

**SYNCHROTRON-BASED INFRARED MICROSPECTROSCOPY AS A USEFUL TOOL TO STUDY HYDRATION STATES OF METEORITE CONSTITUENTS.** L. V. Moroz<sup>1</sup>, M. Schmidt<sup>2</sup>, U. Schade<sup>2</sup>, T. Hiroi<sup>3</sup> and M. A. Ivanova<sup>4</sup>, <sup>1</sup>German Aerospace Center (DLR), Institute of Planetary Research, Rutherford Str. 2, D-12489, Berlin, Germany, [ljuba.moroz@dlr.de](mailto:ljuba.moroz@dlr.de), <sup>2</sup>BESSY GmbH, Albert-Einstein-Str.15, Berlin, D-12489, Berlin, Germany, <sup>3</sup>Department of Geosciences, Brown University, Providence, RI 02912, USA, <sup>4</sup>Vernadsky Institute of Geochemistry and Analytical Chemistry RAS, Kosygin St. 19, Moscow 119991, Russia.

**Introduction:** The meteorites Dho 225 and Dho 735 were recently found in Oman. Studies of their mineralogical and chemical composition suggest that these unusual meteorites are thermally metamorphosed CM2 chondrites [1,2,3]. Similar to Antarctic metamorphosed carbonaceous chondrites, the Dho 225 and Dho 735 are enriched in heavy oxygen compared to normal CMs [1,2]. However, IR studies indicating dehydration of matrix phyllosilicates are needed to confirm that the two new meteorites from Oman are thermally metamorphosed [4]. Synchrotron-based IR microspectroscopy is a new promising technique which allows the acquisition of IR spectra from extremely small samples. Here we demonstrate that this non-destructive technique is a useful tool to study hydration states of carbonaceous chondrites *in situ*. In addition, we acquired reflectance spectra of bulk powders of the Dho 225 and Dho 735 in the range of 0.3-50  $\mu\text{m}$ .

**Experimental Procedures:** We used synchrotron-based IR microspectroscopy to study hydration states of matrices in two polished sections of metamorphosed CM meteorites Dho 225 and Dho 735. We also studied polished sections of normal CM2 chondrites Mighei, Murray, and Cold Bokkeveld for comparison. The IRIS IR Beamline at the BESSY II synchrotron facility in Berlin [5] is equipped with a Nicolet Continuum IR microscope coupled to a FTIR spectrometer operating between 1 and 14  $\mu\text{m}$ . An LN<sub>2</sub>-cooled MCT detector was used for the spectral reflectance measurements. We deposited 1 mm-wide and 100  $\mu\text{m}$ -thick gold lay-

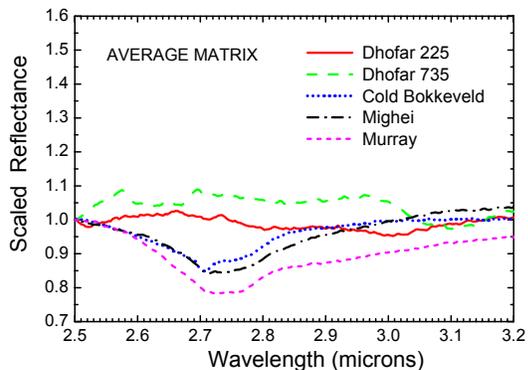


Fig. 1. Average matrix spectra of Dho 225, Dho 735 and normal CM2 chondrites in the region of O-H stretching vibrations.

