Simulating Mercury –Setup of a New High-Temperature High-Vacuum Chamber for Infrared Measurements.

M. P. Reitze[1], A. Morlok[1], H. Hiesinger[1], I. Weber[1], and A. Stojic[1] [1]Westfälische Wilhelms-Universität Münster, Institut für Planetologie, Wilhelm-Klemm-Str. 10, 48149 Münster, maximilian.p-reitze@uni-muenster.de

Introduction: The BepiColombo spacecraft is scheduled to launch in October 2018. The goal of the MERTIS (Mercury Radiometer and Thermal Infrared Spectrometer) instrument is to explore the surface composition of Mercury, to identify and map rock-forming minerals on the surface, and to study the thermal properties and temperatures of the surface [1]. Knowing the surface mineralogy of Mercury will lead to a better understanding of Mercury, its evolution, and history. Such information will improve our understanding of the formation of the Solar System. MERTIS will measure the surface mineralogy in the wavelength region from 7 µm to 14 µm [1] and at a surface resolution of better than 400 m [1]. Simulations of the surface temperature near the equator of Mercury show temperatures at the dayside of ~700 K down to ~100 K at the night side [2]. Thus, in preparation of the experiment, it is necessary to study and understand the behavior of mid-infrared spectra of minerals and rocks at high temperatures and low pressures. Second, it is necessary to understand the process of spectral mixing, because all spectra returned from MERTIS will be spectra of mixed compounds.

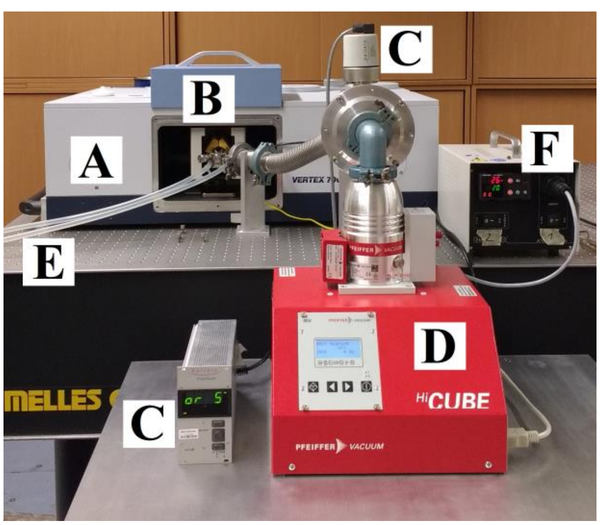

Fig. 1: The new setup in the IRIS lab: **A** Spectrometer with detector; **B** Praying Mantis with sample chamber; **C** Vacuum gauge head and corresponding controller; **D** Vacuum pump; **E** Flexible tubes for water cooling system, which cools the housing of the sample chamber; **F** Heat controller

Methods: In the IRIS (Infrared & Raman for Interplanetary Spectroscopy) laboratory, we use a Bruker VERTEX 70v equipped with a Praying Mantis diffuse reflection chamber and a Harrick High-Temperature Reaction Chamber to measure the reflectance of Mercury analog samples.

The spectrometer uses a liquid nitrogen cooled MCT-detector, which measures in the wavelength range from 2 - 25 µm. For evacuating the sample chamber, we use a Pfeiffer High Cube turbo pump.

Temperatures within the sample chamber range from room temperature up to 723 K. The pressures are on the order of 10^{-5} hPa.

The olivine samples used in our experiments were crushed and sieved to grain size fractions from 0 - 25 µm, 25 - 63 µm, 63 - 125 µm, 125 - 250 µm, and greater than 250 µm.

For microprobe analyses with a JEOL JXA-8530F Hyperprobe electron probe micro analyzer (EPMA) at the Institut für Mineralogie at the Westfälische Wilhelms-Universität Münster, grains from the 125 - 250 µm fraction were imbedded into epoxy resin. These epoxy imbedded samples were grinded and then analyzed with backscattered electron (BSE) imaging and with the wavelength dispersive spectrometers of the microprobe to determine the chemical composition.

Samples: Basaltic high-Mg volcanism on Mercury is well documented through the MESSENGER mission and wide-spread especially at north latitudes [3]. To gain laboratory spectra comparable to the expected MERTIS spectra, we choose mineral samples which match both criteria mentioned above, i.e., the minerals should appear in basalts or komatiites and should have a low Fe-content. In a second step we will include measurements of a mix of minerals to simulate rock or regolith spectra, which we expect of Mercury's surface.

