SPACE WEATHERING BY HIGHLY CHARGED HEAVY IONS IN THE SOLAR WIND. A. Kracher[1], F. Aumayr[2], D.W.G. Sears[1] and M. Kareev[1], [1]Center for Space and Planetary Sciences, and Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701, [2]Institut für Allgemeine Physik, TU Wien, Wiedner Hauptstrasse 8-10, A-1040 Vienna, Austria.

Introduction: Interaction between the solar wind and surface regolith is the most importent phenomenon of "space weathering" on asteroids. Understanding the nature and magnitude of physical and chemical changes induced by these interactions is hampered by the variability and complex nature of the solar wind.

Sputtering: Kinetic energies of solar wind ions are on average ~1keV/amu (440km/s), which is in the range of highest sputtering efficiency. Sputtering by H^+, which accounts for ~85% of the total kinetic energy ($E_{k,tot}$), is relatively inefficient, so that it is usually assumed that He^{2+} (~13% of $E_{k,tot}$) accounts for most of the observed space weathering effects. Only about 2% of $E_{k,tot}$ is carried by heavy ions ($Z \geq 6$), but spacecraft measurements have shown [1] that these also carry ~1keV each in potential (ionization) energy. For targets with high electron conductivity (metals and semiconductors) the charge state of the impinging ion does not affect the sputtering efficiency. However, for insulating targets considerable additional mass reduction due to "potential sputtering" [2] is observed. Experiments with Ar^{q+} (q=1,3,8,9) and Xe^{q+} (q=9, 14,19,25) ions on SiO_2, Al_2O_3 and MgO targets have shown that at least two different mechanisms are involved [3], termed "defect-mediated desorption" and "kinetically assisted potential sputtering".

Implications for asteroid surfaces: Potential sputtering has mostly been studied at kinetic energies lower than those of solar wind heavy ions. In this regime ionic charges typical of solar wind ions considerably increase the sputtering efficiency over +1 ions. A rough estimate can be obtained by expressing the sputtering yield as a fraction of the dissociation energy of the target (typically 4-6eV/atom). In potential sputtering several percent of the total (potential+kinetic) energy of the incident ion are converted to target dissociation, whereas for kinetic sputtering alone the fraction is closer to 0.1-1%. This makes it likely that heavy ions in the solar wind make a higher contribution to space weathering effects than previously thought. Also, potential sputtering of oxide phases preferentially removes oxygen, which could be a factor in the production of nanophase metallic Fe on the surface of regolith particles.

Some caveats in applying experimental results to the asteroid environment: First, experiments have so far been limited to a few simple oxides, and have not been carried out at solar wind kinetic energies. Second, oxide surfaces prepared in a laboratory tend to be O-enriched, which changes their sputtering characteristics compared to asteroid regoliths exposed to space vacuum.

References:

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