Electrodynamic Dust Shield for Space Applications

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Dust Removal

- NASA KSC’s Electrodynamic Dust Shield (EDS) technology removes dust from optical systems and prevents dust accumulation.
- Dust Shield is based on the Electric Curtain concept developed at NASA in 1967.*
- KSC currently developing technology for space applications.

Electrodynamic Dust Shield (EDS)

- EDS generates a non-uniform electric field using a varying high voltage on multiple electrodes.
- The non-uniform field generates a dielectrophoretic (DEP) force which moves the particles.
- Low Power, (mA)
  - High voltage (1kV to 4kV)
  - Low current (µA) signal

Three-phase electrode pattern with phase 1 electrodes at $V_1 = -V$, phase 2 electrodes at $V_2 = +V$, and phase 3 electrodes at $V_3 = +V$. Charged particles will move in a particular direction.
Materials and Uses

- Conductive electrodes can be embedded in different materials for specific applications
  - Thermal Radiators
  - Space Suit Fabric
  - Visors
  - Camera Lenses
  - Solar Panels
Thermal Radiators

• Two kinds of radiators
  
  – Coated metallic surfaces
    • AZ-93 white paint on aluminum
  
  – Second Surface Mirrors
    • Silver on FEP film
    • Aluminum on FEP film
Thermal Radiators

• Coated Metallic Surfaces
  – 130 µm polyimide coating on aluminum surface
  – Copper electrode grid
  – 130 µm coating of AZ-93 inorganic thermal paint (AZ Technology)
    • AZ-93 absorbs 14-16% solar radiation
    • Emits 89-93% internal heat
    • In use on ISS

Schematic of the cross-section of a surface with the Electrodynamic Dust Shield embedded into a substrate coated with AZ-93 thermal paint.
Second Surface Mirrors

• Flexible, Reflective Materials
  – Fluoroethylene Polypropylene (FEP)
  – Transparent polymer
  – Resists oxygen attack
  – Substrate for vapor-deposited metallic layer

• Structure
  – 1000 Å-1500 Å silver or aluminum layer
  – 130 µm FEP
  – Silver or aluminum electrode grid
  – 26 µm FEP protective layer
Solar Panels, Cameras, Visors
Transparent Substrates

• ITO on Glass
  – Three-phase dust shield
  – Indium tin oxide (ITO) transparent electrodes
  – Spiral pattern configuration on a glass substrate
Video Clip: Apollo Sample

- Real time video clip showing Apollo sample removal in vacuum chamber during RGF 2 at lunar gravity. An initial polarization phase removes some dust.
- The video cuts to the dust shield activation phase, which removes dust in less than one second
Advances

• Power Supply
  – Decreased mass and volume
  – Completed unit expected to be less than 500g
Advances

• Photo-lithography
  – used in copper on polyimide film panels of increasing density (electrode spacing left to right: 530µm, 215µm, 160µm)

  – Electrode spacing is one factor in DEP generated by non-uniform, varying E-field.
Advances

- **Shields**
  - Increase in available size
  - Same power supply
    - 40 cm$^2$ glass panel to 1200 cm$^2$ glass panel
  - Decrease in reflection
    - 8% incident reflection to 1% incident reflection
Future Testing

- Materials on International Space Station Experiment (MISSE)
  - Test technology to prove it on platform that mimics aspects of the lunar environment
  - Raise TRL to enable use in future landers, rovers and equipment