THE RELATIONSHIP BETWEEN CHARACTERISTIC OF SECONDARY ELECTRON EMISSION AND IRRADIATION DOSE IN POLYIMIDE

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ABSTRACT

Recently, electrostatic discharge (ESD) phenomenon caused by radio-active rays is reported as the cause in a number of spacecraft accidents. To prevent such accident at the designing stage of spacecraft, the "Multi-Utility Spacecraft Charging Analysis Tool (MUSCAT)" had been devEloped. There is secondary electron emission yield (SEEY) in one of the parameter required for MUSCAT.

Currently, SEEY of beginning of life (BOL) sample is applied to MUSCAT. However, the SEEY of end of life (EOL) is considered to change from BOL in the space. In this report, we measured SEEY of polyimide aged by electron beam. From the results, we discuss the relationship between the SEEY and the irradiation dose.

1. INTRODUCTION

Currently, a large number of spacecraft including space probe and weather satellite are operating. Radiation, High-energy particles (electron, proton, heavy ion) and plasma exist in space. These are cause for charging the insulating material of spacecraft surface. The spacecraft is the origin of charged excessively, an electro static discharge (ESD). ESD is a cause of deterioration of insulating material for spacecraft and failure of on board equipment. In the worst case, it leads to operation anomaly in the orbit. Therefore, to prevent ESD, Satellite developer of Japan analyzes the surface potential of spacecraft with Multi-utility spacecraft charging analysis tool (MUSCAT). In this analysis, MUSCAT requires the electrical properties, volume resistivity, the secondary electron emission yield (SEEY), the photo electron emission yield and so on. Therefore, we focus to study the SEEY.

A number of studies were reported of SEEY on spacecraft surface materials. But, SEEY on aging material have not been seen mostly. To long term operation of spacecraft, it is important that SEEY on the materials degraded by radio-active rays condition of the end of satellite life (EOL) on the orbit. Furthermore, if the SEEY on aged sample was different compared with pristine's result, it should be considered whether the differential is permanent change.

Therefore, in this report, we focused the electron, such as one of the element of space environment. And we study the SEEY on the surface materials of spacecraft irradiated by an electron for simulating EOL radiation condition on GEO.

According experimental results, we compared with the characteristic of SEEY of BOL sample and EOL one and discussed the relationship between the SEEY and the dose.

2. MEASUREMENT SYSTEM AND METHOD

2.1. SEEY measurement system

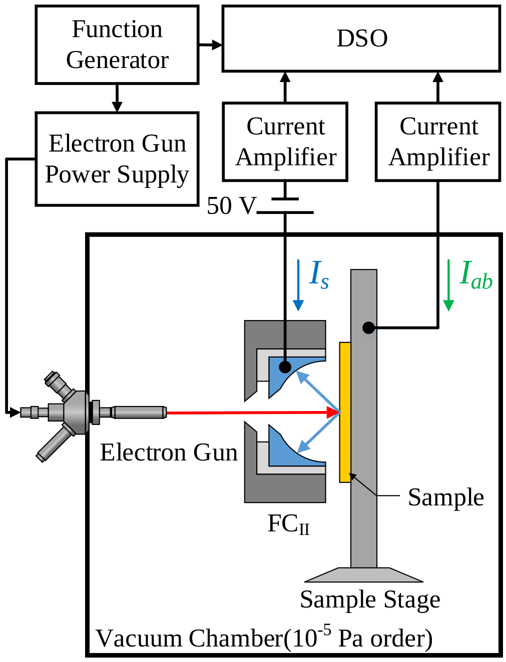


Figure 1. Measurement system

In this section we will describe the experimental setup of our secondary electron current measurement system, which applies pulsed electron beam and Faraday cup as its key components. The schematic diagram of the measurement system is shown in Fig. 1. The electron gun (EGG-3101C, Kimball Physics Inc.) is attached to the vacuum chamber to generate pulsed primary electron beam. This gun can irradiate electron beam of 0.5 ms pulse width. The primary electron beam is irradiated through the hole on the Faraday cup. Secondary electrons generated by this irradiation are captured by the Faraday cup, and their data is obtained as a voltage signal on a digital oscilloscope (DSO, 104MXs, LeCroy Corp.) through a current amplifier (428 Current Amplifier by Kethley). At the same time, the absorption current on sample stage is also observed by the same DSO after it is amplified through another current amplifier.

