THE SURFACE OF VENUS AFTER VIRTIS ON VENUS EXPRESS: LABORATORY ANALOGS AND THE VENUS EMISSIVITY MAPPER.

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Introduction: The permanent cloud cover of Venus prohibits observation of the surface with traditional imaging techniques over most of the visible spectral range. However, Venus' CO_2 atmosphere is transparent exclusively in small spectral windows near 1 µm. These windows have recently been successfully used by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) on the European Space Agency Venus-Express spacecraft, allowing the study of surface composition [1,2]. Analyses of those spectra data are complicated by the fact that Venus has an average surface temperature of 730K. Mineral crystal structures and their resultant spectral signatures are notably affected by temperature, therefore any interpretations based on *room temperature* laboratory spectra database can be misleading [3]. In order to simulate the most likely behaviour of minerals on the hot surface of Venus, we have undertaken a set of measurements at the Planetary Emissivity Laboratory (PEL, Institute of Planetary Research of the German Aerospace Center, Berlin). The unique facilities available at PEL allow emission measurements under purge or vacuum conditions, covering the 1 to 100 µm wavelength range and sample temperatures up to 1000K [3,4]. Data from this facility are providing a baseline for considering a new instrument designs for future Venus missions, as the Venus Emissivity Mapper (VEM).

The Planetary Emissivity Laboratory (PEL): The laboratory is located in an temperature-controlled room at the Institute for Planetary Research in Berlin. PEL currently operates two Bruker Fourier transform infrared (FTIR) spectrometers both located on an optical table and equipped with external chambers for emissivity measurements. A purge gas generator (CMC PG 28L) provides purged dry air for the chambers and drives the air-bearings for the mirrors of both spectrometers (Figure 1).

The main instrument used for this study is a Bruker Vertex 80V. It can be fully evacuated. The main feature of the PEL is a high-temperature chamber attached to the Vertex 80V that allows heating of samples to temperatures up to 1000K under vacuum conditions (medium vacuum - 10-100pa). Samples are placed in steel cups equipped with type K thermopiles as temperature sensors. A copper induction coil installed in the chamber and connected to a Linntherm 1.5kW induction system allows contactless heating of the ferromagnetic sample cups by induction. Spectral coverage is achieved with a combination of a liquid nitrogen-cooled MCT detector and KBr beamsplitter for the spectral range up to 16 µm and a DTGS detector with a multilayer beamsplitter for the remaining spectral range. In addition, a InSb/MCT sandwich detector is used. This detector provides significantly increased sensitivity in the spectral range from 1-5 µm.

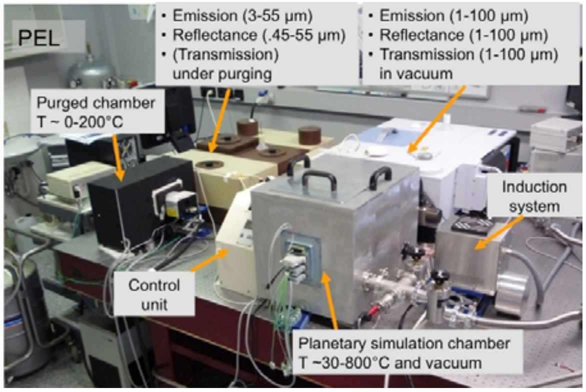

Figure 1. Overview of the setup at the Planetary Emissivity Laboratory (PEL).

Analogue materials suitable for Venus: Venera and VEGA geochemical data suggest that their landing sites had mafic volcanic compositions, with unexpectedly high fractions of K-rich lavas that complicate their petrologic interpretation [5,6]. Interestingly, salts as carbonates and sulfates have been calculated to be abundant as solids [7,8] on the surface of Venus, and have been furthermore been suggested as components in magmas that may enable formation of features resulting from low-temperature fluid lavas [9] on the surface of the planet.

To corroborate this interpretation using appropriate high-temperature reference spectra, we chose to begin our work with single mineral phases, avoiding any possible band superposition. The diversity of the considered igneous rocks induced us to prepare samples of several different silicates and salts suggested by past workers to be present on Venus. Thus we first collected in quantities spectra of pyroxenes, felspathoids, alkali-feldspars, carbonates, sulfates and sand salinifer.

Laboratory experiments: Laboratory experiments: We have started a series of laboratory measurements of several different Venus surface-candidate minerals (Table 1). The potential single-phase samples havce been manually crushed and sieved to a grain sizes <250 µm selected for measurement. The reduced minerals are placed into steel cups and then into the chamber (Figure 2).

