

Experimental Insights into Argon and Water Interactions with Lunar-Relevant Materials. M. J. Poston¹¹Southwest Research Institute (6220 Culebra Rd. San Antonio, TX, 78238; michael.poston@swri.org).

Introduction: We are presently in an era of reexamining the behavior and abundance of volatiles on the Moon, Mercury, Ceres, Phobos/Diemos, and small bodies. While evidence consistent with diurnal variations in adsorbed water content has been primarily at mid latitudes, this process has implications for both migration of water to the poles, and also for the adsorption behavior of water molecules in the polar regions. Differing techniques and modelling approaches have resulted in orders-of-magnitude differences in the quantity of migrating water inferred from spacecraft observations [1,2,3,4]. New laboratory measurements are needed to answer outstanding questions from recent missions and telescopic observations, regarding the possible diurnal water cycle on the Moon. [5] quantified the water desorption dynamics from Apollo lunar samples, placing some limits on water behavior, but concluded that the samples may not have been fully lunar-like. This is because [6] demonstrated that in order to reproduce lunar-like behavior for argon adsorption, it was necessary to activate mineral surfaces immediately before conducting the measurements. (Recent orbital observations are also consistent with strong adsorption for argon on the Moon, e.g. [7].) They did this by crushing a lunar rock in high vacuum, which is challenging and destroys the lunar rock being analyzed. I seek to demonstrate an improved technique that would reduce the amount of lunar sample required to perform the measurement. The technique is also much faster than the legacy measurement, which should provide higher fidelity measurements – accessing the highest energy adsorption sites before the residual gas present even in ultra-high vacuum can react with the fresh sample surfaces.

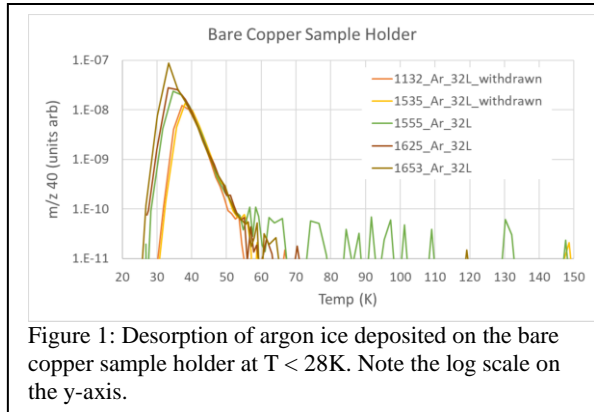
Ion-irradiation experiments performed by numerous investigators in the space weathering community have shown creation of nano-phase iron, amorphous rims, and other aspects of space weathered extraterrestrial samples, but little/no work has been published examining volatile sorption behavior to such an artificially-weathered surface. I am performing experiments to test the following hypothesis: *ion irradiation will activate grain surfaces for lunar-like volatile adsorption*. Should the hypothesis prove true, it will open up a new and widely available technique for creating active grain surfaces. Such a technique would have the potential to revolutionize our ability to understand and predict the behavior of volatiles on rocky, airless bodies. The technique is being tested on lunar surrogates, and if successful, will then be used to

measure the adsorption behavior of water on activated lunar grain surfaces.

Experimental: The Regolith Optical and Sorption Experiments (ROSE) apparatus has been constructed at Southwest Research Institute specifically to address spectroscopic and gas adsorption behaviors of samples that undergo simulated space weathering. The sample is located at the center of a spherical ultra-high vacuum chamber (no-bake 48 hour pressure typically <1E-8 torr, ~3E-9 torr with cryostat chilled) on a thermally-floating sample mount. A 10 K closed-cycle helium cryostat is moved into contact with the copper sample cup to chill the sample and disconnected for resistive sample heating; meanwhile, a Si diode is used to monitor the temperature of the sample cup. The powder layer in the cup is between 100-200 microns thick, to minimize thermal gradients and volatiles diffusion in the particle film. Solar-wind space weathering is simulated by a differentially-pumped and mass-selective ion gun. Argon and/or water are introduced through a micro-capillary array doser, which reduces background volatiles during the experiment by > 90% compared to purely background dosing. Volatiles desorption during the heating phase of the experiment is monitored by a quadrupole mass spectrometer. Meanwhile, diffuse reflectance spectra of the sample are collected from the UV through the MIR at key stages of the experiment, further connecting the experiments with the spacecraft observations.

