LUNAR PSR ICY REGOLITH SIMULANT. K. Šļumba[1,2,*], H.M. Sargeant[1,2] and D.T. Britt[1,2], [1]Department of Physics, University of Central Florida, 4111 Libra Dr., PSB430, Orlando, FL 32816, [2] Exolith Lab, 532 South Econ Cir, Oviedo, FL 32765, [*]karlis.slumba@knights.ucf.edu

Introduction: We are developing a Lunar Permanently Shadowed Region (PSR) icy regolith simulant, which is a mixture of Exolith Lunar Highlands Simulant (LHS-1) and water ice [1]. Our goal is to produce a high-fidelity icy simulant in large quantities (several kg's per batch), that could be used for PSR research.

Method: An overview about other icy simulant production techniques and reasoning for our method was given in our NESF2022 abstract and poster [1].

Our method is based on the hypothesized homogenous distribution of crystalline ice in PSR regolith [2,3] that exhibits high porosity and low cohesion [4,5]. With our setup, LHS-1 (Lunar Highlands Simulant, developed by Exolith lab, UCF, https://exolithsimulants.com) falls under gravity through a chamber as a mist of water droplets are sprayed onto the simulant grains. Wet LHS-1 grains are then collected in a LN2 filled tray. The LN2 freezes the water adhering on the grains, producing an intimately mixed, granular, ice-rich material. After the LN2 evaporates, a highly porous icy simulant remains.

Updates: With our initial method, simulant properties were difficult to reproduce with equivalent water content consistently. Several reasons were found, and we have improved on most of them. Here each of them is discussed:

Water was condensing on the chamber walls and eventually started to pour inside the liquid nitrogen tray, forming ice chunks. We changed this design by decreasing the size of LN2 container, enabling excess water to be separated from the simulant. Measurements show that over 90% of water sprayed inside the chamber was unnecessary and collected as ice chunks, but now is omitted.

We adjusted the production procedure to address an issue with inconsistent water flow rate. Originally, the simulant and water flow started simultaneously. However, the water flow rate ramps up in the first few seconds leading to inconsistent water/simulant ratios. With the smaller collection tray, it is possible to initiate water flow and wait until the flow rate stabilizes while this initial fraction of water is separated from the tray.

LHS-1 particle size distribution is from >0 to 1000 μm. Smallest particles tend to fill any open space, including the nozzle opening. Nozzles sometimes get clogged, we can clean them in ultrasound cleaner, and we can change them as often as necessary. We haven't observed yet if nozzles can get partially clogged, then they could potentially interfere with results. One way to test this is by measuring the water spray rate often, no significant spray rate discrepancies have been found yet.

The most significant problem was with the LHS-1 simulant flow rate consistency. Originally 500 grams of simulant was filled inside a 20cm wide sieve with 1 mm mesh. It was found that the smallest particles of LHS-1 fall through the sieve in just a few seconds, but the largest particles stay in the sieve for tens of seconds. The flow rate was not constant. We designed a dispenser mechanism, that is opening and closing a funnel with an electrical motor. Now simulant is fed in the sieve at a constant flow rate, and then it continues to fall inside the chamber in a consistent flow. Now, the flow rate can be easily controlled by the electrical motor, hence it is easier to calibrate the machine to the necessary water:simulant ratio of our icy simulant.

Discussion and future work: It has been pointed out in previous discussions, that water might separate from LHS-1 grains upon falling inside the LN2 tray. Similarly, ice spheres are made with SPIPA method, as described in [6] and supplementary info. Our initial hypothesis was that water droplets stick to the surface of the LHS-1 grains. And when wet LHS-1 grains fall inside the LN2, then water frost forms on the top of LHS-1 grains. In effect we have water frost and LHS-1 grains in intimate contact. To test this hypothesis, icy simulant should be observed under the microscope. It is complicated, because fresh icy simulant is in LN2 temperature, around 80K. It works as a cold trap for atmospheric water vapor, that condenses on the simulant instantly after production. For a high fidelity test we need to perform it in dry atmosphere.

After the optimization of the production method, we are going to perform more geophysical tests on our newly made icy simulant to characterize the product. Basic tests like gravimetry and porosity will be measured while calibrating the equipment. We performed angle of repose experiment for our previous icy simulant and compared it with dry LHS-1 angle of repose [1,7]. It was previously pointed out, that this experiment should be repeated with better constrained water content, with fresh LHS-1, and with redried LHS-1.

It was shown in [8] and after discussing with an author that LHS-1 might have particle size distribution changes after freezing it. For conservation reasons we reuse LHS-1 after redrying it. In future we will test if the icy simulant made from fresh LHS-1 is significantly different from one using redried LHS-1.

Figure 1 Lunar icy simulant (~30 wt% H_2O) on a cryogenic plate. Notice surface frost formation from atmospheric humidity.

Conclusions: We have been working on the development of Lunar PSR icy regolith simulant and we have achieved significant progress. The initial production design needed improvements for water content to be more precisely controllable. Icy simulant made with the upgraded design will need to be observed under the microscope to test the hypothesis that ice particles are intimately connected with LHS-1 grains. All the geophysical tests will be repeated on the improved icy simulant. Once the icy simulant production design is improved and repeatable icy simulant can be easily produced in large quantities, then the product should be ready for distribution to other researchers interested in Lunar PSR icy regolith simulant.

References:

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