The electrons (including the secondary electron and backscattered electron) from sample are captured by F.C. as I_s. On the other hand, the electrons that is absorbed by sample are captured by sample stage which are observed as I_{ab}. We use Eq. (1) when calculating the SEEY σ.

$$\sigma = \frac{I_S}{I_S + I_{ab}} \quad (1)$$

2.2. SEEY measurement of irradiation sample

We irradiate electron with the conditions which are listed on table 1. As it is considered that 10^{15} cm^2 is equivalent with one year dose at GEO, those conditions are same as electron dose of one and there years operation on GEO. Besides, the irradiation electron energy is 50 keV. In this paper, P.I.1 which is treated with 1 year and 3 years aging is represented as “P.I.1-1” and “P.I.1-3”, respectively. Aged P.I.2 is also represented “P.I.2-1” and “P.I.2-3” with the same rule as P.I.1, respectively.

Figure 2 show the electron beam irradiation system.

Table 1. Electron beam condition

	energy [keV]	current density [nA/cm^2]	irradiation time [min]	P.I.1	P.I.2
1 year	50	45	60	P.I.1-1	P.I.2-1
3 years	50	67.5	120	P.I.1-3	P.I.2-3

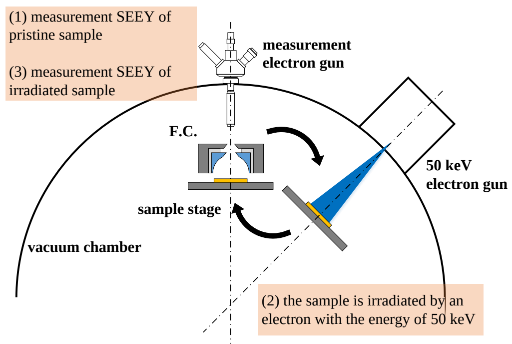


Figure 2. Electron beam irradiation system

Our experiments were treated the following procedure,

(1) Pristine sample is measured of SEEY.

(2) Sample stage is turned to 50 keV electron gun. And electron was irradiate to sample for aging processing.

(3) The stage is set back to original measurement position. And SEEY is measured on aged sample.

3. RESULT AND DISCUSSION

3.1. The change of appearance

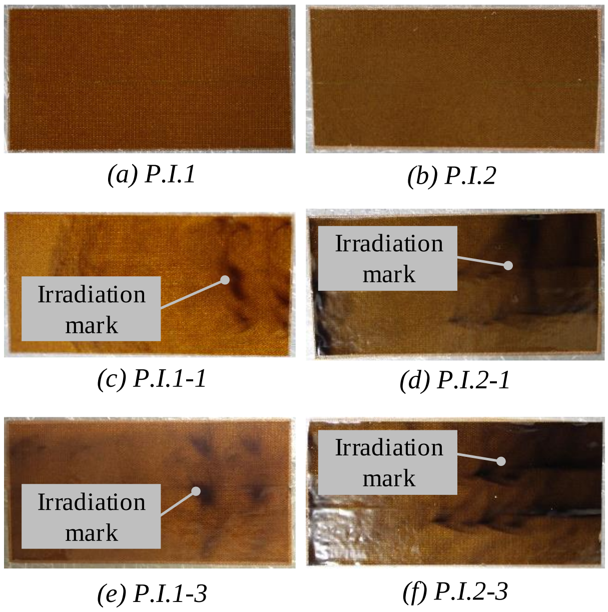


Figure 3. Appearances of P.I.1 (left line) and P.I.2 (right line) before and after irradiated electron beam

Figure 3 shows photo image of aged sample. The simulating operation samples are taken a photo under atmospheric pressure 110 hour after the 50 keV electron beam irradiation.

From figure, discoloured part was observed aged samples. It turned out the irradiation marks are deep in color in P.I.1 comparison with P.I.2 regardless of dose.

3.2. The change of SEEY before and after irradiation electron beam

In this section, we introduce the measurements results of SEEY.

Figure which we show below, the vertical axis represents SEEY σ. The horizontal axis represents the primary electron energy E_p [eV]

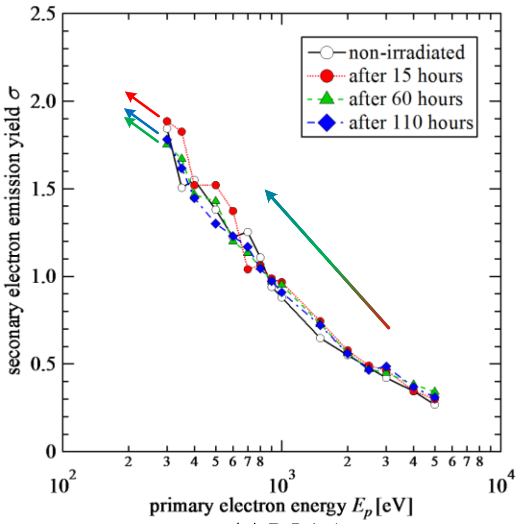
Figure 4 shows the measurement on aged SEEY results of P.I.1 the result of pristine sample is also shown on the same figure. Table 2 shows maximum SEEY σ_m with the primary irradiated electron energy E_m of PI.1.

