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Effect of Space Coverglass Degradation on GEO Spacecraft Charging

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***Abstract*— Previous studies of spacecraft charging have been done using the spacecraft charging parameters of coverglass materials at the Beginning of Life (BOL) as measured in ground-based laboratories. Various studies have shown that coverglass properties degrade with exposure on-orbit to thermal cycling, electron and ion beam radiation, and UV light. The degradation of these properties may change the total secondary electron emission yield. Since much of the total area of a spacecraft covered with solar array coverglass, the spacecraft charging may dramatically change as a result of the degradation. In this paper, we predict how the spacecraft charging changes with coverglass degradation on-orbit.**

We have used the published change in secondary electron yield with spacecraft environmental exposure for CMG-100AR coverglasses and a typical *Nascap* spacecraft model to calculate spacecraft charging changes for each source of degradation. The changes in charging were calculated for four different GEO environments, including the worst-case charging environments of ATS-6 and SCATHA-Mullen 1.

The results of this study will help spacecraft solar array designers understand how coverglass degradation affects spacecraft charging, and, in particular, the differential charging on the solar arrays. It is well known that if the differential charging exceeds a threshold, arcing can occur, and in the worst-case can lead to sustained arcs and solar array failure. Even in the best case, solar array arcing may lead to power degradation and EMI. Design margins against arcing at End of Life (EOL) can be established, and spacecraft designs changed accordingly.

Keywords—spacecraft charging; solar cell coverglasses; aging effects

I. Introduction

Spacecraft charging, which can lead to arcing on spacecraft surfaces and structures and also on solar arrays, with possible severe consequences, depends on surface materials properties and on the space weather environment. In particular, spacecraft solar arrays, with their large areas, often determine the frame and differential charging for the entire spacecraft. Most spacecraft charging designs are based on beginning-of-life (BOL) surface material properties, such as secondary electron yield and photoemission, which can be measured in the laboratory. These properties can change on orbit due to thermal cycling, electron and ion radiation, and UV light from the sun. In fact, according to one expert [1], these properties tend with aging towards those of carbon, so that the end-of-life (EOL) properties are quite different from those at BOL. In this paper we place a typical spacecraft model [2] in four different GEO space plasma environments, artificially age the materials by setting their secondary electron and photoemission properties to those found in [2] but tending toward graphite at EOL, and calculate the maximum, minimum, and frame potentials of the spacecraft after 2000 seconds of charging time.

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II. The Model

In Fig. 1 we show the spacecraft model, essentially the model used in Ferguson and Wimberly [3]. The array backs are made of graphite, to simulate graphite composite honeycomb.

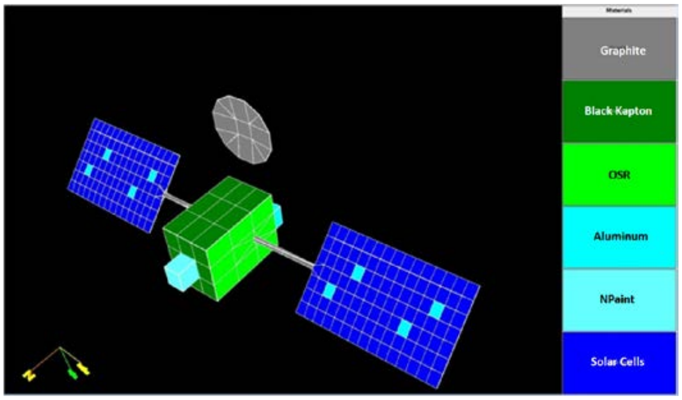

Fig. 1. The materials used in the *Nascap-2k* spacecraft model.

For a list of BOL surface materials properies, see [4]. Solar cell coverglasses were given the CMG-100AR properties measured in [2] after various sequential exposures to laboratory-smulated space environments, with the following abbreviations:

- BOL – pristine, as measured before environmental exposures
- Therm cycl – after thermal cycling
- P-beam – after proton beam exposure
- UV – after ultraviolet light exposure
- EOL – with graphite secondary electron and photoemission yields

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III. The Charging Environments

The plasma conditions of the four charging environments used, Sep. 4, 1997 (a low charging environment), an intermediate environment (Hyp 3'), and the severe charging environments ATS-6 (single Maxwellian) and SCATHA-Mullen 1 (double Maxwellian), are listed in [4], except for the intermediate environment (Hyp 3'). It is a single Maxwellian with the plasma densities and temperatures given below:

- Ne = 1.2 cm^{-3}
- Te = 4000 eV
- Ni = 0.3 cm^{-3}
- Ti = 8000 eV

Nascap-2k runs of 2000 seconds charging time were done for each plasma and exposure condition for both sunlit and eclipse cases.

IV. The Results

A 500 Volt threshold for arcing was assumed. After each run, the maximum spacecraft potential (Max), minimum (Min) and frame potential (Abs) were converted into differential potentials (Max-Min), (Max-Abs), and (Abs-Min). Of these, (Max-Min) and (Abs-Min) may be important for structure arcing, and (Max-Abs) may be important for solar array arcing.

After tabulating all the results, it was seen that the most dramatic changes in differential potential from BOL to EOL were in the cases shown in Figs. 2-5 below. For only one sunlit case was the change big enough to go from an arcing condition (> 500 V) to no arcing (< 500 V). This is shown in Fig. 2. Here, at EOL, the differential potential (Abs-Min), important for structure arcing, goes to zero for the SCATHA-Mullen 1 severe charging environment. All other environments remain in the arcing regime from BOL to EOL.

