Discovery of Unusual 3 μm Bands on Some CM Chondrite Chips of NIPR and Possible Link to Asteroidal Surface Minerals. T. Hiroi[1,2], H. Kaiden[2], N. Imae[2], A. Yamaguchi[2], H. Kojima[2], S. Sasaki[3], M. Matsuoka[4], T. Nakamura[4], C. M. Pieters[1], [1]Department of Earth, Environmental, and Planetary Sciences, Brown University, Providence, RI 02912, USA, [2]Antarctic Meteorite Laboratory, National Institute of Polar Research, 10-3, Midori-cho, Tachikawa, Tokyo 190-8518, Japan, [3]Department of Earth and Space Sciences, Osaka University, 1-1 Machikaneyama-cho, Toyonaka, Osaka 560-0043, Japan, [4]Department of Earth and Planetary Materials Sciences, Tohoku University, 6-3, Aoba, Aramaki, Aoba-ku, Sendai, Miyagi 980-8578, Japan.

Introduction:

In June 2010 we started a visible and near-infrared (VNIR) spectral survey of meteorite samples stored at the National Institute of Polar Research (NIPR) and finished those for lunar, Martian [1], and HED meteorite samples. Then, we began surveying carbonaceous chondrite (CC) samples in November 2012, and the preliminary results of the CM chondrites were presented in March 2014 [2]. In this paper we focus on the discovery of unusual 3 μm absorption bands detected on several spots of CM chondrite chips.

Experimental:

Out of 95 catalogued CCs of the NIPR, 23 CM samples were selected for study by considering weight, freshness, and texture (having a natural, broken surface). 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 either the RISE Project of the National Astronomical Observatory of Japan (NAOJ) or Osaka University. A detailed description of the procedure is given in a separate paper [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.

Results:

Shown in Fig. 1 are five spots on CM chondrite chip samples whose reflectance spectra showed an unusual complex structure near 2.8 μm in wavelength as plotted in Fig. 2. As mentioned in the last section, these spots appeared fresh or did not appear particularly more weathered than other spots. In that sense terrestrial weathering was not considered serious in obtaining the spectral features of indigenous minerals of CM parent bodies.

All the five spectra in Fig. 2 seem to share a common set of three to five absorption bands near 2.8 μm with different relative strengths. They also seem to show similar minor bands over the range of 1.9 to 2.3 μm although some features may due to noise. Deconvolution of the composite 3 μm band into three to five component bands is believed to be fruitful.

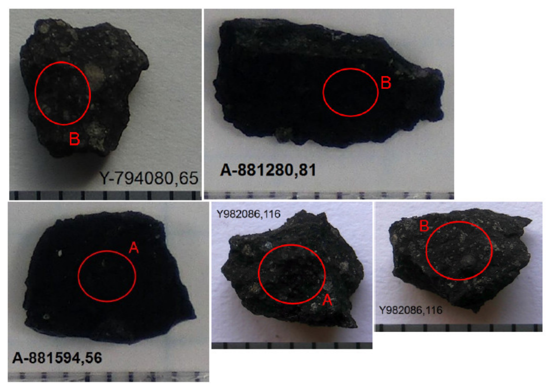

Fig. 1. Spots on CM chondrite chips showing unusual 3 μm absorption bands. The scale is 1 mm.

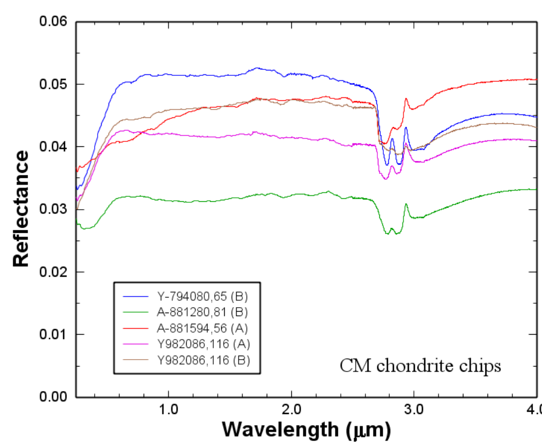

Fig. 2. Bidirectional VNIR reflectance spectra of the spots shown in Fig. 1, wherein three to five absorption bands are detected near 2.8 μm.

