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Reflectance of Rock Forming Minerals on Hot Bodies

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Abstract

We are investigating the effect of high and low temperatures on the spectral reflectance signatures of rock forming minerals. Observations of hot solid-surfaced bodies present unique challenges. We are measuring in-lab thermospectral effects important for proper interpretation of the spectral reflectance for Mercury, Venus, and near Earth asteroids (NEAs) with periapses of similar solar distance. Our temperature (130-650 K) and wavelength (0.2-5.5 μm) ranges, and mineral suite is intended to expand upon previous studies.

1. Introduction

Mercury has low Fe abundance at the surface [1,2, others]. Resolved UV to IR spectra of Mercury from the MESSENGER mission [1, 2] show no 1 μm absorption bands attributable to Fe^{2+} in silicates, yet show a moderate amount of relative variability in the UV-visible portions of the spectrum, suggesting the presence of some iron in surface (ref).

If a 1-μm band in a silicate rock can be subdued by thermal effects at the Mercurian temperatures of up to 700 K, the Fe abundance in silicates may yet be higher than observed, up to the limit of < 2 Wt% Fe inferred by MESSENGER measurements. Critical for the determination of Mercury surface mineralogy is an understanding of the UV-near infrared reflectance variation of surface materials, and consequently the difference in response of those materials at temperature from standard laboratory (room temperature) conditions and conditions in the middle solar system (e.g. remote observations of the Moon and asteroids).

Venus currently has no active surface-observing missions but when in-situ measurements become possible, it will be crucial to understand how reflectance of surface material may be affected by the planet's extreme surface conditions. Venus surface temperatures are elevation dependent, ranging from ~650-750K, varying little over the diurnal cycle [3]. Reflectance properties of silicate minerals are known to change at Earth mantle-like temperatures and pressures and may posses a purely temperature dependent variation.

Near earth asteroids with perihelions within the orbit of the Earth have surfaces that will warm to > 400K. Understanding the extent of temperature dependence in the reflectance spectra of common rock forming minerals would potentially be enabling to the proper interpretation of spectral reflectance measurements from those bodies.

2. Experimental Parameters

The Vis-SWIR spectra are obtained with a purged FTIR spectrometer over a spectral range of ~ 450 nm to 5200 nm. The UV-Vis spectra are acquired separately with a McPherson vacuum capable spectrometer, using a deuterium source, a 1200 rule grating, MgF_2 windows, and a PMT detector to obtain spectra at ~ 1 nm resolution from ~ 130 nm to 450 nm. Samples are maintained under high vacuum (10^{-7}-10^{-10} torr through the desired temperature and wavelength range (Figure 1). Vacuum is essential to reduce the possibility of oxidation at very high temperatures and for cooling the sample effectively.

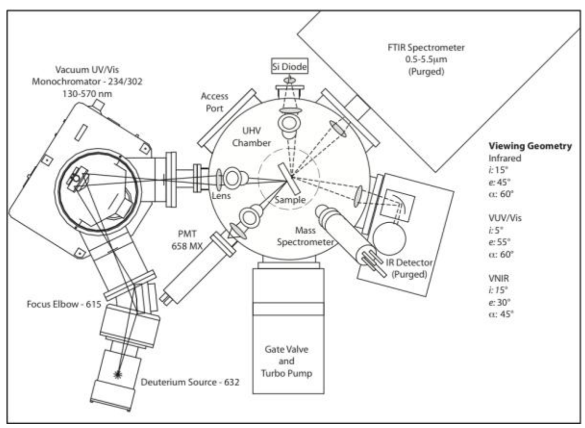

Figure 1: APL Optical Lab Spectrometer setup.

3. Thermospectral Effects

An example of Vis-IR thermospectral effects (wavelength dependent change in reflectance at different temperatures) for an Mg-Olivine is shown in Figure 2. The temperature range of this experiment was 188K to 525 K, and the derived thermospectrum is shown in Figure 3.

In agreement with previous work [4, 5] we note broadening of the 1 micron iron absorption band with temperature. This effect can serve to reduce the apparent signature of low-abundance iron-bearing silicates at high temperatures (such as on the surface of Mercury or Venus).

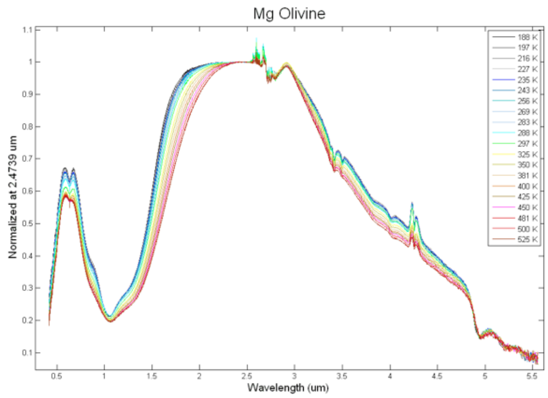

Figure 2. Change in spectral reflectance with temperature, Mg-Olivine, 188-525K.

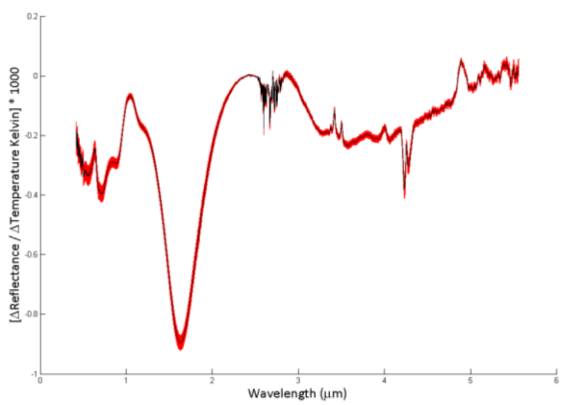

Figure 3. Thermospectrum (Δ Reflectance / Δ Temperature * 1000) for data in Figure. 2.

Our measurements expand the spectral range of previous work into the IR. Observations into the UV-VIS have show far shown very little thermospectral effect. We are refining our calibration ad repeatability of those measurements. In addition, we have acquired hotter observations (to 650K). We have noted at these extremely high temperatures a nonlinear thermospectral effect – a "break" in Δ Reflectance / Δ Temperature beginning above ~500 K (Figure 4). We are exploring whether this is an oxidation effect or some other high temperature effect, such as annealing of crystal flaws [6].

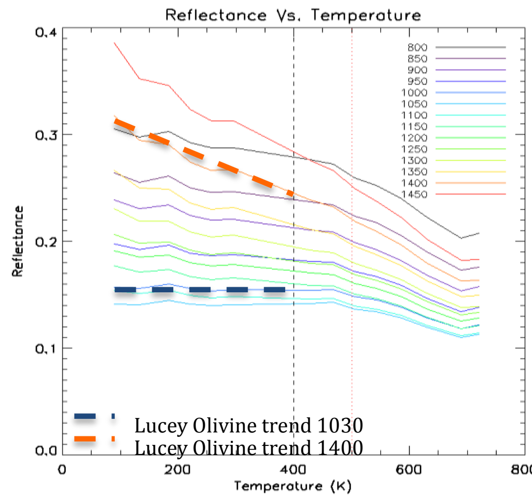

Figure 4. Potential change in thermospectral response at high temperature.

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Acknowledgements

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