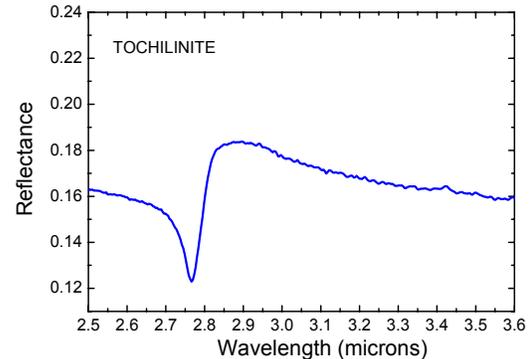


Fig. 2. O-H stretching feature in reflectance spectrum of tochilinite inclusion from CM2 chondrite Murray.

ers directly onto the meteorite polished sections to provide gold surfaces for standard measurements. The use of a synchrotron source allowed us to probe meteorite matrices with a spot size as small as 20 x 20  $\mu\text{m}$ , hence we avoided numerous sulfide, taenite, and tetraenaite grains in our measurements. We used smaller spot sizes of 10 x 10  $\mu\text{m}$  and 5 x 5  $\mu\text{m}$  to acquire IR spectra of the new Ca, Fe-oxysulfide phase recently found in the Dho 225 meteorite [1,6].

We acquired Vis-NIR reflectance spectra of bulk powders of Dho 225 and Dho 735 using the NASA-supported RELAB bidirectional spectrometer in the range of 0.3-2.6  $\mu\text{m}$  at  $i=30^\circ$  and  $e=0^\circ$ . FTIR reflectance spectra were measured in the range of 2-50  $\mu\text{m}$  at biconical geometry using a Nicolet 740 spectrometer. The FTIR spectra were merged with RELABbds spectra at  $\sim 2.4 \mu\text{m}$  to obtain the composite spectra.

**Results and Discussion:** We detected no signatures due to O-H stretching vibrations (in structural OH and/or bound H<sub>2</sub>O) in the 2.7-3  $\mu\text{m}$  spectral region in the Dho 225 and Dho 735 matrices by synchrotron-based IR microspectroscopy. We carefully scanned all the surfaces of our polished sections using a mapping stage but detected no O-H signatures in the spectra of any constituents of these two meteorites. We are aware that the absence of O-H features in reflectance spectra of polished surfaces does not prove the *absence* of hydrated phases in the samples. A significant contribution from specular reflection may mask the O-H stretching features in the 3- $\mu\text{m}$  region. However, we detected the O-H absorption bands in the matrix spec-

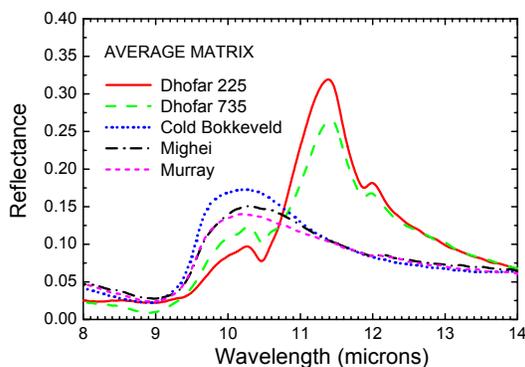


Fig. 3. Average matrix spectra of Dho 225, Dho 735 and normal CM2 chondrites in the spectral region dominated by Si-O stretching features.

tra of normal CM2 meteorites Cold Bokkeveld, Murray and Mighei (Fig. 1), and in tochilinite inclusions of Murray (Fig. 2), studied for comparison. This suggests lower contents of hydrated phases in the Dho 225 and Dho 735 matrices, compared to those in CMs.

Further evidence for the dehydrated state of the Dho 225 and Dho 735 matrices is the position and shape of strong Reststrahlen bands around 10-12  $\mu\text{m}$  due to Si-O stretching vibrations (Fig. 3), consistent with fine-grained Fe-rich olivine. The positions and shapes of the Si-O bands in the IR spectra of the typical CM2 matrices are different, being consistent with mixtures of Fe-rich and Mg-rich phyllosilicates. Such a dramatic difference between non-metamorphosed and metamorphosed CMs in this spectral region is not observed in the reflectance spectra of their bulk powders (Fig. 4). Signatures of olivine dominate the spectra of all CMs in this spectral region. Due to fine grain sizes, transparency features are evident between 12 and 14  $\mu\text{m}$ . In CM2 chondrites olivine is present in chondrules, inclusions, and as single grains in the matrix.

