Summary of Visible to Infrared Spectral Survey of NIPR Carbonaceous Chondrite Chips and Its Application to Hayabusa2 Mission.

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Introduction:

We have just completed the measurement portion of our visible and near-infrared (VNIR) spectral survey of meteorite chips of the National Institute of Polar Research (NIPR) [1], which was started in June 2010. Reported here are the summary of the carbonaceous chondrite (CC) survey results, which also included mid-infrared range, and an attempt of applying them to the Japanese Hayabusa2 mission, which is currently on its course to arrive at its target asteroid 1999 JU_3 in June 2018.

Experimental:

Out of 95 catalogued CC samples of the NIPR, 51 chip samples (3 CIs, 25 CMs, 2 CRs, 2 CHs, 5 CVs, 7 COs, and 7 CKs) were selected considering size, freshness, and texture, which are suitable for our measurements. Bidirectional VNIR diffuse reflectance spectra of one or two spots on each chip sample were obtained at every 5 nm over the wavelength range of 0.25-2.5 µm at NAOJ RISE Project or Osaka University. Detailed descriptions of the procedures are given in [1]. For this study, incident beam size was about 3×2 mm. In addition, biconical Fourier Transform infrared (FTIR) reflectance spectra of those spots were measured at 4 cm^{-1} resolution over the wavelength range up to either 15 µm at Tohoku University or 25 µm at RELAB, Brown University. The FTIR spectra were scaled to connect with the VNIR spectra at 2.5 µm.

Select Results:

Select reflectance spectra of CC chip samples which appear to be in high quality are plotted in Fig. 1. These spectra were chosen based on their apparent relative freshness, showing less terrestrial weathering features. Thermally-metamorphosed (dehydrated) CI and CM samples were subjectively identified based on their UV, 0.7-µm, and 3-µm absorption strengths and separately labeled in Fig. 1. All the CI samples measured were dehydrated. Dehydrated sample spectra tend to show more complex features around 6 and 10 µm, probably due to high temperature silicates such as olivine. The abundance of spectral features exhibited by different classes of CCs in Fig. 1 indicates that remote identification of the CC types is possible through reflectance or emission spectral observations over such a wide VNIR range as in Fig. 1.

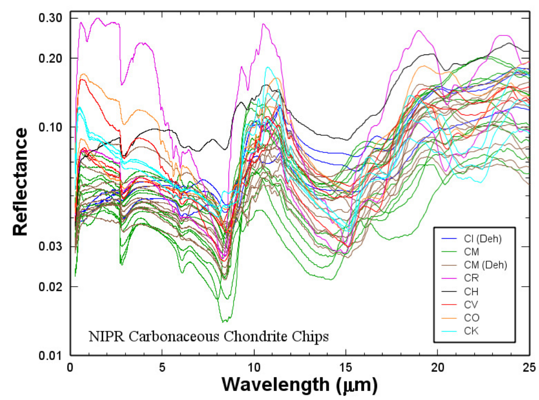

Fig. 1. Reflectance spectra of select CC chip samples. Those labeled as “Deh” are dehydrated samples due to thermal metamorphism.

Application to Hayabusa2 Mission:

Hayabusa2 spacecraft is equipped with two visible to infrared spectral sensors: ONC-T and NIRS3. ONC-T is a multiband imaging camera, having 6 color filters at 390, 480, 550, 700, 860, and 950 nm [2]. NIRS3 is a single-pixel near-infrared spectrometer, covering a wavelength range of 1.8-3.2 µm with 20 nm resolution [3]. Shown in Fig. 2 are the same CC reflectance spectra as in Fig. 1 over the wavelength range corresponding to these two Hayabusa2 onboard instruments.

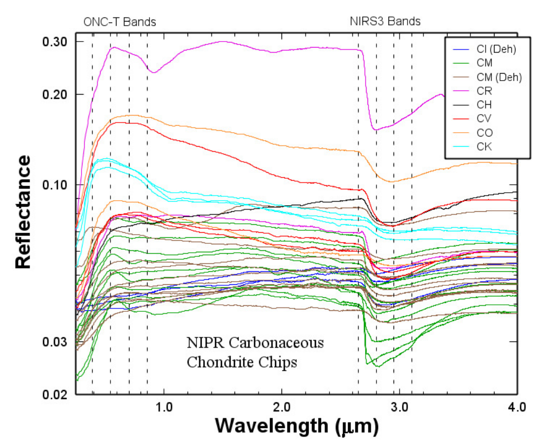

Fig. 2. Reflectance spectra of select CC chip samples plotted with select wavelength bands of Hayabusa2 onboard instruments ONC-T and NIRS3.

