LOW SURFACE ENERGY MATERIALS FOR LUNAR DUST ADHESION MITIGATION. C. J. Wohl[1], V. L. Wiesner[2], G. C. King[2], J. W. Connell[2], S. K. Miller[3], [1]NASA Langley Research Center, 6 West Taylor St., MS 226, Hampton, VA 23681 c.j.wohl@nasa.gov, [2]NASA Langley Research Center, Hampton, VA 23681, [3]NASA Glenn Research Center, Cleveland, OH 44135.

Introduction: A return to the Lunar surface will present an array of familiar and new challenges, especially when considering mission planning and requisite technologies to support an extended or even sustained presence. Many of these challenges will involve Lunar dust interactions and the broadly recognized need to identify and develop materials and strategies to mitigate Lunar dust adhesion and contamination [1].

The most straightforward way to determine the efficacy of a candidate material to perform according to application requirements is to evaluate it in the application environment. The Materials International Space Station Experiment (MISSE) has been utilized to provide a platform for environmental exposure of candidate materials and technologies to a Low Earth Orbit (LEO) environment [2]. Support of a sustained Lunar presence would benefit considerably from a similar experimental platform present on the Lunar surface. NASA's Lunar Surface Innovation Initiative (LSII) is supporting the Patch Plate Materials Compatibility Assessment project to enable evaluation of prospective materials and sensor technologies in a Lunar environment. This experiment will likely be flown on a Commercial Lunar Payload Services (CLPS) mission to enable rapid deployment.

In this paper materials generation and modification efforts to be investigated for Lunar dust simulant adhesion mitigation at NASA Langley Research Center (LaRC) will be discussed. Three broad classes of materials will be pursued including polymeric, metallic, and ceramic matrices. Combined with textiles, superhydrophobic, and work function-matched materials at other NASA centers, a broad suite of materials will be evaluated on this flight experiment and will yield meaningful results across a comprehensive range of exploration applications.

Polymeric Materials: Development of materials toward minimization of adhesion interactions largely draws upon turning two dials; surface chemical and topographical change. Work has been conducted along both of these lines at LaRC involving predominantly polyimide materials [3-5]. This polymer class was chosen due to the extensive space heritage of these materials as well as promising chemical, mechanical, and thermal properties. The surface chemistry of these materials was controllably altered by incorporation of surface modifying agents (typically oligomeric species containing either fluorine or siloxane moieties), which are thermodynamically drawn to the polymer surface (Figure 1). A series of polyimide siloxanes and polyimide alkyl ethers were prepared and characterized for adhesion interactions with a Lunar dust simulant. Results from these studies indicated that consideration of changes in both surface chemistry and surface mechanical properties play a role in the material performance regarding Lunar dust simulant adhesion mitigation. Topographical modification, via laser ablation patterning resulting in improved performance, has been demonstrated on polymeric substrates and will be described in greater detail in the next section.

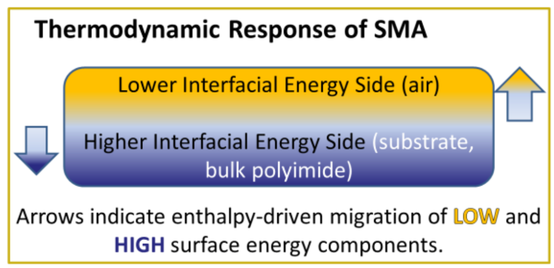

Figure 1. Surface modifying agents are thermodynamically drawn to a surface due to more favorable interactions at the air interface relative to the material matrix.

Surface Engineered Metallics: Laser ablation patterning has been shown to enable relatively facile control of the resultant topographies on a number of different types of materials, including metallic surfaces [3]. Several metallic substrates including aluminum, titanium, and stainless steel alloys have been topographically modified using an array of patterns, laser fluence intensities, and duty cycles (i.e., the portion of the surface that is exposed to direct laser irradiation with a duty cycle of 100% indicating complete coverage) [6]. Variation in a single parameter can have significant influence on several topographical features. As shown in Figure 2, by changing pulse energy while keeping the remaining laser parameters constant, the resultant topographies on Al 2024 T3 surfaces exhibited differences in feature size, feature shape, and the density and morphology of the debris field created as a result of deposition of ejecta material arising from the initial ablation process.

