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

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SSERVI REVEALS Team

rGO + EDS: Patterned substrates

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

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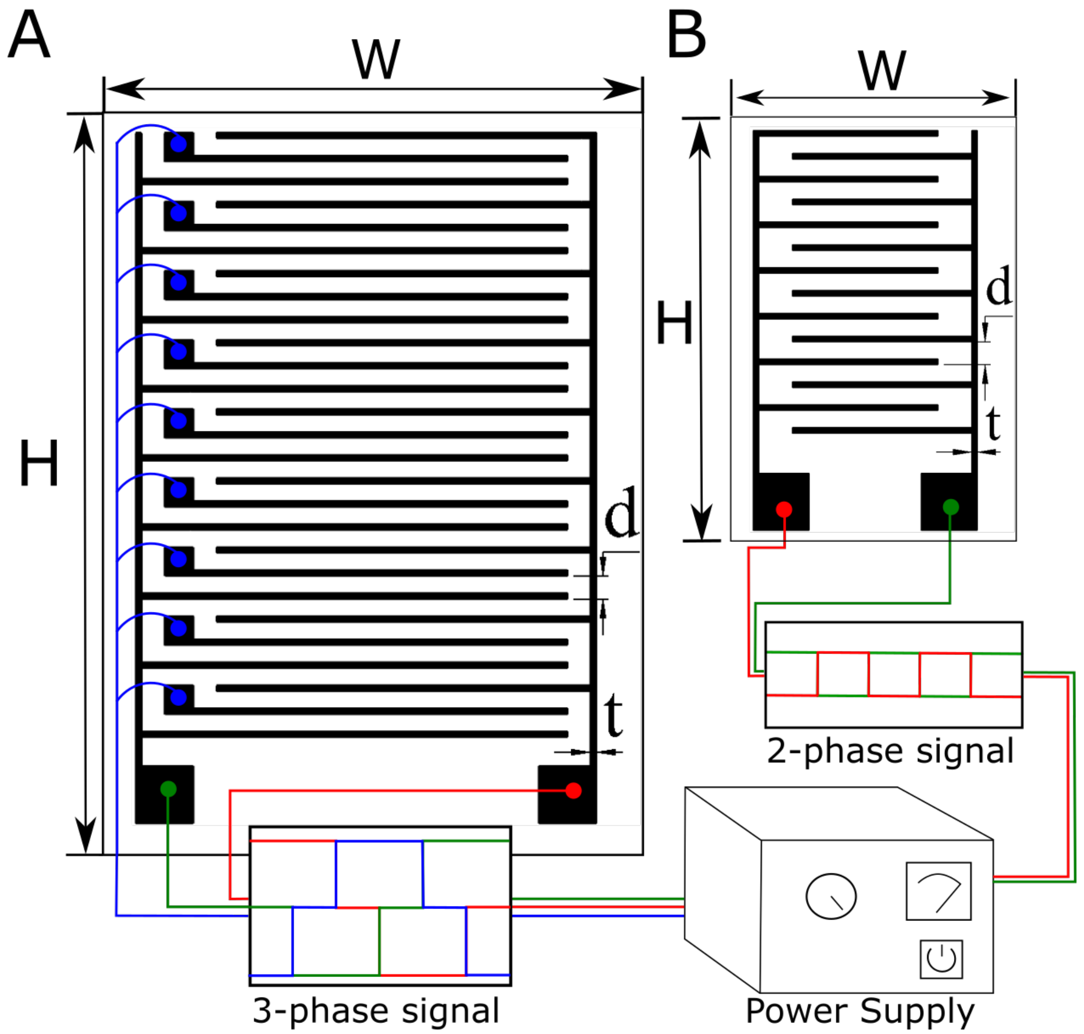
EDS Basics

- 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 × W = 2 × 1.5 in (2p) and 3 × 2 in (3p)
  Electrode trace thickness t = 0.5 mm
  Inter-electrode spacings d = 2 mm



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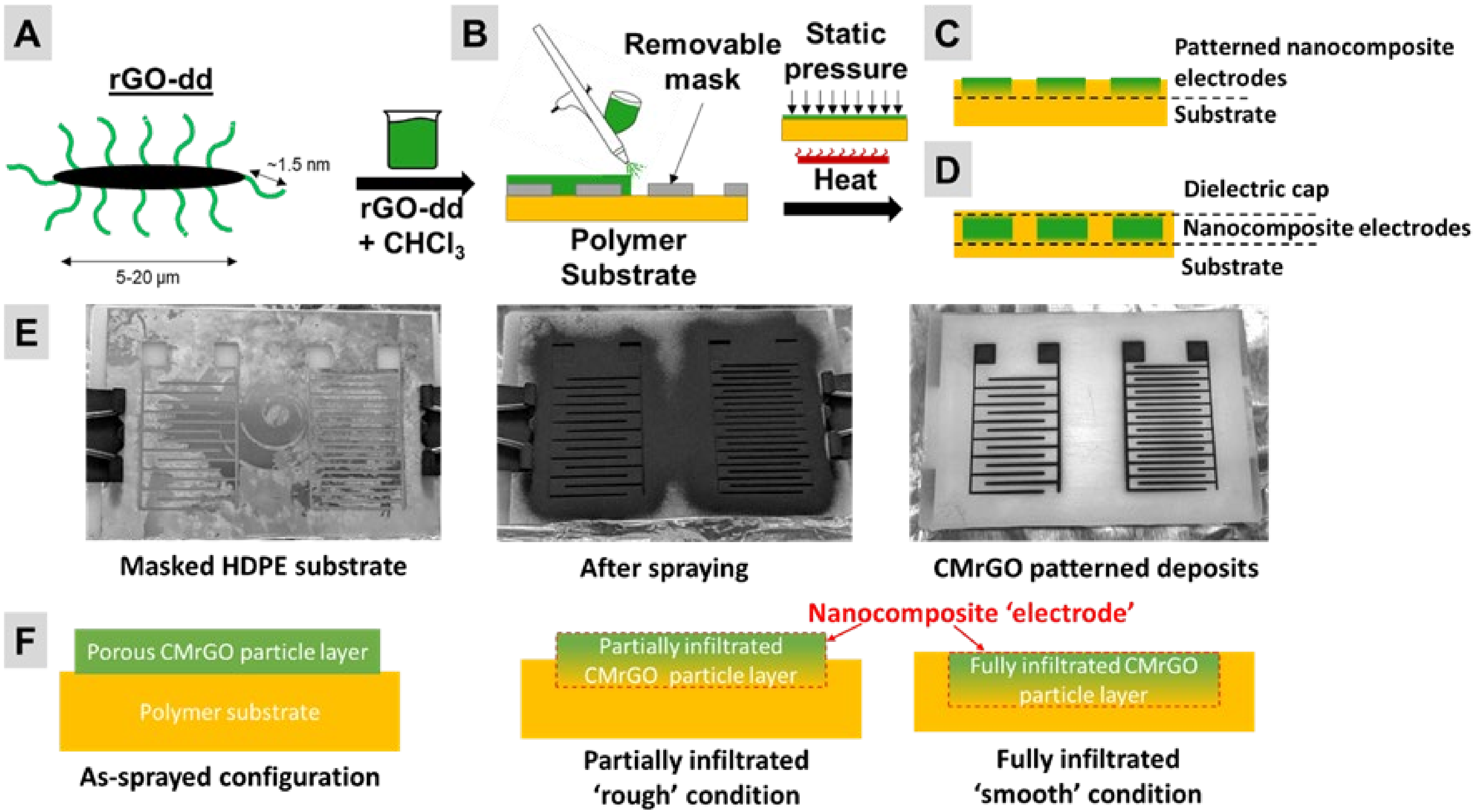
Device Fabrication



