

**POLAR REGOLITH ENVIRONMENT MOLECULAR IMPACT SIMULATION EXPERIMENT.** E. L. Patrick, K. Mandt, S. Escobedo, G. Winters, G. Miller and J. Mitchell, Southwest Research Institute, 6220 Culebra Rd., San Antonio, Texas, 78238, epatrick@swri.edu.

**Introduction:** The persistence of volatiles in regolith materials is a hot topic in space science. Recent discoveries of water trapped in the polar regions of both the Moon [1] and Mercury [2] has initiated a renaissance in the study of planetary regolith environments. Laboratory simulation of these environments not only demands ultra-high vacuum (UHV) conditions, but also requires the introduction of fine powders of either actual regolith or regolith “simulants” into that same vacuum environment. Regolith materials are a rare laboratory commodity and in short supply. Regolith simulants are relatively plentiful, but are fabricated from terrestrial materials (basalts, glasses, etc.) and can manifest serious physical and mechanical limitations (e.g., particle size & distribution, grain morphology, chemical composition, oxidation state of phases, etc.) on their use as analogues for regolith samples [3].

A space environment system known as the Polar Regolith Environment Molecular Impact Simulation Experiment (PREMISE) has been constructed in the Center for Excellence in Analytical Mass Spectrometry (CEAMS) at Southwest Research Institute (SwRI) to simulate both the regolith surface of the Moon using JSC-1A lunar regolith simulant and to expose that surface to simulated pressure “waves” that might occur due to a distant cometary impact. Such simulations not only improve our experience in the handling of regolith-like materials, but also improve our intuition in the design and development of the components and systems necessary to conduct mass spectrometry at the lunar surface.

**Experiment:** PREMISE consists of stainless steel vacuum and gas handling manifolds, each evacuated by separate turbomolecular pumping systems, with a sample vessel fabricated from a seven-port miniature vacuum chamber. Flanged connections to the sample chamber include a UV quartz window, vacuum connection, gas inlet connection, feedthrough flange for dual thermocouples (TCs), sample manipulator flange, residual gas analyzer (RGA) flange and sample cell adapter flange. Figure 1 shows the sample chamber after cleaning upon removing the first charge of JSC-1A lunar regolith simulant.

The sample cell assembly was constructed from brazing a copper gasket to a solid copper disk, thus forming a flat cylindrical zone approximately 2 mm deep with a surface area of approximately 10 . The assembly is subsequently plated in gold. Thermocouples were then affixed to the gold surface of the sample

cell with vacuum-compatible epoxy. The junction of one thermocouple is in direct contact with the sample cell surface, while the second is maintained at approximately 1 mm above this surface. This second thermocouple is thus within the lunar regolith simulant when the cell is filled with sample.



Figure 1: The sample chamber is shown after cleaning subsequent to the first charge of JSC-1A simulant. The two small open ports attach to the mass spectrometer and gas inlet manifolds. The larger open port attaches to the vacuum system. The vacuum feedthrough for the TCs is to the upper right.

The RGA for PREMISE is a quadrupole mass spectrometer with mass scanning capability from 1 to 300 daltons. Mass scans of interest were typically limited to 50 daltons to reduce the size of the accumulated data files, and because the highest molecular weight gas used was (mass 44). However, during system bakeout, laser ablation, or any other disturbance of the system, full-range 300 dalton mass scans were often performed to verify that no unusual gas signatures were present at higher mass ranges.

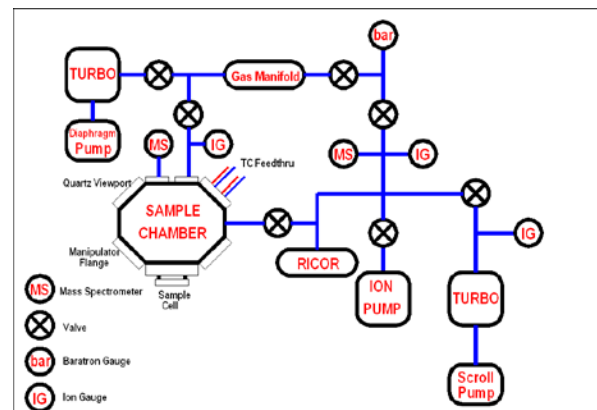


Figure 2: This rough system diagram shows flanged connections to the Sample Chamber that include those for TC feedthroughs,

mass spectrometer, gas inlet, manipulator, vacuum connection and sample holder.

The complete system (Fig. 2) currently includes a Sterling Cycle cryocooler that can be used in future experiments to collect volatiles over time at cryogenic temperatures for subsequent release to a mass spectrometer or other instruments.

