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Experimental and simulated solar wind sputtering of lunar analogue material

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Rocky bodies such as planets, moons or asteroids that do not possess a thick atmosphere are exposed to a wide variety of influences from outer space. Micrometeorite impacts, desorption processes, and ion sputtering change optical characteristics of the surface and cause the release of particles from the surface [1]. Emitted atoms form a thin exosphere around these celestial bodies that can be investigated by a spacecraft to gain information about the original surface composition [2]. This will be, for example, an important aspect of the upcoming BepiColombo mission of ESA to Mercury. The analysis of the exosphere is based on modelling its formation, which requires a fundamental understanding of all the occurring release processes. Sputtering by solar wind ions is a very important process for the emission of refractory elements [3], but experimental investigations on relevant materials are scarce. For this reason, exosphere modelling mostly relies on results of TRIM simulations [4]. However, TRIM does not include all effects that occur during solar wind sputtering.

Therefore, the sputtering of Wollastonite ($CaSiO_3$) as a lunar analogue material is investigated using the quartz crystal microbalance (QCM) technique [5]. Wollastonite is similar to the minerals of the pyroxene group that occur in many lunar rocks. Thin layers of this material were deposited on QCMs using pulsed laser deposition (PLD) and then irradiated with an ion beam. Sputtering yields were obtained under the bombardment with H and multiply charged Ar ions under different angles of incidence and at different kinetic energies. The experimental results are compared to numerical simulations with SDTrimSP and TRIM from the SRIM-2013 package [4, 6]. The simulations show that SDTrimSP is very well suited to describe kinetic sputtering, where the ions charge and chemical reactions do not have to be taken into account. However, the sputtering by multiply charged ions is significantly increased by potential sputtering [7]. On the other hand, experimentally determined sputtering yields by protons, which make up most of the solar wind, are lower than in the simulations as they do not include implantation effects. Based on these experiments, a complete model for solar wind sputtering of Wollastonite is developed that shows the significance of heavy ion sputtering. Furthermore, a very pronounced angular dependence of the sputtering yield can be found, which is important for future investigations of more realistic rough surfaces.

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