TOPOGRAPHICAL MODIFICATION OF MATERIALS FOR LUNAR DUST ADHESION MITIGATION.

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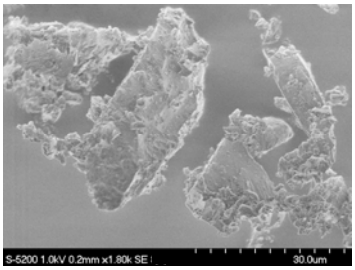
Introduction: Lunar dust possesses many characteristics that not only differ from terrestrial dust, but also introduce obstacles critical to lunar mission success. In a lunar environment, the absence of wind, flowing water, and a protective atmosphere inhibit the smoothing of rough surface features while also allowing micrometeorite penetration. Combined, these factors result in particles with high porosity and surface roughness, high chemical reactivity, and magnetic properties due to the presence of nano-scaled elemental iron deposits. This coupled with the insulating nature of lunar soils and the electrodynamic processes [1] in the lunar environment results in lunar dust particles with a propensity to adhere to exposed surfaces. Lunar dust can clog gears and prevent seals from working properly. Further, radiator surfaces and solar cells will have reduced efficacy due to surface adhesion of lunar dust. Health factors also arise due to the plausibility of lunar dust impacting the respiratory and ocular health of lunar inhabitants. Harrison Schmitt complained of respiratory distress during the Apollo 17 mission and lunar dust was difficult to eliminate from the lunar lander during several Apollo missions.

Figure 1. The irregular shapes and jagged edges displayed in this SEM picture of lunar dust simulant particles are representative of actual lunar dust.



The adhesion mechanism of lunar dust has been theorized to depend upon separation distance.[2, 3] At large separations, lunar dust particles are attracted to surfaces due to electrostatic interactions. However, at distances less than 10 nm, Van der Waals forces dominate. These effects along with the potential for acid-base interactions and physical processes (i.e., mechanical interlocking) present a formidable challenge to identify materials that would be resistant to lunar dust adhesion. There are currently no known materials that exhibit intrinsic dust resistance. While active dust mitigation systems (i.e., electrodynamic dust screens, etc.) [4] have shown great promise towards alleviating lunar dust accumulation, they suffer from incomplete surface cleaning and the requirement of additional resources for operation (e.g. electrical current). Therefore, materials modifications have been pursued to address this deficiency.

Approach: Two approaches will be discussed regarding the modification of polyimide materials. Both involve the introduction of surface topography using techniques and materials that result in either low or high fidelity surface topographies. It was thought that introducing surface topography could reduce available surface area for the adhesion of impinging lunar dust. .

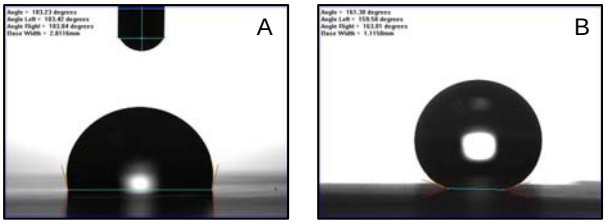
The first approach involves the introduction of polyhedral oligomeric silsesquioxane (POSS) molecules onto a polyimide surface via spray-deposition from an organic solution. Initial results indicated that surface activation by exposure to oxygen plasma aided in increased uniformity of POSS deposition. The resultant topography reduced the surface energy as indicated by water contact angle measurements.[5] However, the topographical features were not consistent across the surface or uniformly reproducible. In fact, further exposure to oxygen plasma resulted in degradation of the underlying polyimide surface. Although the erosion rate appeared to be reduced relative to the native polyimide surface, the POSS surface coating did not introduce atomic oxygen resistance, a property that has recently been ascribed to polyimide materials with incorporated POSS molecules.[6] To achieve greater uniformity, the polyimide substrates were heated during the deposition process (hot-plate POSS deposition) reducing the evaporation time of the organic solvent. The resulting surfaces exhibited different topographies and a further reduction in surface energy as indicated by water contact angle measurements compared to surfaces generated without a heated substrate.

The second approach utilizes laser ablation to modify the topography of polyimide substrates in a controlled fashion.[7] Unlike POSS deposition, surface modification via laser ablation generates repeatable surface structures with little deviation in dimensionality from one topographical feature to the next as well as overall reproducibility. Furthermore, the topography is generated from the substrate material eliminating interfacial interaction concerns. Surface features were controllably altered by changing parameters of

the laser ablation system and the effect on surface energy was determined using contact angle measurements. Variation of substrate chemical composition also changed contact angle and sliding angle values. At optimal ablation conditions, surfaces were generated that exhibited superhydrophobicity (water contact angles > 150°). Correlations were drawn between "pristine" and laser ablated polyimide substrate surface properties.

Figure 2. Optical photomicrograph (A) of a hot-plate POSS deposited polyimide surface [500X magnification] and images of water contact angles before (B) and after (C) hot-plate POSS deposition.

Figure 3. Sessile drop water contact angle measurement images for a polyimide substrate before (A) and after (B) laser ablation.



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