SIMULATING SPACE WEATHERING ON MERCURY: EXCIMER LASER EXPERIMENTS ON MINERAL MIXTURES. I. Weber[1], A. Morlok[1], M. Heeger[2], T. Adolphs[2], M. P. Reitze[1], H. Hiesinger[1], K. E. Bauch[1], A. Stojic[1], H. F. Arlinghaus[2], J. Helbert[3], [1]Institut für Planetologie (IfP), Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (sonderm@uni-muenster.de); [2]Physikalisches Institut, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany; [3]DLR, Institut für Planetenforschung, Rutherfordstr. 2, 12489 Berlin, Germany.

Introduction:

The recently launched joint ESA/JAXA mission BepiColombo to Mercury will allow to determine the mineralogical composition of the planetary surface of Mercury. On-board is the mid-infrared spectrometer (MERTIS-Mercury Radiometer and Thermal Infrared Spectrometer), which will measure the spectral features of the hermean surface in the 7-14 µm range, with a pixel scale of about 500 meters [1,2].

The IRIS (Infrared and Raman for Interplanetary Spectroscopy) laboratory of the Institut für Planetologie in Münster provides spectral data for the continuous compilation of a database that will be used for the correct interpretation of results obtained by MERTIS once it reaches the orbit of Mercury.

Due to the absence of an atmosphere and due to its close distance to the Sun, the surface of Mercury experienced impact cratering at different scales. Therefore, the thin exosphere and the weak magnetic field allow solar wind particles and impactors with various size to reach its surface and alter its mineralogical composition in a significant way over long periods of time. Altogether those processes are referred to as space weathering (SW) [3,4].

Various authors simulated these SW processes with different experimental set-ups [5,6]. However, so far most studies of analog materials (except for meteorite studies) are based on pure single minerals. In our study, we altered terrestrial analog mineral mixtures by pulsed-laser irradiation in order to investigate the effect of SW processes caused by macro to micro impactors. Furthermore, in order to be as close as possible to real conditions, we did not press the material into target pellets.

To study the effects of SW on infrared (IR) spectroscopy, IR spectra were taken before and immediately after irradiation in the MERTIS-relevant mid-infrared range. Contamination is avoided by keeping the mixtures in vacuum for the entire time. After irradiation, changes at nanometer scale are then examined with transmission electron microscopy (TEM).

Samples and Techniques:

Samples: Olivine (Ol=Fo_{91}) from Dreiser Weiher, Germany, and pyroxene (Px=En_{87}) from Bamble, Norway, were analyzed using an electron microprobe analyzer. For subsequent IR measurements the crystals were ground in an agate mortar and the grain size fraction from 63 µm to 125 µm was used for laser irradiation experiments. As a starting material, mixtures of olivine and pyroxene with 70/30 and 30/70 (both in weight %) were prepared.

Techniques: A variety of analytical techniques have been employed:

- Light microscopy: We used a polarized light microscope to determine the purity of the samples (Fig. 1).

- Electron microscopy: To further characterize the samples, we made detailed quantitative analyses of the samples 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.

- IR spectroscopy - FTIR on bulk powders:

FTIR analyses were performed with a Vertex 70v spectrometer at the IRIS laboratory in Münster. First analyses of single minerals were made at 20°(i) and 30°(e) with an A513 variable mirror reflectance stage (Fig. 2). The mixed powdered fractions were placed in an aluminum cup (Fig. 3 insert, diameter 4.5 mm, depth 3 mm) and 512 scans were accumulated for a high signal-to-noise ratio of the analyses of each sample. Before each measurement, a commercial diffuse gold standard (INFRAGOLD^{TM}) was used for background calibration. The sample in the aluminum cup was kept in vacuum within a Reaction Chamber (Fig. 3) covered with a custom-made dome (Fig. 4).

- Irradiation experiments:

The laser experiments were done at the Physikalisches Institut in Münster with an 193 nm ArF UV excimer laser. Before the laser beam hit the sample surface it passes a MgF_2 window installed on top of the dome (Fig. 4). Following (or equal to) experiments done by [6] on single minerals, we start with an energy density of 1 J/cm^2 for each 10 ns pulse. The laser was manually moved across the sample surface in discrete steps. The sample spot in focus was ~ 0.2 mm^2. Furthermore, we irradiated nearly the entire sample surface with a defocused laser beam. In this case, the laser will reach an energy density of ~ 0.01 J/cm^2. This procedure has the advantage that IR studies can be obtained from the entire irradiated area.