Table 1. Examples of selected minerals

Sample	Classification and Nominal Composition
amazonite	Tectosilicate group, K(Na,Ba) Feldspar subgroup, variety of microcline species $KAlSi_3O_8$
augite	Inosilicates, single-width unbranched chains group,(*C*2/c) Pyroxenes subgroup $(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$
barite	Hydrated Acid and Sulfates group, barite subgroup $BaSO_4$
calcite	Anhydrous carbonate group, Calcite subgroup $CaCO_3$
gypsum	Hydrated Acid and Sulfates group $CaSo_4{\cdot}2H_2O$
kyanite	Nesosilicate group, Kyanite subgroup $Al_2(SiO_5)$
sodalite	Tectosilicate, Feldspathoids Sodalite subgroup $Na_8(Al_6Si_6O_{24})Cl_2$

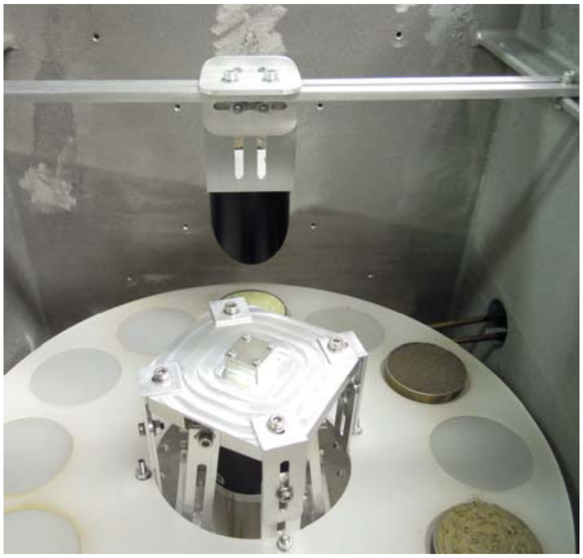

Figure 2. Within the vacuum chamber, the cups are placed on a carousel.

Emissivity will be measured at least at two different temperatures, reaching a maximum of 730K within the range suggested for the surface of Venus.

VEM outlook: The Venus Emissivity Mapper is an instrument conceived for observing the surface of Venus in those windows of the near-IR spectrum that provide the minimal absorption of the atmosphere. It builds on experience gained by VIRTIS on Venus Express, to characterize Venus's surface geology and monitor volcanic activity. It implies a multi-spectral, push-frame imager with no moving parts that maps the surface in all near-IR atmospheric windows. The combined filters have spectral characteristics optimized for the wavelengths and widths of those windows. They also observe bands necessary for correcting atmospheric effects, which provide valuable scientific data on cloud thickness, cloud opacity variations, and H_2O abundance variations in the lowest 15 km of the atmosphere. The achievable ground resolution is 50–100 km, which will be oversampled at a spatial resolution of 10 km. Based on current VenusExpress VIRTIS interpretation, thermal emissivity has to be measured with a relative accuracy of 0.5% at 60km spatial resolution in the five surface windows to constrain surface mineralogy and chemistry [1].

Conclusions: Our ongoing laboratory work shows that the high surface temperature of Venus, as other terrestrial planets, can affect the spectral characteristics of the surface materials. This has to be taken into account when interpreting spacecraft data, but even more so when designing new instrumentation. Build on this acquired knowledge and in combination with a potential new high-resolution radar mapper, VEM will provide new insights into the composition and evolution of the surface Venus. All this will help us to understand better why Venus evolved so differently from Earth, and will provide valuable input for any landing site selections for future Venus lander missions.

References: [1] Müller, N. et al. (2008), *JGR Planets*, *113*, 1-21. [2] Helbert, J. et al. (2008), *GRL*, *35*, 1-5. [3] Helbert, J. et al. (2013), *EPSL*, *371-372*, 252-257. [4] Helbert, J. and Maturilli, A. (2009), *EPSL*, *285*, 347-354. [5] Fegley, B., Jr. et al. (1992) *Proc. Lunar Planet. Sci.*, *22*, 3-19. [6] Kargel, J.S. et al. (1993), *Icarus*, *103*, 253-275. [7] Surkov, Y.A. et al. (1983), *JGR*, *88*, 481-493. [8] Surkov, Y.A. et al. (1986), *JGR*, *91*, 215-218. [9] Kargel, J.S. et al. (1994), *Icarus*, *112*, 219-252.