ELECTROSTATIC DISCHARGE TESTING OF CARBON COMPOSITE SOLAR ARRAY PANELS FOR NASA'S PLANNED EUROPA MISSION TO JUPITER

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ABSTRACT

Carbon composite solar array panel coupons similar to those considered for use on the planned NASA Europa Mission were exposed to energetic electrons to observe the size and rate of electrostatic discharge production. The discharge size and rate were found to be primarily dependent on the quantity of dielectric binder pooled on the surface of the sample. Cooling the samples to cryogenic temperatures increased the size of discharges but an end of mission radiation dose had only minimal effects. Samples were composed of M55J carbon composite impregnated with an RS3 binder. Additional samples tested included a co-cured Kapton surface.

Keywords: Europa, Jupiter, electrostatic discharge, ESD, carbon composite, energetic electrons, temperature, radiation

1 INTRODUCTION

The next proposed NASA mission to visit Jupiter is known as the Europa Mission. The objective of this mission concept is to enter orbit around Jupiter in order to conduct multiple close flybys of the icy moon Europa. After careful trade studies, the mission designers have selected solar arrays as the baseline power system for the proposed mission rather than more traditional radioisotope thermoelectric generators.

In order for solar arrays to be feasible for this mission, the solar array structures would need to be made of carbon composite facesheets with an aluminum honeycomb core. While these composite structures are a good functional substitution for the metallic materials they replace, they present unique spacecraft charging challenges when interacting with the harsh Jovian space environment. As a composite material, they are constructed of more than one material which may show different base properties depending on differing conditions.

In the Jovian environment, with temperatures reaching 50K and under the bombardment from energetic electrons, the non-conducting pre-preg binding materials may heavily influence how these materials respond to the space environment. Before the project selected solar arrays as the baseline power system for the Europa Mission, the response of the carbon composites to energetic electrons while held at cryogenic temperatures was examined.

2 TESTING

2.1 Test Samples

A series of tests were devised to determine the response of a sample solar array panel composed of an M55J carbon weave layup with an RS-3 pre-preg binder. Test coupons were fabricated and exposed to electrons ranging from 10 keV to 100 keV, at 1 nA/cm2, while being held at both room and cryogenic temperatures. Test coupons included samples with only the bare M55/RS3 facesheets similar to what would be found on the rear of the solar array panels and with a co-cured Kapton surface as would normally be used underneath the solar cells.

2.2 Test Results

A summary of the test results including average and maximum electrostatic discharge (ESD) energies and discharge rates can be found in Table 1. The discharge energy given is the fraction of the total discharge that was dissipated in a 50 ohm resistor used in the test system. This value is representative to what might couple into a spacecraft system with a similar impedance. The discharge rate was calculated by dividing the total number of discharges in two difference energy regimes by the total exposure time.

2.3 Surface Preparation

While under electron bombardment, the M55J/RS3 sample produced electrostatic discharges with the majority of discharges occurring with electron energies of 25 keV at 1 nA/cm2 and few to no ESD events with higher electron energies indicating that the material producing the discharges is quite thin and mainly on the surface. A scanning electron microscope was used to image the surface of the 'As Received' M55J/RS3 samples. These images showed of streaks of non-conductive RS3 binder pooled on the surface of the carbon composite facesheets. Since the carbon weave is generally conductive, the binder material on the surface is the element of the composite that retains the incident electrons in sufficient quantity to produce large electric fields and generate the recorded dielectric discharges. In an effort to test this conclusion, the surface of several of the sample coupons was lightly abraded with either a

Table 1. Summary of testing results for M55J/RS3 and co-cured Kapton solar array coupons.

