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VAPOR DEPOSITION OF ICY LUNAR REGOLITH USING THE SWINBURNE DUSTY THERMAL VACUUM CHAMBER

Abstract

Deposits of frozen volatiles, namely water-ice, have been identified within the permanently shadowed regions (PSRs) at the lunar poles. This icy extraterrestrial soil— called icy lunar regolith—is a critical resource that could be harvested to sustain human presence on the Moon and in deep space. What has yet to be determined, is the physical texture or polymorphic structure of these icy deposits. In an attempt to simulate icy lunar regolith, a variety of different preparation techniques have been used resulting in regolith simulants with markedly different physical properties ranging from hard concrete to weak snow. Depending on which simulant is used, various experimental conclusions can be made, with possibly deleterious consequences if flight hardware is tested using inaccurate material prior to deployment to the Moon.

To address this knowledge gap, this study investigated the formation of water-ice under approximated PSR conditions using a dusty thermal vacuum chamber built at the Swinburne University of Technology, in Australia. The objectives of this work were to achieve the desublimation of atmospheric water vapor within a granular material in the absence of water's liquid phase and therefore replicate the ice formation conditions within lunar PSRs – thereby creating a high fidelity icy lunar regolith simulant. Auxiliary objectives included generating a strong vertical thermal gradient on the order of 11 C/cm, and the ability to prepare undisturbed samples ready for analysis using X-ray micro-computed tomography (Micro-CT) and cone penetrations testing (CPT). The equipment, procedures, and results of these experiments using the chamber are presented.

Desublimation of water was carried out using spherical 500 μm soda-lime glass beads and lunar highlands regolith simulant (LHS-1). After desublimation, the physical texture of intergranular ice was studied using a digital microscope. For glass beads, ice formed several cryostructures including classical ice-necks between two spherical grains, tendril-like ice connecting distal grains, and saddle-like ice connecting two grains along the concave transverse of adjacent spherical beads. Vapor deposition into LHS-1 did not form a surface frost or easily observable macroscopic structures. This was likely due to the formation of an ice lens beneath the surface and LHS-1 having mean particle size of only 81 μm, making visibility using

digital microscopy difficult. All objectives were achieved. The findings of this work can also be applied to preparing analogue materials which better simulate icy regolith on airless or near-airless bodies like the Moon, including Mercury, Mars, and comets