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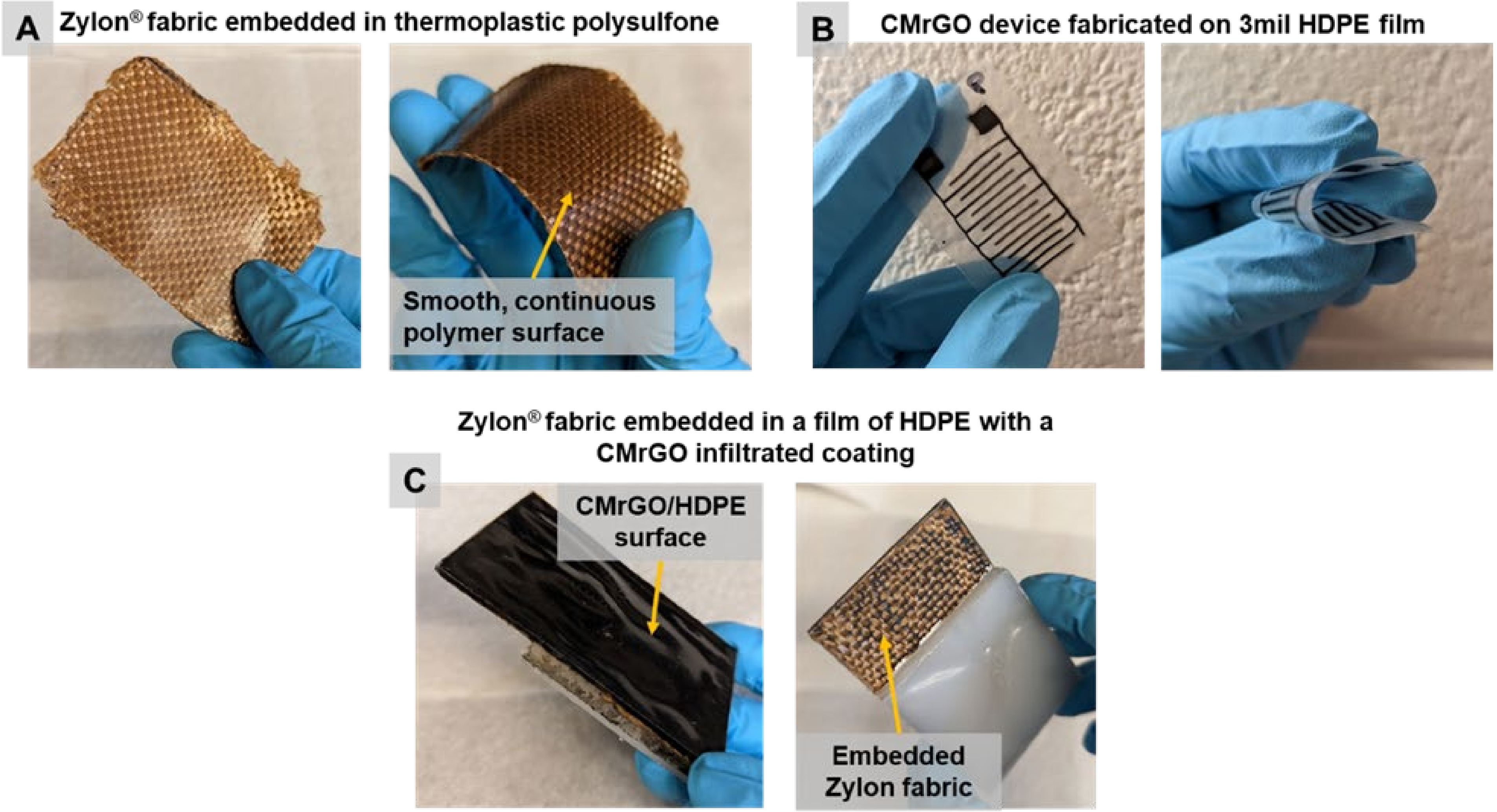
Device Fabrication



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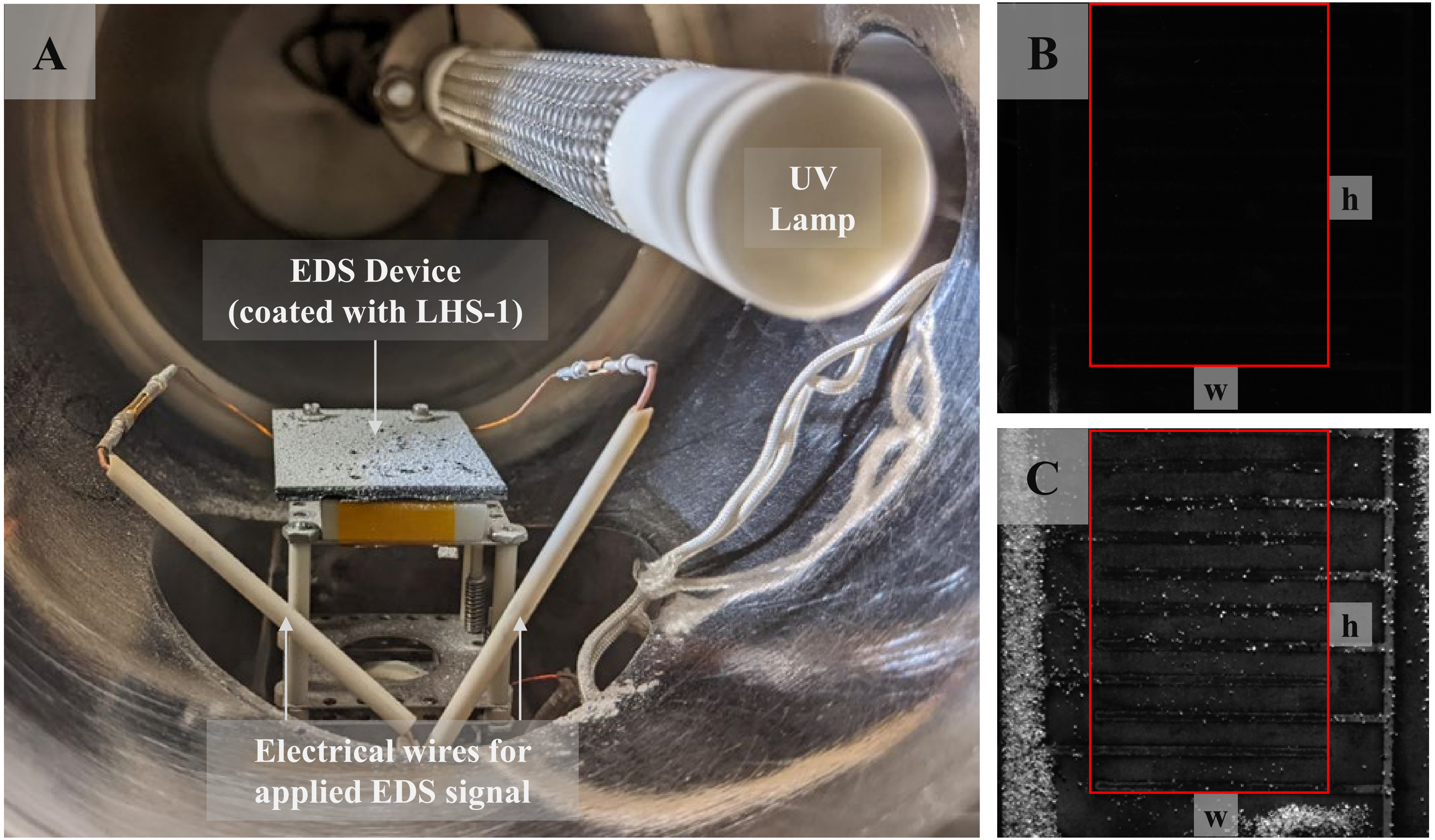
Ryan, Emily; Seibers, Zach D.; Reynolds, John R.; Shofner, Meisha L. (2023) Polymer infiltrated chemically modified reduced graphene oxide coatings for flexible, conductive surfaces for space applications. ACS Journal of Applied Polymer Materials. 5(7):5092–5102

