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Ultraviolet Characterization of Fe-Impregnated Silica Gels as Analogues for Lunar Space Weathering

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1. Introduction

The lunar surface (and other airless planetary bodies) undergoes space weathering by micrometeorite bombardment and charged particle irradiation. Space weathering produces submicroscopic iron (SMFe) particles that are deposited as either fine-grained rims on mineral grains or as larger particles within agglutinates. As a result of space weathering, visible-near infrared (Vis-NIR) spectra display an increase in the continuum slope (redden), a reduction in albedo (darken), and an attenuation of absorption features.

There are also complexities in the manifestation of weathering in lunar spectra that are imposed as a result of Fe particle size; larger Fe particle sizes (<100-3000 nm) only darken, but do not redden the Vis-NIR spectra. Modeling techniques in the Vis-NIR have also advanced with knowledge of this by applying Mie theory to account for the variance in particle size.

All of this information is relevant and critical towards interpreting lunar surface maturity and composition in the ultraviolet as well, but has yet to be fully explored in a similar manner to the Vis-NIR. The Lunar Reconnaissance Orbiter (LRO) features two ultraviolet instruments: the Lyman Alpha Mapping Project (LAMP) and the Lunar Reconnaissance Orbiter Camera Wide-Angle Camera (WAC). In order to examine the LRO ultraviolet data sets more effectively, we aim to perform complementary spectroscopy measurements and microscopy of lunar samples and analogs that provided guidance to the visible and near-infrared.

2. Methods

Spectra were collected in the **L**aboratory for **S**pectroscopy under **P**lanetary **E**nvironmental **C**onditions (**LabSPEC**). Spectra of the standard and sample are collected under high vacuum conditions (10^{-6} to 10^{-7} Torr). Ultraviolet (UV) data are collected using a McPherson spectrometer (150-570 nm) using MgF_2 as the standard. The monochromator and picometer are attached to chamber to enable far-UV data collection. Visible (Vis) data are collected using a Spectra Vista Corporation (SVC) HR-1024i point spectrometer (350-2500 nm) using MgF_2 as the standard. The halogen light source and spectrometer mounted outside chamber at dedicated ports that are 60° apart (i = 15°, e = 45°). Infrared (IR) data are collected using a Bruker Vertex 70 lab FTIR (1.8-8 µm) using Au used as the standard. As with the Vis data, the light source and detector are mounted at the same dedicated ports outside chamber. Both the SVC and IR detectors are mounted on a linear stage that allows us to toggle between the two spectrometers. A full spectrum, from UV (~150 nm) out to IR (~8 µm) is generated by combining three spectral ranges, scaled to the internally-calibrated SVC Vis spectrum.

3. Samples

This study uses silica gels of Noble et al. [1] which are impregnated with Fe particles that vary in size from 5–200 nm. This study included four "series" of silica gels (SG2, SG6, SG25, SG50) with variable pore sizes that allowed different sizes of Fe^0 particles to be impregnated into each gel series in variable abundances (Table 1).

Table 1: Particle size series used in this study.

SG Series	Fe^0 Particle Sizes	Range of Fe^0 Abundance[1]
SG2	5 – 15 nm	0.02 – 1.21%
SG6	10 –25 nm	0.02 – 0.30%
SG25	25 – 50 nm	0.02 – 0.94%
SG50	20 – 200 nm	0.03 – 1.89%

[1]Abundances included in this study

4. Results

Results for the smallest particle sizes (SG2 series) show that spectra show the characteristic darkening and reddening within the Vis-NIR portion of the spectrum with increasing Fe^0 abundance (e.g., Figure 1).

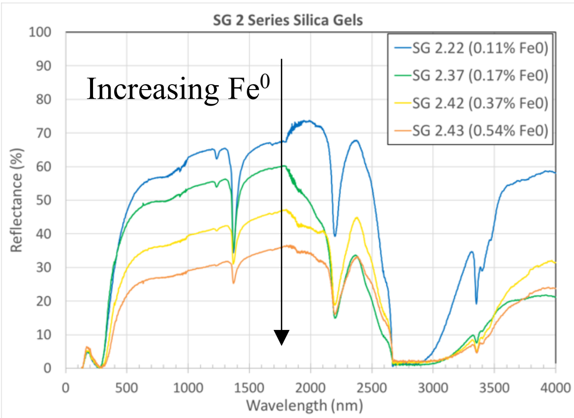

Figure 1: UV-NIR spectra of the SG2 series with variable Fe^0 abundances, which show the darkening effects of increasing Fe^0.

However, when we zoom in on the UV portion of the spectrum (Figure 2), the Vis-NIR relationship between Fe^0 abundance and albedo no longer exists. That is, the sample with the highest abundance of Fe^0 (SG 2.43 with 0.54% Fe^0) has the brightest albedo in the far- to mid-UV (160-280 nm), while the sample with the lowest abundance of Fe^0 (SG 2.22 with 0.11% Fe^0) also has the darkest albedo.

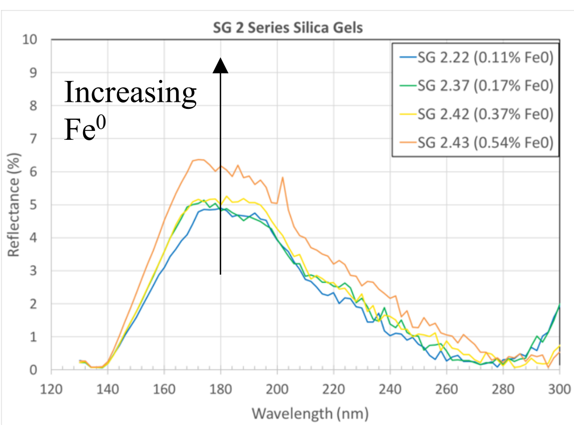

Figure 2: UV spectra for SG2 series with variable Fe^0 abundances. Notice the increasing albedo and correlates with increasing Fe^0 abundance.

5. Future and Ongoing Work

We are working to verify this "UV reversal" within the larger particle sizes series (SG6, SG25, SG50) and will present the UV spectra for all sample sets.

6. Summary and Conclusions

The lunar ultraviolet albedo is very different than the visible albedo [2]. Most mineralogy transitions to opaque in UV because reflections dominate the optical properties independent of mineral color. Furthermore, the mare/highlands contrast is minimal near MUV (~180 nm; [3]) and the mare refractive index and external refraction coefficient is higher than highlands. Indeed, the relative brightness between mare and highlands reverses moving to shorter wavelengths in the far-UV. With this information in mind, the observed characteristics of the samples measured here may be explained by a combination of 1) the apparent brightening with increasing Fe^0 abundance of the smallest SMFe particles (SG2, 5-15 nm) and 2) the influence of larger SMFe particle sizes (>15 nm) with variable Fe^0 abundances.

References

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