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Effect of material properties on spacecraft charging simulation

Kazuhiro Toyoda

***Abstract*—There is no criteria of space environment for simulating worst case of spacecraft charging. A project started to establish ISO of worst case environment for spacecraft charging simulation. In the ISO draft, the worst case environment will be decided by computer simulation with simulation tools. However, the simulation results can change with different material properties like secondary electron yield, photoelectron yield, volume resistivity, and so on. Moreover, these properties can change due to aging effect, like proton, electron, UV, AO, and so on. The spacecraft charging was simulated with material properties before and after aging effect. The calculated potentials had a large distribution after aging effect.**

Keywords—material property; spacecraft charging simulation

I. Introduction

There is no criteria of space environment for simulating worst case of spacecraft charging. A project started to establish ISO of worst case environment for spacecraft charging simulation. In the ISO draft, the worst case environment will be decided by computer simulation with simulation tools. However, the simulation results can change with different material properties like secondary electron yield, photoelectron yield, volume resistivity, and so on. Moreover, these properties can change due to aging effect, like proton, electron, UV, AO, and so on. In this paper, spacecraft charging is simulated with material properties before and after aging effect. This results will be published on ISO draft for suggestion of considering effect of material properties degradation on spacecraft charging simulation.

II. Simulation condition

The calculations were performed with the Multi-Utility Spacecraft Charging Analysis Tool (MUSCAT) [1]. Figure 1 shows the spacecraft model for calculation. The satellite model for simulation was a cube of 3 meter. The satellite body is aluminum. The insulator is mounted on +X face and +Y face. The Kapton and the coverglass CMG100-AR were used as insulators.

The calculation dimension is 32 x 32 x 32. The grid size is 0.5m. The angle of sunlight is (1, 0, 1).

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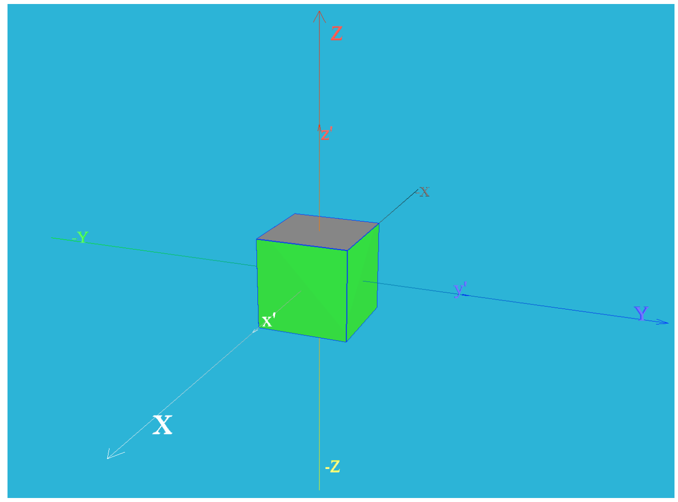

Fig. 1. Calculation model.

Table I shows the plasma environment for the calculation. These environments were used in the round-robin simulation between MUSCAT and NASCAP-2k [2]. The SCATHA Mullen-1 is the double Maxwellian distribution and was selected as the worst case environment from the results of the round-robin simulation.

The material property for the simulation is listed in Table II. Three materials were used in the simulation. The secondary electron yield and photoemission were measured for Kapton after aging effect of proton, electron, UV, and AO[3]. The bulk conductivity was also measured after Proton and electron irradiation. The bulk conductivity after UV and AO was not measured, so the same value as nominal sample was used for UV and AO.

The secondary electron yield of CMG100-AR was also measured after proton, electron, and UV irradiation[4]. Multi means the irradiation of proton, electron, and UV. The secondary electron yield after multi irradiation was same as UV irradiation. The typical values were used for the other propeties.

III. Results

Table III shows the simulation result with the insulator of Kapton. The light side means the Kapton mounted on the surface of +X. The dark side means the Kapton mounted on the surface of +Y. The frame is the potential of aluminum. The potential of frame was wihin 3kV difference from -13kV to -

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10.7kV. On the other hand, the potential difference between Kapton and frame had a large distribution from -8.9kV to 0.6kV for light side, from -17.5kV to -6.5kV.

Table IV shows the simulation result with the insulator of CMG100-AR. The result also had a large distribution in potential after aging.

IV. Conclusions

The simulations were performed with different material properties by MUSCAT. The calculated potentials had a large distribution after aging effect.

Acknowledgment

The authors would like to acknowledge Dr. Kiyokazu Koga and Dr. Shinji Hatta for greatly helping to perform MUSCAT analysis.

References

[1] S. Hatta, T. Muranaka, S. Hosoda, J. Kim, M. Cho, H. Ueda, K. Koga, and T. Goka, "Multi-utility spacecraft charging analysis tool (MUSCAT): development overview," 9th Spacecraft Charging Technology Conference, Tsukuba, Japan, 2005

[2] K. Toyoda and D. C. Ferguson, "Round-Robin Simulation for GEO Worst-Case Environment for Spacecraft Charging," 13th Spacecraft Charging Technology Conference, Pathadena, USA, 2014

[3] Y. Chen, J. Wu, T. Okumura, M. Takahashi, T. Endo, M. Iwata, K. Toyoda, M. Cho, "Investigation on Space Environmental Degradation Effects of Solar Cell Coverglass," IEEE Transactions on Plasma Science, vol. 41, No. 12, pp. 3471–3476, 2013.