EDS System



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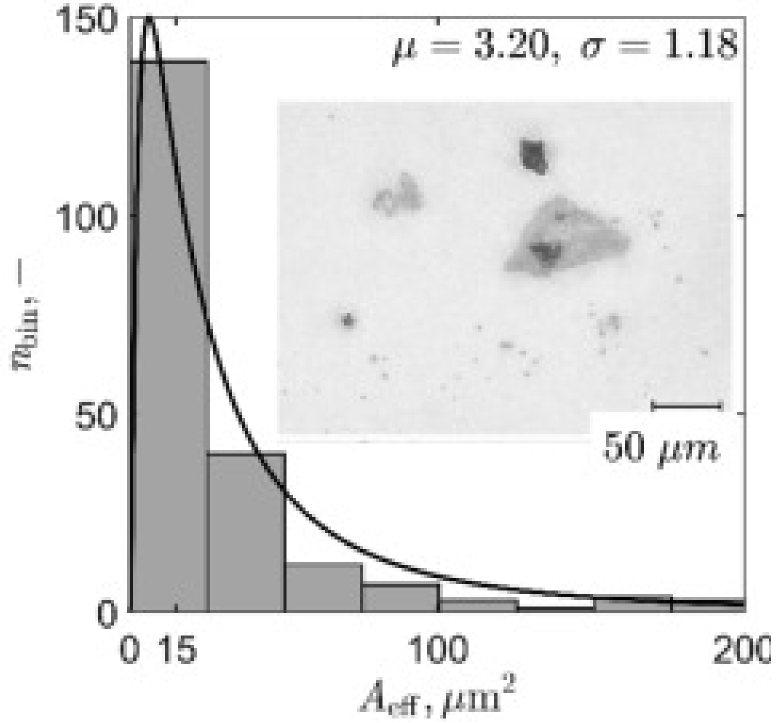
Dust Characteristics

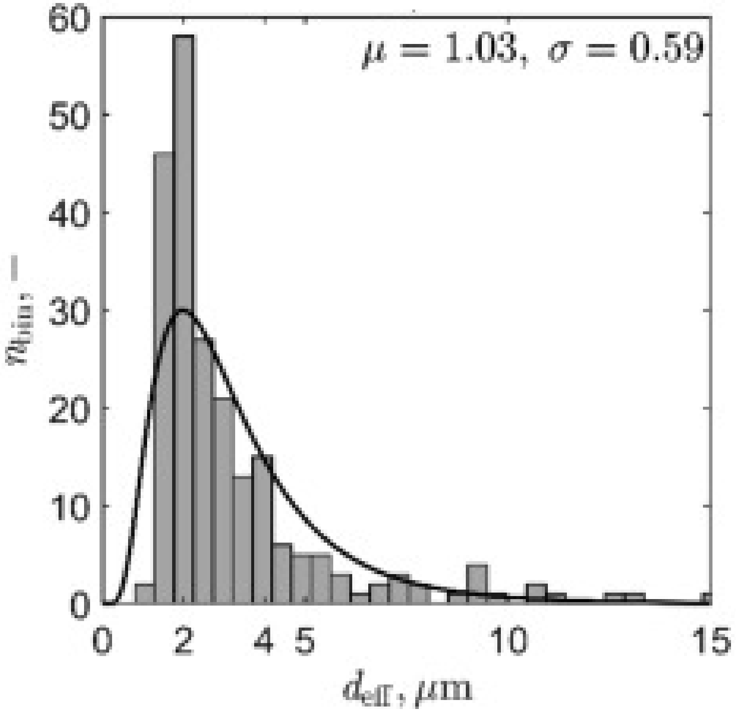
Simulants are compositionally and physically like lunar regolith.

Size and shape distributions for LHS-1 from optical microscopy images.

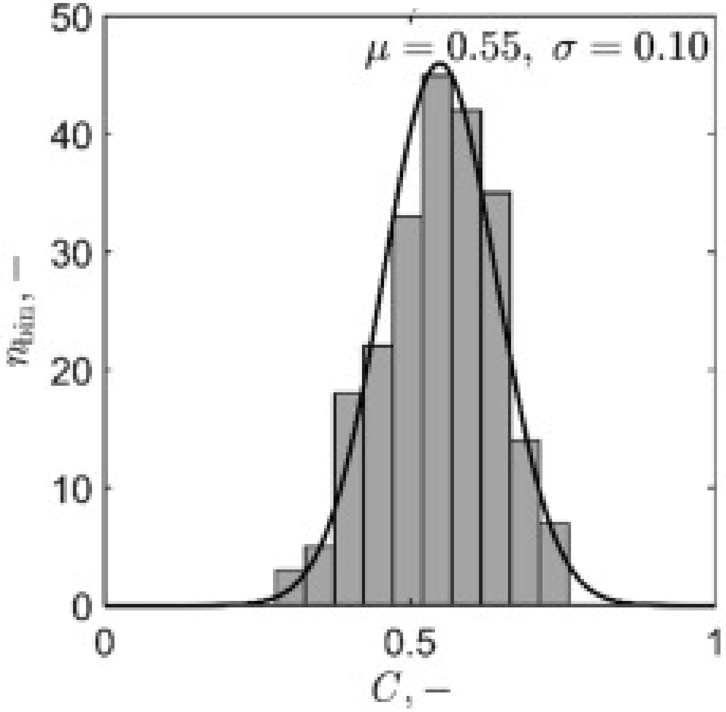
Effective surface area



Effective diameter



Circularity



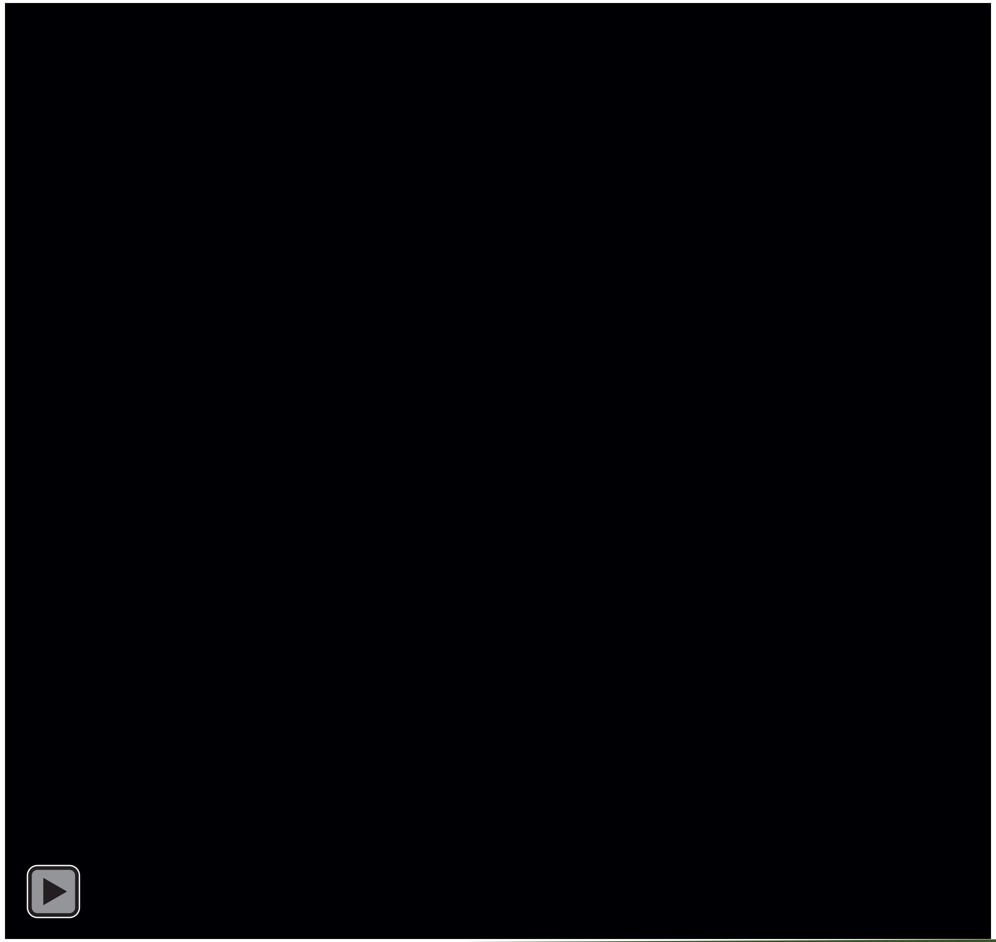
The μ and σ correspond to the mean and standard deviation of the fitted distribution.

