SPACE WEATHERING FROM MERCURY TO PLUTO: A NOVEL SIMULATED ENVIRONMENT CHAMBER.

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Introduction: Exposure to UV radiation, micrometeorite impacts, cosmic rays, solar wind, and other phenomena alter the physical and chemical properties of airless body surfaces in our Solar System [e.g., 1]. Combined, these alteration processes are known as space weathering. Understanding how planetary surfaces are modified as a result of space weathering processes can aid in linking meteorites to their parent bodies and understanding their evolutionary history [e.g., 2]. The way in which material changes due to space weathering depends on its composition and location within the Solar System [e.g., 1]. Space weathering on the lunar surface and on S-type asteroids is well understood; the albedo is lowered, the visible to near infrared (VNIR) spectra reddens, and spectral features weaken with maturity due to the formation and accumulation of nanophase iron [e.g., 1]. However, space weathering on other bodies in the Solar System, such as C-type asteroids, Mercury, and icy bodies like Europa and Enceladus, is less understood. Performing simulated space weathering experiments in a laboratory using well-characterized planetary surface analogs, and comparing those lab measurements to remote sensing observations of the relevant target bodies can shed light on how space weathering alters surfaces across the Solar System.

Historically, space weathering has been successfully simulated in laboratories utilizing pulsed laser irradiation to simulate micrometeorite bombardment [e.g., 3, 4, 5] and ion bombardment to simulate the solar wind [e.g., 6,7]. Galactic cosmic ray, solar cosmic ray, and solar UV radiation exposure has not been simulated to the same extent as they are more time consuming to simulate. Additionally, the majority of previous space weathering experiments have focused on the Moon and asteroids, where micrometeorite bombardment and solar wind are the dominant space weathering processes [1]. The Space Weathering Environment for Exploring Planetary Surfaces (SWEEPS) is an ultra-high vacuum environment chamber capable of simulating galactic cosmic ray, solar cosmic ray, magnetospheric radiation, and solar UV radiation exposure under a wide variety of environments within the Solar System utilizing an electron gun and UV source. SWEEPS can help shed light on these underexplored mechanisms of space weathering.

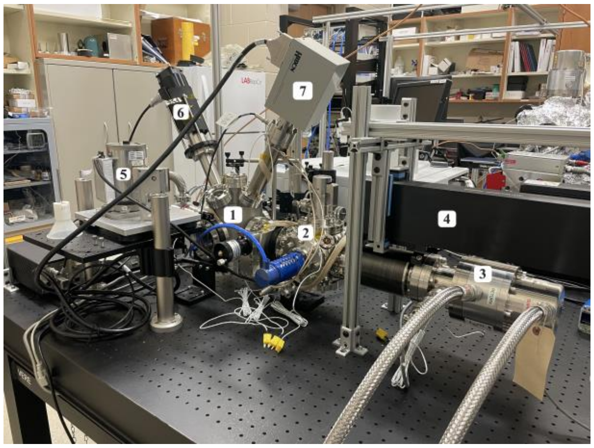

Figure 1. SWEEPS with chamber components labeled: (1) measurement chamber, (2) sample preparation chamber, (3) custom-built cryostat, (4) horizontal translation stage, (5) external detector for FTIR spectrometer, (6) UV source, (7) QMS

SWEEPS Chamber: SWEEPS can simulate a variety of environments within the Solar System, such as the surfaces of asteroids, comets, Trans-Neptunian Objects (TNOs), Kuiper Belt Objects (KBOs), the Moon, Mercury, and Titan. The SWEEPS chamber can be evacuated to achieve pressures on the order of 10^{-9} torr or filled with gas mixtures to replicate environments such as Titan or Mars. SWEEPS is composed of two chambers: the sample preparation chamber and the measurement chamber. The sample is moved between the chambers utilizing a horizontal translation stage attached to a custom-built cryostat that has the capability to cool down the sample holder to a temperature of approximately 10 K or heat it to 1000 K.

The sample preparation chamber can be isolated from the measurement chamber during sample preparation in order to prevent damage to the Potassium Bromide (KBr) windows or the Quadrupole Mass Spectrometer (QMS). Experiments with volatiles can be prepared via direct injection into the sample preparation chamber for condensation onto the sample utilizing a fine-needle leak valve. Combined with the pressure and temperature capabilities of SWEEPS, the capability to directly inject volatiles into the chamber allows for the creation of ice analogs for the surfaces of TNOs, KBOs, and other icy bodies in the Solar System.

