

EMISSIVITY OF POWDERED SILICATES IN TIR SPECTRAL RANGE (7-14 μm) UNDER SIMULATED DAYTIME SURFACE CONDITIONS OF MERCURY AND THEIR DETECTION FROM THE ORBIT.
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Introduction: The mid infrared (MIR) spectral region is especially sensitive to the abundance of Si-O, unlike the visible-near infrared spectral region. Though the geochemical suite on the NASA MESSENGER spacecraft to Mercury revealed compositionally diverse crustal materials [1], the spectrometer suite (MASCS; VIS-IR) could not reveal the silicate mineralogy of crustal materials due to the Fe²⁺-poor nature of the silicate minerals on the surface of Mercury.

On October 20, 2018, ESA/JAXA's BepiColombo mission was successfully launched to Mercury. MERTIS (Mercury Radiometer and Thermal Imaging Spectrometer) onboard BepiColombo will be the first thermal infrared (TIR) hyperspectral imager (7 – 14 μm) and radiometer (7 – 40 μm) to orbit Mercury mapping global spectral emissivity and surface temperature of Mercury at a spatial resolution of ~500 m/pixel and ~2 km/pixel respectively [2]. MERTIS will therefore provide spatially resolved information on mineralogy of various geological terrains including hollows and pyroclastic deposits, rock abundance, grain size, thermal inertia, and surface temperature [3]. Studying the thermal emissivity measurements of silicates at Mercury surface temperatures up to 450°C and under vacuum will help us to create the standard spectral library for MERTIS data analysis.

Sample selection and preparation: Over a decade, the Planetary Spectroscopy Laboratory in the Department of Planetary Laboratories at the Institute for Planetary Research, DLR, Berlin has been undertaking huge efforts in collecting natural silicate endmembers from various sources in preparation to MERTIS data science [4]. These silicates are suggested by ground-based observations of Mercury and indirect mineralogy derived from NASA MESSENGER geochemistry suite [e.g., 1,5] and they include; a) olivine: forsterite, b) pyroxenes: enstatite, diopside, c) plagioclase feldspar: hypersthene, anorthite, labradorite, andesine, oligoclase, orthoclase, and d) nepheline. Here we present the emissivity of these silicates (at grain size of <25 μm) at 7-14 μm as a function of temperature under vacuum conditions.

Facility and Methods: A Bruker Vertex 80V instrument with MCT HgCdTe detector (cooled by liquid nitrogen) and KBr beamsplitter is used at PSL to measure the thermal infrared (TIR) emission spectra of the samples. This spectrometer is attached to an external

chamber where the samples are placed in steel cups which are heated up to Mercury's peak daytime temperatures via induction technique under vacuum (Fig. 1). Each sample is heated from 100° to 500°C (step 100°C) at medium vacuum (0.7 hPa) and then cooled down in vacuum. Radiance from the heated samples is collected by a gold (Au) coated 90° off-axis parabolic mirror and reflected into the spectrometer. It samples the thermal emission spectra of the silicates at wavelength intervals of 7-14 μm at spectral resolution of 4 cm^{-1} (Fig. 1). The spectra are calibrated following the standard PSL calibration procedure. A blackbody target with a known emissivity spectrum is measured at the same geometry and temperature as the samples. Emissivity is derived by dividing the sample signal by the blackbody signal correcting for the emissivity spectrum of the calibration target. Figure 2 shows the resulting emissivity measurements at temperatures of 100°C, 200°C, 300°C, 400°C, and 500° C.

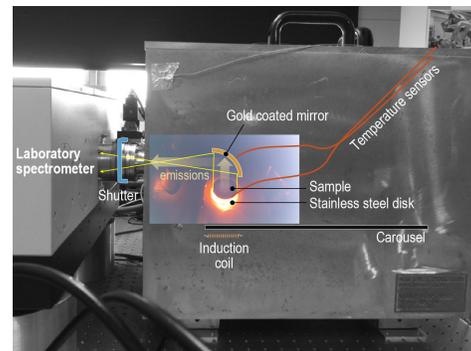


Figure 1. Laboratory setup at PSL for high temperature emissivity measurements.

Results: Christiansen feature (CF) and Reststrahlen bands (RBs) in the TIR spectra are widely used for remote identification and characterization of silicate minerals. CF is an emissivity maximum and has been used as the indicative of silica polymerization where the CF position shifts to shorter wavelengths for highly polymerized silicates [6, 7]. However, some silicates have overlapping CF positions which makes it difficult for unique identification of minerals; e.g., anorthite and enstatite belonging to feldspar and pyroxene group respectively share similar CF positions which makes them difficult to distinguish when only CF is used to identify the surface mineralogy (see Fig. 2). RBs relate to fundamental vibration bonds due to stretching and

bending of Si-O and various cations and therefore RB positions are used to identify the nature of the minerals such as olivines, pyroxenes, and feldspars [e.g., 8, 9, 10].

