Implantation of Helium into JSC-1A Lunar Regolith Simulant for Volatile Extraction System Testing

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Introduction: Research is ongoing at the University of Wisconsin-Madison to develop a prototype lunar volatiles extraction system that will demonstrate a process for acquiring helium-3 (^3He) for future fusion power plants that would produce little to no radioactive waste, and other volatile gases that can be used for life support in space (Wittenberg et al. 1986). The prototype system is called the Helium Extraction and Acquisition Test bed (HEAT) and is based on past lunar volatiles miner designs that were developed at the University of Wisconsin Fusion Technology Institute (Sviatoslavsky and Jacobs 1988). Testing of HEAT will focus on obtaining information on the rate of ^3He extraction possible and to what extent thermal energy recovery can be employed in this kind of volatile extraction system. Before demonstrating the evolution of ^3He out of regolith simulant, simulant that is embedded to a known concentration must be available in order to gauge the performance of HEAT. Beyond the Apollo and Lunakhod lunar soil samples, there is no regolith or regolith simulant that has already been implanted with solar wind volatiles that is available for experimental studies. In the past lunar analog materials have been implanted for similar studies using Plasma Source Ion Implantation (PSII) (Kuhlman and Kulcinski 2012). The PSII method worked well enough for small samples of a few grams, but isn't practical for batches of hundreds of grams to a few kilograms of implanted simulant. An implantation device is being developed to implant helium into batches of JSC-1A regolith simulant for HEAT. The device under development is referred to as the Solar Wind Implanter (SWIM). The concept for SWIM consists of having a controllable downward flow of simulant (coming out of a hopper/feeder device) that passes between planar electrode grids that produce a lateral (perpendicular) stream of electrostatically accelerated helium ions inside of a vacuum chamber. The voltage potential between the electrodes determines the energy that the helium ions pick up before impacting the falling simulant particles. The solar wind that impacts the lunar surface is traveling between 300-900 km/s with an average of ~450 km/s. To mimic that amount of energy (~1-2 keV/amu), a potential of around 4-12 kV is required between a set of parallel electrodes. There are essentially four parts to SWIM: a hopper/feeder system, the system's support structure, the electrodes and tungsten filaments needed to drive helium ions into the simulant and a collection bin for the implanted simulant. As of early 2016, the SWIM device has been assembled and preliminary testing to characterize the system's ability to implant as desired have been done. The elements of SWIM can be seen in Figure. 1 along with an illustration of the operation of the device.. An illustration of SWIM implanting just short of 75 g of simulant to 20ppb of helium-4 can be seen in Figure 2.

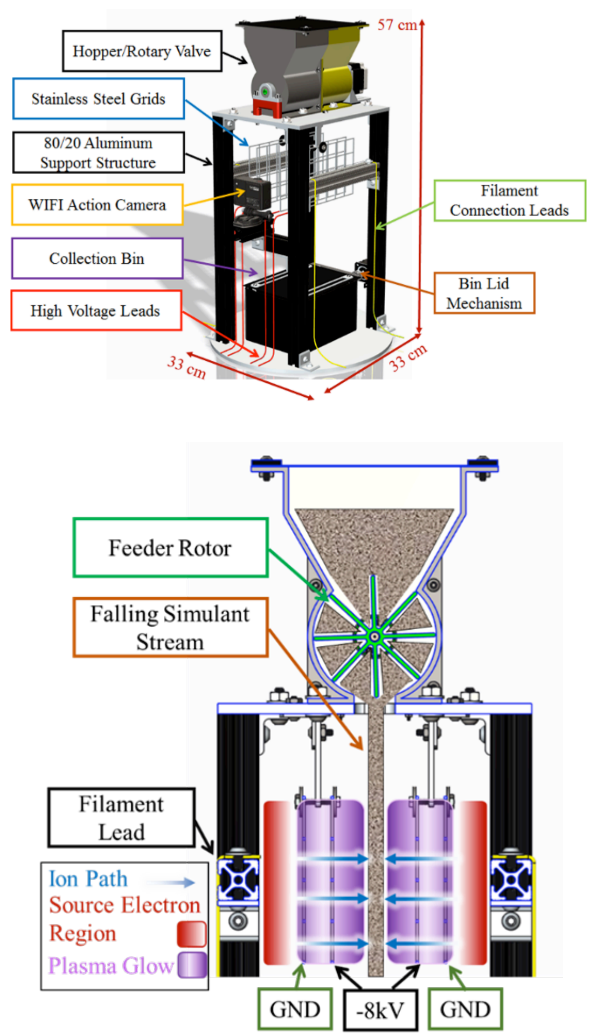

Figure 1. Components of the SWIM device (top) and an illustration of the device's operation (bottom)

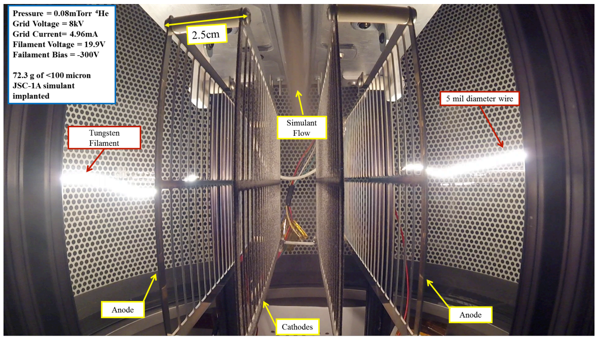

Figure 2. SWIM in operation at NASA Kennedy Space Center's Swamp Works labs in December, 2015.

References:

[1] Kuhlman, K., and Kulcinski, G. L. (2012). "Helium Isotopes in the Lunar Regolith - Measuring Helium Isotope Diffusivity in Lunar Analogs." Moon: Prospective Energy and Material Resources, Springer Praxis, 22–56. [2] Sviatoslavsky, I. N., and Jacobs, M. K. (1988). "Mobile Helium-3 Mining and Extraction System and Its Benifits Toward Lunar Base Self-Sifficiency." Wisconsin Center for Space Automation and Robotics Technical Report (WCSAR-TR) AR3-8808-1. [3] Wittenberg, L. J., Santarius, J. F., and Kulcinski, G. L. (1986). "Lunar Source of He-3 for Commercial Fusion Power." Fusion Technology, 10, 167.

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