A MID-INFRARED REFLECTANCE DATABASE IN PREPARATION FOR SPACE MISSIONS.

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Introduction: Infrared spectroscopy is a well-established remote sensing technique used in space and planetary sciences, e.g., the VIRITS [1] instrument on the Rosetta and the VIR instrument on the DAWN [2] missions. In addition, the BepiColombo mission, to be launched in 2018, includes the MERTIS [3] instrument - a thermal infrared imaging spectrometer combined with a radiometer.

In order to accurately interpret the spectra from those missions a reference mid-IR database is needed similar to other databases [4]. We are creating such a database, hosting spectra of minerals, meteorites, and synthetic materials that were ideally measured under P/T conditions equivalent to the investigated bodies. For example, to simulate the P/T conditions on Mercury and other bodies, we use a Harrick heating and variable pressure stage [5].

Another step is to combine all these data and compare them with the remote sensing data by data-deconvolution [6].

The database is currently based on spectra of an ongoing series of publications [e.g., 7-9]. Starting with rock forming minerals known from terrestrial planets such as various pyroxene, olivine, and feldspar, the database was recently expanded to meteorites, lunar samples, terrestrial impact rocks, as well as synthetic glasses with compositions based on remote sensing data of planetary bodies, e.g., Mercury [10-14].

Furthermore, to investigate the effects of the space environment on surface materials of airless bodies like Mercury and the Moon, the effects of space weathering on the IR spectra is investigated [15]. The bombardment of micrometeorites was simulated with a Nd:YAG (1064 nm) laser. We are in the process of extending these experiments by using an excimer laser as proposed by [16].

Our database is focused on the wavelength range of 2 to 18 µm, which coincides with the wavelengths covered by many spectrometers on space missions, as well as general laboratory IR studies. This range contains the characteristic spectral mid-infrared fingerprints of most rock-forming minerals. Silicates show strong features between 8 and 13 µm, oxides like quartz between 8 and 10 µm, carbonates exhibit broad bands between 6 and 8 µm, as well as peaks between 11 and 14 µm, and sulfides show bands around 10 µm. Moreover, a change in the band position and shape is correlated with changes in the composition of the mineral (e.g., varying Mg/Fe ratios in olivine) orientation, and lattice deformation (e.g., shock metamorphism) [17].

Database, Samples, Preparation and Methods:

Database

A preliminary IRIS database is already available online at http://www.uni-muenster.de/Planetology/ifp/ausstattung/iris_spectra_database.html. An open web-accessible database using PostgreSQL, which will be expanded continuously, is under development. The focus is on easy handling, allowing, for example, keyword search (Fig. 1). The mid-infrared spectra in the database are complemented by detailed characterization of samples with electron microscopy, Raman spectroscopy, and sample images. Metadata (such as spot size, geometry, temperature) of each analysis are also provided.

Samples. At the moment, the database contains spectra of:

1) Pure minerals and endmembers.

These samples allow for a direct comparison with other laboratory studies, and in combination provide most adequate surface information (or: the ground 'truth') of planetary bodies within our Solar System. In the future the database will also contain a series of spectra for solid solutions, e.g., of olivine and/or feldspar with variable compositions.

2) Terrestrial and extraterrestrial impact rocks:

These samples allow us to observe the effect of impact shock on spectral features. So far, we studied a suite of samples from terrestrial impact craters [7]. Furthermore, heavily shocked meteorites provide another source of such materials – (like those in the Chelyabinsk chondritic meteorite) [14,18].

3) Extraterrestrial rocks:

Meteorites and sample return material are representative of planetary bodies in our Solar System as they provide information on conditions other than on Earth. Thus, our database already contains spectra of various meteorites, as well as lunar samples [19].

4) Synthetic analogues:

Remote sensing data, for example, of Mercury were used to experimentally produce analogue synthetic glasses from which no natural equivalent is available. At the moment, the database contains spectra of these synthetic glasses [14].

5) Space weathered samples:

Effects of space weathering on spectral information has been investigated by various authors [e.g., 20] and we are particularly interested in spectral changes caused by the space environment [21,22].

