Negative Secondary Ion Sputtering by Solar Wind Energy Ions on Lunar Samples. J. W. Keller[1], D. J. Chornay[1,2], and J. L. McLain[1]. [1]Goddard Space Flight Center, Greenbelt MD, 20771. [2]University of Maryland College Park, MD 20742.

Introduction: The solar wind modifies the surface of the Moon and other solar system objects through implantation of- and sputtering by- energetic ions. Included in the sputtering products are negative ions, which have short lifetimes in space when exposed to solar radiation, but nevertheless provide insight into sputtering processes and open chemical pathways not available to the neutral and positive ion components.

Sputtered products from solar wind impacts contribute to the exospheres of planetary bodies which in turn are connected to the transport of volatiles to regions of long-term stability such as the permanently shaded regions of the Moon or Mercury.

Here we will report preliminary results from time-of-flight (TOF) mass analysis of negative ions sputtered from lunar samples when exposed to ions with solar wind energies.

Background: The solar wind consists of ions and electrons moving outwardly from the sun, with flow velocities ranging from 250 to 750 km/s and averages to ~400 km/s on the ecliptic plane. Its ion composition consists primarily of protons (~95%) and alpha particles (~4 %) and with the heavy ion population (e.g. C, O, Fe) less than 1%, although these ratios can change significantly during solar energetic events such as coronal mass ejections[1]. While dominated by protons, impacts on surfaces at these velocities by protons, and to some extent alphas, compared to heavier ions are fundamentally different with proton sputtering yields less than one compared to heavy ions which sputter multiple atoms. In addition, protons travel more deeply and can imbed into the structure of the surface mineral when this is less likely for heavy ions. Because multiple particles are sputtered by heavy ions, there is an opportunity for chemical reactions to take place in the expanding plume, and this is further enhanced by secondary ions in the plume when long-range coulombic forces come into play.

For positive ions, secondary ion yields are strongly dependent on the first ionization potential of sputtered atoms, while negative ion yields depend on the atom's electron affinity, thus the reactants in subsequent ion molecule chemistry will be significantly different in the case of negative vs. positive ions.

Experiment: An ion beam configured to simulate the solar wind is directed toward samples under ultra-high vacuum, fig. 1. By pulsing the beam to effect sputtering and through phased extraction of the sputtered particles into a reflectron-time-of-flight (RTOF) analyzer, we determine their composition and velocity distribution. We compare ion sputtering yields and velocity distribution from primary ions Ar^+ and H_2^+ from 1 amu to ~100 amu.

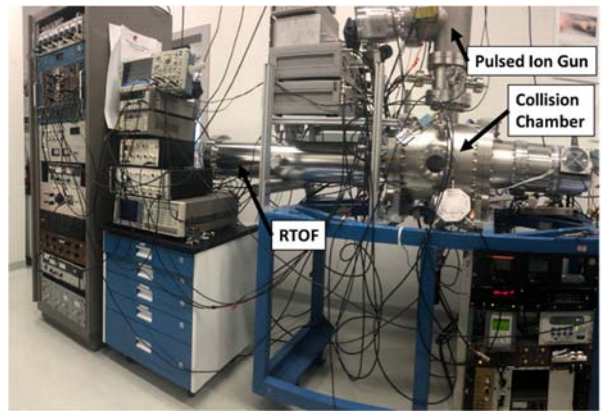

Figure 1 Image of the experimental apparatus

Results: We will report results from measurements of negative ions sputtered from lunar samples for protons, alpha particles at solar wind energies and we will simulate higher mass elements using 4 keV argon ions. In the latter case, the argon beam energy is lower than is typical in the solar wind (e.g. ~16 keV for O^{6+}) but serves to illustrate qualitative differences in sputtering from heavy ions vs light ions. In the latter case we observe evidence of molecular formation in the expanding plume, which may have implications for the formation of water and other volatile compounds on the Moon. This is illustrated in figure 2 where we assign to O_2H^- and O_3H^- to peaks in the heavy ion impactor spectrum, but we stress that these ions likely result from adsorbed water which was not removed from the

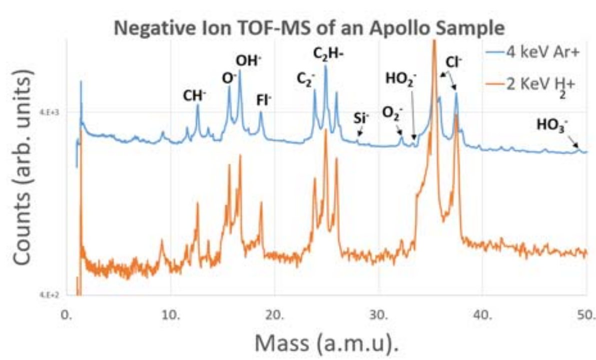

Figure 2 Preliminary RTOF spectra of negative ions sputtered from a lunar sample. For clarity, the Ar^+ sputtered spectrum is elevated above the H^+ spectrum.

sample. In our presentation, we aim to report results from samples that have been heated *in situ* prior to sputtering with most, if not all, water removed.

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References: [1] Ogilvie K. W. and Coplan M. A. (1995) Rev. Geophysics Supl. 615. [2]