PARTICLE SIZE DISTRIBUTION INFLUENCE ON ACCESS OF SOLAR WIND TO LUNAR REGOLITH. A. V. Kulchitsky[1], D. M. Hurley[2], J. B. Johnson[1], P. Duvoy[1], M. Zimmerman[2] [1]University of Alaska Fairbanks, Institute of Northern Engineering, P.O. Box 755910-5910, Alaska 755910, USA, anton.kulchitsky@alaska.edu, [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723.

Introduction: Solar wind protons potentially are a source of hydration for the lunar regolith. This occurs because the solar wind impinges uninhibited on the lunar surface when the Moon is in the solar wind. The protons implant themselves ~10 nm into the surface of the regolith grain encountered. The subsequent processes are more poorly quantified, but might include diffusion out of the grain, formation of OH bonds, or the release of H_2O molecules.

Owing to the porosity of regolith on the Moon, the ions have access through pore space to grains that are partially or fully buried. This work quantifies the relationship between regolith particle size distribution and solar wind access.

The Approach: In the previous work [1] we developed a method of using a discrete element method (DEM) model COUPi [2] to study the penetration depth of solar wind protons into the upper level of lunar regolith. We created regolith particle beds of different porosity by gravitational deposition of polyhedrons representing grains. We achieved the porosities in a range from 0.43 to as high as 0.61. The previous work dealt with mono-disperse particle size distributions. In this work we study how particle size distribution (PSD) affects the proton penetration depth.

To study the influence of regolith PSD we used an actual PSD of JSC1a lunar simulant [3]. Fig. 1 shows the log-normal approximation of the distribution by mass in logarithmic scale. We generate particles with sizes distributed within a cut window shown in gray. The window is a symmetrical window in logarithmic scale around the mean value. The cut window can be described by the ratio between the maximum grain size and minimum grain size. We used 1.5x, 2x, 3x, 4x, 5x, and 6x wide windows to study how particle size distribution affects the access of the solar wind.

Using a wider window is computationally too demanding for the DEM model as a difference of six in window size leads to 216 difference in volume between the largest and the smallest possible grain.

There are two issues that emerged during the simulations. First, to make a reasonable comparison between different grain ensembles, one needs to control porosity. Second, the regolith bed created during settlement of DEM particles is uneven and one needs to define the surface topography to determine the distance that a proton travels into the regolith.

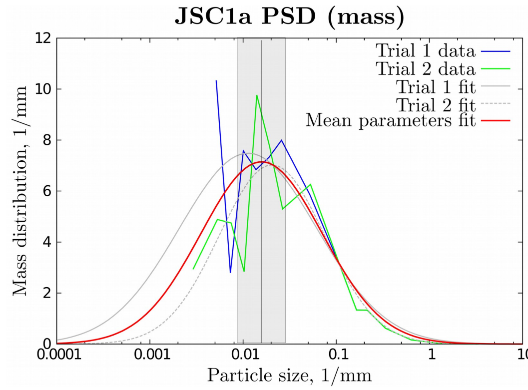

Figure 1 JSC1a Particle size distribution by mass (red) in log scale. Gray area shows a window cut that is used to generate grains particles (gray, semi-transparent) and protons (red) before and after the simulation.

We generated regolith particle beds for different PSDs using different cut window sizes with porosities between 0.52 and 0.53. The zero level for the depth is calculated from an enveloping surface around the grains as shown in Fig. 2.

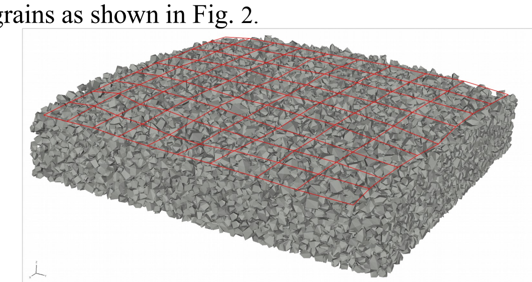

Figure 2 Zero level surface.

After the regolith grains are settled, the protons, represented by point particles of infinitely small size, are generated randomly above the regolith bed. The protons are fired with constant velocity into the regolith. The angle of incidence α is varied to find the dependence of the penetration depth with incidence angle. As soon as a proton hits a regolith particle, it stops. After all protons stop, they are counted and the distribution function of protons is built depending on the depth measured in mean size of the particles. The maximum of the distribution function is assigned to the surface level.

Results: We run a series of cases using solar wind incidence angles (calculated from the normal to the surface) of 0, 15, 30, 45, and 60 degrees. An example of the results is shown in Fig. 3.

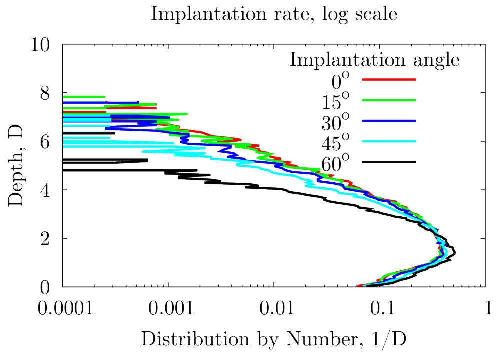

Figure 3 Proton implantation rate depending on incidence angle for 0.52-0.53 porosity and 6x cut window. The depth is measured by mean particle size *D*.

The implantation rate curve shows how many protons can go at the certain depth measured by mean grain size *D*. First solar wind particles hit the top of the upper grains and the maximum number of particles hit at about 1D distance from the surface.

To compare the results we use the depth that 1% of the solar wind protons pass e.g. 1% of all implanted protons go deeper than this depth. The results are summarized in Fig. 4.

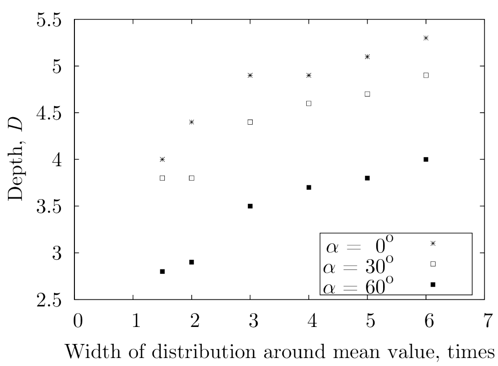

Figure 4 The level passed by 1% of protons during the implantation for different incidence angles and different PSD cut window. The depth is measured by mean particle size D.

Increasing the grain size variation also increases the access of solar wind into the regolith if the porosity of the regolith is the same. Most of the protons travel longer distances around large particles and thus reach larger depth in spite of using a wider PSD cut window, which allows smaller particles into the regolith.

The results show that the protons can travel long distances into the regolith and provide the source of volatiles in its upper layer.

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References:

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