From figure 4, we did not find difference SEEY between before and after irradiation most of all E_p range.

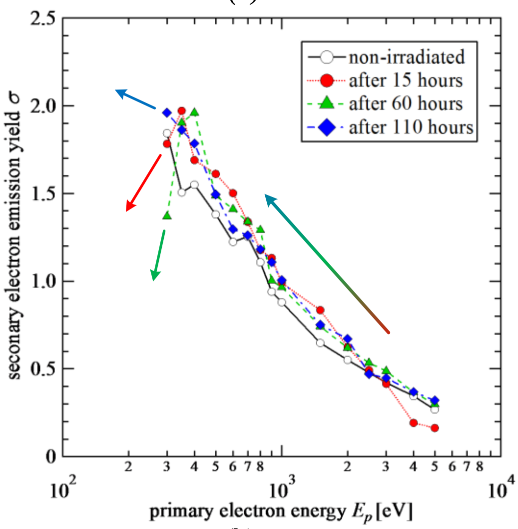
From figure 4, it is find that σ_m of irradiated sample was shift to high E_p side. In high energy side, E_p = 4, 5 keV, σ was reduced at 15 hours relaxation sample. However, although σ of 110 hours relaxation sample on the range between 3 and 6 keV was higher than pristine sample, the tendency of SEEY was similar pristine sample.

Figure 5 shows the measurement SEEY results of ages P.I.2 Table 3 shows maximum SEEY σ_m with the primary irradiated electron energy E_m of P.I.2.

From the figure, we found that σ_m is reduced in both radiation dose. In E_p = 5 keV, we confirm that SEEY is increased after 15 hours relaxation sample. The SEEY became to close to the value of pristine sample with relaxation time progress. Concerning the low E_p region of SEEY, σ_m was decreased. The SEEY of P.I.2-1 sample is decreased with time progress. On the other hand, the relaxation on peak of the 60 and 110 hours relaxation sample appeared it is considered that the σ peak was shifted to the high energy region from the view point of national energy bond structure, the energy structure uses modified due to the irradiation. Although it may cause the s difference, we need to study more deep for understanding the phenomena.

