Igneous Rock Emissivity Measurements at High Temperatures in Support of Thermal Modeling and Infrared Imaging of Venus' Canali and Lava Flows. N. T. Mueller[1], A. Maturilli[1], J. Helbert[1], L. Elkins-Tanton[2]. [1]German Aerospace Center (DLR), Institute of Planetary Research, Rutherfordstr. 2, 12489 Berlin, Germany (nils.mueller@dlr.de). [2]DTM, Carnegie Institution, 5241 Broad Branch Rd, Washington DC 20015.

Introduction: The 100-1000s km long Venusian canali [e.g. 1] and lava flows [e.g. 2] pose a puzzle because basalt lavas could cover such distances only under extreme environmental or eruptive conditions. Basalt lava commonly erupts at temperatures close to its liquidus (>1400 K), and cools and solidifies quickly when exposed to the current Venus surface environment (625-750 K) [e.g. 3]. In case of canali the morphology even suggests mechanical erosion and sedimentary deposition, features that are difficult to reconcile with basaltic lava [4,5].

Carbonatite lava has been proposed as an alternative [1,3,4]. The natrocarbonatite lava of the volcano Oldoinyo Lengai in Tanzania has a solidification temperature close to current Venus surface temperature [6]. The climate of Venus may have been hundreds of K hotter in the past [7]. Therefore the natrocarbonatites and other carbonatites with low solidus temperatures and little silicate could have formed the canali by mechanical erosion, analogous to terrestrial rivers [4].

Any stable deposits of these lava 'rivers' might be detectable using near infrared emissivity observations through atmospheric windows at 1.02, 1.10 and 1.18 µm [e.g. 8]. The observations of the instrument VIRTIS on the ESA mission Venus Express provide an indication of emissivity variations at 1.02 µm for most of the southern hemisphere [9].

If carbonatite lavas are common on Venus they may also form sheet flows when solidification temperatures are above current environmental temperatures [6]. The different thermophysical and rheological properties of carbonatite lavas could be an explanation for lava flows extending for several hundreds of km. Such chemically unusual lava flows might be detectable in VIRTIS or other infrared imaging data.

Surface emissivity is not only relevant for the interpretation of near infrared images, but also for thermal modeling of the lava flows. Flows with relatively low emissivity lose less heat by radiation and can reach greater distances before solidification [e.g. 3]. Emissivity can change with temperature [e.g. 10, 11] and possibly with phase changes, therefore we have started acquiring emissivity spectra of carbonatites and other relevant samples over a range of temperatures including and surpassing the melting temperature.

The measurements cover the wavelength range from 1 to 16 micron, thus include the atmospheric windows observed by VIRTIS as well as the range in which lava flows lose most energy by thermal emission radiation.

Laboratory setup: The measurements have been carried out at the Planetary Emissivity Laboratory (PEL) at DLR in Berlin. The facility core is the emissivity spectrometer laboratory, with a supporting spectrometer laboratory for reflectance and transmission measurements, sample preparation equipment, and an extensive collection of rocks and minerals.

For high temperature emissivity measurements, the Bruker 80V FTIR spectrometer coupled to a planetary simulation chamber is used. Both systems can be individually evacuated to 10^{-4} bar. An induction heating system heats the samples in a stainless steel cup to temperatures of up to 1000K, while the surroundings remain cold. A computer-controlled carousel can be rotated via a stepper motor, allowing to measure up to 11 samples without breaking the vacuum.

For these measurements we used a nitrogen cooled sandwich detector, which combines a HgCdTe and an InSb detector with the same field of view. The InSb detector was used for the 1-5 µm range due to its higher sensitivity; however we did not test it before at comparably high sample temperatures. We measure every cup containing the heated sample, with a temperature sensor embedded in the sample surface, reading the temperature of the emitting skin. Placing the sample and the calibration blackbody on the sample carousel permits measuring the two sources with exactly the same observation geometry and allows us the determination of an absolute value of sample emissivity. As calibration blackbody, we use a blast furnace slag with high emissivity independent from temperature variations and exhibiting no change due to thermal cycling [12]. Each sample cup, after preparation, was placed on the carousel, over the induction coil, and a T sensor embedded in the upper layer. Successively, the emissivity chamber was evacuated and then induction switched on at moderate intensity. For each step, 1 hour waiting time allowed to reach a stabile surface temperature. After each measurement, the induction power was brought to the next level and relaxation time was waited before a new measurement could be performed.

