DEVELOPMENT OF MATERIALS AND EVALUATION METHODS CONCERNING LUNAR DUST ADHESION.

Christopher J. Wohl,[1] Yi Lin,[1] Marcus A. Belcher,[1] Brad M. Atkins,[2] and John W. Connell,[3] [1]National Institute of Aerospace, 100 Exploration Way, Hampton, VA 23666, christopher.j.wohl@nasa.gov, [2]Langley Aerospace Research Summer Scholars Program, NASA Langley Research Center, MS 226, Hampton, VA 23681, [3]NASA Langley Research Center, MS 226, Hampton, VA 23681.

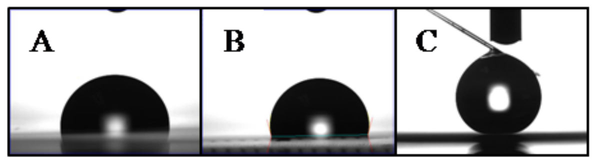
Introduction: Extended lunar surface exploration missions will present many challenges the Apollo astronauts did not face. Although the Apollo astronauts experienced unforeseen difficulties resulting from exposure to lunar dust (seal compromise, visor and space suit abrasion, lunar rover impedance, respiratory difficulty, etc.),[1] the lunar dust problem was not directly addressed due to the brief lunar surface exposure. For future missions, with surface habitation timelines of weeks and longer, the impact from lunar dust will be much more significant.

Micrometeorite impacts and comminution, among other processes, have generated highly porous, abrasive lunar dust particles with a broad size distribution extending down to sub-micrometers. Exposure to solar radiation and other high energy particles electrostatically charges the lunar dust. Likewise, the presence of nanophase elemental iron introduces magnetic properties.[2] Combined, these properties engender the lunar dust with the capability to adhere to any exposed surfaces.[3] Adhesive interactions can arise from several different intermolecular forces, thus requiring mitigation strategies that encompass a broad approach. To that end, generation and modification of low surface energy materials were investigated as a passive means to reduce the intrinsic adhesive interactions with lunar dust simulant (NASA/USGS Lunar Highland simulant, maximum particle diameter < 30 μm). Similarly, analytical techniques to quantify the adhesion of lunar dust simulant have been surveyed and developed.

Materials for Particulate Abhesion: Low surface energy materials have been generated by changing the surface chemical composition and introducing topographical features.[4] Polyimide copolymers possessing a surface modifying agent (**SMA**) were synthesized. SMAs are thermodynamically driven to the surface due to unfavorable interactions with the polymer matrix enabling the surface chemistry to be controllably altered.

Topographical modifications were investigated using several methods including laser ablation patterning, photolithography, and templating techniques. These techniques have been used to generate surface features on a micrometer scale and have resulted in superhydrophobic surfaces.

Figure 1. Reduction in surface energy of the material progressing from polyimide (A) to polyimide copolymer (B) to laser ablation patterned copolymer (C) as evidenced by the increase in advancing water contact angle.



Lunar Simulant Adhesion Testing: The efficacy of the modified surfaces could not be evaluated due to the lack of an existing technique to quantify lunar dust simulant adhesion properties. In fact, no quantitative adhesion force information regarding either actual lunar dust or lunar dust simulant on any surface exists. Therefore, several techniques were investigated to develop lunar dust simulant adhesion testing procedures. Atomic force microscopy (AFM) and a sonic wand adhesion testing device were selected for this purpose.

Adhesion force testing using AFM is well-known and has been applied to characterize a variety of interfacial interactions. To investigate adhesive interactions with lunar dust simulant, AFM cantilever tips have been modified by the attachment of simulant particles. Materials that exhibit minimal adhesion force values determined with the modified AFM cantilevers are anticipated to exhibit resistance to lunar dust adhesion in a lunar environment.

Additionally, a particulate adhesion testing device was generated employing a sonic wand and an optical particle counter. The device is modeled after a similar instrument described in the work of Mullins et al.[5] To conduct an adhesion experiment, a sample is coated with a monolayer of lunar dust simulant and attached to the tip of the sonic wand, which is placed above the opening of an optical particle counter. By changing sonic wand power amplitude, the surface acceleration experienced by the attached sample is altered. Once this acceleration force supersedes the adhesion force, the particle detaches from the sample surface and is detected by the optical particle counter. After the sonication study is completed, the sample is then examined using optical microscopy to determine the remaining particle size and count on the surface. This information provides a minimal adhesion force for the remaining particles. Initial studies have indicated that the introduction of SMAs into the polyimide matrix lowers the remaining particle count after the sonication study (Table 1). The count and size of remaining particles is dramatically reduced after topographical modification, such as laser ablation patterning.

Figure 2. Schematic of the sonic wand adhesion testing device. The instrument is housed in a vacuum chamber.

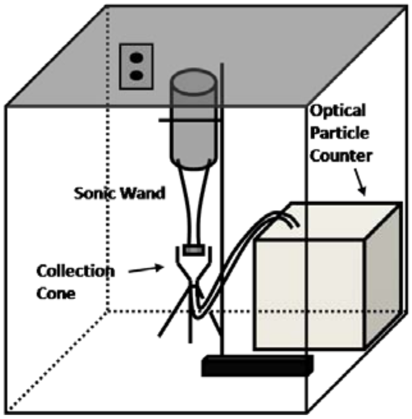


Table 1. Preliminary adhesion testing results for surfaces tested with the sonic wand adhesion testing device.

Sample	Adhesion Force, nN	Particle Count
Polyimide	156	~ 380
Polyimide Copolymer	111	~ 250
Laser Patterned Polyimide Copolymer	10 - 68	1 - 2

Correlation can be drawn between reduction in surface energy, as determined by water contact angle values, and the adhesion strength of lunar dust simulant. Results will be presented concerning low surface energy materials generation and performance in preliminary adhesion studies.

References: [1]Taylor, L., Schmitt, H., Carrier, W. D., Nakagawa, M. (2005) 1st Space Exploration Conference: Continuing the Voyage of Discovery.
[2]Taylor, L., Meek, T. (2005) *J. Aerospace Eng.*, *18(3)*, pp. 188 - 196.
[3]Walton, O. (2007), Vol. NASA/CR-214685.
[4]Wohl, C. J., Belcher, M. A., Chen, L., Connell, J. W., manuscript in preparation.
[5]Mullins, M., Micheals, L., Menon, V., Locke, B., Ranade, M. (1992) *Aerosol Sci. Technol.*, *17*, pp. 105 - 118.