PRELIMINALY STUDY OF THE INFLUENCE OF SOLAR CELL DEGRADATION DUE TO ESD ON SOLAR ARRAY POWER GENERATION

Teppei Okumura[1], Kazuhiro Toyoda[1], Shirou Kawakita[2], Mitsuru Imaizumi[2], Mengu Cho[1]
1. Department of Electrical Engineering
Kyushu Institute of Technology, 1-1 Sensui, Tobataku, Kitakyushu 804-8550, Japan
2. Japan Aerospace Exploration Agency

ABSTRACT

In space, an electrostatic discharge (ESD) can occur on a solar array due to the plasma interaction. One of the issues of ESD is the degradation of solar cell electric performance. To establish the power degradation estimation method due to ESD in solar arrays, light current-voltage characteristics are evaluated in the current value at maximum power. From the results of the calculation, InGaP/GaAs/Ge solar arrays potentially suffer more serious power degradation than Si solar array.

1. Introduction

The electrostatic discharge, the so-called primary arc, occurs on solar arrays because of the plasma interaction. The detail phenomenon about primary arcs is described in Ref. 1. In order to establish an international standard for solar array primary arc tests, the collaboration research is carrying out in France, USA and Japan[2]. Because one of the issues of primary arcs is the degradation of solar cell electric performance[3][4], the primary arc test on Silicon with integrated bypass function solar cell (Si w/IBF cell), Silicon solar cell (Si w/o IBF cell) and InGaP/GaAs/Ge solar cell (3J cell) have been carried out[5].

Originally, only the radiation particles have been considered as the cause of solar cell degradation. Therefore, the solar cell degradation due to primary arcs should be combined with the estimation method for solar array power generation in satellite life. The solar array power degradation due to primary arcs is examined as a preliminary study in this paper.

2. Experiment

The 3J cell, Si w/IBF cell and Si w/o IBF cell are shown in Fig. 1. The solar cell performance is flight quality. The size of the cell is about 40mm×80mm. The solar cell is attached to an aluminum plate which was covered with a polyimide sheet using a silicone adhesive (RTV-S691). The thickness of the coverglass was 100μm. The bus bar was insulated with a silicone adhesive as in the real solar array design.

Fig.2 shows the light current-voltage characteristics (Light IV) and the light power-voltage characteristics (Light PV) of a 3J cell. Because the solar array is operated under constant voltage, the current value at maximum power (I_{mp}) is defined as the characteristic value of the light IV. The change in I_{mp} by one primary arc is defined as dI_{mp} obtained from eq.1.

$$dI_{mp} = \frac{(I_{mp\_before} - I_{mp\_after})}{I_{mp\_before} \times N_{arc}} \times 100, \% \quad (1)$$

The discharge circuit is shown in Fig.3. The primary arc experiment has been carried out under plasma conditions (LEO environment) and high energy electron beam conditions (GEO environment). The detail of the experiment condition is described in Ref.5.

A typical current waveform is a pulse whose duration is approximately 10μsec. We can adjust the peak value of the primary arc current and the primary arc energy by changing C_{ext}. The primary arc energy is obtained from two calculation methods. Under LEO environment, the primary arc energy (W_{arc_LEO}) is obtained from eq.2 where T_{ini} and T_{end} are the beginning and the end time of the primary arc current. Because of the malfunction of the voltage probe in a GEO environment, the arc energy (W_{arc_GEO}) is obtained from eq.3. Q_{arc} is the charge value of the primary arc[5].

$$W_{arc\_LEO} = \int_{T_{ini}}^{T_{end}} I(t) \times V(t)\, dt, \ J \quad (2)$$

$$W_{arc\_GEO} = Q_{arc}^2 / 2 \times C_{ext}, \ J \quad (3)$$

3. Results and Discussion

Fig.4 shows the relationship between dI_{mp} and W_{arc} of a 3J cell. dI_{mp} increases with an increasing value of W_{arc}. The maximum dI_{mp} is 14% at 30mJ of W_{arc_LEO}. The minimum dI_{mp} is 0.05% at 0.8mJ of W_{arc_GEO}. Fig.5 shows the relationship between dI_{mp} and W_{arc} on a Si w/IBF cell and on a Si w/o IBF cell. The minimum W_{arc} for the degradation is 30mJ of W_{arc_LEO}; dI_{mp} is 0.2%. The maximum dI_{mp} is 1.5% at 280mJ of W_{arc_GEO}. Because the silicon solar cell is more robust than the 3J cell as reported in ref.5, dI_{mp} of the Si cell is much smaller than that of the 3J cell under the same W_{arc}.

