

EXCIMER LASER IRRADIATION OF ANALOG MINERAL MIXTURES OF MERCURY'S SURFACE: FTIR STUDIES OF SMOOTH PLAINS ANALOGS. I. Weber¹, M.P. Reitze¹, A. Morlok¹, A.N. Stojic¹, K.E. Bauch¹, H. Hiesinger¹, J. Helbert², ¹WWU, Institut für Planetologie, Wilhelm-Klemm-Str. 10, 48149 Münster (sonderm@uni-muenster.de), ²DLR, Institut für Planetenforschung, 12489 Berlin.

Introduction: Infrared (IR) spectroscopy is very common in space exploration, since Fourier-transform IR is a method that has been known for decades [e.g., 1]. Therefore, the BepiColombo mission [2], launched in October 2018, also contains a thermal infrared imaging spectrometer combined with a radiometer - the MERTIS instrument [3]. The spectrometer will observe the spectral properties of Mercury's surface in the wavelength range of 7 μm – 14 μm with a pixel scale of about 500 meters, while the radiometer will study the surface in the range of 7 μm – 40 μm . In this context, MERTIS pursues the following scientific goals:

- globally map the mineralogy of the surface,
- identify rock-forming minerals,
- study surface temperature and thermal inertia.

The goal of our study is to establish a mid-IR reflectance database in the MERTIS-relevant range from 7 μm – 14 μm by measuring Mercury-relevant minerals and their space-weathered samples.

In the Infrared and Raman Laboratory for Interplanetary Spectroscopy (IRIS) at the Institut für Planetologie in Münster, we produce spectra of a variety of materials measured under different environmental conditions. These materials include typical rock-forming minerals like pyroxenes, olivines, and feldspars, and mixtures of these minerals.

Furthermore, the influence of micrometeorite bombardment as a form of space weathering (SW) typical for planets without atmosphere – like Mercury – is investigated. In this study, this type of SW was simulated with an 193 nm ArF UV excimer laser.

Samples and Techniques:

Samples: For the present study five different mixtures of natural olivine (Fo₉₁), pyroxenes with En₈₇Wo₁₃ (En) and En₄₆Wo₅₀Fs₄ (Di), labradorite (Plag; An₅₁Ab₄₇Or₂) and a pure quartz (Qz), were prepared based on experiments and calculations of [4] for the Smooth Plains on Mercury. A possible glass component was not considered in order not to falsify a potential formation of glass during laser irradiation. All samples have an identification number before and after irradiation. The minerals were mixed as follows: ID 359 – Fo10%, Di19%, Plag59%, En12%; ID 360 – Fo11%, Di4%, Plag61%, En24%; ID 361 – Fo100%, ID 362 – Fo49%, Di36%, Plag11%, En1%, Qz3%, ID 363 – Fo63%, Di37%.

Before starting the mixing process single minerals were ground in a steel mortar and a grain size fraction from 63 μm to 125 μm was used for subsequent

experiments. The sample material was then pressed into pellets for laser irradiation with a diameter of 6 mm and a thickness of 2-3 mm. After laser irradiation all samples received a new ID number: ID 359 → 364; ID 360 → 365; ID 361 → 366; ID 362 → 367; ID 363 → 368.

Techniques: A variety of analytical techniques have been used for sample characterization and further investigation:

Images of the pressed powder pellets before and after irradiation were obtained using a Keyence optical camera system and a JEOL 6610v scanning electron microscope (SEM) using the low vacuum method. Detailed sample characterization and quantitative analyses were performed with a JEOL JXA-8530F Hyperprobe Electron Probe Microanalyzer (EPMA) equipped with five wavelength dispersive spectrometers (WDS).

FTIR analyses were achieved with a Vertex 70v spectrometer at the IRIS laboratory. The pressed powder pellets were placed in the sample holder of the redesigned Praying Mantis™ High Temperature Reaction Chamber, which was evacuated down to at least 10⁻⁴ Pa. The chamber guarantees a high vacuum before, after, as well as during irradiation. With the Praying Mantis™ the highly diffuse biconical reflection is measured using two fixed parabolic mirrors through IR transparent KBr windows. During measurements the compartment was flooded with zero air at room temperature (RT ≈ 23°C) to avoid interfering atmospheric bands. Prior to each measurement, a commercial diffuse gold standard (INFRAGOLD™) was used for background calibration.

Laser irradiation experiments were performed with an 193 nm ArF UV excimer laser at the Physikalisches Institut in Münster. The laser beam hit the sample surface after passing through a MgF₂ window installed on top of the dome. The material was irradiated with an energy density of 2 J/cm² on average for each 10 ns pulse with 3 shots per point, with a sample spot of ≈ 0.2 mm² in focus. To simulate a real micrometeorite impact, the laser was moved over the sample surface in such a way that an area of un-irradiated material was left free between the irradiated areas, so that ejected material could be also be examined later.

Results:

Mid-IR spectra generated with the Praying Mantis™ chamber of all samples (raw samples in black; irradiated samples in red) are presented in Fig. 1. Mid-IR spectra of the single minerals are presented in Fig. 2.