Clendenen, A. R., Aleksandrov, A., Jones, B. M., Loutzenhiser, P. G., Britt, D. T., & Orlando, T. M. (2022). Temperature programmed desorption comparison of lunar regolith to lunar regolith simulants LMS-1 and LHS-1. *Earth and Planetary Science Letters*, *592*, 117632.

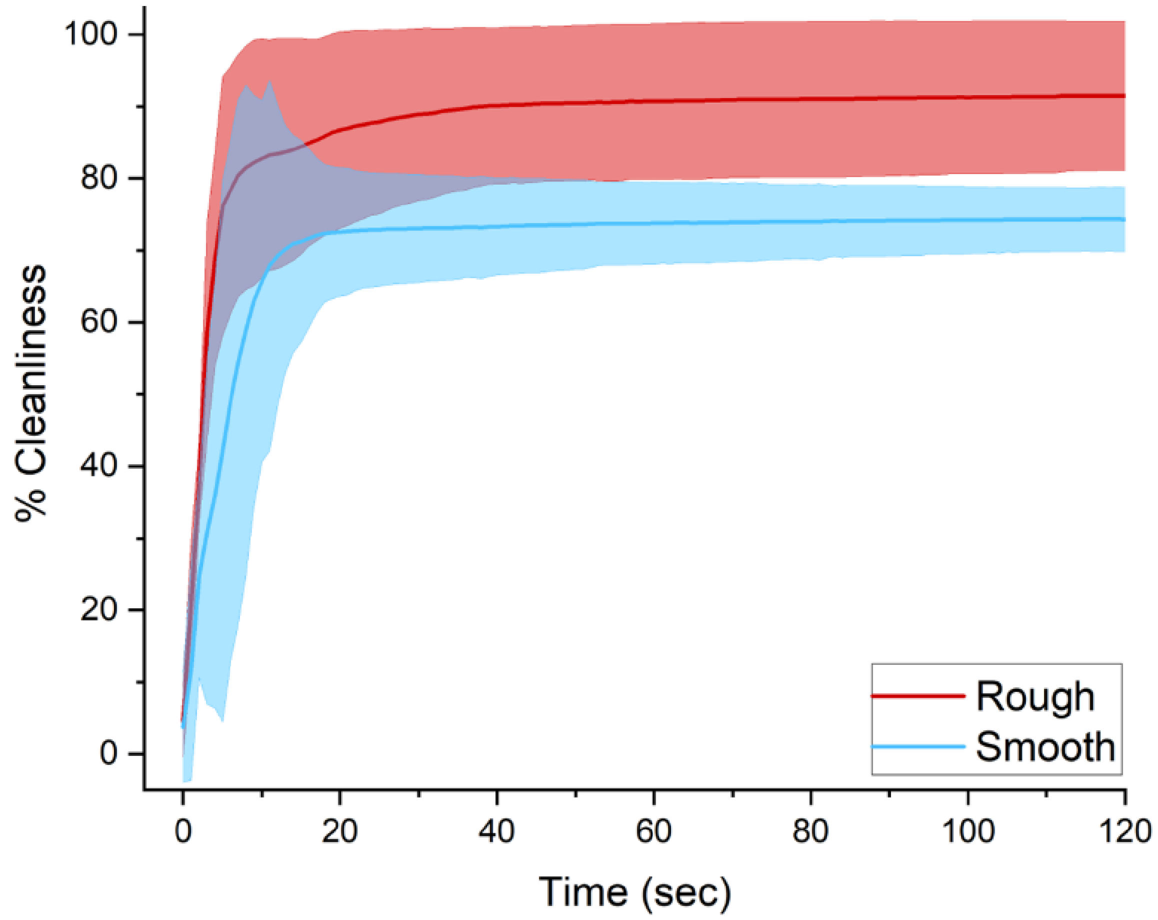
Rough 2-phase devices

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

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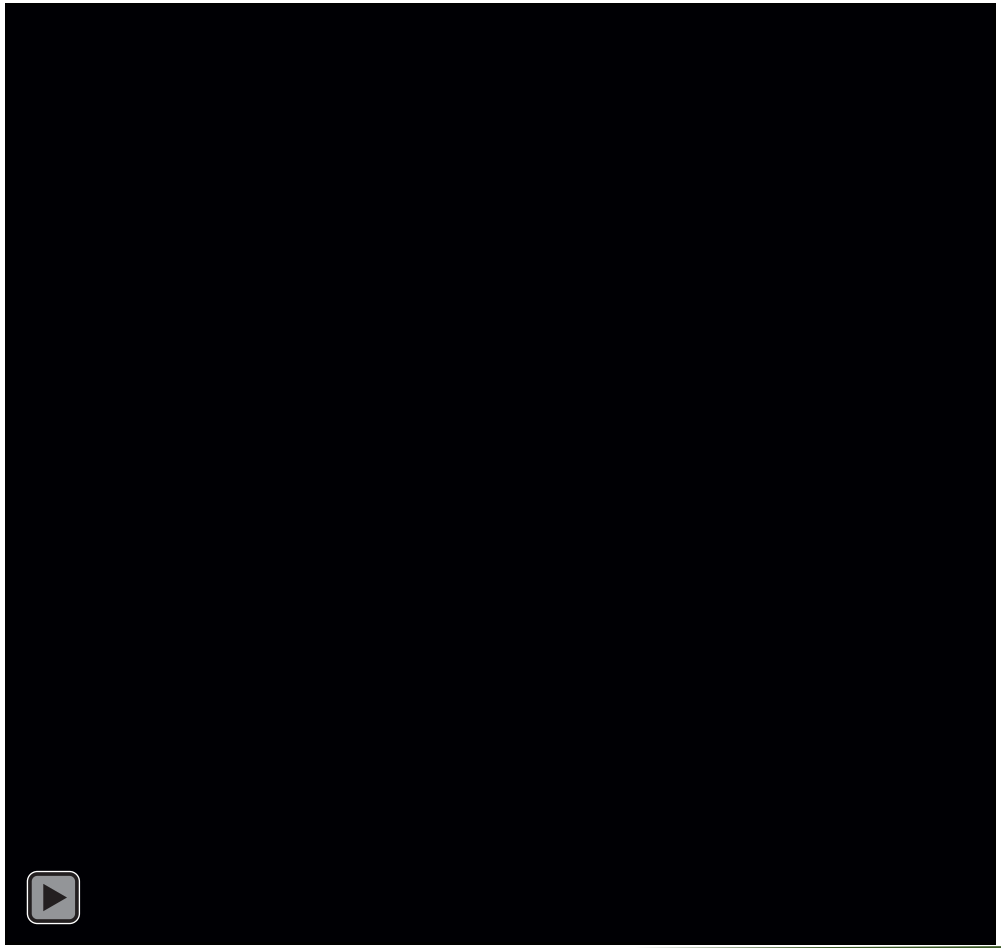
Smooth 2-phase devices

