Charging mitigation on solar cell by using semi - conductive coating for Horyu IV and MicroDragon satellites

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1. Research background and purpose

Spacecraft charging is the buildup of spacecraft surface potential and in the spacecraft interior. Dícharges resulting from spacecraft charging induce many kinds of effects, such as structure damage, degradation or failure of spacecraft components and operation anomalies due to damage of electronic devices. A majority of satellite failure has been reported is caused by charging and discharging phenomena, especially on solar array, which is one of the most important systems on every satellite. A charging mitigation method on solar array using semi-conductive Antimony Tin oxide (ATO) coating is being developed in Laboratory of Spacecraft Environment INteraction Engineering (LaSEINE). The purpose of this research is to study the effectiveness of ATO coating in mitigating charging-discharging phenomena on solar cells.

2. Experiment method

By applying an ATO coating on entire solar cell surface, it will connect cover glass of solar cell to the satellite's ground. The coating layer allows charge to conduct to satellite's chassis and mitigate local surface charging on solar cell and keep it at a safe level, there will be no significant potential difference between cover glass surface and satellite's ground. Therefore discharges will not occur.

To evaluate performance of ATO coating, it is necessary to conduct four kinds of experiments. First is charging mitigation experiments. the coated solar cell coupon is connected to the ground and irradiated under high-energy electron beam. After a certain of time, surface potential of coupon is measured with non-contact high voltage probe.

Once the effectiveness of ATO coating is confirmed by charging mitigation capability, discharge experiment is conducted. In this experiment, solar cell coupon is biased at -5kV and irradiated under the same electron beam condition in charging mitigation experiment.

After applying a coating on solar cell surface, power generation of solar cell is the most important factor that needs to be considered. Therefore, it needs to be measured before and after applying coating. The effect of coating to power loss of solar cell could be estimated by comparing these two results.

Thermal cycling test also needs to be conducted to investigate thermal variation effect to ATO coating performance.

3. Experiment results

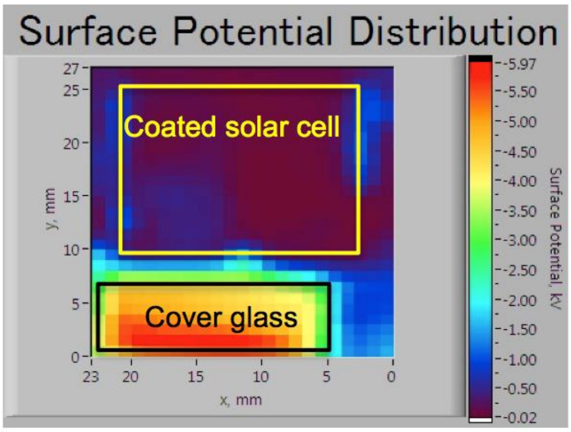

Figure 1 Surface potential of coated solar cell and cover glass.

Figure 1 shows surface potential of a coated solar cell coupon and a non-coated cover glass under electron beam at 10keV in charging mitigation experiment. From the color scale, it is clear that cover glass surface is highly charged up to -6kV while coated solar cell coupon is hardly charged.

During the discharge experiment, there were several discharge points observed on non-coated solar cell while no discharge occurred on coated solar cell. The number of discharge observed in experiment is shown in table 1. The effectiveness of ATO coating could be verified.

Table 1 Number of discharges

E-beam energy (KeV)	Number of discharge	
	Non-coating	Coating
7	1	0
8	4	0
9	2	0
10	3	0
11	2	0

Power generation of solar cell coupon with and without coating are shown in the Figure 2. By comparing the two results, power generation of the coupon after coating is decreased about 2.4% at peak power point. This is significant improvement in comparison with the result of previous research, which was 35.5% [1].

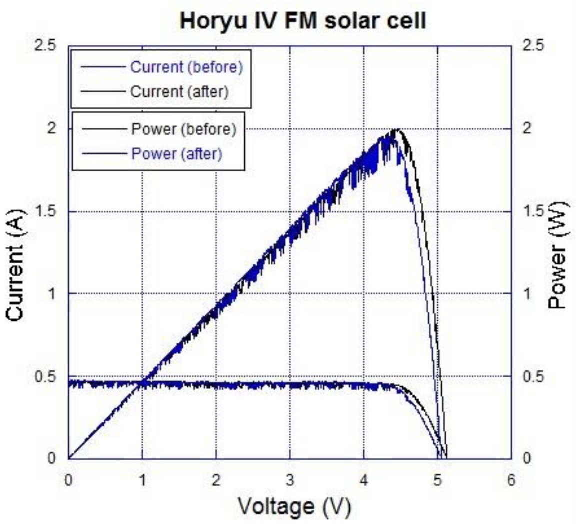

Figure 2 I –V characteristic of solar cell with and without coating.

Thermal cycle test is also conducted and no affect after 50 thermal cycles could be found in charging mitigation capability of ATO coating.

After doing necessary experiments on ground, a coating solar cell coupon is attached on Horyu IV satellite. Discharge experiments on solar cell coupons were conducted to evaluate charging mitigation capability of ATO coating in Low Earth Orbit. A camera was used to detect the discharge position if it occurred. Experiment results show that the coating is not fully effective to prevent discharges on solar cell. Several discharges were observed and images of discharge points were captured. Reason of discharges occurred is the coating might not well cover the edges of solar cell, when it is exposed to space environment, they become very weak points against discharges.

Two other triple junction solar cells are prepared and will be mounted on MicroDragon satellite after doing same experiments with solar cell coupon on Horyu IV satellite. One I-V measuring circuit is designed in order to measure power generation of both coated and non-coated solar cell. Measured data shall be used to calculate power loss of coated solar cell when it is operating in space.

4. Summary

This charging mitigation method using ATO coating is intended to implement on Geosynchronous Orbit (GEO) satellite. However, it is difficult for a student research to have a chance to attach solar cell coupon on a GEO satellite. On ground experiment results showed a high capability of ATO coating in charging mitigation but Horyu IV's on orbit experiment results show that this ATO coating could not prevent discharge on solar cell. Therefore, to make the coating works in LEO environment, we need to conduct more experiments to find a better coating condition to mitigate charging-discharging phenomena on solar cell while keeping its power generation.

Reference

[1] A. Takahashi, R. Muraguchi, M. Iwata, and M. Cho, "Charging and Arcing Test on Semiconductive Coated Solar Coupon Panel", IEEE Transactions on plasma science, Vol. 43.