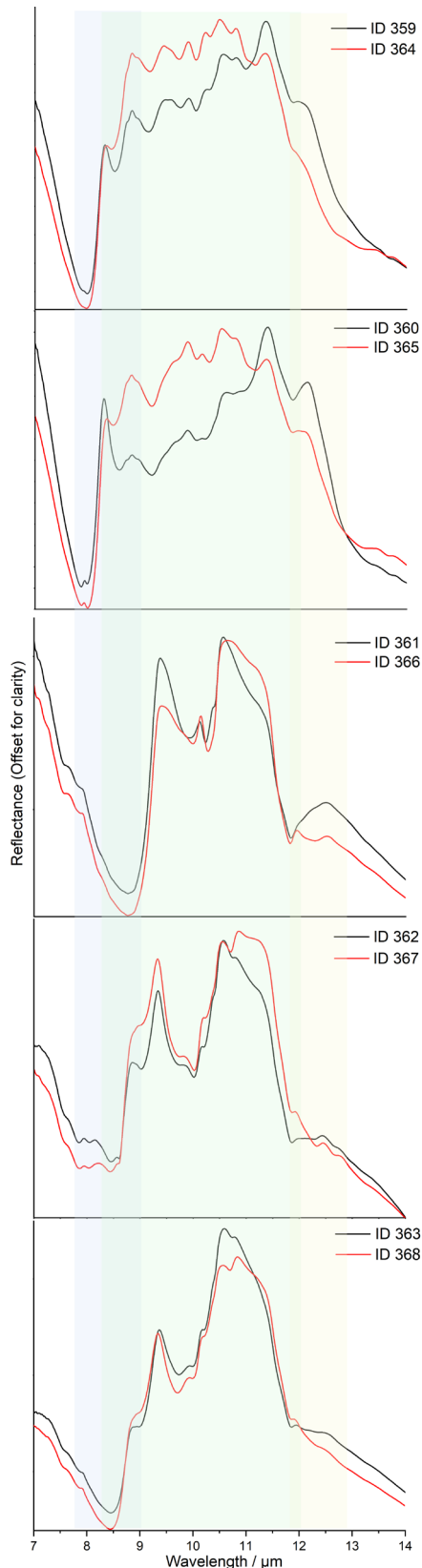


Fig. 1: Mid-IR spectra of the studied mineral mixtures in the MERTIS range. Regions of diagnostic spectral features are highlighted in blue (CF), green (RBs), and yellow (TF). Unirradiated spectra are shown in black, whereas the irradiated spectra are given in red.

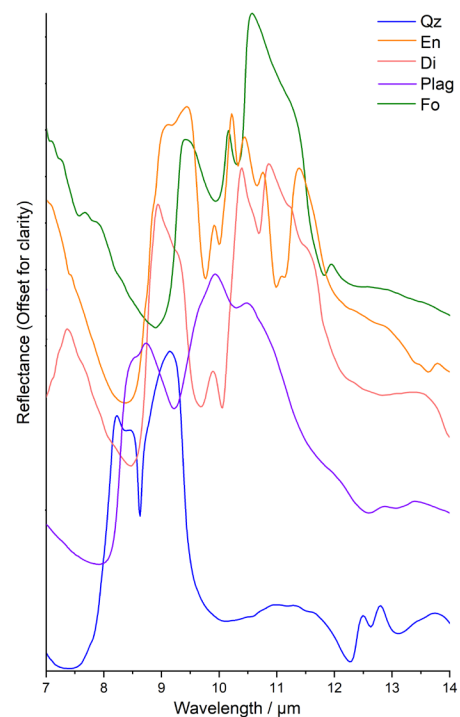


Fig. 2: Mid-IR spectra of the studied minerals in the MERTIS range.

From Figure 1 it can be seen that the resulting spectra are mixed spectra of the starting materials (Fig. 2), especially in the region of the Reststrahlen bands (RBs). At first glance, the location of the Christiansen feature (CF) can be considered characteristic of the main mineral in the mixtures. However, it seems to be very sensitive to other components of the mixture, even if the amount is very small. This is especially visible in samples with the IDs 359/365 and 362/367. Both the RB of diopside as well as the CF of quartz appear to have a large influence on the overall CF. The Transparency feature (TF), which is always clearly visible in the unirradiated samples due to the small grain size (triggered by pellet pressing), disappears in the irradiated samples (Fig. 1). This means that the surface has become much coarser after irradiation, which is due to the agglomeration of the small grains and possibly the formation of glass by the irradiation. Especially the Plag- and Ol-rich mixtures lose their mineral diagnostic Reststrahlen bands in advantage of pyroxene and/or glass [5,6]. In particular the RBs of the IDs 364 and 365 are dominated by pyroxene after irradiation, whereas ID 366 and 367 shows a peak broadening. Thus, considering SW, not only the laboratory spectra of individual minerals should be used for comparison when interpreting MERTIS spectra.

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References: [1] Coradini et al. (2007) *Space Sci. Rev.* 1-4, 529-559. [2] Benkhoff J. et al. (2022) *Space Sci. Rev.* accept. [3] Hiesinger H. et al. (2020) *Space Sci. Rev.* 216:110. [4] Namur & Charlier (2017) *Nature Geosci.* 10, 9 – 13. [5] Moroz et al. (2014) *Icarus*, 235, 187 – 206. [6] Weber et al. (2021) *EPSL* 569, 117072.