After the sample has been prepared in the sample preparation chamber, it can be moved to the measurement chamber utilizing the horizontal translation stage. The measurement chamber is capable of performing diffuse reflectance spectroscopy with an incidence angle of 30° and an emergence angle of 0°, which with a phase angle of 30° can be compared to data obtained with NASA's RELAB facility. Spectra are obtained utilizing a Fourier Transform Infrared Reflectance (FTIR) spectrometer external to the chamber. The incident beam path is directed outside of the FTIR spectrometer and into the chamber utilizing a series of mirrors and the reflected beam is directed to an external detector, as shown in Figure 1. The FTIR spectrometer can obtain spectra over a wavelength range of 0.5-25μm utilizing combinations of a silicon (Si) or Mercury Cadmium Telluride Broadband (MCTB) detector and a KBr or Quartz beam splitter. A silver diffuse reflector with an SiO_2 protective coating to prevent oxidation is used to take calibration spectra, as it can be used in both the VNIR and mid-infrared (MIR) wavelength ranges.

Space weathering processes can be simulated in SWEEPS utilizing an electron gun and/or a UV light source. The electron gun can be used to simulate the linear energy transfer events by electrons and ions from both galactic cosmic rays and solar cosmic rays. The flux and incident energy of the electrons can be adjusted to reflect the environment that is being simulated. The UV source can simulate UV solar radiation, where the UV photon flux of the UV source corresponds to a specific location within the Solar System [8]. The measurement chamber also has a QMS attached that can monitor volatile loss during the irradiation of samples.

Testing Phase Plan: San Carlos olivine will be crushed and sieved to a maximum particle size of 75μm in accordance with previously conducted experiments [3, 8]. Six samples with a mass of 2g each will be created, three of which will be weathered via electron bombardment with the remainder undergoing UV irradiation. Electron flux and UV photon flux will be comparable to the cosmic ray flux and UV photon flux at the lunar surface at 1 AU from the Sun. Samples will be space weathered for different exposure times to understand what lengths of time are necessary to achieve measurable weathering effects. Reflectance spectra will be collected before, during, and after irradiation. Thermal infrared emissivity spectra will also be obtained after weathering using the Planetary Analogue Surface Chamber for Asteroid and Lunar Environments (PASCALE) [9]. In addition, we will characterize the physical and chemical changes of the samples utilizing a Scanning Electron Microscope (SEM) and Transmission Electron Microscope (TEM), both of which are capable of performing Energy Dispersive X-ray Spectroscopy (EDS).

Future work: Over the next few years, the environments that will be simulated in the SWEEPS chamber include C-type asteroids and Mercury.

C-type asteroids. The observed spectral changes of C-type asteroids due to space weathering has shown to be more complex than that of lunar material and S-type asteroids [e.g., 1]. Currently, the role that individual organic species and nanophase opaques play in space weathering is not well-characterized. In order to assess the role that these materials play in space weathering, we will work with the CLASS Exolith lab to create a CI simulant devoid of carbon [10]. The new simulant will be doped with simple organics, such as benzene, in varying weight percentages and space weathered utilizing electron bombardment and UV irradiation. Composition, morphology, and formation of nanophase opaques will be studied utilizing SEM/EDS and TEM/EDS analysis. Additionally, meteorite analogs to the C-type asteroids will be similarly space weathered and analyzed including Murchison (CM2), Jbilet Winselwan (CM2), Allende (CV3), Tagish Lake (C2), and Northwest Africa 852 (CR2).

Mercury. The darkening of Mercury's surface has been hypothesized to result from an intense space weathering environment, opaque mineral phases within the crust, or a combination of both [e.g., 11, 12]. Evidence for carbon present on the hermean surface is seen in deposits of excavated low-reflectance material (LRM), and these exposures are thought to have 2-2.5 weight percent (wt.%) and up to 5 wt.% of excess carbon [13]. The ways in which the presence of carbon might alter the regolith environment remains elusive. Is it possible that this carbon, when combined with a harsh space weathering environment, could produce nanophase carbon on grain rims? We aim to conduct Mercurian space weathering experiments to answer this question via the use of low- to Fe-free analogs and multiple types of carbon opaques, which will be mixed in accordance with the weight percentages described above. Samples will be put under vacuum and heated to 700 K before they are irradiated using a UV source.

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