

## SOLAR ION PROCESSING OF MAJOR ELEMENT SURFACE COMPOSITIONS OF MATURE MARE SOILS: INSIGHTS FROM COMBINED XPS AND ANALYTICAL TEM OBSERVATIONS.

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**Introduction:** Solar wind ions are capable of altering the surface chemistry of the lunar regolith by a number of mechanisms including preferential sputtering, radiation-enhanced diffusion and sputter erosion of space weathered surfaces containing pre-existing compositional profiles. We have previously reported in-situ ion irradiation experiments supported by X-ray photoelectron spectroscopy (XPS) and analytical TEM that show how solar ions potentially drive Fe and Ti reduction at the monolayer scale as well as the 10-100 nm depth scale in lunar soils [1]. Here we report experimental data on the effect of ion irradiation on the major element surface composition in a mature mare soil.

**Methods:** Using XPS supported by in-situ ion irradiation with 4 keV Ar<sup>+</sup> and He<sup>+</sup> ions, we measured changes in the major element surface chemistry of mature mare soil 10084 as a function of incremental ion fluence. The approach differed significantly from Apollo-era XPS studies [2] in that we also performed supporting irradiation of pristine lunar minerals, with follow up TEM analysis, to calibrate the fluences at which key changes such as amorphization, or chemical alteration by preferential sputtering, would be expected to occur in the sample.

**Results.** During in-situ ion irradiation the major element atomic ratios O/Si, O/Fe, Al/Si, Mg/Si, Ti/Si, Ca/Al, and Mg/Al all increase, while Fe/Ti and Fe/Si decrease. The changes become most notable at Ar<sup>+</sup> fluences above the 10<sup>15</sup> ions/cm<sup>2</sup> range, which is higher than the threshold for plagioclase and pyroxene amorphization and the fluence where we have shown surface reduction of Fe to the metallic state becomes complete [1]. The element ratio trends with ion fluence were evaluated with respect to two models, one based on preferential sputtering of an average 10084 surface composition that was homogeneous with depth, and the other based on sputter erosion of a model compositional profile based on analytical TEM studies of space weathered grain rims in mature mare soils [3]. Although most of the element ratios vary with fluence in a manner consistent with their relative sputtering yields modeled by SRIM [4], the O/Si, O/Fe and Al/Ti ratios trend opposite to expectations based on a preferential sputtering model. These anomalous trends, as well as those for the other elements, are alternatively consistent with what should occur if the Si-, Fe-rich and O-poor outer portions of grain rims are progressively removed by sputter erosion. Given the thickness of these outer rim layers [3], the average total sputtering yield for the 10084 sample would have to be ~6X higher than values currently known for 4 keV Ar<sup>+</sup> in crystalline silicates. Such an increase is not, however, inconsistent with sputtering yield variations with angle occurring in a granular sample.

**References:** [1] Christoffersen, R. et al. 2010. 73<sup>rd</sup> Meteoritical Society Annual Meeting, #5379. [2] Housley, R.M. and Grant, R.W. 1975, Proc. 6<sup>th</sup> Lunar Sci. Conf., p. 3269. [3] Keller, L. P. and McKay, D. S. 1997. *Geochim. Cosmo. Acta* 61:2331. [4] Ziegler J. F. et al. 2008. *SRIM—The stopping and range of ions in matter*. Lulu Press. 250 p.