As indicated with vertical broken lines in Fig. 2, only four bands (390, 550, 700, and 860 nm for ONC-T, and 2650, 2800, 2950, and 3200 nm for NIRS3) were chosen to be used for this study. For our analyses, the following band strength (*BS*) parameters are defined:

$$BS_{UV} = lnR_{390} - lnR_{550}$$
$$BS_{700} = lnR_{700} - (160\, lnR_{550} + 150\, lnR_{860}) / 310$$
$$BS_{2800} = lnR_{2800} - lnR_{2650}$$
$$BS_{2950} = lnR_{2950} - lnR_{2650}$$

where R_λ denotes reflectance at λ nm in wavelength.

Shown in Fig. 3 is a plot of the absorption band strengths at UV and 700 nm defined above. This result suggests that the four bands of ONC-T may be able to distinguish CC types even if the asteroid surface may be covered with rocks and pebbles as in the case of the asteroid Itokawa visited by Hayabusa.

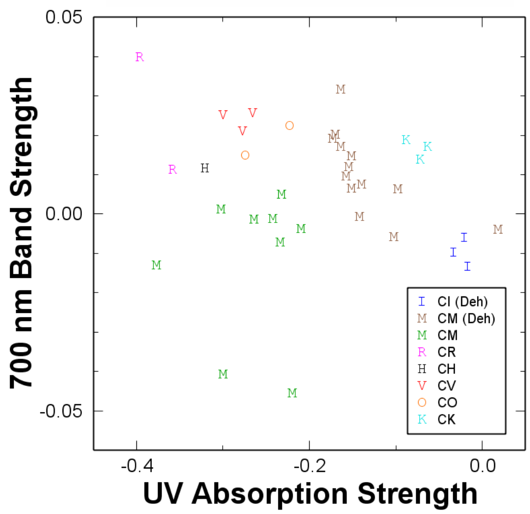

Fig. 3. A plot of the absorption band strengths at UV (390 nm) and 700 nm of CC spectra shown in Fig. 2.

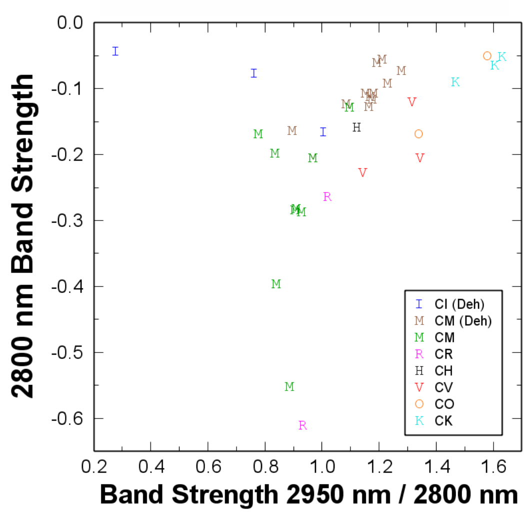

Fig. 4. A plot of the absorption band strength and ratio at 2800 and 2950 nm of the CC spectra shown in Fig. 2.

On the other hand, the NIRS3 band plot shown in Fig. 4 exhibits a complexity and difficulty in distinguishing CC types. One reason may be that terrestrial weathering (hydration etc.) strongly affects this wavelength region.

For this reason, we have applied Principal Component Analysis (PCA) on the NIRS3 band data. Shown in Fig. 5 is the plot of principal components 1 and 2 of the result. This plot shows a more encouraging trend for distinguishing CC types using the NIRS3 spectral data.

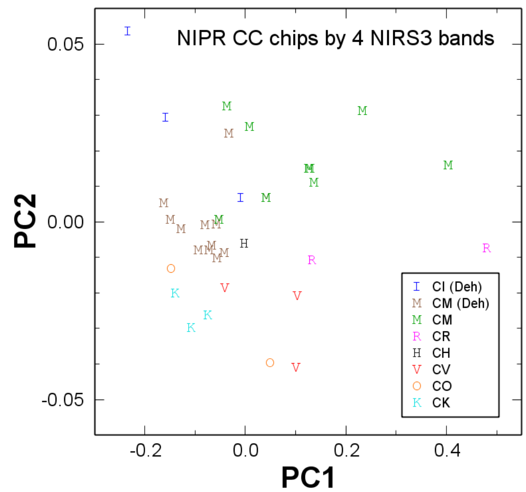

Fig. 5. A plot of the principal components 1 and 2 of the CC spectra shown in Fig. 2, using reflectance values at 2800, 2950, and 3100 nm normalized by that at 2650 nm.

Summary:

This study using the VNIR reflectance spectra of NIPR CC chips demonstrates that certain combinations of even a small number of spectral bands available for Hayabusa2 mission could distinguish CC types if the surface materials of the target asteroid correspond to them. However, reflectance spectra of dark materials are usually strongly influenced by particle size and viewing geometry. The NIPR samples studied here also may suffer significant terrestrial weathering that could have altered these results. Furthermore, the effects of space weathering would need to be considered. Thus, this study should probably be combined with the traditional ones using fresh CC powder samples.

Acknowledgment:

All the meteorite samples were kindly loaned from NIPR. Part of this research was supported by JSPS Grant-in-Aid for Scientific Research (C) and NASA SSERVI to T. H.

References:

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