Introduction

- The Artemis missions will require robust solutions to the lunar dust problem.
- Novel implementations of Electrodynamic Dust Shield (EDS) technology are being developed by the SSERVI REVEALS team at Georgia Tech.
- As a part of NASA’s 2021 Big Ideas Challenge, students proposed a handheld brush structure with integrated EDS technology and UV photolelectric enhancement.
- A proof-of-concept system was tested in a high vacuum environment.
- Further development of EDS systems are described here.
  1. An investigation and reproduction of known 2D-EDS effects using electrodes made from a novel conductive polymer composite developed by the SSERVI REVEALS team [2].
  2. Enhancement of 2D-EDS efficiency using UV radiation to induce photolelectric charging of dust grains.
  3. Development of 3D-EDS brush systems using a flexible electrode array set in a bristle structure.

Methodology for investigation of 2D-EDS

- The 2D-EDS systems tested were made using laminated chemically modified reduced graphene oxide (rGO-dd) as the electrode material.
- rGO-dd is a conductive polymer composite developed by the REVEALS team for lunar environments.
- rGO-dd is spray coated and can be applied to flexible films and thermoplastic backings in arbitrary patterns by using masks.
- The EDS chips were constructed by laminating the rGO-dd into black HDPE to improve contrast with the LHS-1 lunar simulant.
- Following previous work on 2D-EDS systems, [3] the supplied EDS signals are 2-phase, 180-degree offset, bi-polar square waves at 5 Hz. The voltage were varied within the range 0-3 kV peak to peak (p2p) using Matsusada AS-1.5B2 High Voltage Power Supplies controlled using LabVIEW.
- The experiments were conducted between 10\(^{-6}\) and 10\(^{-4}\) torr and ambient temperatures. The sample was held level and a light coating of dust, weighing less than .1g, was applied on its surface. Experiments were run for multiple minutes and images were captured at a rate of 1/sec.
- Images were processed using ImageJ to determine the dust coverage on the EDS surfaces.

Results of 2D-EDS Experiments

![Figure 1: Vacuum chamber with 2D-EDS sample mounted for experiment. The UV lamp is in the top right.](image)

![Figure 2: The starting, dusted condition of the EDS chip (left) and the final cleaned state of the same chip after EDS activation (right).](image)

![Figure 3: A line plot comparing the performance of the smooth and rough surface conditions.](image)

UV Enhancements to EDS Functionality

The performance of the EDS system was also tested while illuminating the dust surface with a 25 W, 172 nm excimer UV lamp placed several centimeters above.
- UV light is known to electrostatically charge lunar dust grains through photolelectron emission.
- Larger charges on the surface increase the strength of the electrodynamic forces on the dust grains while the EDS is running. This allows for greater repulsion and permits repulsion at lower voltages.

Experiments were conducted using the Smooth, Rough, and LPDE laminated conditions.
- The large error in the Rough UV condition was caused by degrading performance between the three experiments performed.
- Experiments conducted with a thin layer of LPDE covering the rGO-dd showed no dust movement at 3000 V p2p applied voltage when no UV was present, but with UV the surfaces could be cleaned reasonably well.
- It was observed that cycling the UV lamp on and off at five second intervals enhanced the EDS cleaning effect.
- Again, 100% cleanliness could be achieved at higher applied voltages, but this caused breakdown in the rGO-dd.

Additionally, by attaching a vacuum compatible voice coil alongside the EDS and UV, the sample could be made to vibrate.

The vibration helped break up clumps of simulant and can also induce tribocharging of the grains.

A coating is desired for implementation to protect the electrodes in the bristle structure.

Investigation of 3D-EDS

Low fidelity experiments of the 3D-EDS system involved a row of electrodes embedded in bristles at an angle. While these experiments demonstrated that EDS affects dust caught within bristles, it required significant refinement. Ongoing efforts are focused on aligning a matrix of electrodes among bristle clusters within a brush. It is expected that the 3D-EDS will be able to better repel dust grains out of the volume using this arrangement. Alternate bristle materials that tolerate high temperatures and have high dielectric permittivity are also being investigated. While one of the ultimate goals of this research is to demonstrate functioning 3D EDS, the 3D EDS direction has been the focus recently so that relevant knowledge can be implemented in the 3D EDS designs.

Conclusions and Future work

The findings shown here demonstrate the capabilities of the rGO-dd based EDS and hybrid EDS with UV and vibration enhancements. The Rough condition showed to have significant promise for further investigation due to its low voltage requirement. The hybrid condition, while showing lower cleanliness, is also promising for eventual use in a 3D-EDS structure.

Future work will continue to refine the performance metrics used so that more accurate predictions of the system performance. Other coatings will be tested as well, with a focus on thinner coatings with higher dielectric strengths than LPDE. Further experiments will also consider surfaces that are kept at angles to see if the gravitational effects can be used to assist in dust removal. Lastly, the knowledge gained from these 2D experiments will be used to generate a mid-fidelity 3D EDS tool. The embedding of bristles with rGO-dd will be investigated as a possible method to create electrodes in the bristle structure.

References


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