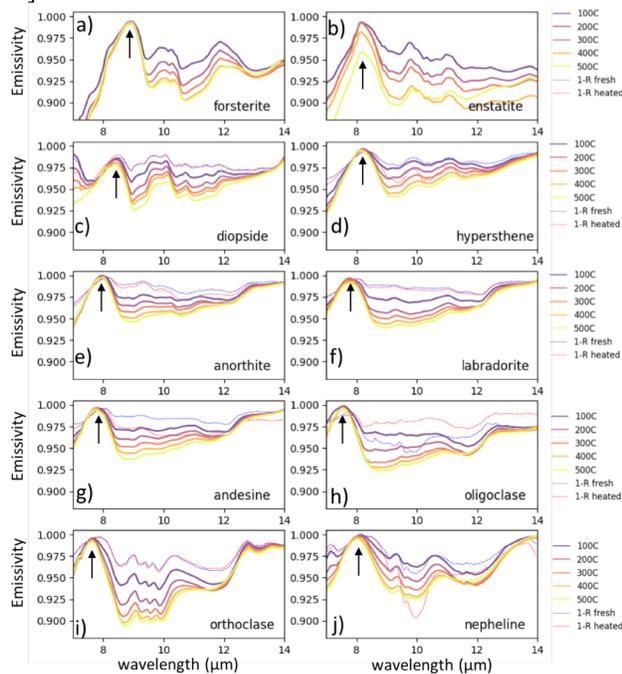


Figure 2. (a-j) Emissivity of silicates as a function of temperature studied. Black arrow indicates the position of CF position for all silicates. 1-R fresh and heated spectra is the inverted reflectance spectra of the fresh and thermally weathered silicates at room temperature under vacuum measured at phase angle of 26° .

In order to enable remote detection of these silicate groups, we introduce CF vs RB1 plot where CF position (emissivity maxima) for all the silicates studied is plotted against RB1 position where first RB minimum longward of CF position occurs for all temperatures as shown in Fig. 3. CF vs RB1 plot (Fig. 3) shows that CF position of plagioclase feldspars (Group A) and forsterite (olivine) is least affected with increase in temperature; however, the RB1 position increases to longer wavelengths with increase in temperature. On the other hand, pyroxene group and nepheline show that with increase in temperature CF position shifts shortwards and RB1 position only slightly shifts longwards. The significant result from the CF vs RB1 plot (Fig. 3) is that the olivine, pyroxenes (and nepheline) (Group B) and plagioclase (Group A) classes of silicates can be unambiguously identified when comparing two spectral parameters instead of one (CF position). This will enable us to do first-hand surface mineral identification of Mercury in MERTIS and ground-based telescope observations of Mercury in the TIR spectral region.

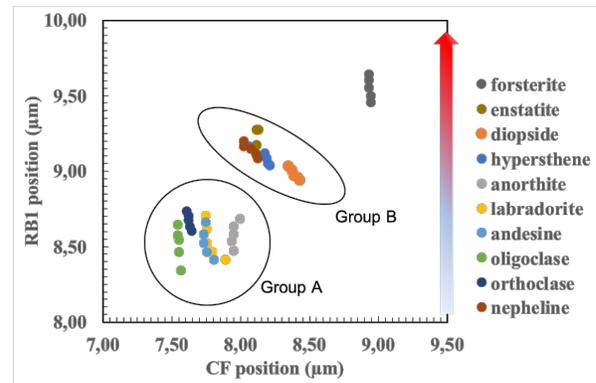


Figure 3. The plot between CF position and RB1 position shows that forsterite (olivine), pyroxenes including nepheline (silica undersaturated group belonging to feldspathoid), and plagioclase feldspars cluster them to discrete classes. RB1 position shifts longwards for all silicates with increase in temperature and is denoted by blue-red color scale indicated the low (100°C) to high (500°C) temperature measurements respectively.

Conclusions: The emissivity measurements in the study will support the MERTIS payload of ESA/JAXA BepiColombo which will study the surface mineralogy at wavelength range of 7-14 μm at spatial resolution of 500 m/pixel. CF vs RB1 plot introduced in this study can be widely used for detection of surface mineralogy of planets studied in the TIR spectral region.

References: [1] Vander Kaaden, K et al. (2017) *Icarus*, 285, 155-168. [2] Hiesinger, H. and J. Helbert (2010) *PSS*, 58(1-2): pp. 144-165. [3] Helbert J. et al. (2013) *SPIE*, 8867, 886705. [4] Helbert J. et al (2007) *Adv. Space. Res.*, 40, 272-279. [5] Namur and Charlier (2017) *Nat. Geosci.*, 10, 9-13. [6] Conel J.E. (1969) *JGR*, 1896-1977, 74, 1614-1634. [7] Logan L.M. et al. (1973) *JGR*, 1896-1977, 78, 4983-5003. [8] Donaldson Hanna K.L. et al. (2012) *JGR Planets*, 117. [9] Hamilton V. (2000) *JGR Planets*, 105, 9701-9716. [10] Lyon R.J.P (1965) *Econ. Geol.* 60, 715-736.