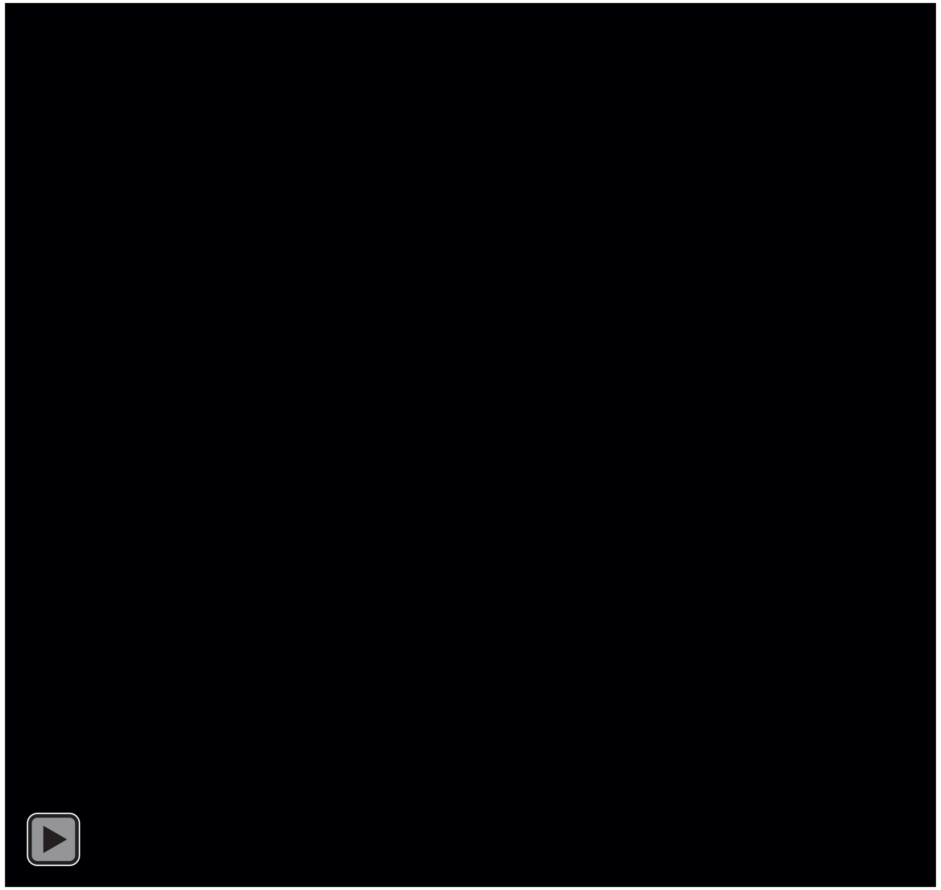
1st dust deposition

3rd dust deposition



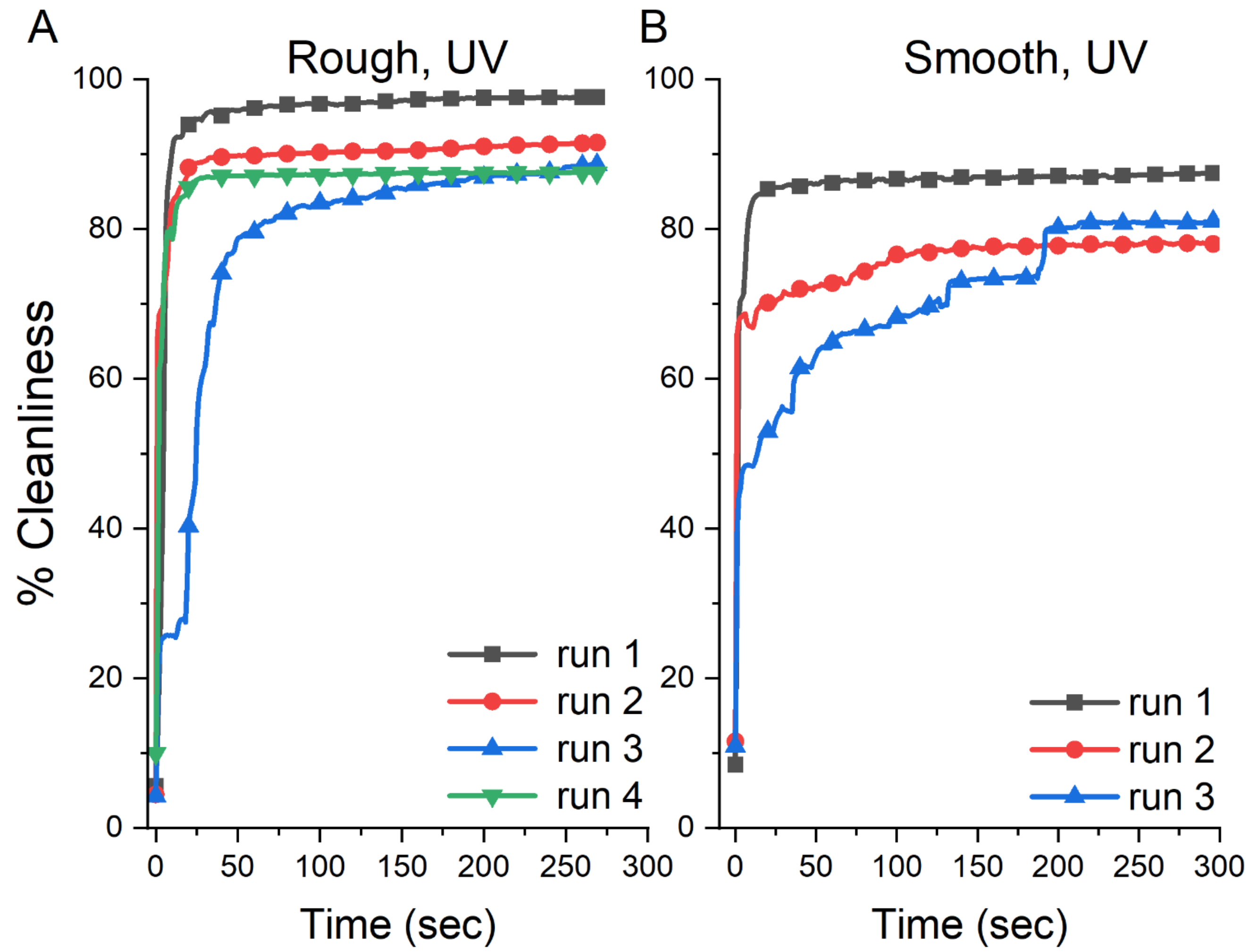
Rough 2-phase devices + UV

1st dust deposition



6th 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