TABLE I. Plasma environments

Environment Name	Ne1	Te1	Ne2	Te2	Ni1	Ti1	Ni2	Ti2
	(m^{-3})	(eV)	(m^{-3})	(eV)	(m^{-3})	(eV)	(m^{-3})	(eV)
SCATHA-Mullen1	2.00E+05	400	2.30E+06	24800	1.60E+06	300	1.30E+06	28200

TABLE II. Material property

Material	Aging effect	δ_{max}	E_{max} (eV)	Photoemission ($A\ m^{-2}$)	Bulk Conductivity ($x10^{-14}\ \Omega^{-1}m^{-1}$)	Dielectric Constant	Thickness (μm)
Aluminum	None	0.97	300	40	-1	1	1000
Kapton	None	1.69	150	3.2	0.7	3.5	25.4
	Proton	1.66	150	7.9	1.6	3.5	25.4
	Electron	1.97	150	3.3	2.9	3.5	25.4
	UV	2.12	150	8.7	0.7	3.5	25.4
	AO	1.1	700	3.0	0.7	3.5	25.4
CMG100-AR	Nominal	6.76	1000	20	1.0	3.8	125
	Proton	2	350	20	1.0	3.8	125
	Electron	6	1000	20	1.0	3.8	125
	UV & Multi	1.8	200	20	1.0	3.8	125

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TABLE III. Simulation result of Kapton.

Aging	Light side	Dark side	Frame	Light-Frame	Dark-Frame
Nominal	-17300	-19900	-13000	-4300	-6900
Proton	-11900	-23400	-10700	-1100	-12600
Electron	-20400	-29000	-11500	-8900	-17500
UV	-10300	-18200	-10900	600	-7300
AO	-16900	-19500	-13000	-3900	-6500

TABLE IV. Simulation result of CMG100-AR

Aging	Light side	Dark side	Frame	Light-Frame	Dark-Frame
Nominal	-1800	-19900	-3000	1200	-16900
Proton	-4000	-29800	-6900	2900	-22900
Electron	-2500	-22800	-4500	1900	-18300
UV	-4000	-30200	-6800	2800	-23500

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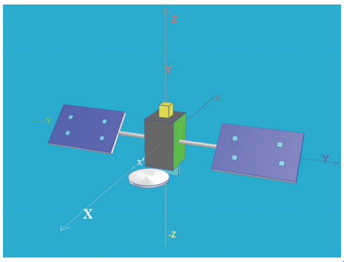
Spacecraft worst case charging simulation

Plasma environment
- proton
- electron

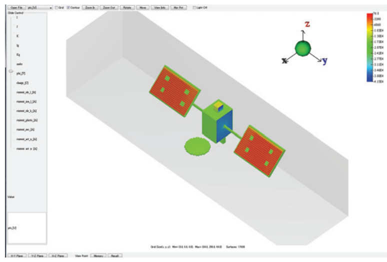
Material property
- secondary electron
- photoelectron
- resistivity
- etc.

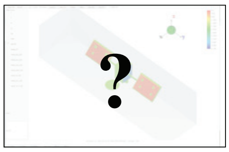
Aging effect
- proton
- electron
- UV
- AO
- etc.

Model



Result





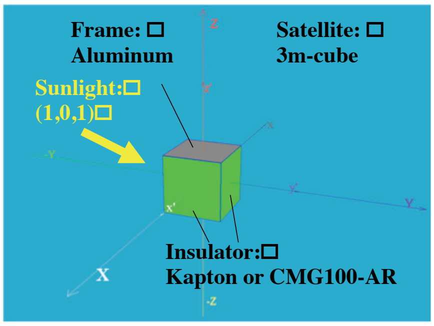
How much difference?

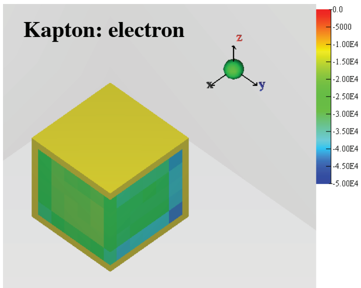
Purpose

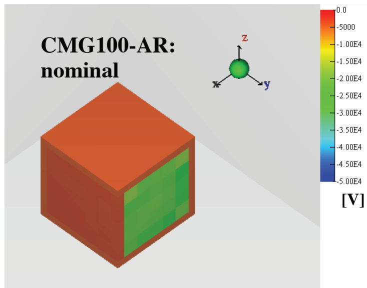
Investigate the effect of material property on simulation result

Simulation

Multi-Utility Spacecraft Charging Analysis Tool (MUSCAT)







Calculation volume: 32 x 32 x 32 Grid: 0.5m

Input parameter

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Kapton

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CMG100-AR

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Summary

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- This results will be published on ISO draft (worst case environment for spacecraft charging simulation) for suggestion of considering effect of material properties degradation on spacecraft charging simulation.