A Closer Look at Solar Wind Sputtering of Lunar Surface Materials


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CONTEXT: Solar wind induced potential sputtering of the lunar surface may be a more efficient erosive mechanism than the “standard” kinetic (or physical) sputtering. This is partly based on new but limited laboratory measurements which show marked enhancements in the sputter yields of slow-moving, highly-charged ions impacting oxides.

Lunar surface sputtering yields are important as they affect, estimates of the compositional changes in the lunar surface; its erosion rate, as well as its contribution to the exosphere.

GOALS: The enhancements seen in the laboratory can be orders of magnitude for some surfaces and highly charged incident ions, but seem to depend very sensitively on the properties of the impacted surface in addition to the fluence, energy and charge of the impacting ion. For oxides, potential sputtering yields are markedly enhanced and sputtered species, especially hydrogen and light ions, show marked dependence on both charge and dose.

Potential sputtering data for lunar regolith analogs are nonexistent. Limited data and the rudimentary nature of our understanding of the underlying processes, however, keep the question of the relative importance of potential sputtering an open issue.

APPROACH: To help answer this question, we plan to (1) measure some relevant sputter yields at Oak Ridge National Laboratory’s Multicharged Ion Research Facility (MIRF) using lunar simulant materials, (2) develop a kinetic model to quantify the degree and temporal behavior of the contribution of potential sputtering to solar-wind sputtering of lunar surface materials.

Interactions of the solar-wind ions with lunar regolith

- Protons and multiply charged ions striking amorphous surfaces at 1 keV/amu:
- Surface atoms (in addition to ions, electrons, and photons) are ejected as the solar-wind ions get neutralized in the surface:
- The penetration depth of these ions is ~10 nm, i.e. comparable to the thickness of the rim found on regolith soil grains.
- 80% of ejected (or sputtered) species are neutral atoms with rather wide energy and angular distributions.

Kinetic vs. potential sputtering

Kinetic sputtering is an inelastic microscopic process with kinetic energy transfer to a small number of surface atoms via binary collisions.
- It is the dominant sputtering mechanism for metals and semiconductors, whereas any induced electronic excitation can be rapidly accommodated.
- Insulator surfaces have reduced electron mobility; hence fast electron removal from the target leads to structural modifications.
- This is enhanced for highly charged ions since they “carry” a large amount of “potential energy” given by the sum of the ionization potentials of the ions. This energy is dissipated rapidly through electron transfer and Auger de-excitation processes.
- For many surfaces potential sputtering is significantly more important than kinetic sputtering.

Potential sputtering, in addition to significantly enhanced sputter yield, has some exceptional sensitivities!