**Experiment Procedure:** After baking of the simulant to drive off atmospheric volatiles, gas is introduced to the sample volume through a leak valve at a selected pressure and for a fixed period of time. Pressures to which the sample chamber and simulant were exposed were in the range of  $1 \times 10^{-8}$  to  $1 \times 10^{-6}$  Torr. Exposure times were typically 600 seconds in length.

Initial gas exposures of the simulant were conducted with argon due to its inert nature, its measurement at the lunar surface by the Lunar Atmospheric Composition Experiment (LACE) deployed during the Apollo 17 mission [4], and recent interest in detecting its presence remotely in the lunar exosphere with the Lyman-Alpha Mapping Project (LAMP) aboard the Lunar Reconnaissance Orbiter (LRO) [5].

Persistent gas peaks within the PREMISE system, subsequent to episodes of gas exposure, influenced early operation and led to improvements to the vacuum integrity of the system. Currently the background pressure above the JSC-1A lunar regolith simulant is approximately  $1 \times 10^{-8}$  Torr prior to the start of experiments.

Thus far, insertion and use of the JSC-1A lunar soil simulant in the vacuum system has been without incident. Provided the material is handled carefully, one can avoid migration of small particles during system evacuation or when backfilling with to atmospheric pressure.

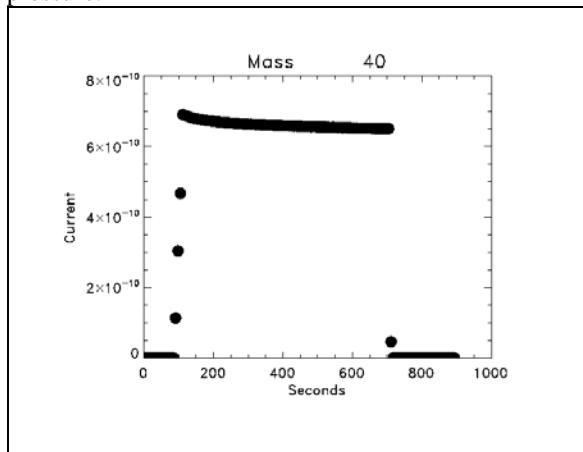


Figure 3: After exposure to argon for 10 minutes, the gas inlet valve is closed, causing the signal in the mass 40 channel to drop to zero.

**Preliminary Results:** Tests using laser ablation and light emitting diodes (LEDs) to drive volatiles from the simulant found that laser ablation produced

excessive pressures and was not necessary. LEDs in both UV and “white light” were found sufficient to volatilize materials for a mass spectrometer at the lunar surface. A mechanical disturbance to the desiccated simulant, even under UHV conditions, caused a significant release of entrapped gases suggesting another effective mechanism for in-situ measurement of volatiles. Finally, we found that Argon is not trapped in the desiccated simulant after exposure at room temperature for approximately 10 minutes. Figure 3 is a plot of the primary ( $\text{Ar}^+$ ) mass channel (40 dalton) of the mass spectrometer over time and shows that argon signal fell immediately to zero upon valve closure.

**Conclusions:** Argon is routinely sampled as a means for determining ages of mid-ocean ridge basalts (MORBs) using the potassium-argon (K-Ar) geochron. Argon exposure to processed basaltic ash (JSC-1A) may be relevant to the study of both terrestrial and lunar basalts [6]. Water is the typical background contaminant in UHV systems and described as a “virtual leak” when observed. Atmospheric components ( $\text{H}_2$ ,  $\text{CO}_2$ ,  $\text{Ar}$ ) evolve from chamber surfaces over time alongside the observed water ( $\text{H}_2\text{O}$ ) signature. While argon does not persist in the desiccated regolith simulant, future tests are necessary to determine its retention in simulant exposed to water vapor.

Data obtained are not only applicable to past and current investigations of the lunar exosphere, but also suggest approaches for future laboratory and space-flight mass spectrometer investigations into SBEs and the nature of volatiles exposed to, and trapped within, regolith surfaces.

**References:** [1] Gladstone, G. R., et al., (2010) *Science*, 330, 474. [2] Lawrence, D. J., et al., *Science* (2012) doi 10.1126/science.1229953. [3] Taylor, L. A. and L. Liu, (2010) *Earth and Space 2010*, 106. [4] Hoffman, J. H., et al., *LPSC 4*, 2865. [5] Stern, S. A., et al. (2012) *GRL* 39, L12202. [6] Keeling, D. A. and Naughton, J. J. (1974) *GRL* 1, 43.