Solar Electron Radiation Effects on NASA Space Station Samples

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INTRODUCTION

Space is an extremely harsh environment for space-faring vehicles. This is partly due to high energy particles that make up solar radiation. One component of the radiation is high-energy electrons that can induce charging when colliding with spacecraft.

If that charging reaches a certain voltage, electrostatic breakdown (ESD) occurs. ESD, often manifested through arcing (sparks of electricity), can be very destructive and it may cause system or complete mission failures.

This experiment examined 4 samples, sent from NASAs Gateway Space Station project, any resulting ESD from electron beam induced charging.

Specific samples examined:

- Beta Cloth (complex fiberglass weave) with Aluminum coating
- RMS736 (a carbon lubricant)
- Beta Cloth with Polytetrafluoroethylene (PTFE) coating - signs of damage
- Teflon Perfluoroethylene (PFA) - signs of damage

METHODS

- Materials were photographed before exposure
- Samples were prepared for the high vacuum chamber, by removing moisture and were then placed inside the chamber
- The High Energy Electron Diffraction (HEED) Gun was turned on and began bombardment at 30keV, a current of 30 mA, diameter of around 5mm, and a current density measured in I/Area in nA/cm^2
- Exposure lasted about 1-2 minutes
- Video and Current data recorded during bombardment
- Gaps in recorded data are known as “dead time”, and are due to data in-between transmissions not being recorded and sent to the oscilloscope
- The Samples are removed from the chamber and photographed once again

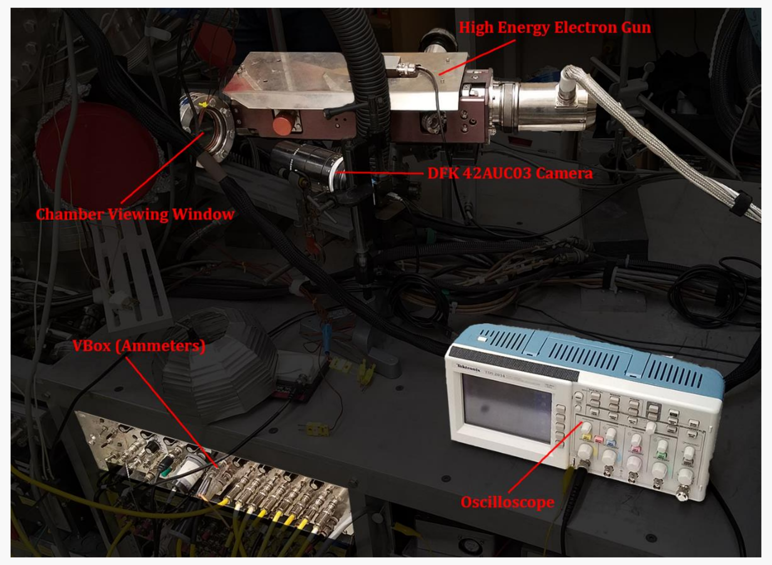

Figure 1: Experiment setup

ACKNOWLEDGMENTS

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CHARGING EFFECTS

Whether ESD occurs or not is dependent on how conductive the samples are.

- **Low Conductivity:** (PFA and Beta Cloth-PTFE samples) Where a material cannot effectively dissipate charge, and instead accumulates it. The incoming electrons charge up the material and cause an eventual breakdown. Examples in Figures 2 and 3.

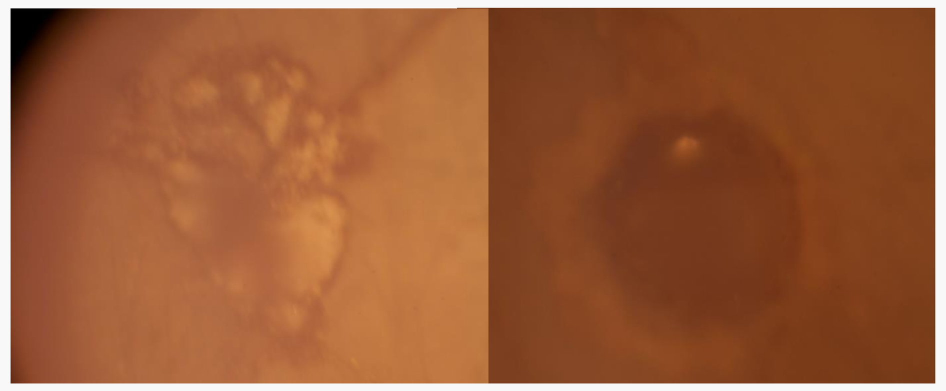

Figure 2: Examples of *low* conductivity; A Teflon sample after irradiation, accumulated charge

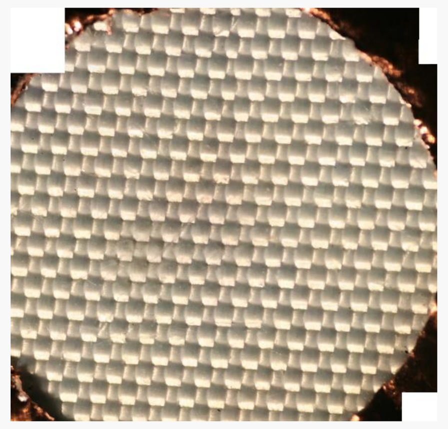

Figure 3: Examples of *low* conductivity; Beta Cloth-PTFE side up after irradiation, accumulated charge and has slight discoloration

- **High (enough) Conductivity:** A material can handle the high level of incoming electrons without breaking down, effectively dissipating charge. This results in virtually no change in the sample long term.

