Material Adhesion/Abrasion Detection (MAD) Experiment on the Rashid Rover 2 Lunar Mission

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Abstract

The Material Adhesion/Abrasion Detection (MAD) experiment, scheduled for deployment on the Rashid Rover 2 lunar mission, aims to evaluate the performance of novel nano-material coatings in mitigating lunar regolith adhesion. This study investigates four different surface treatments on aluminum substrates: FeCu, TiO_2, Graphene, and an uncoated control. The coated samples will be mounted on the rover's wheel, allowing for real-time observation of their interaction with lunar dust. Through continuous imaging and subsequent analysis, this experiment seeks to quantify the effectiveness of each coating in repelling regolith particles. The results of this study have significant implications for the design and longevity of future lunar exploration equipment, potentially leading to more efficient and durable technologies for sustained lunar presence.

Introduction

The Material Adhesion/Abrasion Detection (MAD) experiment is a cutting-edge investigation scheduled to be conducted onboard the Rashid Rover 2, set to land on the Moon. This experiment aims to evaluate the performance of various nano-material coatings in repelling lunar regolith, a critical factor in the longevity and efficiency of lunar exploration equipment. The MAD experiment will utilize four aluminum substrate strips coated with different nano-materials: FeCu, TiO_2, Graphene, and a control sample. The size of each sample in 20x40 mm. These samples will be mounted on the rover's wheel surface, allowing for real-time observation of their interaction with the lunar environment.

The Rashid Rover 2 mission represents a significant step forward in the United Arab Emirates' space exploration program. By integrating the MAD experiment into this mission, researchers seek to gather crucial data on material behavior in the lunar environment, potentially informing future design choices for lunar vehicles and equipment.

Literature Review

Lunar regolith, the layer of unconsolidated rocky material covering the Moon's surface, poses significant challenges to lunar exploration efforts. Its unique properties, particularly its adhesive nature, have been a subject of study since the Apollo missions.

Lunar dust, a component of regolith, is exceptionally fine-grained and abrasive. Gaier (2005) reported that lunar dust particles are typically 50-70 μm in diameter, with some as small as 10 nm. These particles are formed by micrometeorite impacts, which result in jagged, sharp-edged grains with high surface energy. This combination of properties makes lunar dust highly adhesive and potentially damaging to equipment.

The damaging effects of lunar dust on instruments and equipment have been well-documented. Kobrick et al. (2010) conducted experiments simulating lunar dust exposure and found significant abrasion on various materials, including spacesuit fabrics and metallic surfaces. This abrasion can lead to degradation of optical surfaces, clogging of mechanical components, and overheating due to changes in thermal properties.

Addressing these challenges, researchers have explored various coating technologies. Berkebile and Gaier (2012) investigated the effectiveness of work function matching coatings in reducing dust adhesion. Their findings suggested that certain coatings could significantly reduce the adhesion of lunar simulant particles.

The MAD experiment builds upon this body of research, aiming to evaluate the performance of novel nano-material coatings in the actual lunar environment, providing valuable data for future lunar exploration technologies.

Methodology

Material Preparation and Synthesis

The MAD experiment utilizes four aluminum substrate strips, each coated with a different nanomaterial. Figure 1 will showcase all samples after preparation with their mass:

1. FeCu Coating: A novel iron-copper nanocomposite will be synthesized using a ball milling process of copper and iron powder on the aluminum substrate.

Figure 1: FeCu Ball Milling

2. TiO2 Coating: Titanium dioxide nanoparticles will be synthesized using griding titatium with a surfactant. The nanoparticles will be annealed to achieve the desired crystalline phase before being incorporated into a coating formulation.

Figure 2: TiO2 Annealing

3. Graphene Coating: Graphene will be produced using ball milling graphite on the aluminum substrate

Figure 3: Graphene Ball Milling

4. Control Sample: An uncoated aluminum strip will serve as the control.

Figure 4: samples lined up after coating showing their mass, left to right: FeCu, Tio2, Graphene, Control

Each coating will be applied to the aluminum substrates ensuring a uniform coverage. The coated samples will undergo thermal and ultrasonic sonication curing to enhance adhesion and durability. The thickness, deposition and uniformity of each coating will be verified using a Raman spectroscopy shown in Figure 2.

