Discharge Breakdown Analyses

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Recommended Citation
Sam Hansen, JR Dennison and Allen Andersen, "Electrostatic Discharge Breakdown Analyses," American Physical Society Four Corner Section Meeting, Utah Valley University, Orem, UT; October 17-18, 2014. Presentation received award for Undergraduate Poster.
Breakdown Analysis of Electrostatic Discharge

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Project Summary

Electrostatic discharge (ESD) is the associated material breakdown is the primary cause for spacecraft damage due to space environment interactions. This phenomenon occurs when the space plasma fluxes charge a craft to high voltages where insulating materials then break down. This failure allows current to flow freely through the material which can damage or destroy onboard electrical systems. My work focuses on the effects of these breakdowns on suspect materials commonly used for electrical insulation in space. The USU Material Physics Group has performed ESD tests on hundreds of samples to date. The ESD damage sites of these samples have been analyzed for parameters including breakdown size, shape, location, thickness, and analyzed type. More data has become available, including thickness, breakdown voltage, and breakdown E field. These results have been recorded in an ESD Quality Summary Table. Which we utilize for sorting potential correlations. Trends within this data have been identified and are being investigated more thoroughly.

This research is specifically being done in conjunction spacecraft charging applications where point source charging is an issue. Other potentially useful applications for our research include the possibility of updating our nation’s existing power grid from alternating current (AC) to high voltage direct current (DC) current. Our work would be important to create insulating products to prevent corona discharge in power lines.

Apparatus

Figure 3. Materials Physics Group electrostatic discharge apparatus.

This device is a simple parallel plate capacitor in high vacuum. The six electrode carousel applies up to 30 kV and can reach temperatures between 150 K and 330 K with a 4 N reservoir and resistive heater.

Procedure

1. Breakdown samples were imaged under microscope
2. Measured along their major and minor axis using photo editing software.
3. Breakdown sites were categorized by site attributes within the matrix.
4. Measured for thickness
5. This data was then entered into our database known as the ESD Quality Summary Table.
6. Data from the matrix was sorted and information such as eccentricity, area, and breakdown field strength were extrapolated for graphing purposes.
7. This information was plotted graphically, curve fit functions were used to look for trends and correlations.

Our table is essentially a “living” matrix, capable of being updated with new test results in the future. Features within the table allow for categorical sorting to view and compare different parameters. Trends within the data set are compared graphically for analysis.

Breakdown Samples

Breakdown Site Area and Thickness

At left is a comparison of breakdown area and thickness. Area was approximated by multiplying the major and minor axis of each sample. This comparison includes each sample type in our matrix, as well as each test type. Sample thickness was measured and averaged for each sample with an uncertainty of y = 0.005mm

Analysis

Analysis of the ESD affected samples as shown here indicates:

• Breakdown sites are elliptical rather than circular
• Material type does not influence size or shape of breakdowns
• Breakdown shape becomes more irregular with larger sized sites
• Increased breakdown E field does not influence damage size
• There is no correlation between area and thickness of breakdown sites

Our data set is predominantly populated with Low Density Polyethylene samples rather than a complete range of materials. Work is currently still being done to populate the matrix with different sample types. There also exists potential to find trends within the current data set. For future work I would like to analyze the spatial variability of breakdowns on samples. Doing this would accomplish several things:

• Quality control
• Locate sample material defects and the relationship that exists
• Look closer at causes of breakdown related to our equipment

Accurately mapping breakdown sites has many challenges associated with it but may tell us more about the process involved with material failure on high voltage scenarios.

The ESD Table is designed in such a way that it can continue to be updated with new data so future work can continue and be compared to current results.

Breakdown Characteristics for Comparison

Breakdown E Field vs Breakdown Area and Thickness

Comparison of ESD field strength to the resulting damage area and thickness is shown above. The initial hypothesis was that an increase in applied energy would result in greater material destruction. The total area of each breakdown site could not be measured accurately so a relative area was used by multiplying the major and minor axis together. Lack of observed correlation between E field and destroyed material tells us that there is a more complex process in the breakdown than previously thought. This data set includes all sample and test types found in our matrix.

Breakdown Diameter Comparison

Test Type Comparison

Material Comparison

Comparison of breakdown site, axis lengths for LDPE and Kaption™ data

References