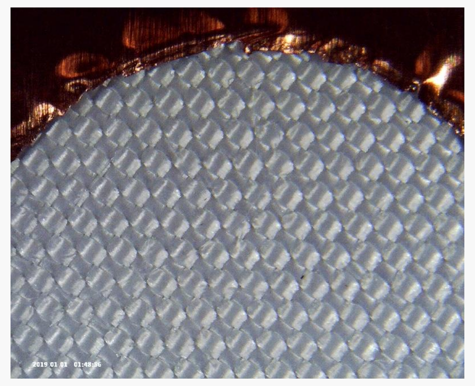

Figure 4: Examples of *high* conductivity; Beta Cloth-Aluminum side up to the left

RESULTS

- The resulting video data from the Gateway samples indicated two samples of particular interest, PFA and Beta Cloth-PTFE side up.
- Figure 5 shows PFA arcing during beam exposure, as well as the resulting damage pattern from irradiation.
- Beta Cloth-PTFE up showed some slight discoloration after exposure (Figure 3), which can raise the temperature of the material due to the darker color.

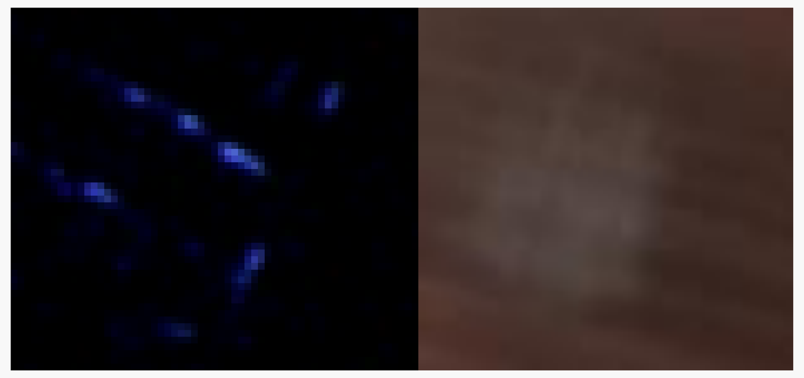

Figure 5: recorded arc in the video on the left, and the damage of the sample after it was taken out on the right

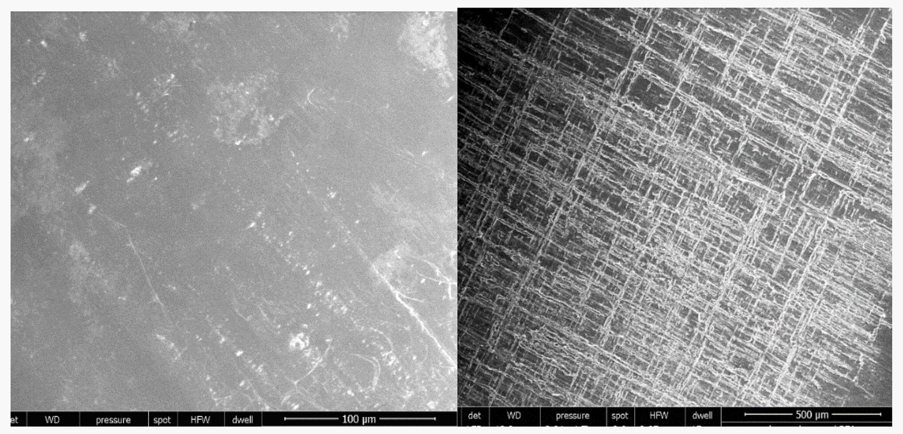

Figure 6: a non-damaged surface of PFA to the right and a damaged PFA to the left.

- Scanning Electron Microscopy (SEM) images were taken to give further scrutiny to the surface and any damage effects. Figure 6 shows a few these images for PFA
- Collected oscilloscope data was analyzed, and a resulting graph (Figure 7) shows the voltages of an arc on the PFA sample. These measurements are critical for any comparison to space and exposure times.

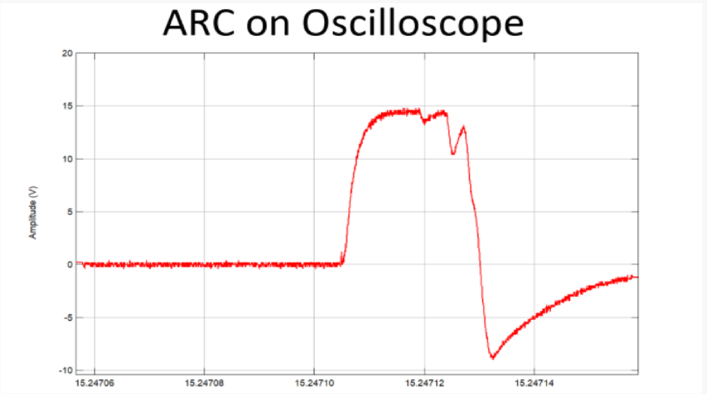

Figure 7: Electrometer trace and arc profile

CONCLUSION AND FUTURE WORK

Both PFA and Beta Cloth-PTFE are clearly susceptible to ESD from electron beam exposure. Teflon-PFA would fully erode in a relatively short amount of time in space, at an equivalent beam of current 20-30 nA, which poses obvious concerns if this were to be used for Gateway. The Beta Cloth-PTFE samples discoloration could raise the temperature of the space station and sabotage the project. This breakdown or heating could completely erode the material and possibly destroy other components of the Gateway Project if these materials were to be used.

Further work on this experiment includes improving sensor sensitivity, reduction of dead time, and simply more material testing. Increased time resolution for ammeters (current data collection), and the addition of more sensors could all improve the quality of experimental data as well.

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