Reflectance and Emissivity Spectra of Grafite as Darkening Agent for Mercury from the UV to TIR: Comparison with MESSENGER and BepiColombo (MERTIS)

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Introduction

- For long time Mercury was considered a planet very similar to the Moon
- Both small rocky bodies in the inner solar system with thin exospheres and no large scale traces of recent geological activity
- Mercury’s surface reflects much less sunlight than the Moon
- NASA MESSENGER instruments found only small abundances of iron, confirming earlier ground-based spectroscopy observations, and virtually no titanium
- MESSENGER data acquired for the darkest regions suggest the unknown darkening material to be carbon: graphite abundance in the darker regions is predicted to be 1 to 3 wt% higher than the surroundings (Peplowski et al., 2016).
Spectral Measurements

• At Planetary Spectroscopy Laboratory (PSL) of DLR we measured reflectance spectra for several phase angles of graphite, from UV to TIR spectral range (0.2 to 20 µm).

• Samples measured fresh and after successive steps of heating at 400°C in vacuum for 8 hours.

• Reflectance spectra of Komatiite (Mercury surface simulant, after Maturilli et al., 2014) measured alone and mixed with few % of graphite for comparison with data acquired from MDIS + MASCS instruments on MESSENGER.

• Emissivity of same samples in vacuum (< 0.8 mbar) for successive cycles of 4 surface temperatures from 100°C to 400°C in the TIR spectral range (1 to ~18 µm) in preparation for the Mercury Radiometer and Thermal Infrared Spectrometer (MERTIS), onboard the ESA BepiColombo Mercury Planetary Orbiter (MPO), 2018.
MERTIS - Mercury Radiometer and Thermal infrared Imaging Spectrometer

Principle Investigators

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• Monoblock
• 3.1 kg - 10W
• Uncooled microbolometer
• 7-14μm @ 200nm
• Global coverage @ up to 280m
• Integrated μ-radiometer 7-40 μm
• No comparable instrument on the NASA MESSENGER mission
Scientific goals of MERTIS

MERTIS has four main scientific objectives, building on the general science objectives of the Bepi-Colombo mission.

1. Study of Mercury’s surface composition in the TIR
2. Identification of rock-forming minerals
   - Spectral range 7-14μm
   - Spectral resolution better than 200nm
3. Global mapping of the surface mineralogy
   - Global mapping with spatial resolution better than 500m
   - 10% of the planet with better than 500m resolution
4. Study of surface temperature and thermal inertia
   - NETD <1K for typical nightside temperature of 80K
Integrated on the spacecraft in October 2013
Spectral Measurements at PSL
PSL Overview

- Two FTIR spectrometers, both same exact model Bruker Vertex 80V
- Optical units (Detectors, Beamsplitters, Accessories, …) can be shared between the 2 instrument, maximizing the data collection
- With Spectrometer 1 (S1) we measure in vacuum bi-directional reflectance in the UV+VIS+NIR+MIR spectral range; the same we do with Spectrometer 2 (S2) covering the MIR+FIR spectral range
- Same wide spectral range is covered for under purging hemispherical reflectance measurements (by means of 2 integrating spheres)
- Both spectrometers have attached emissivity chambers: S1 has a purged chamber for measurements from 30° to 150° C, S2 has a vacuum chamber for measurements from 50° to at least 600° C
- Emissivity of Hi-T samples (fine powders to chunks and slabs) can be measured from 0.7 to above 100 µm
- Transmittance measurements (filters, optical windows, pellets, …) made in vacuum in the whole 0.2 to above 100 µm spectral range
Spectral Measurements on fresh samples

00001154 Komatiite + 5% grafite

00001027 grafite 0–50 μm
Spectral Measurements on heated samples

00001155 Komatiite + 5% grafite

00001037 grafite 0–50 μm
Emissivity Measurements

T ambient
Emissivity Measurements
Emissivity Measurements

T 200°C
Emissivity Measurements

T 300°C
Emissivity Measurements

T 300°C – no light
Emissivity Measurements

T 400°C
Emissivity Measurements

T 400°C – no light
Emissivity Measurements

komatiite 0–25 μm + 5% grafite

graﬁte 0–25 μm
Stability of komatiite + 5% grafite

See Maturilli et al., 2014, EPSL 398
Stability of komatiite + 5% grafite

500°C

Emissivity

Wavelength (μm)

Day1  Day4
Day2  Day5
Day3  Day6
Carbon possible detection at 600 nm
Carbon possible detection at 600 nm

[Graphs showing reflectance vs. wavelength for graphite heated at 26° phase and Komatiite + graphite heated at 26° phase]
Summary and outlook

- Set of experiments to investigate detectability of grafite on remote sensing observations of Mercury surface
- VIS+NIR+TIR reflectance spectra of grafite are featureless
- TIR emissivity spectra of grafite show a tiny spectral feature around 8 μm, the same feature is absent in komatiite alone but can be found when komatiite is mixed with 5 wt% of grafite
- Komatiite+5%grafite spectra differs significantly from pure Komatiite.
- Further effects of grafite mixed to komatiite can be seen in the CF and surrounding regions
- MERTIS on BepiColombo will have the opportunity to detect grafite features in Mercury surface spectra in the 7-14 μm spectral range
- Grafite detection at 600nm could not be so far experimentally reproduced
- A follow-up experiment to use a finer grafite sample (g.s. < 10 μm)