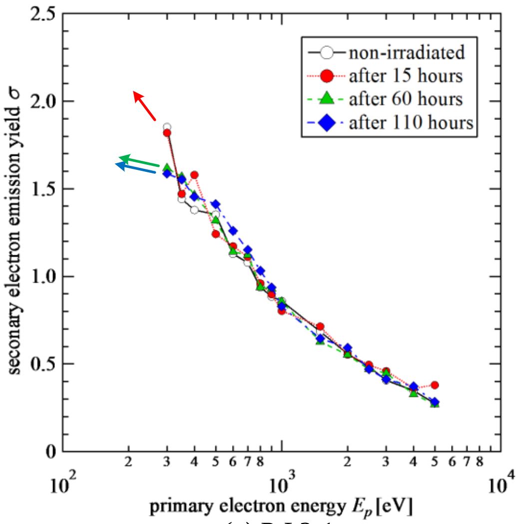


(a) P.I.1-1

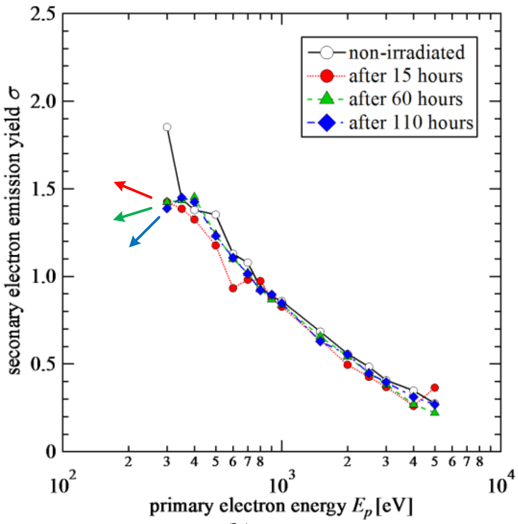


(b) P.I.1-3

Figure 4. The SEEY change of P.I.1 before and after irradiated electron beam



(a) P.I.2-1



(b) P.I.2-3

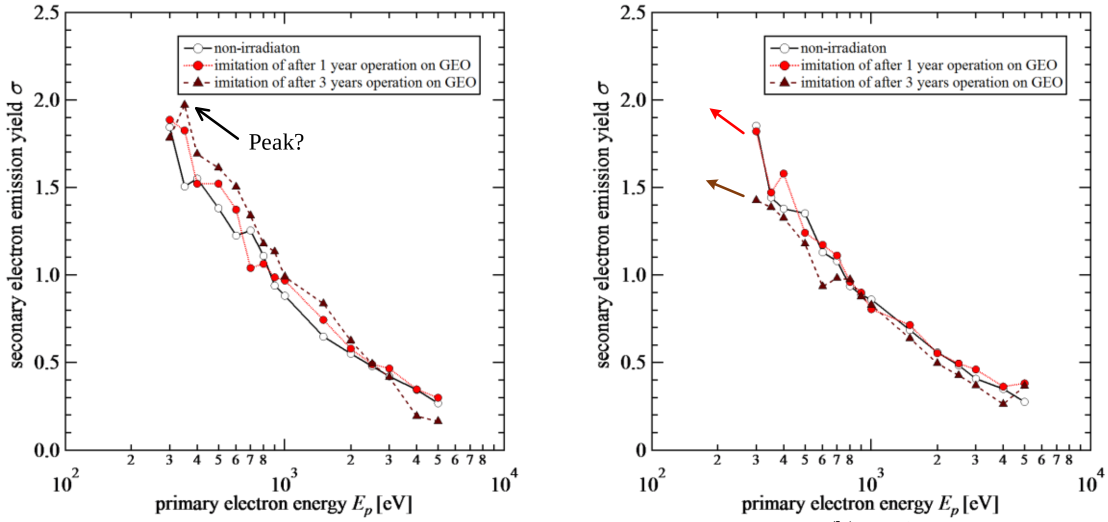
Figure 5. The SEEY change of P.I.2 before and after irradiated electron beam

Table 2. σ_m and E_m of P.I.1

simulating operation P.I.1 for 1 year				
	non-irradiated	after 15 hours	after 60 hours	after 110 hours
σ_m	1.844	1.885	1.753	1.781
E_m	300	300	300	300
simulating operation P.I.1 for 3 years				
	non-irradiated	after 15 hours	after 60 hours	after 110 hours
σ_m	1.844	1.972	1.961	1.960
E_m	300	350	400	300

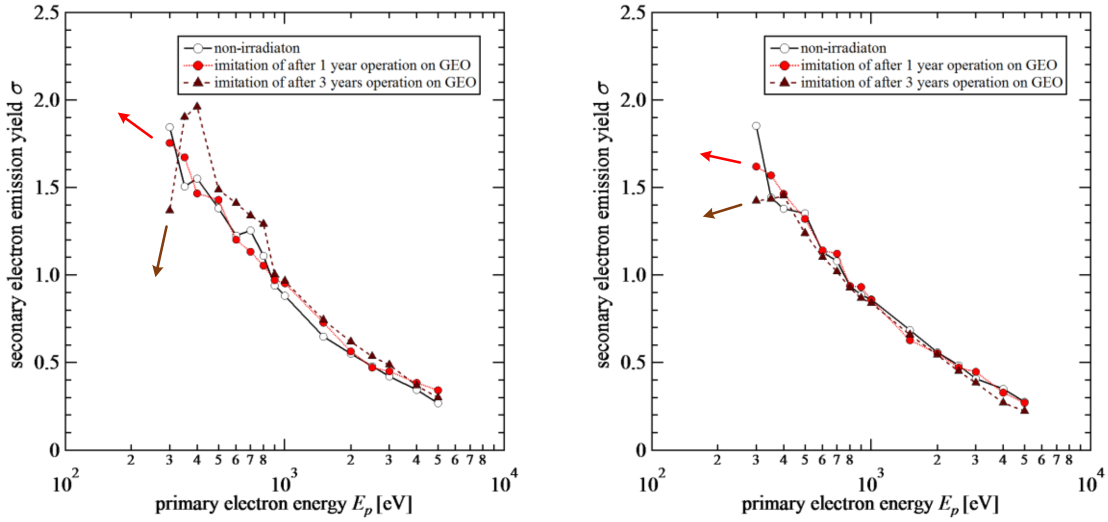
Table 3. σ_m and E_m of P.I.2

simulating operation P.I.2 for 1 year				
	non-irradiated	after 15 hours	after 60 hours	after 110 hours
σ_m	1.852	1.819	1.618	1.586
E_m	300	300	300	300
simulating operation P.I.2 for 3 years				
	non-irradiated	after 15 hours	after 60 hours	after 110 hours
σ_m	1.852	1.425	1.452	1.451
E_m	300	300	400	350



