**AN ACTIVE DUST MITIGATION TECHNOLOGY FOR MARS EXPLORATION.**
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**Introduction:** As is well known, dust storms of local and global proportions occur on Mars with some frequency. This dust storm activity, combined with the more frequent appearance of dust devils, results in the constant deposition of dust on the surfaces of solar cells, equipment, thermal radiators, spacesuits, and other hardware likely to be used in exploration missions. The performance of solar panels, thermal radiators, and optical systems is thus degraded by the accumulation of dust. Mechanisms and other such systems are also compromised by the presence of dust.

We have developed an active dust mitigation technology capable of preventing the accumulation of dust on the surfaces of these devices. The technology is also capable of removing dust already deposited.

**Description of the Technology:** The Electrodynamic Dust Shield (EDS), a system based on the generation of changing non-uniform electric fields able to accelerate charged dust particles has been described in some detail elsewhere [1-5]. The EDS is a dielectric coating with a thin electrode grid running a multiphase AC signal in the milliwatt range which generate a non uniform traveling electric field. Electrostatically charged dust particles, such as those on the lunar surface, are carried along by the field under the action of the Coulomb and dielectrophoretic forces set up by this non-uniform field.

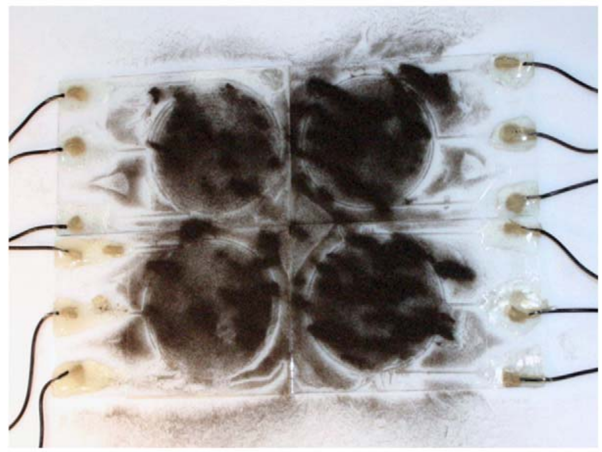
The EDS coating can be applied to metallic and electrically insulating surfaces. For optical systems, astronaut visors, and viewports, the electrode grid uses transparent indium tin oxide (ITO) or carbon nanotube formulations on a glass substrate. For thermal radiators with painted metallic surfaces, a dielectric layer of 130 µm is added to separate the electrode layer from the metal surface of the radiator. For spacesuits, a carbon nanotube formulation is used as the electrode grid which is applied directly to the fabric.

**Experiments:** Experiments with JSC Mars-1 simulant in a carbon dioxide atmosphere at 9 mbars have been performed. We have also performed extensive testing at high vacuum with JSC-1A lunar simulant. Several size fractions, including the under 10 micrometer fraction expected to be present in the Martian atmosphere, were used in our experiments.

For these experiments, the simulants are kept in a vacuum oven at all times. Automated dust feeders deposit dust onto the EDS panels inside the evacuated vacuum chambers and loading of the dust feeders is performed in a glove box at 0% relative humidity.

Figure 1 shows the performance of a transparent EDS for optical systems. A substantial amount of simulant is deposited on the panels. Activation removes dust from the entire area over the circular transparent ITO electrode configuration.

a



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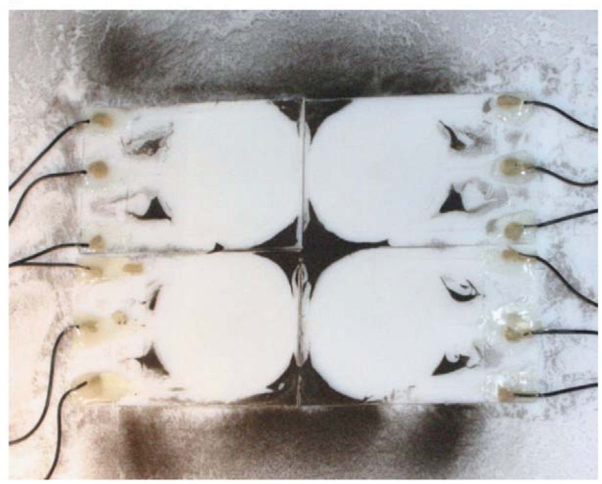

**Figure 1**. Transparent EDS coating on glass (a) before and (b) after dust removal.

Similar transparent dust shields were placed on commercial solar panels under an incandescent light source inside a vacuum chamber at $10^{-6}$ kPa of pressure. The energy output of the solar panel was reduced to 22.5% of its original output after 20 mg of simulant were placed over the EDS covering the solar panel (Fig. 2). Activation of the EDS restores the solar panel output to within 98% of its original output.