Sample Preparation

The surfaces of planets consist of particles with a wide grain size range. Grain sizes strongly affect band intensities and band shapes in IR spectra [e.g., 23] . Therefore, we produced size fractions of bulk material described above in order to accommodate for these effects. We obtained size fractions from representative bulk mineral and rock samples in the ranges of 0-25 µm, 25-63 µm, 63-125 µm, and 125-250 µm.

For studies using FTIR-microscopy or other in-situ techniques for characterization, we prepared polished thin sections and/or blocks of the same bulk material.

Methods. A variety of analytical techniques have been employed:

- Light microscopy: We use a KEYENCE Digital Microscope VHX-500F to perform normal light and polarized light microscopy in order to acquire fast information about the overall homogeneity and crystallinity of the investigated material. Optical microscopy also allows us to quickly identify minerals in the samples.

- Electron microscopy: To further characterize the samples, we make detailed quantitative analyses of the samples as well as backscattered electron (BSE) images with a JEOL JXA-8530F Hyperprobe electron probe micro analyzer (EPMA) equipped with five wavelength dispersive spectrometers (WDS) at the Institute for Mineralogy in Münster.

- Raman spectroscopy: All Raman measurements are performed using an Ocean Optics IDR-Micro Raman system (IfP, Münster), working with a OneFocus optical system.

- IR spectroscopy of powders or polished minerals/rocks:

FTIR on bulk powders:

We use a Vertex 70v system at the IRIS (InfraRed and Raman for Interplanetary Spectroscopy) laboratory in Münster for FTIR analyses. The powdered sieve fractions are placed in an aluminum cup (diameter 1 cm, depth 0.5-0.1 mm) and 512 scans are accumulated for a high signal-to-noise ratio for the analysis of each size fraction. A commercial diffuse gold standard (INFRAGOLD) is applied for background calibration. In order to emulate various suspected observational geometries, analyses are obtained in a variable geometry stage (Bruker A513). The results in the database are obtained at 30° incidence (i) and 30° emergence angle (e) or 20° (i) and 30° (e).

Micro-FTIR on thin sections:

In cases where only small amounts of material are available or particles of interest (e.g., inclusions) are difficult to separate from a larger sample, additional Micro-FTIR analyses are made. For such point analyses, we use a Bruker Hyperion 2000 IR microscope attached to the external port of a Bruker Vertex 70v at the Hochschule Emden/Leer. The aperture size can be varied from 256×256 µm to 1000×1000 µm depending on the sample size. Usually 128 scans are accumulated.

For mapping with very high spatial resolution, and additional point analyses, we use a PerkinElmer Spotlight-400 FTIR spectrometer and an adjoining microscope mapping unit at the University of Manchester, using a cooled mercury-cadmium-telluride (MCT or HgCdTe) detector.

Conclusions:

The results of all measurements are structured in the database as shown in the block diagram in Figure 1. We are currently working on the web-accessible form of the database, which will be presented at the meeting in detail.

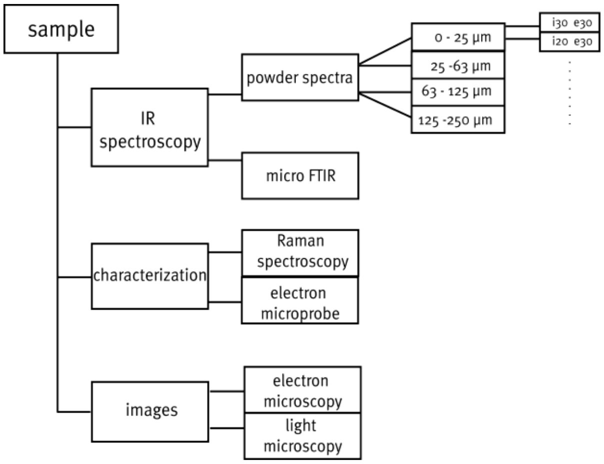

Fig. 1: Block diagram of the database structure.

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