Sample Name	Temp.	Elec. Energy	50 ohm ESD Energy – Average	50 ohm ESD Energy – Max	Discharge Rate >1 nJ	Discharge Rate >1 µJ
As Received	298K	10 keV	103.8 µJ	1.116 mJ	12 mHz 1 per 84 s	9.9 mHz 1 per 101 s
As Received	93K	10 keV	258.2 µJ	2.210 mJ	6.3 mHz 1 per 158 s	5.3 mHz 1 per 186 s
As Received	298K	25 keV	1.944 µJ	97.17 µJ	185 mHz 1 per 5.4 s	51 mHz 1 per 19 s
As Received	93K	25 keV	12.85 µJ	477.3 µJ	134 mHz 1 per 7.5 s	65 mHz 1 per 15 s
As Received Post-Rad	93K	25 keV	12.61 µJ	679.8 µJ	153 mHz 1 per 6.5 s	64.6 mHz 1 per 15 s
Scotchbrite Post-Rad	93K	25 keV	1.020 µJ	41.60 µJ	119 mHz 1 per 8.4 s	21.2 mHz 1 per 47 s
Sanded Post-Rad	93K	25 keV	10.68 nJ	145.3 nJ	4.5 mHz 1 per 222 s	none
Co-Cured Kapton	298K	25 keV	1.886 mJ	8.506 mJ	6.7 mHz 1 per 149 s	5.8 mHz 1 per 173 s
Co-Cured Kapton	93K	25 keV	7.023 mJ	20.89 mJ	6.8 mHz 1 per 146 s	6.0 mHz 1 per 168 s
Co-Cured Kapton Post-Rad	298K	25 keV	567.7 µJ	2.245 mJ	4.9 mHz 1 per 202 s	4.5 mHz 1 per 222 s
Co-Cured Kapton Post-Rad	93K	25 keV	5.320 mJ	17.95 mJ	8.2 mHz 1 per 121 s	6.5 mHz 1 per 153 s

red 3M Scotchbrite pad to produce the ‘Scotchbrite’ samples or more heavily abraded with 220 sandpaper to produce the ‘Sanded’ samples. In both cases, a portion of the pooled binder material was removed. Scanning electron microscope images of these modified sample surfaces showed a substantial reduction in the quantity of the pooled dielectric. When exposed energetic electrons, the ESD size and rate of occurrence on these samples decreased by orders of magnitude validating the earlier conclusion.

The surface of the co-cured Kapton samples is composed of a continuous sheet of the dielectric negating the need for additional surface modification. When these samples were exposed to 25 keV electrons, the resulting discharges were two to three orders of magnitude larger than the unmodified M55J/RS3 samples. This result furthers the observation that the size of the resulting discharge is related to the total area of dielectric on the surface of the exposed sample.

2.4 Temperature and Radiation Effects

Since the temperatures in the Jovian environment are projected to reach down to 50K and the solar arrays will receive a heavy radiation dose, it was decided to include the effects of temperature and radiation dose when testing materials. The solar array sample coupons were tested at both room temperature and liquid nitrogen temperatures both before and after receiving an end-of-mission level of radiation dose. The radiation dose was provided by exposing samples to 1 MeV electrons at a flux of 1×1011 electrons/cm2/second until reaching a total fluence of 6.5×1015 electrons/cm2.

During testing, the sample coupons were mounted on a cold stage and exposed to 25 keV electrons at 298K and 93K, the lowest level available using a liquid nitrogen cooling system. Samples were held at these temperatures under continuous electron bombardment for six hours while being monitored for the production of discharges. Samples tested at both temperatures included the ‘As Received’ M55J/RS3 samples and the co-cured Kapton samples. In an additional round of testing, the abraded ‘Scotchbrite’ and ‘Sanded’ samples were tested at the worst case conditions of 93K after receiving the end-of-mission radiation dose.

As seen in Table 1, the results indicate that a decrease in temperature to liquid nitrogen temperatures increased the magnitude of the resulting discharges by a factor of approximately five. The end-of-mission radiation dose showed little change to the overall levels of discharges on the M55J/RS3 coupons and a small decrease in the size and quantity of events on the co-cured Kapton sample.

3 CONCLUSION

The results indicate that dielectric discharges are primarily produced due to the presence of large regions of the non-conductive pre-preg binder on the surface of the carbon sheets. The frequency and magnitude of discharges decreased when layers of the dielectric material were removed from the composite surface. Decreasing the temperature of the samples by approximately 200 degrees K caused an increase in the size of the discharges by a factor of five. Radiation exposure had a minimal effect on the M55J/RS3 samples, and caused a small reduction in the size of the discharges from samples with a co-cured Kapton surface. These tests indicate that solar array panels may be used by the Europa Mission in the Jovian environment, but that electrostatic discharges could be expected on the carbon composite solar arrays.

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