 μm in wavelength. The spectral slope in Vis-IR range decreases by ~35% with increasing heating-degree (Fig. 1). The 0.7-μm band, which arises from Fe^{3+}-Fe^{2+} charge transfers in phyllosilicates, appears in HS-I spectra only. On the other hand, the 3-μm band due to O-H stretching vibration in hydrous minerals appears in all spectra, and becomes shallower and more rounded with increasing heating degree. The band depth changes at 0.7 and 3 μm is consistent with the previous study of furnace-heating experiments using CM chondrite Murchison [2, 10]. Only Jbilet Winselwan exhibits a sharp absorption peak at 2.72 μm.

The Christiansen features, which means a reflectance minimum presented at IR range, shift ~0.5 μm toward longer wavelength with increasing heating-degree: from ~8.7 μm of HS-I and II samples to ~9.2 μm of HS-IV samples. The Reststrahlen bands of both HS-I and II samples are present at ~11.4 and ~12.2 μm, and those of HS-IV samples exhibit at ~11.6 and ~12.7 μm, shifting toward longer wavelength, which is consistent with previous study of spectroscopy of CM and CI chondrites [11]. The intensity of Reststrahlen band at longer wavelength of HS-IV samples is ~1.3 times greater than that of HS-I and II samples.

In terms of grain-size effects based on the spectra of three chondrites (Murray, Y-793321, and B-7904), with grain-size decreasing from <3350 μm to <77 μm, (1) the Vis-IR spectra becomes redder (e.g., Vis-IR slope changes from almost zero of <3350 μm to ~0.04 of <77 μm for Murray spectra), (2) the Christiansen feature shifts ~0.5 μm toward longer wavelength, and (3) the Reststrahlen band shifts ~1.2 μm toward longer wavelength. The 3-μm band shape and depth show no change with the grain-size variation.

Discussion: Here we define the Vis-IR slope as the reflectance ratio of 0.39 to 0.95 μm as $(R_{0.95} - R_{0.39})$ /0.56, and the 3-μm depth D as $1 - R_{2.75}/R_{2.50}$, where R_λ stands for reflectance at λ μm in wavelength. From HS-I to HS-IV, the Vis-IR slope, D value, and reflectance ratio of $R_{11.5}/R_{12.5}$ are decreases by ~25 % from ~0.04 to ~0.03, by ~80% from ~0.39 to ~0.07, and by ~25%

from ~1.01 to ~0.75, respectively. Therefore, we consider that spectral flattening and the 3-μm band depth decreasing start simultaneously at an early stage of heating, and then the intensity of the Reststrahlen band at ~12.7 μm becoming higher with increasing heating-degree, which may reflect the progress of amorphization and dehydration of hydrous minerals of heated carbonaceous chondrites. In the case of interpretation observed spectra of asteroidal surface, it may be useful that heating-degree and grain-size are distinguishable based on Vis-IR spectra: heating-degree increasing produces spectral flattening and the 3-μm band depth decreasing, but grain-size variation affects only spectral slope. In particular, for the 3-μm band, there is a contribution of interlayer molecule water in amorphous textures and also absorption water, so we are going to perform spectral measurements of meteorite samples at elevated temperatures with vacuum condition. The detailed mineralogical changes of hydrous carbonaceous chondrites during heating can be described by transmission electron microscope (TEM) observation of HS-I, II, and IV samples, and the observation is now underway.

Summary: Reflectance spectra of hydrous carbonaceous chondrites show Vis-IR slope and the 3-μm band depth decreasing with increasing heating degrees. The dehydration and amorphization of hydrous minerals are likely to cause spectral flattening and band-depth decreasing.

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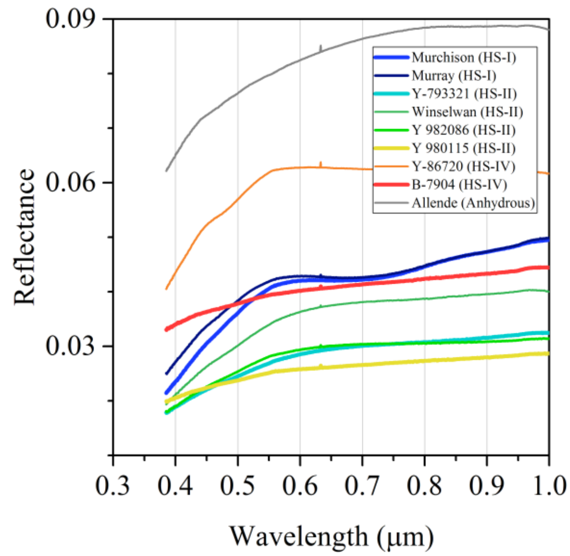

Fig. 1. Vis-IR spectra of carbonaceous chondrites. The grain size of Murray, Y-793321, and B-7904 is <77 μm, and that of the other chondrites is <155 μm.