Results: Figure 2 shows two reflectance spectra of the same olivine (Fo 90.8) sample at room temperature but under different pressures. The blue line is at ambient pressure and the red line is at $5.6 \cdot 10^{-3}$ Pa (±30 %). The Restrahlen bands are indicative for forsterite. The measured Christiansen Feature (CF) is shifted to shorter wavelength compared to typical values of the CF of pure olivine. This effect could be explained by the fact that the natural olivine sample contains chromite. Although the chromite causes no features in the observed wavelength region, the wavelength of the CF depends on the complex index of refraction [4]. Because the mixture of the two components will have a complex index of refraction, which is affected by the indices of refraction of both components, this could lead to the observed shift of the CF.

Figure 3 shows the wavelength range in which the CF of the two reflectance spectra of the olivine-chromite sample are located. The CF in both spectra is marked with a black line. The feature shifts with decreasing pressure to shorter wavelengths, i.e., from 8.49 µm (ambient pressure) to 8.46 µm ($5.6 \cdot 10^{-3}$ Pa.).

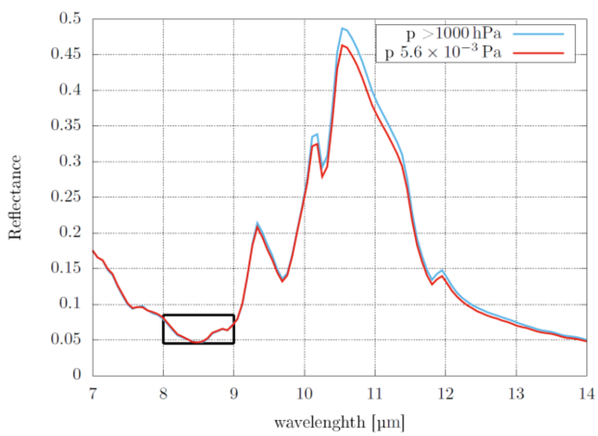

Fig. 2: Full olivine (63 µm - 125 µm fraction) reflectance spectra at room temperature and ambient pressure (blue line) and $5.6 \cdot 10^{-3}$ Pa (red line). Box shows the CF displayed in Fig. 3.

Such a shift of the CF was also observed for a granite powder sample in emissivity measurements and it was explained with an increased spectral contrast [5]. The plagioclase solid solution studied by [6] also shows a pressure-depended shift, which is comparable to our findings for the olivine-chromite sample.

In addition to the shift of the CF, we observed a slight decreasing spectral contrast at the two strongest Reststrahlen bands from ambient pressure to $5.6 \cdot 10^{-3}$ Pa.

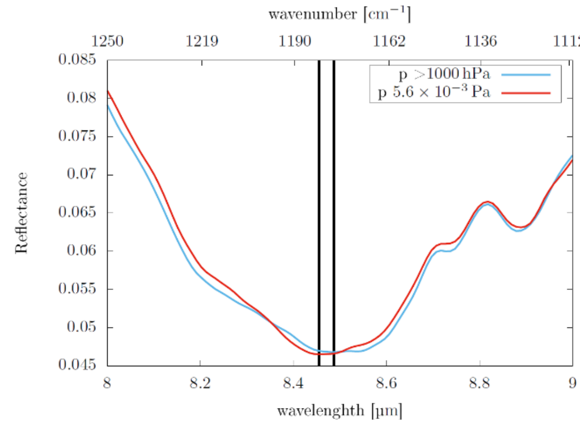

Fig. 3: Pressure-depended shift of the CF (marked with two black lines) of an olivine sample with grain size of 63 – 125 µm at room temperature.

Conclusion/Outlook: With the new setup, we are able to measure samples at high vacuum and at temperatures from room temperature up to 723 K. The setup was tested with an olivine sample, which shows a pressure-depended shift of the CF. A pressure-depended shift of the CF of 0.03 µm was measured. Pressure-depended shifts were also observed by [5] and [6]. In the future we will measure several Mercury analog minerals and mineral mixtures in order to deconvolute spectra, which will be returned from Mercury by MERTIS.

References: [1] Hiesinger, H., J. Helbert and MERTIS co-I Team (2010) *Planet. Space. Sci, 58*, 144-165. [2] Bauch, K et al. (2016) *EGU 18*, Abstract #16736-4. [3] Head, J. W. et al. (2011) *Science, 333*, 1853-1856. [4] Clark, R. N. (1999) *Remote Sensing for the Earth Sciences: manual of Remote Sensing, volume 3, chapter Spectroscopy of Rocks and Minerals, and Principles of Spectroscopy 3rd edition*, Wiley [5] Salisbury,J. W. (1993) *Topics in Remote Sensing 4. Remote Geochemical Analysis: Elemental and Mineralogical Composition*, Cambridge University Press, 79-98 [6] Donaldson-Hanna, K. L. et al. (2012) *J. Geophys. Res.*, 117, E11004

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