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Spectroscopy of sulfides in the simulated environment of Mercury and their detection from the orbit

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1. Introduction

Understanding the distribution and abundance of volatiles in the planet's surface helps to understand the thermal evolution of planet itself. Mercury Surface, Space Environment, Geochemistry, and Ranging (MESSENGER) revealed that Mercury (unlike Moon) has been formed at highly reducing environment with high magnesium and surprisingly sulfur abundances [1]. Sulfide minerals are strongly proposed to be identified in Mercury in regolith. Sulfides in the shallow regolith probably include major FeS and CaS [2]. MESSENGER also suggests the presence of MnS, FeS, CrS, and TiS on the surface [3]. The sulfides are also positively detected in the Dominici crater using MESSENGER Mercury Atmospheric and Surface Composition Spectrometer (MASCS) datasets [4].

In order to detect the mineral diversity of these sulfides, it is essential to study the spectral variations along broad wavelength range in their respective simulated laboratory conditions. The spectral reflectance of sulfides which are thermally processed under Mercury conditions for the wide spectral range (0.2-100 µm) was mostly missing so far. In this study, we report the measured reflectance of a large set of sulfides in 0.2-100 µm at various phase angles. This supports the analysis of measurements from past (MASCS on MESSENGER at phase angle > 80°) and future missions (visible–near-infrared imaging spectrometer (VIHI) of Spectrometer and Imagers for MPO BepiColombo – Integrated Observatory SYStem (SIMBIO-SYS) on BepiColombo at phase angle < 30°) (Fig. 1).

2. Samples

The synthetic powdered sulfides used in the study includes MgS, FeS, CaS, CrS, TiS, NaS, and MnS. They have typically grain size of about ~10 µm. Our measurements are carried out on these synthetic samples of at least 99% purity procured from certified industrial suppliers.

3. PSL

Two Bruker Vertex 80V instruments hosted at Planetary Spectroscopy Laboratory (PSL) at the Institute of Planetary Research (PF) at the German Aerospace Center (DLR), Berlin are used for the emissivity and reflectance measurements. One of these instruments is attached to an external emissivity chamber for direct emissivity measurements at very high temperatures. One of the spectrometers is optimised for spectral measurements in the ultraviolet (UV: 0.2-0.6 µm), visible-infrared (VIS-IR: 0.4-1 µm) range, the second for the mid infrared (MIR: 1-25 µm), and Far infrared (FIR: 14-100 µm). Their corresponding specifications are tabulated in Table 1.

Table 1: Detector and Beamsplitters used for Reflectance measurements

Spectra	Detector	Beam-splitter
UV	GaP	CaF_2
VIS/IR	Si diode	CaF_2
MIR	MCT	KBr Broadband
FIR	DTGS201	Mylar

4. Methods

In the study, we thermally processed the fresh synthetic sulfides by heating them slowly up to 500ºC in vacuum and during the process, we measured the thermal radiance/emissivity of these sulfides in the thermal infrared spectral region (TIR: ~7-14 µm) at the interval of every 100ºC [5, 6]. After this, we collectively measured the spectral reflectance at vacuum of fresh and heated synthetic sulfides at wide spectral range (0.2-100 µm) at four different phase angles, 26º, 40º, 60º, 80º.

5. Results

As reported before [6] the emissivity is measured at thermal range of 7-14 µm at temperatures of 100-500 °C which will support the Mercury Radiometer and Thermal Imaging Spectrometer (MERTIS) payload of BepiColombo mission.

The thermally processed samples are then used to measure the spectral reflectance at wide spectral range of 0.2-100 µm at four phase angle measurements. The spectral profile for Phase 80° (Fig. 1a) will further help us to identification of sulfides in available MESSENGER MASCS datasets. In the UVVIS spectral range (0.3-0.6 µm), both fresh and heated sulfides of CaS, NaS, and MgS show stronger absorption near 0.3 µm at UV wavelength. MnS show distinctive spectral bands at 0.52 µm. All the fresh and heated sulfides both show minor and sharp bands near 0.22 and 0.26 µm. These spectral features did not change with respect to phase angle and temperature.

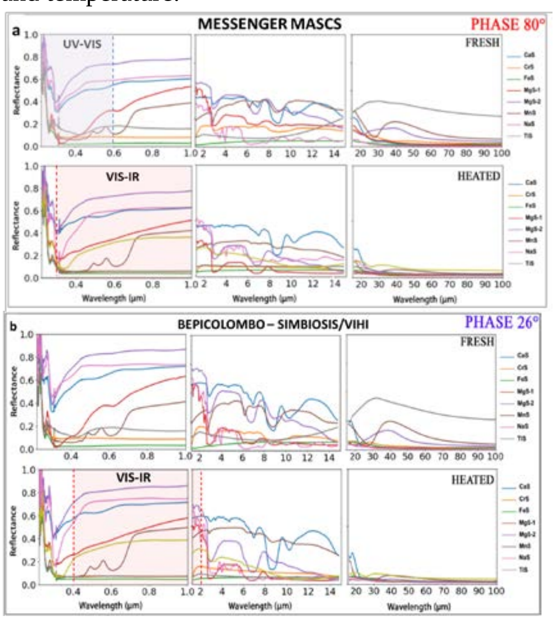

Figure 1: a) The spectral measurements supporting the detection of fresh and heated sulfides in available MESSENGER MASCS; b) The spectral reflectance measurements of fresh and heated sulfides supporting their detection by BepiColombo-Simbio-sys/VIHI.

The thermal weathering of sulfides did not influence their spectral nature in the ultraviolet. In the laboratory reflectance spectra of fresh and heated sulfides in the MASCS VIRS spectral channel (0.3-1.45 µm) spectral channel do not show any distinctive bands except for MnS which shows strong spectral absorption features near 0.52 and 0.6 µm. However most of the sulfides have a steeper slope gradient at 0.3-0.4 µm with minor absorption near 1.1 µm (Fig.1). It is important to understand the spectral behavior of these sulfides as a function of phase angle and temperature effects. Fig. 1(a,b) shows that sulfide spectra are immune to phase angle effects with decrease in spectral range of measurement. UVVIS (0.3-0.6 µm) show no spectral variations in accordance with the change in phase angle, however, the absorption strength and albedo of the spectra is slightly diminished with increased phase angle observation in the spectral range > 1 µm. Also, the reflectance spectra of heated sulfides in FIR spectral range (15-100 µm) show an almost complete loss of the spectral features of their fresh counterparts. In order to understand the behavior of the spectral features of sulfides with respect to temperature, further extended studies are ongoing. The future work will concentrate on prolonged heating of sulfides in Mercury environmental conditions and their step-by-step change in spectral behavior along with its crystallography.

References

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