Dho 225 contains the first Ca, Fe-oxysulfide phase

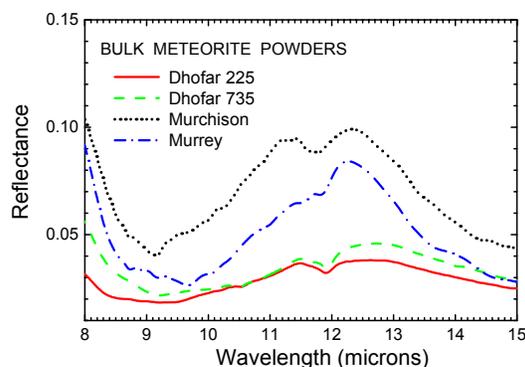


Fig. 4. RELAB spectra of Dho 225 and Dho 735 bulk powders compared to the spectra of normal CM2 chondrites Murchison and Murray (from ASTER library, particle size <75  $\mu\text{m}$ ).

found in nature [1]. Its best-fit stoichiometry and low analytical total indicate a formula of  $(\text{Ca}_{4.66}\text{Fe}_{0.34}^{2+})_5\text{Fe}^{3+}_6\text{S}_5\text{O}_9$  [1]. Another possible formula is  $\text{Ca}_4\text{Fe}^{2+}_5\text{S}_4(\text{OH})_4\text{O}_3$  [1], but the Ca, Fe-oxysulfide inclusions appear to lack OH, since they are stable under an electron beam. We have not detected absorption bands of structural OH at 2.7  $\mu\text{m}$  in these grains. Taking into account the presence of strong structural OH signatures in our spectra of an OH-bearing sulfide mineral tochilinite (Fig. 2), this result strongly suggests the lack of OH in the structure of the Ca, Fe-oxysulfide.

Fig. 5 shows the Vis-NIR reflectance spectra of powdered Dho 225 and Dho 735 samples. The spectra have flat NIR slopes and are featureless, except for the UV-falloff typical of carbonaceous chondrites.

**Conclusions:** Our results confirm that the matrices of Dho 225 and Dho 735 are dehydrated compared to normal CM2 chondrites. Along with chemical, mineralogical, and isotopic studies, this indicates that the two new meteorites from Oman are the first non-Antarctic metamorphosed carbonaceous chondrites. Synchrotron-based IR microspectroscopy is a useful non-destructive method to study the hydration state of meteorite phases. For silicates, the spectral region where Si-O stretching vibrations occur is particularly promising.

**References:** [1] Ivanova M. A. et al. (2002) *LPS XXXIII*, Abstract #1437. [2] Ivanova M. A. et al. (2003) *MAPS* 38, A28. [3] Ivanova M. A. et al. (2005) *LPS XXXVI*, Abstract #1054. [4] Clayton R. N. and Mayeda T. K. (1999) *GCA*, 63, 2089-2104. [5] Schade U. et al. (2002) *Rev. Sci. Instr.*, 73, 1568-1570.

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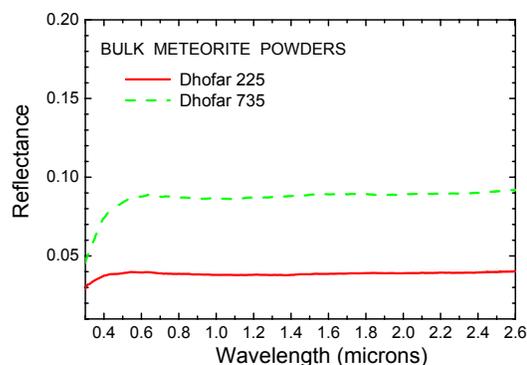


Fig. 5. Bidirectional Vis-NIR spectra of Dho 225 and Dho 735 bulk powders. Particle sizes are <125  $\mu\text{m}$  and <150  $\mu\text{m}$ , respectively.