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EXPERIMENTAL STUDY OF SOLAR ARRAY-PLASMA INTERACTION

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The results are presented of an experimental study of arc phenomena and snapover for five types of solar array samples immersed in xenon plasma. I-V curves are measured, and arc and snapover inception voltages, essential parameters, and arc rates are determined. It is shown that the array with wrapthrough interconnects has the highest arc threshold and the lowest current collection. Coverglass design with overhang results in decrease of current collection and increase of arc threshold. Doubling coverglass thickness does not improve measured array parameters. Both arc inception voltage and current collection increase significantly with increasing a sample temperature to 80 C. Arc sites have been determine by employing a video-camera. The results obtained seem to be important for the progress toward employment of high- voltage solar array in Low Earth Orbit.

1. Introduction.

The main obstacle to the implementation of a high-voltage solar array in space is arcing on the conductor-dielectric junctions exposed to the surrounding plasma. One obvious solution to this problem would be the installation of fully encapsulated solar arrays which were not having exposed conductors at all. However, there are many technological difficulties that must be overcome before the employment of fully encapsulated arrays will turn into reality. An alternative solution to raise arc threshold by modifications of conventionally designed solar array looks more appealing, at least in the nearest future. A comprehensive study of arc inception mechanism[1] suggests that such modifications can be done in the following directions: i) to insulate conductor-dielectric junction from a plasma environment (wrapthrough interconnects); ii) to change a coverglass geometry (overhang); iii) to increase a coverglass thickness; iiii) to outgas areas of conductor-dielectric junctions. The operation of high-voltage array in LEO produces also the parasitic current power drain on the electrical system. Moreover, the current collected from space plasma by solar arrays determines the spacecraft floating potential that is very important for the design of spacecraft and its scientific apparatus. In order to verify the validity of suggested modifications and to measure current collection five different solar array samples have been tested in large vacuum chamber. Each sample (36 silicon based cells) consists of three strings containing 12 cells connected in series. Thus, arc rate and current collection can be measured on every string independently, or on a whole sample when strings are connected in parallel. The heater installed in the chamber provides the possibility to test samples under temperature as high as 80 C that simulates the LEO operational temperature. The experimental setup is described below.

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2.Experimental setup

Low Earth Orbit (LEO) plasma environment was simulated in two different vacuum vessels: 1) small bell jar (45 cm diameter and 75 cm height); 2) large vacuum tank (1.8 m diameter and 3 m height). The vacuum equipment provided pressure as low as 0.5 μTorr. One Penning source was installed in a small tank to generate argon (or xenon) plasma with electron density n_e=(0.1-10)$\cdot 10^5$ cm^{-3} , temperature T_e=1-1.2 eV, and neutral gas pressure p=(0.7-7)$\cdot 10^{-5}$ Torr which could be kept steady during the experiment. To supply large tank with plasma the hollow cathode was installed, and it provided plasma with lower electron temperature T_e=0.5-0.8 eV and the same density. Later this hollow cathode was exchanged on Kaufman source that generated plasma with close parameters. To measure plasma parameters, Langmuir probes with diameter 2 cm were employed (one in bell jar and two in large tank). To determine an ion distribution function and to improve measurements of electron temperature one retarding potential analyzer (RPA) was mounted on the bottom of large tank. It was found that the ion (xenon) thermal flux in the experiment is about three times lower than ram ion flux in LEO, and the electron temperature is 5-10 times higher than in ionosphere. However, the number densities are simulated with a quite high accuracy, and one can believe that the results of high-voltage experiments in vacuum chambers are fairly adequate to the outcomes of processes in LEO plasma. To control plasma chemical composition (particularly, water vapor and oil partial pressures) a quadruple mass spectrometer was installed in large vacuum tank.

The sample (or set of samples) is vertically mounted in the middle of the chamber, and it is biased to a voltage power supply through a capacitor and a 10 kΩ resistor network back to ground. An additional power supply (Solar Array Simulator-SAS) is used to generate electrical field perpendicular to the dielectric side surface for investigating arc inception on semiconductor-dielectric junction and inception of sustained discharges between adjacent strings. Diagnostic equipment includes two current probes to measure discharge current and SAS current, and one voltage probe that allows us to register voltage pulse on the sample during the discharge. To measure optical spectra of arc plasma an intensified CCD camera with optical spectrometer is installed. The most probable arcing sites are determined by employing a video camera and VCR. Most experiments were performed at room temperature (15C), but some tests had been done at the temperature +80 C simulating the exposure of solar array to full sun in LEO.

