Space Plasma interaction experiment on solar array

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Abstract: Multi junction solar cells from different vendors are used for fabricating solar panels by ISRO. In order to understand the behavior of such solar arrays in LEO and GEO plasma environment three coupons were fabricated and measured at ISRO's SPIX(Spacecraft interaction experiment) facility established at FCIPT, IPR. The results reveal no significant threshold variations in all three coupons for both GEO and LEO environment.

Introduction

Electrostatic Discharge (ESD) occurring in solar panels is a major concern for space photovoltaic engineers. This phenomenon occurs at insulator, conductor and space plasma junction commonly known as triple junction in literature. Although there have been efforts to make the surfaces as conductive as possible, spacecraft area still consists of insulating materials like solar cell cover glass. In order to understand the impact of plasma on solar array and study the power degradation, experiments were conducted on a set of solar coupons in simulated GEO and LEO environment at "SPIX (Spacecraft interaction experiment) facility in Institute for plasma research established by ISRO satellite center. Multi junction solar cells from various vendors are being used in spacecraft launched by ISRO. This study compares the behavior of three solar coupons fabricated in UN grouted process with exposed interconnectors in plasma environment. The coupons are fabricated with solar cells from different vendors and vary in cover glass (CG) and interconnector(IC) material.

Table 1 Coupon description

COUPON	Description
Coupon A	CG type 1 & IC type 1
Coupon B	CG type 2 & IC type 1
Coupon C	CG type 1 & IC type 2

Experimental set up

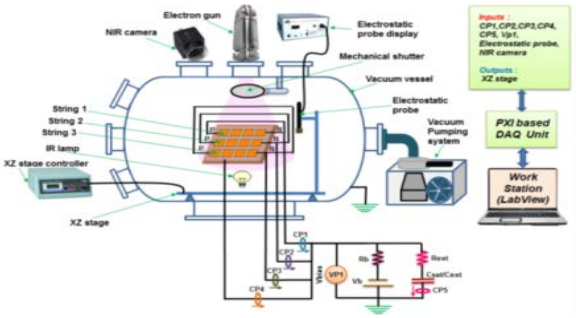

Fig 1 Experimental Setup for primary experiments

The facility at IPR has been established based on the guidelines of ISO standards for spacecraft charging induced ESD test methods. The facility consists of 1m long 1m wide vacuum chamber in which a 300mm X 300mm solar coupon can be mounted and checked for plasma interactions. The chamber is mounted with electron gun of variable energy to simulate GEO environment and argon plasma source to simulate LEO environment. An efficient camera is used to capture the arcing phenomenon. In GEO environment a non-contact probe along with XY stage controller is used to measure the surface potential of the coupon. A highly capable Data acquisition system based on Lab view is used to integrate and interface the subsystems.

LEO PRIMARY

In the LEO primary environment the thresholds of different coupons were measured and compared. The arc location statistics was also observed and compared.

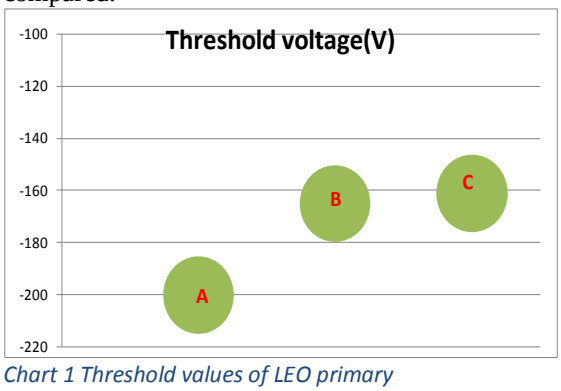

Chart 1 Threshold values of LEO primary

Table 2 Threshold values of LEO primary

Coupon	Threshold voltage(V)
Coupon A	-200
Coupon B	-160
Coupon C	-161

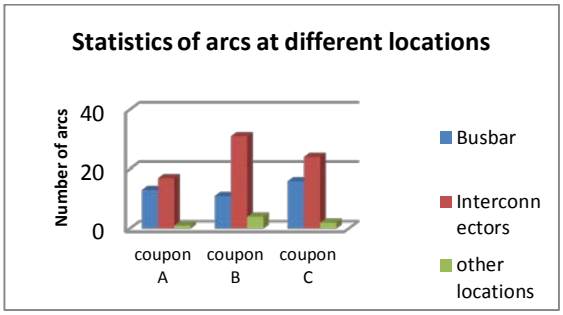

Chart 2 Statistics of arc location in primary experiments

The threshold values of all three coupons are in -160 to -200 V range. The threshold values obtained are similar to the values obtained in silicon solar coupons in ref [1].The CG type2 has more surface resistivity compared to type 1. However remarkable difference in threshold values is not observed due to this. As far as arc location statistics all coupons show maximum arcs in the interconnector cover glass junction compared to bus bar owing to more number of exposed interconnectors. The other locations is between cover glass and kapton covered substrate or between cover glass and back contact. The shape of solar cell and inadequate cover glass overhang may be the reason for the arcing at these locations

GEO PRIMARY

In GEO primary experiments apart from threshold measurements differential potential between cover glass and interconnector was obtained from the surface potential measurements of the coupon. This is compared with spenvis simulation in average GEO environment as per NASA guidelines.