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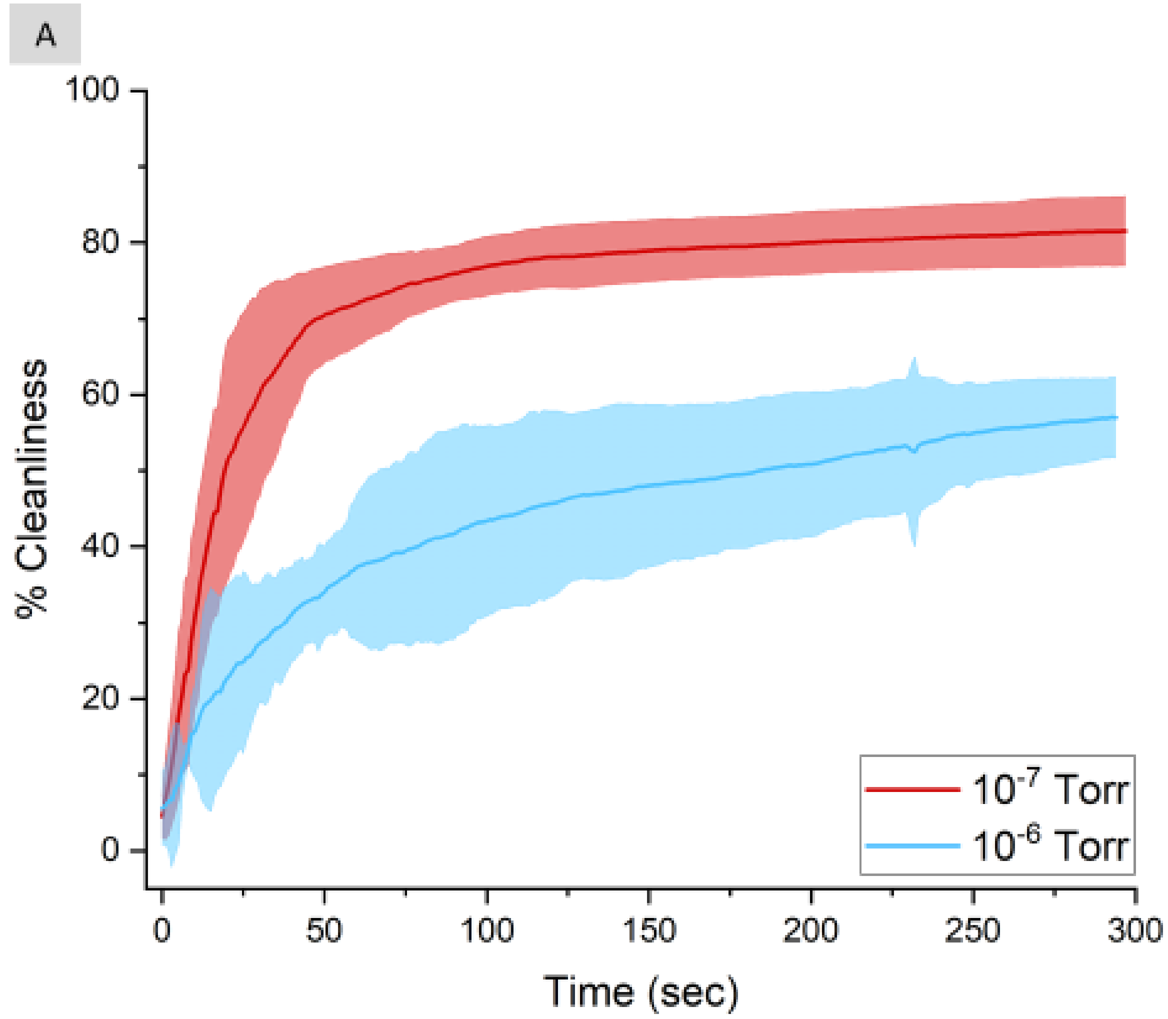
Bare 3-phase devices



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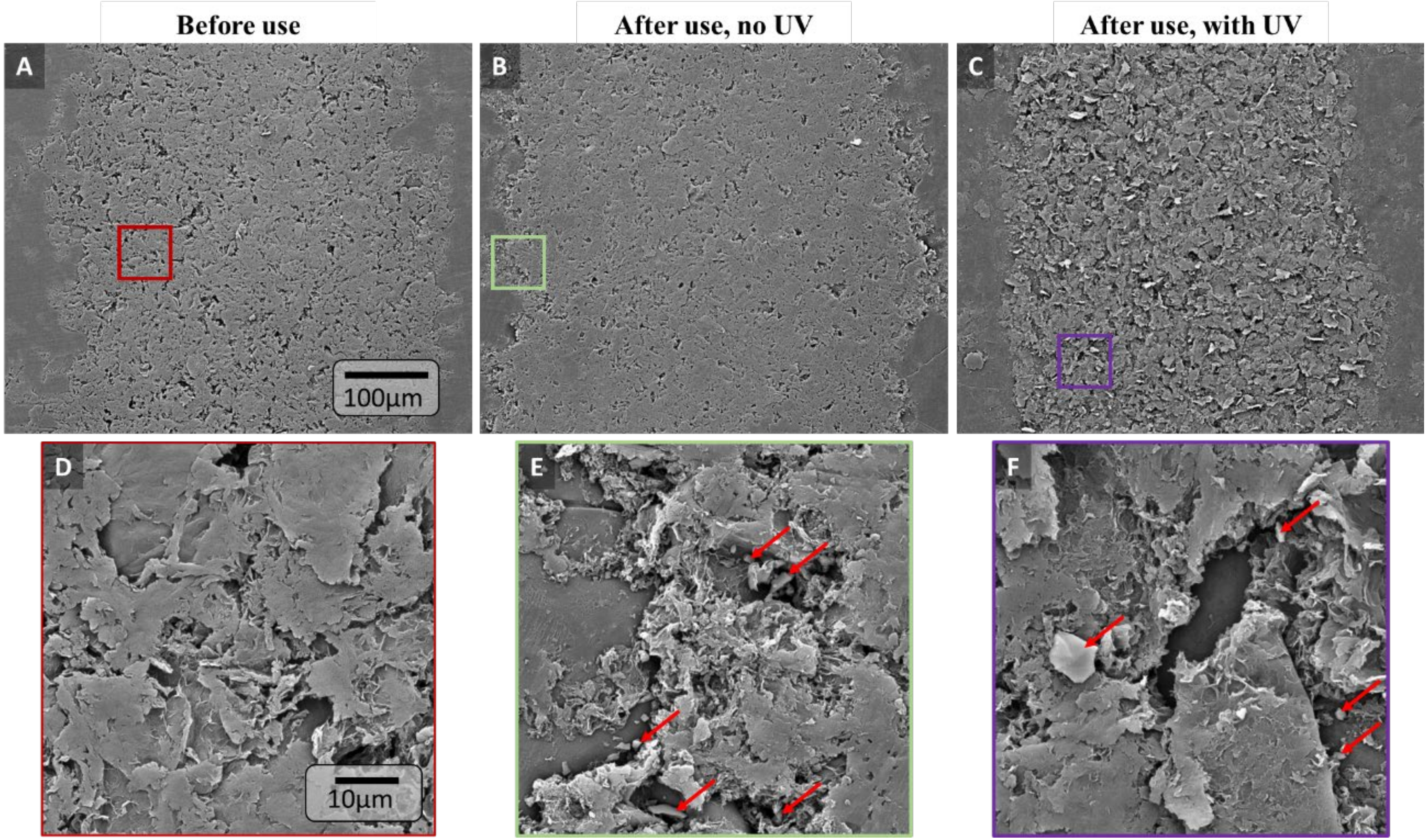
Materials Effects