3. Experimental results.

Each string (12 cells in series) of five types of solar arrays was tested separately, and measurements revealed significant differences in arc rates even for strings belonging to one sample. There are two reasons explaining such observations: manufacturing process peculiarities and geometrical design of a sample. Manufacturing peculiarities demonstrate themselves when one compares arc parameters for two outer strings and finds considerable differences. And arc sites are located mostly on interconnects for middle string while great part of arcs on outer strings has been observed on cell edges. To preserve the homogeneity of collected data one common experimental procedure is used for all measurements of arc inception voltages and arc rates: 1) string is initially biased to voltage well below an expected arcing threshold; 2) 15-30 minute time interval is allowed to register (or to not register) an arc; 3) voltage is increased on 10-20 V; 4) arc rate is defined as an average over a respective time span. Some results of measurements are shown in Fig.1.

Short electrostatic discharges studied above are certainly undesirable events that must be prevented for reliable operation of the spacecraft. However, this kind of transients are not damaging solar array irreversibly. Sustained discharges initiated between adjacent cells with a few tens volt potential difference are much more dangerous because they can destroy cells and underlying substrate that results in considerable loss of power. Three samples have been tested against an inception of sustained arc between two strings. Test starts with lower limits on SAS voltage and current. After the registration of 5-10 arcs these parameters are gradually changed and more arcs are generated until initial sign of sustained discharge is seen on the oscilloscope. This sign represents the SAS current pulse that continues much longer than original arc. The corresponding SAS current and voltage are considered as threshold parameters because even a small increase of them (10 V and 0.25 A) results in spectacular event shown in Fig. 2. In this case the sustained discharge has been quenched after 20 s by turning SAS off. Significant area of the sample around arc site was damaged. Threshold parameters depend on solar array design. (For details see Ref. [2]).

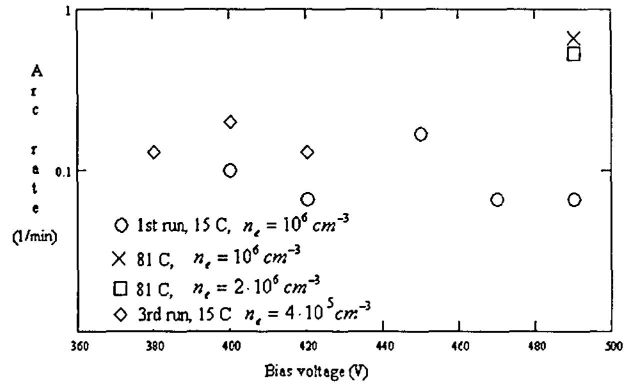

Fig.1. Arc rates are shown under different conditions for the middle string with coverglass thickness 150 μm.

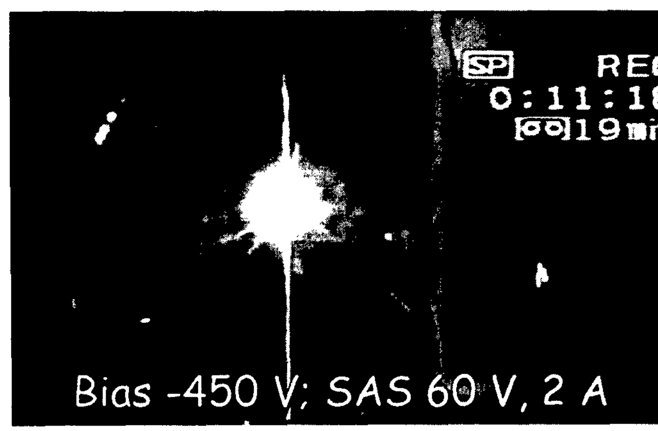

Fig.2. One frame of a 20 s long video record of a sustained arc.

Comprehensive tests of five different types of solar array samples in simulated LEO plasma environment have demonstrated that the highest arc threshold (440 V) can be achieved for an array with wrapthrough interconnects if edges of strings are not exposed to the plasma. This design is also effective in decreasing of an array current collection. The design with exposed interconnects but with coverglass overhang also provides significant improvement comparatively to the conventional design. Particularly, arcing on the sample cannot be initiated at potentials below 300 V even under room temperature, and arc threshold increases to 420 V under temperature 72 C. The increase of coverglass thickness itself appears to be useless in this respect.

References

1. Vayner, B.V., Galofaro, J.T., and Ferguson, D.C. Proc.XXth ISDEIV, 2002, Tours, France, pp.80-83
2. Vayner, B.V., Galofaro, J.T., and Ferguson, D.C. Journal of Spacecraft and Rockets, 2003, in press.