



Spectral analysis of silicate glasses analog of Mercury's geochemical terrains and comparison with MESSENGER and BepiColombo data

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Introduction

Mercury, the closest planet to the Sun, has been studied by two NASA missions: Mariner 10 and MESSENGER (Mercury Surface, Space Environment, Geochemistry, and Ranging). They provided much information about the surface of the planet including the unique surface composition—characterized by a strong depletion in iron for example—and the identification of distinct regions with varying chemical compositions. However, one remaining question about Mercury is the mineralogical composition of its surface. Visible to near-infrared observations from the Mercury Atmospheric and Surface Composition Spectrometer (MASCS) aboard MESSENGER lack absorption features of mafic minerals. One hypothesis for the absence of spectral signatures typically associated with mafic minerals is the low abundance of FeO [1]. Furthermore, Mercury's complex geological history, involving extensive volcanic activity, impact melting, and intense space weathering, likely resulted in the production of substantial amounts of glass at the surface, which may significantly influence the planet's spectral properties [2]. The ESA's BepiColombo mission, launched in 2018, will soon be in its polar orbit around Mercury. Two key instruments will help characterize the surface mineralogy of the planet: MERTIS (Mercury radiometer and thermal infrared spectrometer), a radiometer and thermal infrared spectrometer operating between 7 and 14 μm and SIMBIO-SYS (Spectrometers and Imagers for MPO BepiColombo Integrated Observatory System), a high-resolution camera, a stereo camera and a near infrared hyperspectral imager operating between 0.4 and 2 μm . The aim of this study is to spectrally characterize glassy synthetic analogs with compositions similar to the five main geochemical regions of Mercury. This work is done at the Planetary Spectroscopy Laboratory (PSL) of the German Aerospace Center (DLR), Berlin. The spectral measurements will be compared to MASCS data and used for the interpretation of SIMBIO-SYS and MERTIS data. Thus, it will be possible to identify the effect of volcanic glass and their specific compositions characterized by a range of MgO content and low FeO.

Samples

The samples used in this study have been synthesized at the University of Liège by mixing high purity oxides and melting them in a Platinum crucible at 1500°C for 1 hour. The silicate melts were quenched in water to produce glass beads, similar to the volcanic glass expected on Mercury. The compositions are analogs to five hermean regions [3]: the Low-Mg Northern Volcanic Plains (Low-Mg-NVP), the High-Mg Northern Volcanic Plains (High-Mg NVP), the Smooth Plains, High-Mg Province

and the Intermediate Terrains (ICP-HCT). The geochemical compositions of the samples are given in Table 1. In order to investigate the effect of glass particle size, each sample has been crushed in two different grain sizes: <125 μm and 125-250 μm , thus a total of 10 samples have been measured.

Table 1: Selected chemical compositions of glassy analogues (in wt%) [3].

Region	SiO ₂	Al ₂ O ₃	MgO	CaO	Na ₂ O	Total
Low-Mg NVP	63.36	14.40	10.21	5.78	6.25	100.00
Smooth Plains	59.90	16.03	11.40	7.35	5.32	100.00
High-Mg NVP	60.43	12.31	16.89	6.44	3.92	99.99
ICT HCT	55.76	12.70	21.73	5.70	4.11	100.00
High-Mg Province	55.82	7.05	26.80	7.14	3.19	100.00

Experimental procedure

Firstly, the bidirectional reflectance of the samples has been measured in a range of ultraviolet (UV) to the mid-infrared (MIR) to cover the wavelength domains of MESSENGER's (0.3 to 1.45 μm) and BepiColombo's instruments (0.4 to 2 μm and 7 to 14 μm). Several illumination conditions and viewing geometries have been used to obtain bidirectional reflectance spectra in the same conditions of MASCS and SIMBIO-SYS observations. The reflectance measurements were supplemented with hemispherical reflectance data acquired in the MIR domain. Then, the samples have been heated up at temperatures from 250°C to 450°C to simulate the surface temperature of Mercury, and measure the emissivity every 50°C in the MIR - spectral range of the MERTIS instrument. After heating the samples, reflectance measurements in the UV to MIR were acquired again, to investigate the effect of the heating at Mercury's day-side temperature. All the measurements have been performed under vacuum to simulate Mercury's surface conditions.

Preliminary results

After calibrating and merging the different wavelengths for the bidirectional reflectance, we obtained the spectra shown in Figure 1. A decrease of reflectance is visible when the phase angle increases before and after heating. After heating, the sample ICP-HCT shows an increase of the reflectance in the visible to NIR and a decrease of the hemispherical reflectance in the MIR spectral domain. In the MIR, the sample exhibits a strong Christiansen Feature (CF) - reflectance minimum - at around 8.25 μm . Calibration and processing of the emissivity measurement data are currently in progress.

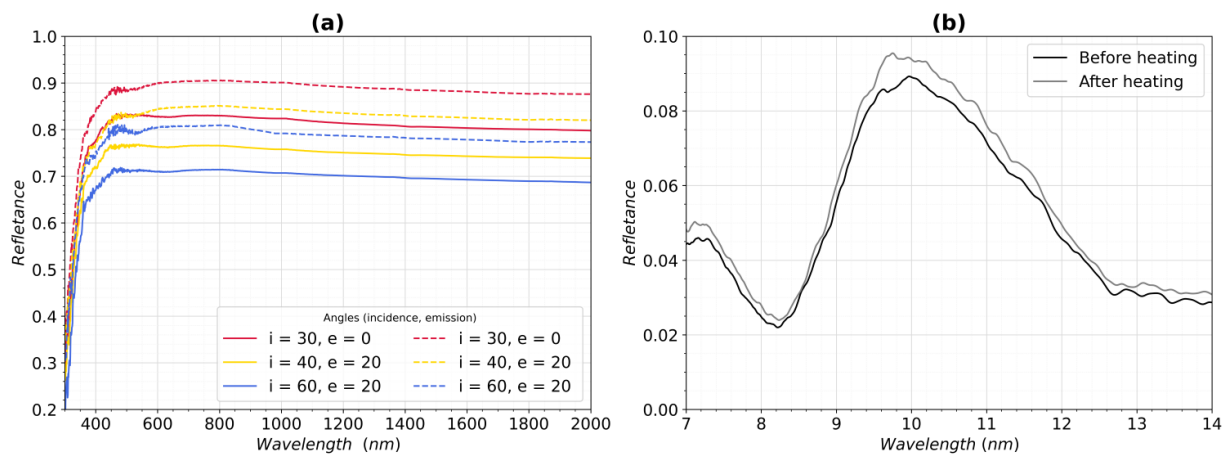


Figure 1 : (a) Bidirectional reflectance of ICP-HCT (125-250 μm) before heating (solid line) and after heating (dashed line) at 3 different geometries in the UV, visible and near-infrared. (b)

Hemispherical reflectance of the same sample before and after heating in the MIR spectral domain.

Conclusion

In this study we measured unique samples simulating volcanic glass of different geochemical regions of Mercury. We obtained the reflectance of the samples before and after heating at Mercury's day-side temperature, through different illumination and viewing geometries, in a wavelength range covering the range of both MESSENGER's and BepiColombo's instruments. Emissivity spectra were also completed while heating the samples to simulate the temperature of Mercury's surface. The measurements will be compared to MASCS/MESSENGER observations and will be used for the interpretation of SIMBIO-SYS and MERTIS observations by the BepiColombo spacecraft.

References

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