Laboratory simulations of solar wind-driven space weathering on olivine powder.

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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, decreasing risk to future missions. TREX studies are organized into four Themes: (1) Lab studies, (2) Moon 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 planetary science, reflectance spectroscopy is a technique used to characterize the surfaces of airless planets, moons, and asteroids. This is achieved by collecting sunlight scattered from these space bodies. Most studies have focused on the spectral range covering the ultraviolet-visible-near-infrared (UV-Vis-NIR) portion of the spectrum [1].

Surfaces in space are exposed to a plethora of energetic particles and radiation. Through this interaction, surface properties can be altered, in a process called space weathering. In the study of airless bodies via reflectance spectroscopy, space weathering is of interest because it can alter the optical properties of regoliths [2].

The solar wind is considered one of the main agents driving space weathering. It mostly consists of electrons and protons originated in the solar corona. The solar wind characteristics vary significantly across locations in the Solar System. At 1 AU, the solar wind has an average flow velocity of 440 km s^{-1} with typical proton densities of 8 cm^{-3}. These conditions correspond to particle energies of ~1 eV amu^{-1} and fluxes of $4x10^{8}$ cm^{-2} s^{-1} [3].

Motivation: With in situ spacecraft missions being extremely limited, the study of solid surfaces in the solar system continues to rely strongly on remote sensing observations like reflectance spectroscopy. Thus, laboratory simulations of space weathering are a necessaryimportant tool for understanding the characteristics of surfaces of airless bodies. They give access to techniques and methods on analog environments, that are otherwise unfeasible.

The most reliable laboratory simulations of space weathering by solar wind ions require: (1) regolith-like loose powders, (2) sample generation and handling in an inert environment to avoid atmospheric contamination, (3) ion irradiation using solar wind-like conditions (~ 95% H and 5% He ions, with beam energies of 1 keV amu^{-1}), and (4) *in situ* and *in vacuo* diagnostics to prevent atmospheric contamination of the samples.

Considering these four conditions, our work focuses on conducting reliable laboratory simulations of solar wind-driven space weathering under conditions that most closely replicate those taking place on the surface of airless planetary bodies. Here, we report the progress in the development of this protocol.

Sample handling: To assess the effects of surface contamination due to exposure of the samples to air, we conducted reflectance and x-ray photoelectron spectroscopy (XPS) in the IGNIS (Ion-Gas-Neutrals Interaction with Surface) facility. Two methods were used to prepare fine loose olivine powders as samples for this work:

1. The olivine powders were prepared in air before transferring to IGNIS, resulting in direct exposure of the powders to reactive gases and air contaminants.
2. The powders were prepared and transported in controlled environments, preventing direct contact with air. The preparation was performed in a glovebox under an inert atmosphere, while transfer to IGNIS was done using a vacuum suitcase.

The reflectance spectra and XPS obtained from powders prepared using the two methods described above were compared to determine the influence of air exposure on the properties of samples. Reflectance spectra were used to determine if the surface contamination has any effect on the optical properties of regolith-like powders; XPS was used to track the surface chemistry and assess its interaction with reactive species in air.

Ion irradiation: Ion irradiations were performed on the prepared olivine powders. The irradiations were performed in IGNIS, with *in situ* characterization. The irradiation steps were alternated with characterization to track the surface evolution under the increasing irradiation fluence. The irradiations were performed using 1 keV hydrogen ions on loose olivine powder. The irradiations were performed in fluence steps of

$2\text{x}10^{17}$ cm^{-2}, until a total fluence of $1\text{x}10^{18}$ cm^{-2} was achieved. By performing diagnostics *in situ*, surface contamination was prevented. Reflectance spectra of the pristine and ion-irradiated powders were collected to evaluate the effect of the irradiation on their optical properties (**Fig 1**); XPS was recorded to analyze the response of the surface chemistry to the ion bombardment (**Fig 2**).

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References: [1] Cloutis, E. A., et al. (2018) *Primitive Meteorites and Asteroids: Physical, Chemical, and Spectroscopic Observations Paving the Way to Exploration*, 273–343. [2] Hapke, B. (2001) *J. Geophys. Res. E Planets*, 30, E5, 10039–10073. [3] Gosling, J. T. (2014) *Encycl. Sol. Syst.*, 261–279.

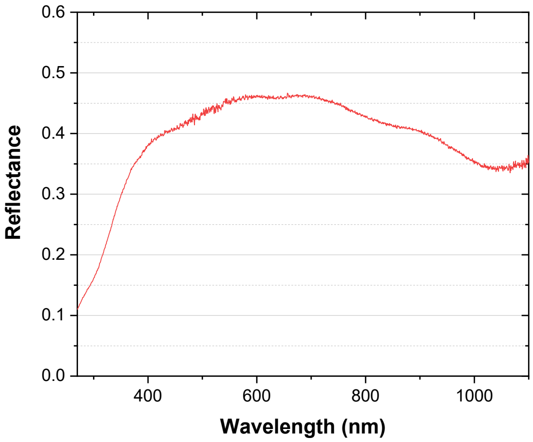

Figure 1: Preliminary results on non-irradiated olivine loose powder: Reflectance spectrum covering the UV to NIR region.

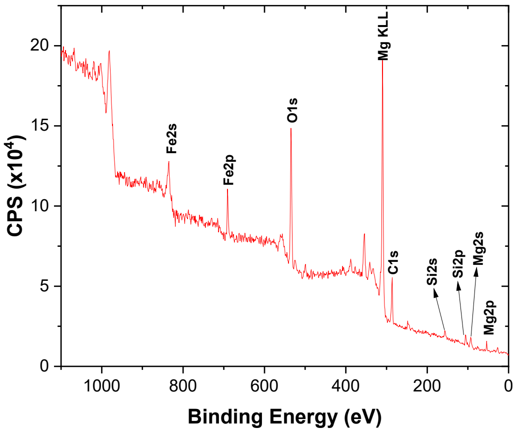

Figure 2: Preliminary results on non-irradiated olivine loose powder: XPS spectra covering the spectrum range from 0 to 1100 eV binding energy