In general, the solar array is operated under a constant voltage. Therefore the output voltage of each solar cell is briefly determined by the number of solar cells and the output voltage of the solar array. In the case of the 3J solar array (output voltage; 60V, output current; 0.45A, output power; 27W, number of 3J cell;

30), the decrease of the output current by 14% in one 3J cell causes a decrease of 0.7% in output power.

4. Summary and Future work

In order to establish the estimation method for solar array power degradation due to primary arcs in solar arrays, the preliminary study was carried out. Because the solar array is operated under constant voltage, the light IV characteristic is evaluated at the current value at maximum power.

From the results of the examination, the decrease value of the current output is increasing with arc energy in the case of the 3J cell. In the worst case, the 3J cell loses around 10% of its output current from a single arc. In the case of the Silicon cell, the decrease value of the current output does not have a strong relationship with the arc energy. In the worst case, the Silicon cell loses around 1% of its output current from a single arc.

Acknowledgement

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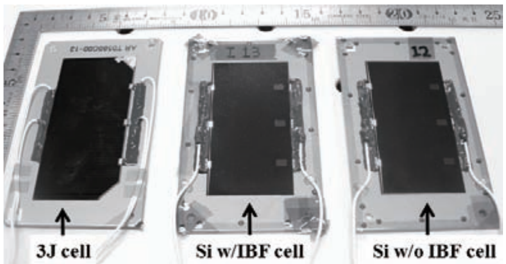

Fig.1 3J cell, Si w/IBF cell and Si w/o IBF cell

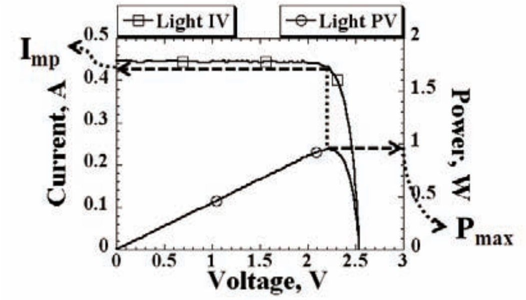

Fig.2 Light current-voltage characteristics and light power-voltage characteristics of a 3J cell

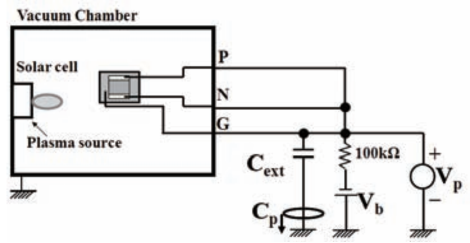

Fig.3 Discharge circuit

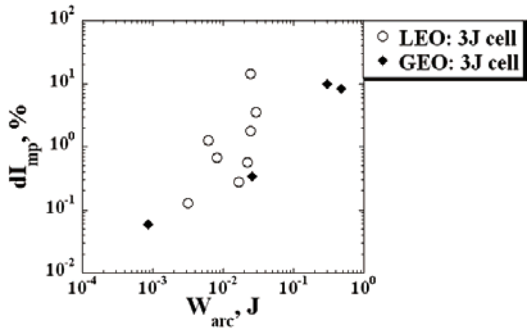

Fig.4 Relationship between dI_{mp} and W_{arc} on a 3J cell

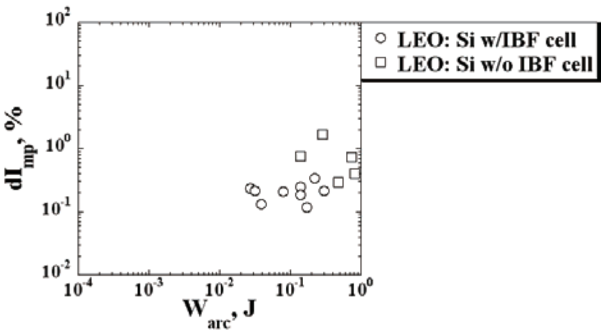

Fig.5 Relationship between dI_{mp} and W_{arc} on a Si w/IBF cell and on a Si w/o IBF cell