Figure 5: Raman spectroscope

All samples will be securely attached to the wheel surface of the Rashid Rover 2 using epoxy PR100, ensuring they remain in place throughout the mission while allowing for clear visibility for imaging purposes.

Experimental Procedure

The MAD experiment will be conducted in the following stages:

1. Pre-mission Imaging: High-resolution images of each sample will be taken before the rover leaves the landing module. These images will serve as a baseline for comparison.
2. Initial Lunar Surface Contact: As the rover begins its journey on the lunar surface, a series of images will be captured to document the initial interaction between the coated samples and the lunar regolith.
3. Continuous Monitoring: Throughout the rover's traverse, regular imaging intervals will be established to track the accumulation or repulsion of lunar regolith on each sample.
4. Data Transmission: Images will be transmitted back to Earth for analysis. The transmission will occur at predetermined intervals to ensure a comprehensive dataset while managing data volume constraints.
5. Image Analysis: Upon receiving the images, a team of researchers will employ advanced image processing techniques to quantify the amount of regolith adhering to each sample. This analysis will include particle size distribution, coverage area, and any visible abrasion or degradation of the coatings.
6. Comparative Assessment: The performance of each nano-material coating will be evaluated based on its ability to repel lunar regolith compared to the control sample. Factors such as initial adhesion, accumulation rate, and any self-cleaning properties will be assessed.

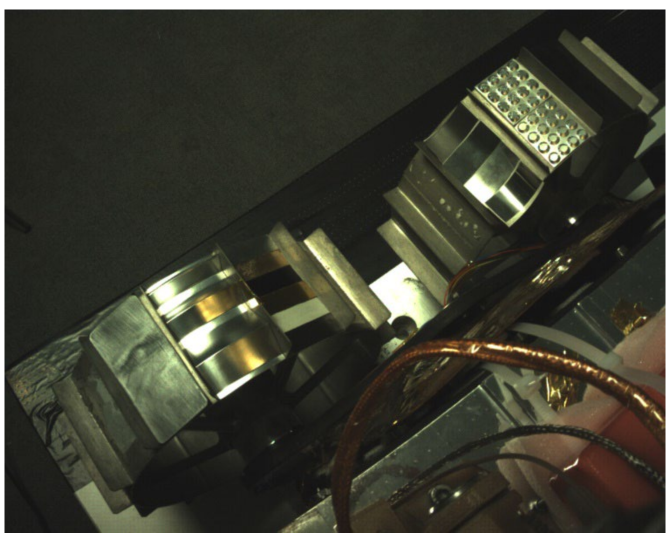

Figure 6: Final mounting on the Rover Wheel.

Conclusion

The Material Adhesion/Abrasion Detection (MAD) experiment onboard the Rashid Rover 2 lunar mission represents a significant opportunity to evaluate the performance of advanced nano-material coatings in the challenging lunar environment. By directly comparing the behavior of FeCu, TiO_2, and Graphene coatings against a control sample, this experiment aims to provide crucial insights into potential solutions for mitigating the adhesive and abrasive effects of lunar regolith on exploration equipment.

The results of this experiment are expected to inform future designs of lunar vehicles, spacesuits, and other equipment destined for lunar operations. By identifying the most effective coating materials, we can potentially extend the operational lifespan of lunar equipment, reduce maintenance requirements, and enhance the overall efficiency of lunar exploration efforts.

Furthermore, the MAD experiment demonstrates the value of integrating materials science research into lunar exploration missions. This approach not only maximizes the scientific output of each mission but also accelerates the development of technologies critical for sustained lunar presence and future deep space exploration.

As we continue to push the boundaries of space exploration, experiments like MAD play a crucial role in addressing the unique challenges posed by extraterrestrial environments. The knowledge gained from this experiment will contribute to the growing body of research on lunar dust mitigation strategies, paving the way for more robust and reliable lunar exploration technologies in the future.

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