Samples: As a first test we have acquired spectra from two samples, an ijolite and a MgO-rich carbonatite. The samples are from the Gula massif in Siberia (siberia.mit.edu). The ijolite has a theoretical liquidus temperature of 850°C calculated by pMELTS [13].

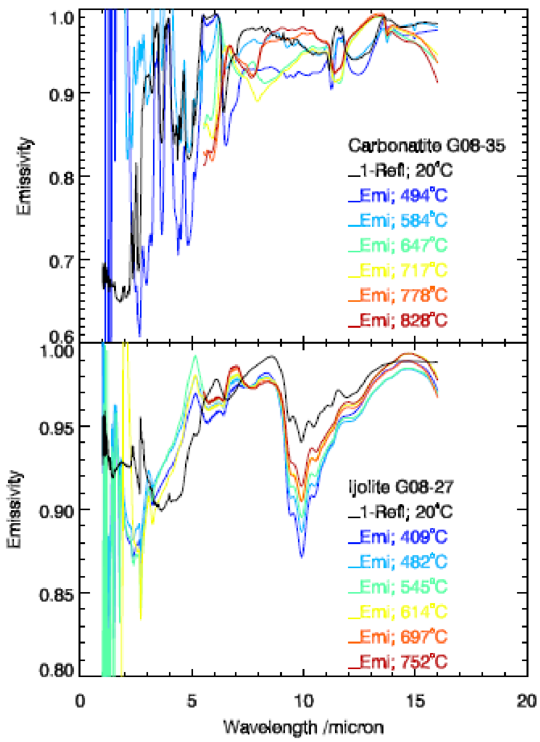

Fig. 2. Emissivity spectra of two samples (grain sizes 63–250µm) at different temperatures. The detector reaches saturation somewhere short of 5 µm. The black plot is one minus reflectivity at room temperature for reference.

The samples were crushed and sieved, and the fraction with grain sizes 63-250 µm selected for measurement.

Results: *Melting temperatures:* The maximum temperatures reached within the sample holding cups were 828°C for the carbonatite sample and 752°C for the ijolite sample, and neither sample showed signs of melting. The carbonatite sample showed signs of degassing, as a part of the sample was ejected from the sample cup in the evacuated measurement chamber.

Emissivity Spectra: Figure 2 shows the emissivity spectra acquired at various temperatures. Unfortunately the readings of the InSb detector (1-5 µm) are unreliable due to the onset of saturation. In future experiments this will be corrected by choosing a smaller aperture.

Nevertheless, the longer wavelengths show clear signs of systematic variation with temperature, generally on the order of 5-10%. In the carbonatite spectra, absorption/emission features near 6 and 11.5 µm recognizable in the reflectance and lower temperature emissivity spectra become features with locally low emissivity at higher temperatures. The opposite is observed at 12-13 µm. In the 5-6 µm range the variation in emissivity with temperature is nearly 20% and thus might have some relevance for the radiative heat loss from lava flows at Venus temperatures. It is difficult to judge the spectra short of 5 µm. The lowest temperature emissivity spectrum shows some resemblance to the reflectance spectrum, and if anything, hints towards lower emissivity at temperatures close to Venus conditions.

Conclusions and outlook: The first results are very encouraging, however the experimental setup needs some improvements to reach higher temperatures, actually melt the samples and to record emissivities down to 1 µm. The next step will see the use of a tungsten cup with a higher magnetic permeability than the stainless steel cup. The tungsten cup should reach and withstand higher temperatures in our induction heating system.

The initial results indicate that emissivity variation with temperature may be significant for thermal modeling of carbonatite flows. As the maximum thermal emission at Venus temperatures (and above) occurs short of 5 µm, knowledge of emissivity and its behavior with temperature in this region might prove critical.

Other candidates for channel forming lavas have melting temperatures in the range reached by the current setup, e.g. natrocarbonatite samples from Oldoinyo Lengai in Tanzania [6]. Observing the emissivity changes during melting might provide some insight whether the use of a constant effective emissivity for all temperatures and even the liquid portion of a lava flow [e.g. 3] is appropriate for thermal modeling.

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