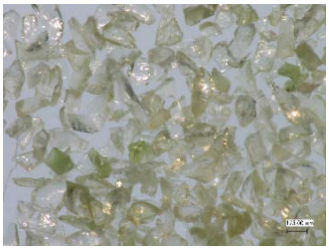

Fig. 1: Light microscope image of the Dreiser Weiher olivine (grain size fraction: 63 – 125 µm).

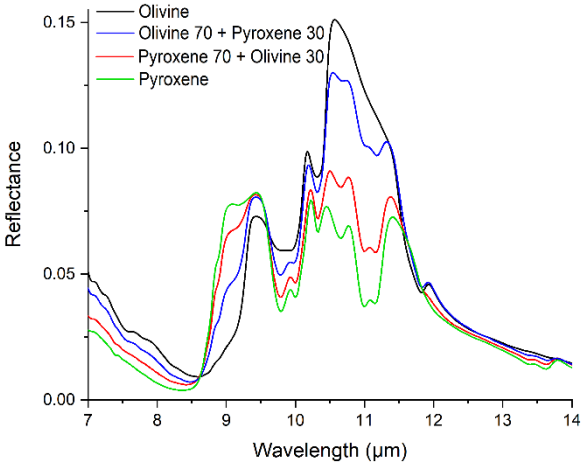

Fig. 2: IR reflectance spectra of olivine, pyroxene, and mixtures of both silicates with the ratio 70/30 and 30/70 in the MERTIS relevant wavelength region of 7 – 14 µm.

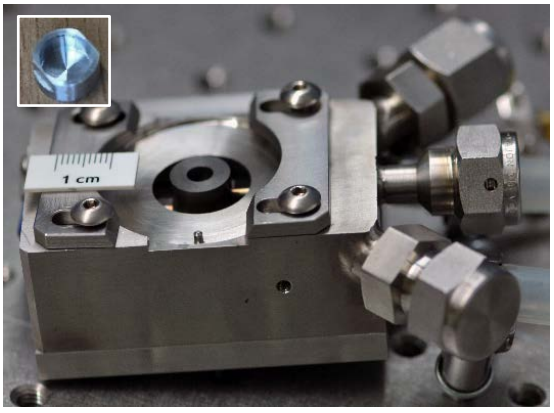

Fig. 3: Praying Mantis™ HighTemperature Reaction Chamber. Insert top left: Aluminum cup for mixed powdered fractions.

Fig. 4: Top view of the custom-built dome for laser experiments. The laser is shot through a MgF_2 window perpendicular to the sample.

-TEM: To investigate the nanostructure of the irradiated sample, we first fixed the powder with a known resin glue. Afterwards, regions of interest were cut out in thin section via ultramicrotomy. For TEM analyses we used a Titan Themis G3 300 TEM operating with 300 keV equipped with a Z contrast imaging HAADF detector.

First Results:

Images taken with a light microscope show the overall homogeneity of the single silicates used for laser experiments. An example is given in Figure 1, which shows the olivine of Dreiser Weiher in the particle size fraction of 63 – 125 µm.

IR spectra made at 20°(i) and 30°(e) with an A513 variable mirror reflectance stage of olivine, pyroxene, as well as of mixtures of olivine and pyroxene with 70/30 and 30/70 (in weight %, grain size fractions: 63 – 125 µm) are presented in Figure 2.

Pure olivine and pyroxene show typical Christiansen Feature (CF) and Reststrahlen bands (RB) for these silicates [7, Fig. 2]. The Ol70/Px30 mixture shows a significant blue shift of the CF. In addition, a new RB shoulder at 9µm and a peak split of the original olivine RB at 10.6 µm is visible. The RB shoulder at 11.3 µm turns out as a separate RB feature.

The CF of the Px70/Ol30 mixture is shifted to higher wavelength similar to the former pyroxene RB at 10.4 µm with a red shift to 10.5 µm and a significantly higher reflectance.

It is remarkable that the olivine rich mixture exhibits rather more of the olivine's reflectance in contrast to the pyroxene rich mixture. This illustrates the difficulties in the deconvolution of mineral mixtures.

Results of IR investigations in vacuum within a Reaction Chamber on the same mineral mixtures before and after laser irradiation will be shown at the meeting.

The comparison of these measurements with data of a deconvolution program for silicates of the same composition are presented by [8] in this issue of the meeting.

References:

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Additional Information: This work is supported by DLR grant 50 QW 1302/1701 in the framework of the BepiColombo mission.