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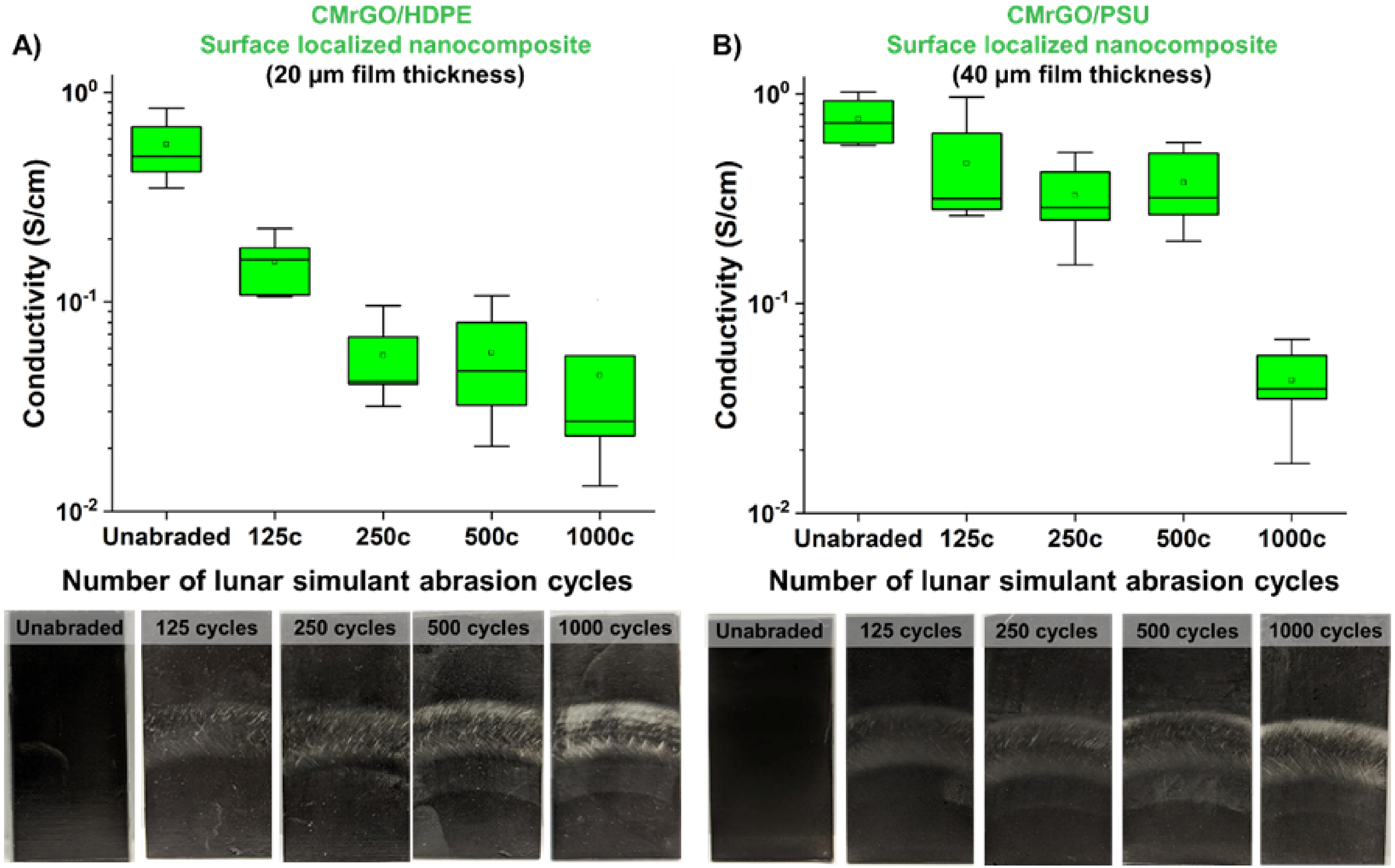
Surface Durability



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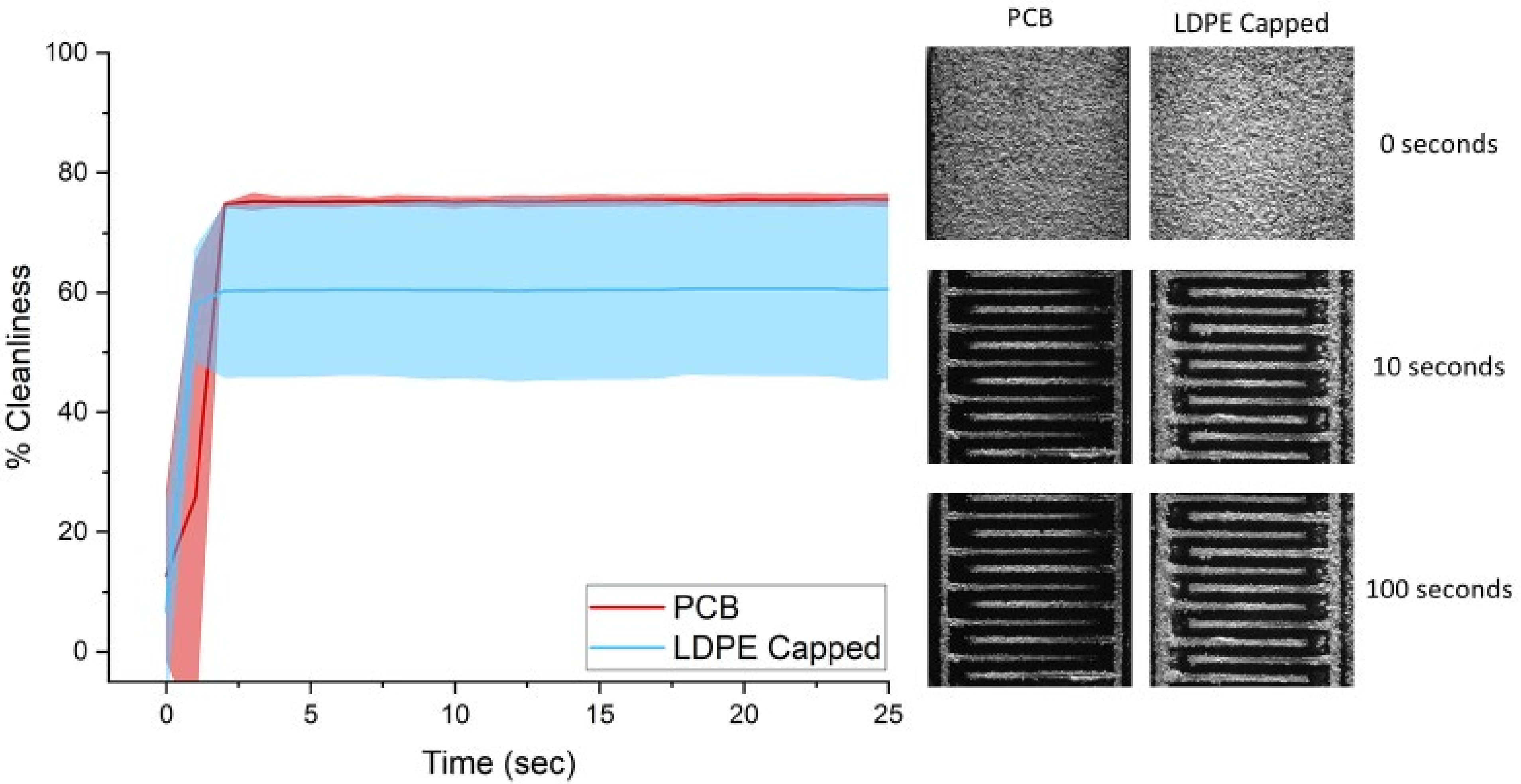
Testing Capped Devices