The primary length scale of controllable surface features through direct-write laser ablation patterning is several micrometers due to the beam spot size, among other contributing factors. Hierarchical topographies will be created by leveraging Laser-Induced Periodic

Surface Structures (LIPSS). In this process an interference pattern is believed to be present at the time of laser irradiation resulting in formation of rippled structures with a periodicity at shorter length scales than the irradiation wavelength [7].

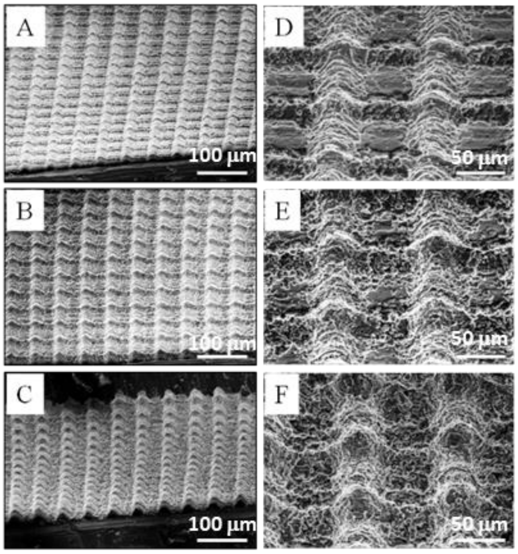

Figure 2. Scanning electron microscope images of aluminum alloy 1100 laser ablation cross-hatch patterned surfaces exposed to 40 µJ/pulse (A and D), 65 µJ/pulse (B and E), and 99 µJ/pulse (C and F) with a line spacing of 50.8 µm.

Ceramics Materials: A number of ceramic systems have been identified in literature as candidate materials and coatings that may discourage lunar dust adhesion while providing enhanced durability due to superior wear properties in comparison with traditional polymeric and metal-based materials [8]. However, ceramics have largely remained unexplored regarding their utility for lunar dust adhesion. In order to down-select promising ceramics for application in the Lunar Surface Patch Plate experiment, ceramic powders, including oxide-based ceramics, will be prepared into discs by cold pressing and then densified by conventional sintering methods. The subsequent discs will be evaluated for lunar dust adhesion using the ultrasonic particle detachment instrument described below. In addition to lunar dust adhesion behavior, microstructure and composition of densified specimens will be characterized via Archimedes density, scanning electron microscopy and X-ray diffraction analysis. Promising ceramic materials will be prepared for further evaluation and potentially topographical modification using laser ablation patterning.

Material Efficacy Evaluation: Evaluation of candidate materials for Lunar dust simulant adhesion mitigation efficacy requires evaluation and down-select of materials on Earth. Evaluation techniques of increasing complexity will be utilized for this purpose. An ultrasonic particle detachment experiment, described below, will be the first approach utilized for materials testing at NASA LaRC [9]. Candidate materials will then be sent for evaluation in the NASA Glenn Lunar Dust Adhesion Bell Jar followed by other atmospheric exposure testing prior to being approved to be flown on the patch plate experiment.

Ultrasonic particle detachment. Ultrasonic agitation of a particulate contaminated surface is utilized to cause particle dislodgement. A force-balance diagram is shown below (Figure 3). For this technique, contaminant particles are aerosolized and allowed to settle on the surface of interest. Dislodged particles are detected using an optical particle counter and the efficacy of a test surface is determined by calculating the force required to remove 50% of the contaminant particles.

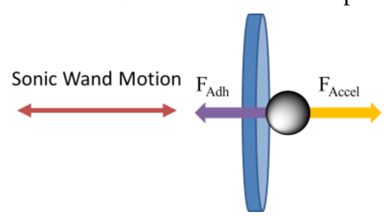

Figure 3. Displacement of the material affixed to the sonic wand tip will impart an acceleration force. Once this force exceeds the adhesion force, the particle will detach from the surface.

Outlook: Collectively, the materials described here represent a subset of all of the material types of interest for inclusion on the Lunar Surface Patch Plate Experiment. Other material types include bulk metallic glass, seal materials, textiles, etc. It is envisioned that many different material types will be represented on the Patch Plate Experiment to ensure that the greatest breadth of application space is considered.

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