

**ON THE SIMULATION OF ADSORBED WATER ON THE MOON.** Raúl A. Baragiola and Catherine A. Dukes, University of Virginia, Laboratory for Atomic and Surface Physics, Thornton Hall, Charlottesville, VA 22904. E-mails: raul@virginia.edu, cdukes@virginia.edu.

**Introduction:** Water can be formed by combining implanted solar wind protons with oxygen in lunar soil. The question of how *likely* this effect is was renewed by recent observations of  $\sim 3$   $\mu\text{m}$  structure in infrared spectra of three different spacecraft [1-3]. The fact that such structures were not observed by previous studies using Galileo and Clementine [4] remains unexplained.

**Recent experiments:** In our laboratory, careful *in situ* studies of proton irradiation of minerals [5] found no evidence for the amounts of water required to explain the 2009 reports. Baragiola and Dukes [6] suggested that the origin of global surface water could be ejecta from the ice in polar cold traps evidenced by LCROSS [7]. Water molecules released by meteoritic or ionic impact, or thermal desorption, will hop across the lunar surface by surface-exosphere diffusion assisted by photodesorption and sputtering, in a non-random walk affected by temperature and solar exposure. A similar idea was advanced independently by Farrell et al [8]. In addition, surface water may originate from sub-surface water deposited by accumulated cometary impacts [6, 9].

**Notes on laboratory simulations:** There are many differences between laboratory mineral or rock samples and lunar soil, the question is which ones are relevant to the processes of water formation and retention. A very important property of lunar soil is that grain have been denatured by solar wind irradiation in a surface region corresponding to the depth of penetration, transforming the samples into amorphous glasses with significant oxygen depletion and formation of nanoscopic metallic Fe [10]. This occurs on lunar rocks and grains, producing amorphous surface layers with different composition from that of the underlying soil.

To mimic mature lunar soil in the laboratory, the best samples are those containing mafic silicates that have been heavily irradiated with solar wind ions [6]. Alternatively, it is possible to coat the surface with vapor from laser ablation of minerals, to simulate deposits produced by ejecta of meteorite bombardment. Loeffler et al [11] have shown that coatings from laser ablation of olivine are amorphous and contain metallic iron nanoparticles.

Both the oxygen deficit and the presence of metallic iron can affect water formation and retention. Lunar soil is moderately porous ( $\text{m}^2/\text{g}$ ), and this can cause two main effects: (i) reduce sputtering yield by 30-70% due to redeposition of ejecta, and (ii) increase the area available for adsorption and of volatiles.

**Returned samples and lunar simulants:** Artificial lunar simulants are designed to reproduce bulk properties but they should not be used when the fidelity to surface properties is important. That is the case for several surface sensitive processes such as water adsorption, electrostatic charging, desorption and sputtering, where the state of the topmost monolayer is crucial. Even the best simulant will have its surface contaminated by exposure to laboratory air, which deposits hydrocarbons and water, and possibly other tightly bound molecules. Such molecules cannot typically be removed by heating alone, at least without at the same time radically altering the sample. Gentle exposure to low energy plasmas can efficiently remove contaminants [12]. More energetic protons and helium ions can clean the surface but also alter it by amorphization, ion implantation and preferential sputtering.

The alternative to use directly lunar soil is not without caveats. Although actual lunar grains have been processed by the solar wind, exposure to atmospheric contaminants will produce drastic changes in surface chemistry. Exposure to water even in 'dry' environments is likely sufficient to partially replenish the surface oxygen. In addition, water reacts with radiation damaged surfaces, altering surface composition, as seen in the exceptionally fast depletion of Mg from irradiated olivine after immersion in water, or even after exposure to atmospheric humidity [13]. Strong cation depletion has recently been observed in simulations of space weathering in forsterite, augite, albite and anorthoclase [14].

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#### References:

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