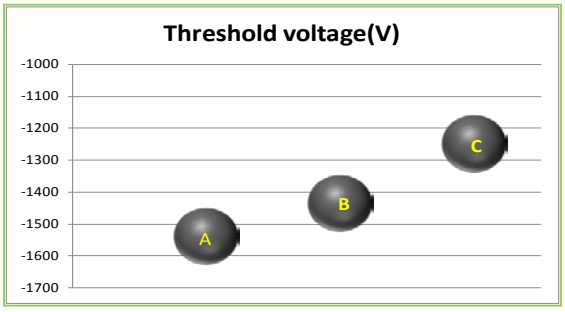

Chart 3 Threshold values of GEO primary

Table 3 Threshold values of GEO primary

Coupon	Threshold voltage(V)
Coupon A	-1540
Coupon B	-1437
Coupon C	-1250

Table 4 Differential potential values

Differential potential between Cover glass and Interconnectors in volts	
Coupon A	**200**
Coupon B	**200**
Coupon C	**210**
Differential potential between cerium doped glass and silver according to calculation using Spenvis	**200**

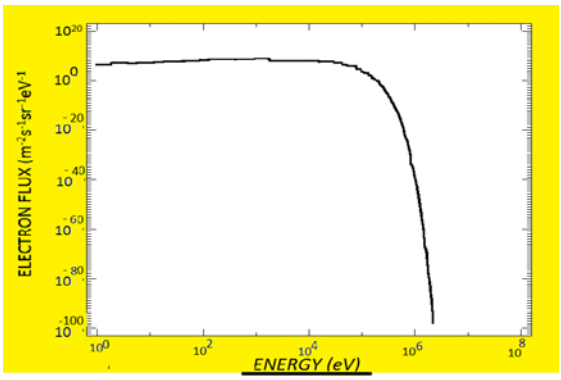

Chart 4 Plot of electron flux in simulation

The threshold values of all the three coupons are in the -1200V to -1550V zone. The differential potential between coverglass and interconnector is matching with the simulation of a cerium doped glass and silver in Spenvis EQUIPOT surface charging simulation.

GEO SECONDARY

The GEO Secondary experimental set up is shown in figure 2 .The energy of electron gun is set for 4 KeV. The bias voltage for the coupon is -3500V. With this settings results of Coupon B in

secondary arcing is given in Table5. From the results the NSA threshold is higher for 2mm string gap than for 1 mm string gap. The GEO secondary experiments for other coupons need to be performed for comparison.

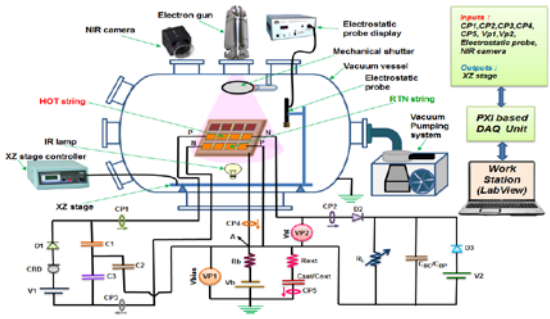

FIgure2 Circuit for GEO secondary arcing experiment

Table 5 GEO secondary experiment results

Coupon type	Inter string gap	No of arcs	arc details	String voltage	String Current
Coupon B	1mm	5	PA-2, NSA-3	50V	0.5A
	2mm	5	PA-5, NSA-0	50V	0.5A
	2mm	5	PA-3, NSA-2	50V	1A
	2mm	5	PA-4, NSA-1	50V	1.5A
PA- primary arc ,NSA non sustained arc					

Conclusion

The plasma interaction of cells at LEO and GEO with two types of cover glass and interconnector were compared.

- The CG type2 has higher transmission and it is desired compared to CG type1. However surface resistivity of CG type2 is higher compared to CG type1. But from the above results all the coupons threshold values both in GEO and LEO falls in same zone showing no significant differences.
- Ic type 1 is made of alloy with silver coating and Ic type 2 is made up of silver. No significant change in the differential potentials were observed in GEO experiments.
- The differential potential between CG and IC is comparable with Spenvis calculation in Average GEO environment as per NASA guidelines.
- In the GEO secondary experiment on coupon B the NSA threshold is higher for 2mm string gap than for 1 mm string gap. The GEO secondary experiment s for other coupons need to be performed for comparison.

Acknowledgement

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Refernce

1) “High Voltage solar array for 400V operation in LEO plasma environment” by Satoshi Hosoda & Teppai okumura Mengu cho
2) “Mitigation techniques for arcing on space solar panels- results from ISRO” by Suresh E.Puthanveettil, M.Sankaran and S.B.Gupta