

UV-Visible reflectance measurements of minerals before and after exposure to air. C. Jaramillo^{1*}, N. Pearson², A. Hendrix², F. Vilas², J. P. Allain¹, R. Clark², D. W. Savin³, and D. L. Domingue². ¹Ken and Mary Alice Lindquist Department of Nuclear Engineering, Pennsylvania State University, University Park, PA, U.S.A. (*camilojar@psu.edu), ²Planetary Science Institute, Tucson, AZ, U.S.A., ³Columbia Astrophysics Laboratory, Columbia University, New York, NY, U.S.A.

Introduction: The Toolbox for Research and Exploration (TREX) is a NASA SSERVI (Solar System Exploration Research Virtual Institute) node. TREX (trex.psi.edu) aims to develop tools and research methods for the exploration of airless bodies, specifically the Moon, the Martian moons, and near-Earth asteroids. TREX studies are organized into four Themes: (1) Lab studies, (2) Lunar studies, (3) Small bodies studies, and (4) Field work. The work presented here is part of Theme 3: Investigations of fine-grained materials on the surface of small bodies.

Background: In the last couple decades, sample return missions are becoming more common: Recently, Chang'e-5 successfully returned lunar samples, Hayabusa2 successfully returned with samples from asteroid Ryugu; OSSIRIS-REx successfully retrieved samples from asteroid Bennu and is on route to Earth; sample return missions to the Moon and Mars are being planned. The availability of samples from other planetary bodies is expected to increase in upcoming years.

Sample return missions enable the study of planetary materials in a laboratory setting, allowing the use of additional characterization techniques that are otherwise unfeasible for remote-based observations, and the comparison to observations performed via remote sensing of planetary bodies.

In planetary science, reflectance spectroscopy is largely used to study the mineralogic characteristics of planets, moons, and asteroids [1]. Moreover, comparison between reflectance spectra of returned samples versus spectra from remote observations has provided evidence of additional space processes (e.g., space weathering on the surface of the Moon [2]).

Motivation: One of the major implications of samples returned to Earth from planetary bodies for laboratory studies is the requirement of appropriate sample handling techniques and protocols. Earth's atmosphere is rich with reactive species that will promptly interact with any surface exposed to it. For instance, exposure to O₂ leads to the formation of oxide layers on the surface.

Samples that are brought to Earth contain invaluable information in their pristine state. Exposing them to air will inevitably result in the alteration their surface properties. Typically, the compromised fraction of the sample will be limited to a surface layer with a thickness

in the order of ~1 nm. Bulk properties can essentially be retained, although diffusion of adventitious species can occur over longer periods of time.

The way in which surface contamination can affect the properties measured are dependent on each measurement technique, its probing depth, and its surface sensitivity. The effect of surface contamination must be systematically evaluated for each characterization technique.

In this work, we focus on evaluating the effect of surface contamination on the spectral characteristics of analog minerals collected via reflectance spectroscopy in the ultraviolet to visible (UV-Vis) wavelength range. This is achieved by collecting spectra of air-exposed minerals, and comparing them to spectra of protected minerals, i.e. minerals that were never exposed to air. The spectra of both air-exposed and protected minerals were recorded using the same experimental setup. Protected minerals emulate the characteristics of returned samples.

Limited availability or low volumes of samples retrieved by sample return missions are expected. For this reason, in this work, low volumes of samples (< 30 mg) were used in all cases. This was chosen to more fully emulate the scenario common to the laboratory characterization of retrieved planetary samples.

Sample preparation: Both air-exposed and protected samples were generated following the same procedure: Fine grain powders (<25 µm) were produced by grinding down coarse grains using a mortar and pestle. The ground powders were sifted to produce samples of a specific grain size range, and eliminate any potential effect of the sample morphology on the characteristics of the spectra. Sample grain size has been shown to influence the characteristics of their spectra [3].

The main difference between the preparation of air-exposed and protected samples was the generation environment:

- (1) Air-exposed samples were prepared in the laboratory without any special environment. Samples were in direct contact with air during the preparation process.
- (2) Protected samples were prepared inside a glovebox under a controlled N₂ environment with low contents of water (<1 ppm) and oxygen (<0.1 ppm). By processing the minerals

into fine powder inside the glovebox, grains with fresh faces that were never exposed to air were generated.