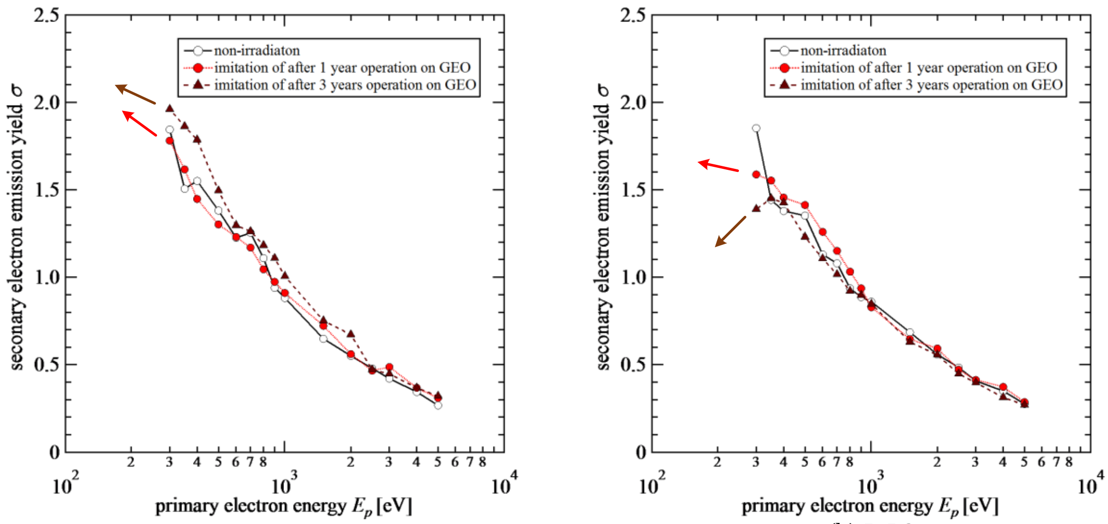
(a) P.I.1 *(b) P.I.2*

(A) Irradiation electron beam after 15 hours



(a) P.I.1 *(b) P.I.2*

(B) Irradiation electron beam after 60 hours



(a) P.I.1 *(b) P.I.2*

(C) Irradiation electron beam after 110 hours

Figure 6. The change of SEEY by electron beam irradiation dose of P.I.1 (left line) and P.I.2 (right line)

3.3. The change of SEEY by electron beam irradiation dose

Figure 6 shows the SEEY differential between 1 and 3 years aging by electron beam irradiation dose of P.I.1 and P.I.2

As shown in the fig.6 (A) - (a), we found that of P.I.1 is increased by electron beam irradiation in low E_p region. Concerning P.I.1-3, although σ_m appeared on the 15 hours relaxation sample and shift to higher E_p side on the 60 hours relaxation sample, σ became a close value with pristine samples.

On the other hand, we found that σ of P.I.2 was decreased by electron beam irradiation in low E_p region. Concerning PI2-3, the σ_m was shifted to the high energy side at the 60 and 110 hours relaxation sample. Furthermore, no big difference was obserbed at the results after 60 hours relaxation samples.

According above results, we have found that P.I.1 have a recovery characteristic of SEEY. On the other hand, P.I.2 does not have the characteristic.

4. CONCLUSION

In this paper, we measured the SEEY of aged P.I.1 and P.I.2.

From this study, we understood the followings.

① The SEEY was changed due to aging.

② σ_m was shift to high Ep side on the P.I.1 and P.I.2 sample aged with a condition of 3 years on GEO.

③ Although P.I.1 showed the recovery characteristic, SEEY of P.I.2 didn’t have the revitalization.

We should keep to study for understanding the phenomenon.

Therefore, as it can be predicted that the SEEY peak appears in the low Ep region, we need to measure the SEEY at a lower primary electron energy to measure the SEEY of the sample immediately after electron beam irradiation. Now, we are constructing new SEEY measurement system. In near future, we will provide the deterioration phenomena of aged PI using our new system.

5. REFERENCES

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