Solar Wind Sputtering Investigations on Planetary Mineral Analogues

P.S. Szabo, H. Biber, N. Jäggi[1], M. Brenner, D. Weichselbaum, M. Wappl, M.V. Moro[2], A. Niggas, R. Stadlmayr, D. Primetzhofer[2], A. Nenning[3], A. Mutzke[4], M. Sauer[5], J. Fleig[3], A. Foelske-Schmitz[5], K. Mezger[6], H. Lammer[7], A. Galli[1], P. Wurz[1], and F. Aumayr

Institute of Applied Physics, TU Wien, 1040 Vienna, Austria
(corresponding author: P.S. Szabo, e-mail: szabo@iap.tuwien.ac.at)

[1] *Physics Institute, University of Bern, 3012 Bern, Switzerland*

[2] *Department of Physics and Astronomy, Uppsala University, Ångströmlaboratoriet, 752 37 Uppsala, Sweden*

[3] *Institute of Chemical Technologies and Analytics, TU Wien, 1060 Vienna, Austria*

[4] *Max Planck Institute for Plasma Physics (IPP), 17491 Greifswald, Germany*

[5] *Analytical Instrumentation Center, TU Wien, 1060 Vienna, Austria*

[6] *Institute of Geological Sciences, University of Bern, 3012 Bern, Switzerland*

[7] *Space Research Institute, Austrian Academy of Sciences, 8042 Graz, Austria*

Planets, moons and asteroids that are not protected by a significant atmosphere are strongly exposed to the so-called space weathering effects. Here sputtering by solar wind ions plays an important role [1]. Together with electron-stimulated desorption, UV photon-stimulated desorption and micrometeorite impacts, it affects the surfaces of rocky bodies severely [2]. Their optical properties are changed and surface atoms are emitted to form a thin atmosphere, a so-called exosphere [3]. Understanding both these effects is of great interest for remote investigations in planetary science. Spectroscopy of the light reflected at the surface as well as analyzing the exosphere's composition allow probing the surfaces of planets and moons without performing an expensive spacecraft landing. Exosphere analysis, for example, is an important scientific goal for ESA's BepiColombo mission, which has recently launched to Mercury.

In order to correctly interpret remote analysis results, laboratory experiments with analogue minerals are essential. Especially for solar wind sputtering, knowledge of the occurring effects is still lacking and sputtering estimations mostly rely on TRIM simulations [4]. For example, changes in the surface composition resulting from preferential sputtering or effects that go beyond the kinetic sputtering from the ion-induced collision cascade need to be better understood.

For this reason, we have investigated sputtering of the pyroxene minerals wollastonite $CaSiO_3$ and augite (Ca, Mn, Fe)SiO_3, which are expected to make up a large part of the surfaces of Moon and Mercury [5]. Thin films of these materials were deposited on Quartz Crystal Microbalances (QCM) to allow in-situ real time sputtering yield measurements [6]. These targets were irradiated with different ion species at energies corresponding to 1 keV/amu representative for the solar wind, which contains about 96% H^+, 4% He^{2+} and minor contributions from heavier multiply charged ions [7].

Kinetic sputtering yields were measured for different ions at varying energies. Based on these findings adapted input parameters for simulations with the software SDTrimSP were defined [8], which consistently reproduce measured sputtering yields. Potential sputtering, which enhances the erosion of insulating surfaces by multiply charged ions, was especially investigated for He^{2+} and Ar^{q+} ($q \leq 8$). Linearly increasing sputtering yields with potential energy as well as strong decreases with ion doses were found. The latter effect could be connected to a preferential O depletion from potential sputtering by modelling the surface composition changes [9].

Based on these findings, the total effect of solar wind sputtering on pyroxene minerals was estimated. Due to the small H^+ sputtering yields, He^{2+} becomes more important. Especially its potential sputtering contribution will cause more release into the exosphere as well as significantly reducing the surface O content. These results agree with previous models (see for example [10, 11]), which gives a consistent view on solar wind sputtering effects from laboratory experiments to model predictions.

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