Shown in Fig. 3 are the VNIR-FTIR combined spectra of these spots. It is interesting that the features near 6, 9, and 15 μm appear to be correlated to the relative strengths of component bands of the 3 μm absorption.

In addition, as shown in Fig. 4, relatively weak absorption bands appear near 4.5 and 4.7 μm in three out of these five spectra, which are not seen in other "normal-looking" CM chondrite spectra.

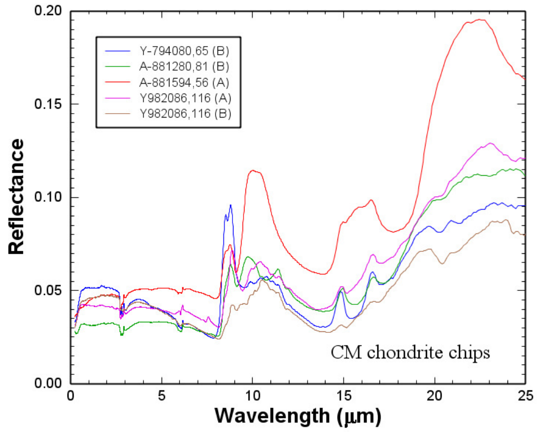

Fig. 3. Biconical FTIR reflectance spectra of the same spots shown in Fig. 1, wherein the spectra are scaled and connected to the VNIR spectra in Fig. 2.

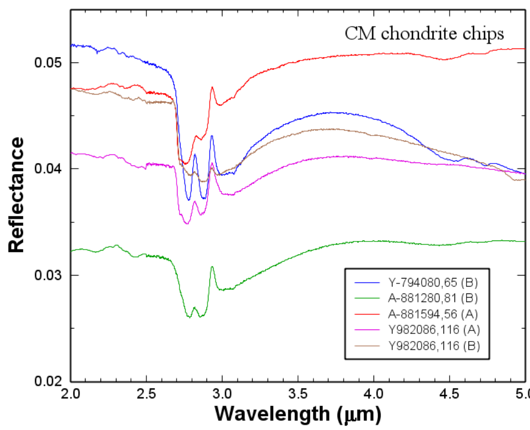

Fig. 4. The same spectra as in Fig. 3 and 4 plotted to focus on their 2.8 and 4.5 µm band regions.

Discussion:

NASA Dawn spacecraft discovered dark, hydrogen and volatile rich areas on asteroid Vesta, which showed complex 3 µm absorption bands [3] in the Visual InfaRed spectrometer (VIR) onboard Dawn. Although the VIR spectra do not match exactly with any of our CM chondrite spectra, the pattern that multiple discernible absorption bands appear in the 3 µm range is significant, especially considering the fact that some of the dark areas also show a 0.7 µm band which is specific to CM chondrites [4] among CCs. These two facts indicate a possibility that the unusual 3 µm bands we detected are indigenous to the CM chondrite parent bodies which also fell onto Vesta.

Because CM chondrites are the most abundant among CCs, they may have accumulated on other asteroids than Vesta. In fact, recent analysis of Galileo NIMS data showed a 2.82 µm absorption band on S-type asteroid 951 Gaspra along with 3.39 and 4.47 µm bands [5]. As shown in Fig. 4, three of our CM chondrite spectra show a weak 4.47 µm band. The small size of asteroid Gaspra should not be a problem for such mixing because even a small near-Earth asteroid 2008 TC3 had multiple unrelated meteorite classes recovered as Almahata Sitta meteorite [6].

Conclusions:

This study has proven that VNIR spectral measurement of CM chondrite chips is highly useful for identifying and characterizing the component minerals, including those having unusual 3 µm absorption bands. Therefore, this technique will be valuable in future spacecraft missions to small primitive asteroids such as Hayabusa 2 and OSIRIS-REx, especially during their close-up observation and touchdown phases and lander/rover operations. Because of its nondestructive nature, this survey can potentially be done for all the samples of our meteorite collections.

Future studies would include identifying minerals responsible for these unusual 3 µm bands and judging whether terrestrial weathering played a role in forming those minerals.

References:

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Acknowledgment:

Part of this research was supported by JSPS Grant-in-Aid for Scientific Research (C) and the NASA SSERVI.