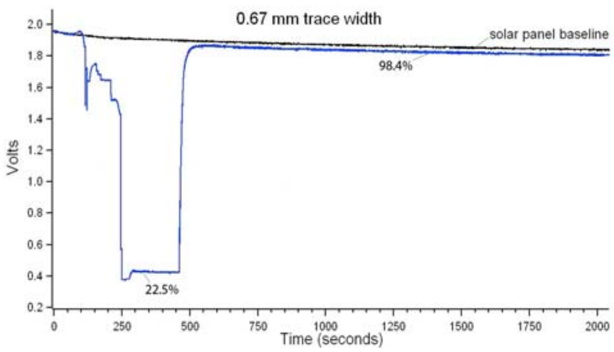


**Figure 2**. Solar panel response to JSC-1A dust loading and removal. Baseline voltages are shown for comparison.. Performance is relative to baseline values.

EDS panels for thermal radiators were also developed and tested. Figure 3 shows the schematic diagram of the EDS multicoating for painted thermal radiators and for second surface mirrors.

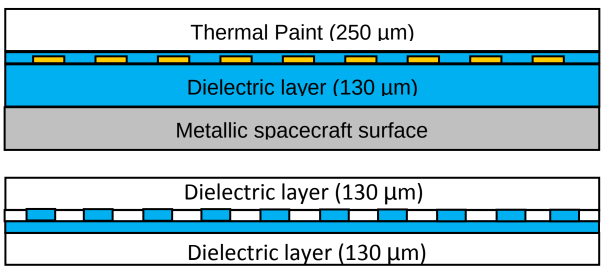


**Figure 3.** (Top). Schematic diagram of the multi-layer Electrodynamic Dust Shield coating for painted metallic radiators. (Bottom) Schematic diagram of the multi-layer Electrodynamic Dust Shield coating for second surface mirrors. The small yellow and blue rectangles represent the electrode grid.

To determine the effectiveness of the dust removal, reflectance measurements for all three EDS radiators were performed with a Jasco V670 UV-Vis/NIR spectrometer. Spectral data was collected for the EDS radiators before dust deposition (red lines) and after activation of the EDS systems for dust removal (Fig. 4). As the three graphs illustrate, the difference in radiance between the clean EDS radiators and the post-run EDS radiators is very small, indicating that the cleaning efficiency is very high.

**Conclusions:** Martian exploration missions may be jeopardized by the presence of dust that will adhere electrostatically to the surfaces of optical systems, solar panels, viewports, thermal radiators, instrumentation, and spacesuits. We have developed and tested an active dust mitigation technology, the Electrodynamic Dust Shield, a multilayer coating capable of removing dust adhering to surfaces or of preventing dust accumulation on such surfaces. Extensive testing shows that high dust removal performance can be achieved with our systems.

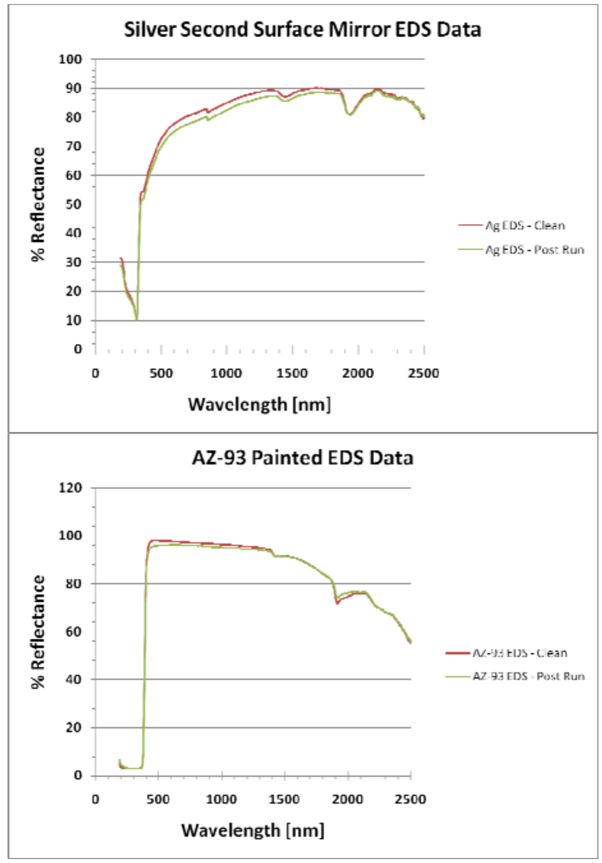


**Figure 4. (Top)** Reflectance spectra from 190 nm to 2500 nm for EDS on second surface mirrors (silver/fluorinated ethylene propylene) clean (red line) and after dust loading and removal (green line). **(Bottom)** Reflectance spectra for painted EDS radiators clean (red line) and after dust removal (green line).

**References:** [1] Calle C. I., et al., (2011), *Acta Astronautica 69*, 1082-1088. [2] Calle C. I. et al., 2009, *J. Electrostatics 67*, 89–9. [3] Calle C. I. et al., 2010, *AIAA Space 2010*, August 2010 Anaheim, CA. [4] Calle C. I. et al., 2006, *Proceedings of the International Astronautical Congress*, Valencia, Spain. [5] Calle, C. I. et al., 2007, *Proceedings of the International Conference on Exploration and Utilization of the Moon*, Sorrento, Italy.