Status: Preliminary results were presented at the Lunar Polar Volatiles meeting in November 2022; however, further control experiments since that time have modified those conclusions. Specifically, the apparent increase in argon adsorption to the LMS-1-dust sample after 4 keV He⁺ irradiation has been shown to be due to a previously undiscovered systemic effect within the apparatus. Thus, at present, experiments have instead placed upper limits on the creation of new adsorption sites via irradiation fluence equivalent to one day of solar wind irradiation on the Moon. Larger irradiation fluences are underway, as well as fabrication of a new sample holder designed to boost the sensitivity and detection limits of the apparatus.

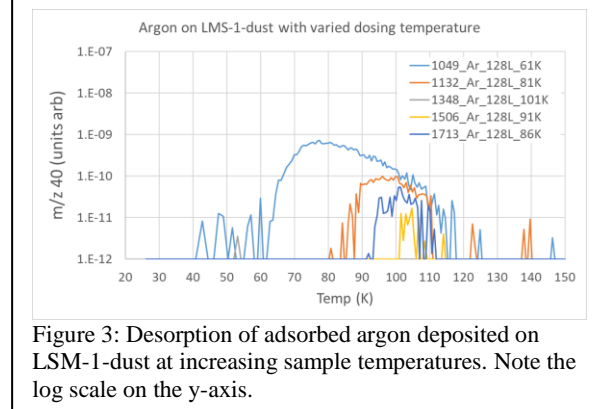
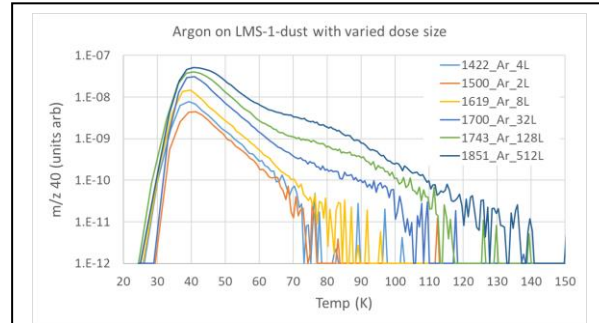
Meanwhile, argon and water adsorption without irradiation have been characterized, in a fashion similar to [5,8]. Figure 1 shows a control experiment: argon ice desorption from the sample holder with no sample. Direct dosing from the micro-capillary array doser produced an order of magnitude more adsorption



than the same quantity of argon flowed into the chamber with the doser instead pointed at the chamber wall (“withdrawn”). Both approaches showed a desorption peak that consistently dropped below detection by 60K during the heating phase of the experiment.

Figure 2 shows argon desorption after dosing the sample with varying quantities of argon with the sample cup at 31K. See [5,9] for discussion of the Langmuir (L) exposure unit when used for powder samples. The powder layer was kept very thin (estimated about 150 microns), so the thermal gradient within the sample should be minor. The 31K dosing temperature was chosen because it is estimated to have the same vapor pressure for argon as water has at 165K, enhancing comparison to [5]. The powder presents an estimated 217x more surface area than the bare copper holder, so depending on the sticking coefficient, the 512L exposure may approach saturation of the strong argon adsorption sites on the mineral surfaces. Even the smallest doses showed enhanced water desorption, which extended to higher temperatures than the bare copper TPDs.

The shape of the curves at higher doses, and especially the relative shape with increasing dose size, may indicate a contribution of Knudsen diffusion to the desorption results. Figure 3 shows a control experiment conducted to test this. Argon was dosed with the sample held at warmer temperatures, up to 101K. These results confirm adsorption while the sample was as warm as 91K. This outcome is consistent with contributions from strong adsorption of argon (relative to argon ice), but a small amount of diffusional-broadening of the desorption feature cannot be ruled out. The heating was continued up to 450K. In contrast to the results of [8], which were concluded to



show significant Knudsen diffusion (for water) in a powder layer of similar thickness, a high temperature feature was not observed here.

Preliminary results with water (not shown) appear qualitatively similar to prior works with lunar-relevant powders [5,8,9]. Experiments continue, including plans for characterizing adsorption from additional irradiated samples, and the latest results and interpretations will be presented at the meeting.

References: [1] Hendrix et al. (2019), GRL, 10.1029/2018GL081821. [2] Li and Milliken (2017) Sci. Adv., 10.1126/sciadv.1701471. [3] Bandfield et al. (2018) 10.1038/s41561-018-0065-0. [4] Wohler et al. (2017) Sci. Adv., 10.1126/sciadv.1701286. [5] Poston et al (2015) Icarus, 10.1016/j.icarus.2014.09.049. [6] Bernatowicz and Podosek, (1991) Proc Lunar Planet Sci Conf 21st, 21, 307. [7] Hodges and Mahaffy (2016) GRL, 10.1002/2015GL067293. [8] Jones et al. (2021) JGR-Planets, 10.1029.2019JE006147. [9] Poston et al. (2013) JGR-Planets, 10.1029/2012JE004283.

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