Chemically modified reduced graphene oxide (CMrGO)-based Electrodynamic Dust Shield (EDS) devices for lunar dust mitigation

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**Highlights:**

- Spray-coated EDS systems were produced using a conductive nanocomposite material (CMrGO).
- Both 2-phase and 3-phase device configurations efficiently removed >80% of deposited dust.
- The 2-phase devices were cleaned at ~50% lower voltage when illuminated with UV light.
- Using a dielectric cap eliminates electrical discharges on the surface.

**EDS Basics**

- The 2-phase devices use 10 Hz square waves 180 out of phase
  - A standing wave potential is generated above the device surface for 2-phase
- 3-phase devices use a Moesner and Higuchi waveform
  - A traveling wave is formed above 3-phase devices
- $H \times W = 2 \times 1.5 \text{ in (2p)}$ and $3 \times 2 \text{ in (3p)}$

Electrode trace thickness $t = 0.5 \text{ mm}$

Inter-electrode spacings $d = 2 \text{ mm}$

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Device Fabrication

Device Fabrication

**A** Zylon® fabric embedded in thermoplastic polysulfone

**B** CMrGO device fabricated on 3mil HDPE film

**C** Zylon® fabric embedded in a film of HDPE with a CMrGO infiltrated coating

Simulants are compositionally and physically like lunar regolith. Size and shape distributions for LHS-1 from optical microscopy images.

The $\mu$ and $\sigma$ correspond to the mean and standard deviation of the fitted distribution.
Rough 2-phase devices

1st dust deposition

4th dust deposition
Bare 2-phase devices

- Dust is efficiently and repeatably removed from 2-phase CMrGO EDS devices
  - A minimum voltage of 1000 V is required for the rough condition
  - A minimum of 2000 V is required for the smooth
- Discharges/dielectric breakdown occurs for several seconds after EDS activation
  - Persistent hot-spots lead to trace failure
  - Smooth devices have fewer discharges and less degradation
  - But worse performance

Smooth 2-phase devices

1\textsuperscript{st} dust deposition

3\textsuperscript{rd} dust deposition
Rough 2-phase devices + UV

1\textsuperscript{st} dust deposition

6\textsuperscript{th} dust deposition
Bare 2-phase devices + UV

- Dust cleared at 800 V, for the rough configuration
- Cleared at 1000V for the smooth configuration
- The dust surface was UV illuminated at 5 sec intervals to avoid heating
- UV illumination caused the devices to degrade more rapidly

Bare 3-phase devices

Larger applied voltages were required to remove grains from both rough (1500 V) and smooth (3000 V) devices.

Materials Effects

Surface Durability

**Dust Deposition System**

- Vibrationally driven dust hopper to deposit dust onto EDS surfaces under high vacuum conditions
- Based on a home-made voice coil and permanent magnets
- Vibrational amplitude can be controlled to vary the rate of dust deposition onto the surface below
Dust Deposition System

- Activate 2-phase EDS (1500 V)
- Initiate dust deposition with EDS activated
- After ~5 min, EDS is deactivated while dust is still being deposited
- Dust accumulates on deactivated surface for several minutes
- Finally, EDS is reactivated to clear off accumulated dust
Moving Forward

- Continue testing EDS devices by dropping charged dust grains onto an activated surface and with EDS devices in flexure.
- Explore alternative capping materials
  - nanostructured materials to reduce surface adhesion
  - improve the cleaning performance of devices for the smallest size grain fractions
- Incorporate with additional mitigation strategies such as vibrational tribocharging, and electron bombardment
Supplemental Slides
Grain Size After EDS removal

- Device – 3 phase smooth device after use, no wiping/washing/dust disturbance (outside of covered transport to microscope)
- Images - taken at 5x and 50x to show overall surface variability and measure particle size
- *Note: Only in focus particles were measured for analysis

Total survey: 92 particles, 4 regions
4.02 μm average diameter
(min: 1.25μm, max: 9.86μm)
Rough 2-phase devices + vibration