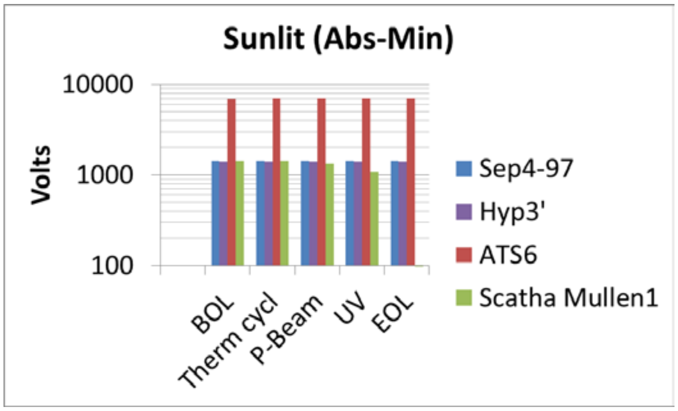

Fig. 2. (Abs-Min) for four sunlit environments.

As shown in Figs. 3-5, it is the eclipse differential potentials that change most dramatically. In Fig. 3, (Max-Abs) goes in eclipse from greater than 500 V to less than 500 V for the ATS-6 environment. This means that solar array arcing may be less likely for the ATS-6 environment at EOL than at BOL. For all other environments the arcing status is unchanged.

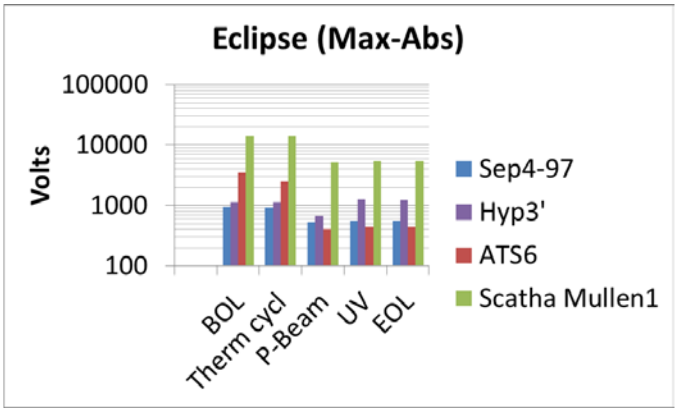

Fig. 3. (Max-Abs) in eclipse.

Fig. 4 shows (Max-Min) in eclipse. Again, for the ATS-6 environment, the differential potential drops below the 500 V assumed arcing threshold at EOL. Here, however, the potential in the September 4, 1997 environment also decreases dramatically at EOL, reaching only 600 V after starting out at BOL well over 1000 V. Thus, for a wider range of environments, eclipse arcing may be lessened by coverglass aging.

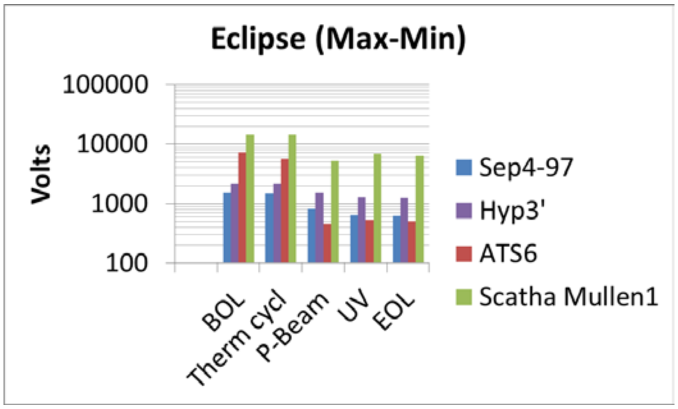

Fig. 4. (Max-Min) in eclipse.

Finally, in Fig. 5 is shown (Abs-Min) in eclipse. In this case, differntial charging for all of the first three environments start out at or above arcing levels at BOL, but drop significantly below arcing levels by EOL. The exception is the SCATHA-Mullen 1 environment, where differential potentials remain high throughout the spacecraft life. For all except the most severe charging environment, then, structure arcing in eclipse should be lessened with coverglass degradation.

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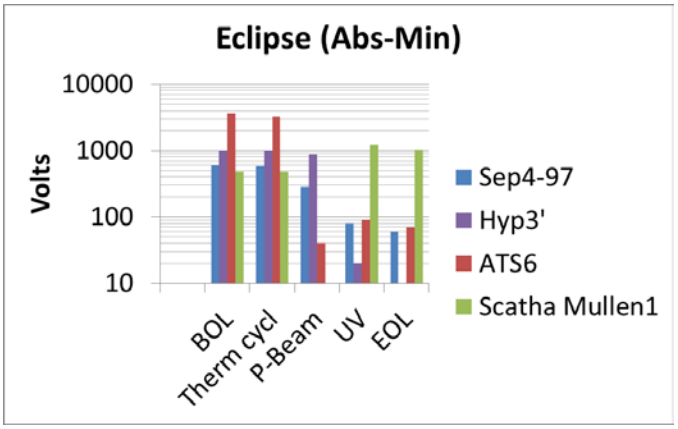

Fig. 5. (Abs-Min) in eclipse.

V. Conclusions

Assuming that CMG-100AR solar cell coverglasses degrade with exposure to the space environment as in [2], ending up with secondary electron and photoemission yields like those of graphite at EOL, spacecraft differential potentials, almost withut exception, are lessened by aging in the space environment, making structure and solar cell arcing less prevalent. This is in contrast to what [5] found for solar cell arc thresholds for realistic space solar arrays with grouted edges. In this paper, no attempt to account for changing arc threholds has been made.

References

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