To measure the sample's UV-Vis reflectance properties, the processed samples were loaded into a portable sample capsule. This capsule can preserve samples for at least 3 weeks in a controlled environment using an inert background gas (N_2) [4]. The sealed capsule was integrated into the spectrometer setup (figure 1). Spectra were recorded while the samples remained inside the sealed capsule.

The measurements were performed using an AvaLight-DH-S-BAL light source (Avantes) containing a halogen and deuterium lamp, and an AvaSpec-ULS2048XL-EVO spectrometer (Avantes). Both lamp and spectrometer were connected to a goniometer via fiber optics to adjust the illumination/collection geometry. In this work, all measurements were performed at a 0° and 30° collection and illumination geometry.

Preliminary results: Spectra were collected on various minerals. As an example, the top plot in figure 2 shows the spectra of air-prepared versus protected olivine powder ($< 25\mu m$). There is a clear decrease in albedo from the spectra of the protected- to air-exposed sample. After recording spectra of the protected sample, it was exposed to air for 1 minute, and new spectra were collected, this is also shown in figure 2 (labelled as Exposed). A partial reduction of the reflectance signal was also observed in the freshly exposed sample. The bottom panel in figure 1 shows the ratio of the Air-prepared and Exposed signal with respect to the Protected sample spectra; the dashed line corresponds to unity. The ratios show that the reduction of the signal intensity takes place across the entire measured wavelength range. Moreover, the way the spectra change varies for different wavelengths.

New minerals are being studied following the same procedure. This work is expected to reveal how exposure to air can potentially affect the spectral characteristics of different minerals. This will provide insight into the mechanism(s) responsible for the spectral variations.

Acknowledgments: This work is funded by the National Aeronautics and Space Administration through the Solar System Exploration Research Virtual Institute 2016 (SSERV16) Cooperative Agreement TREX (NNH16ZDA001N).

This work has been performed at the Materials Research Laboratory at the University of Illinois at Urbana-Champaign.

References: [1] Cloutis, E.A., et al. (2018) *Primitive Meteorites and Asteroids: Physical, Chemical, and Spectroscopic Observations Paving the*

Way to Exploration, Elsevier, 273–343. [2] Adams, J.B. and Jones, R.L. (1970) *Science*, 737-739. [3] Cloutis, E.A., et al. (2015). [4] Jaramillo, C. et al. (2021) *AGU Fall meeting*, P11A-06.

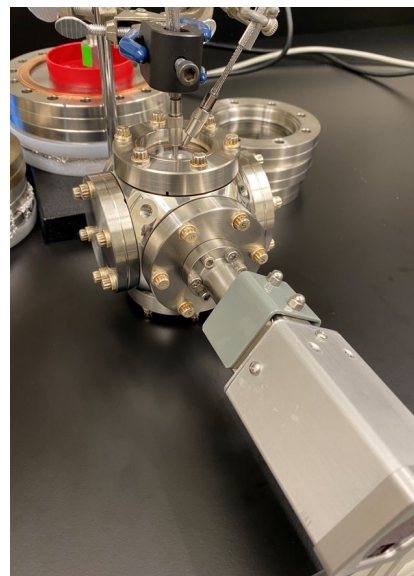


Figure 1: Sealed sample capsule integrated with into the reflectance spectroscopy setup

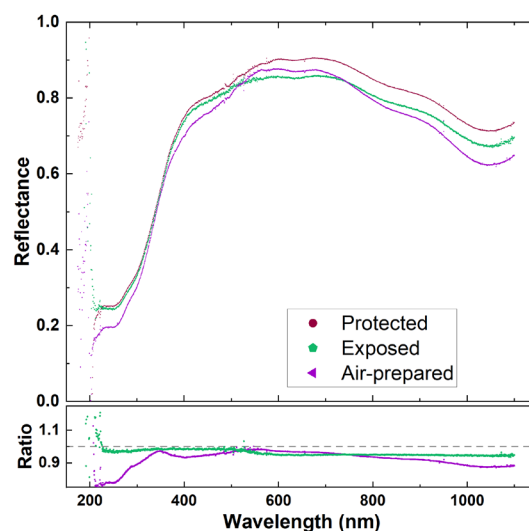


Figure 2: Variation of the spectral characteristics between olivine powders prepared in air and in a controlled environment. Top: UV-Vis reflectance spectra of olivine powders corresponding to samples prepared under air- and controlled environments; Bottom: Ratio of the Air-prepared- and Exposed samples with respect to the Protected sample reflectance spectra