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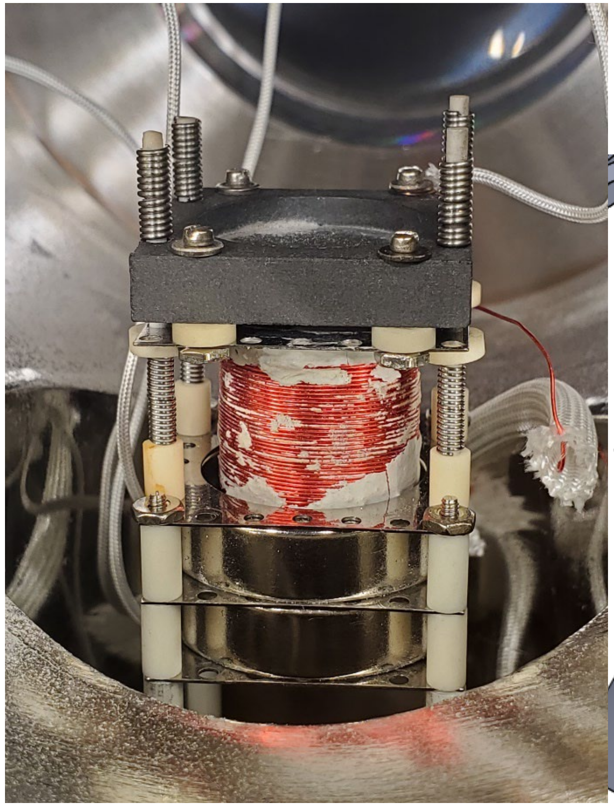
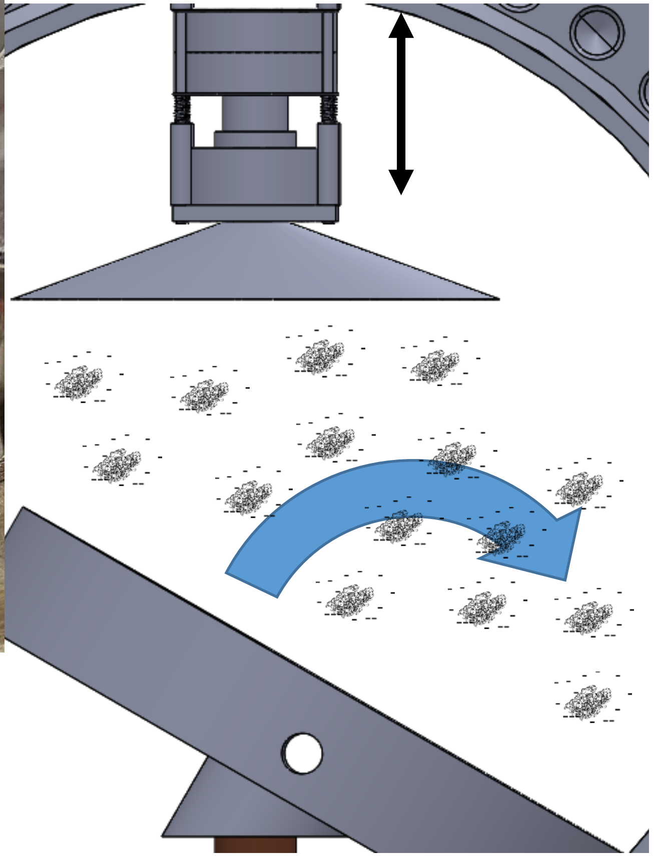
Dust Deposition System





- 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

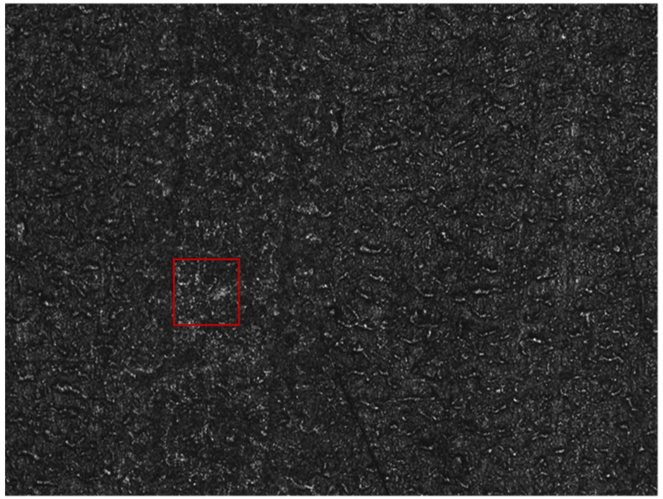
- Activate 2-phase EDS (1500 V)
- Initiate dust deposition with EDS activated
- After ~5 min, EDS is deactivated while dust is still being deposited
- Dust accumulates on deactivated surface for several minutes
- Finally, EDS is reactivated to clear off accumulated dust

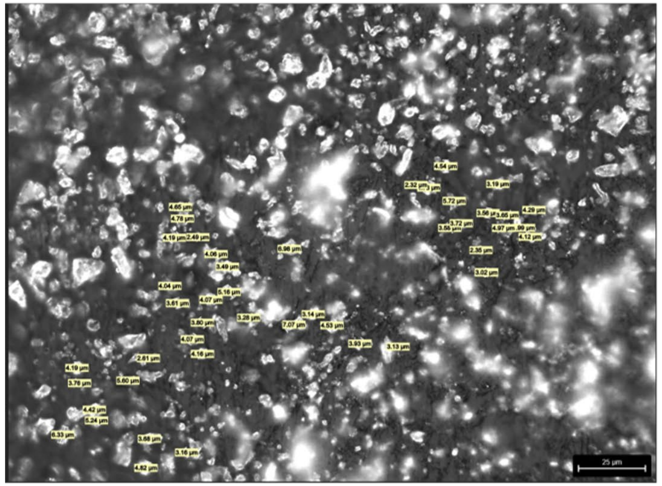
Moving Forward

- 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

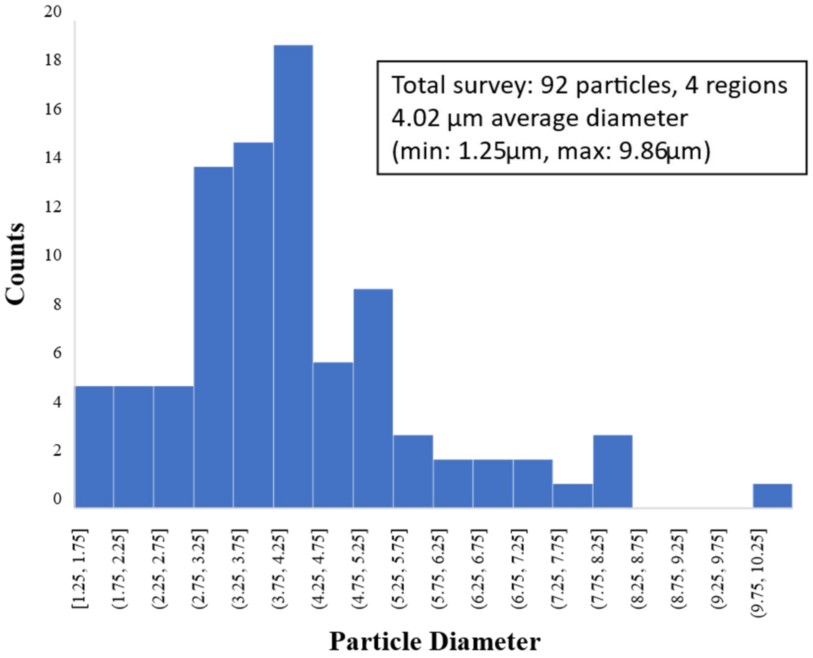
Supplemental Slides

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



Discharges on EDS Activation

Rough 2-phase devices + vibration