Effects of Device Packaging and PC Board Materials on Radiation Dose in the Die

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INTRODUCTION

The total incident dose durability (TIDD) of an electronic device is a key performance parameter for the assessment of the device's potential space flight application. An important part of this assessment is modeling the expected total incident dose (TID) provided by the orbital space radiation environment. In an earlier paper [1] we demonstrated that spherically equivalent representation of a spacecraft can lead to an incorrect assessment of the radiation dose inside the spacecraft. The study also demonstrated that the dose inside a multiple-board electronics box can be reduced several orders of magnitude by selection of the backplane board's orientation , the board order on the backplane, and devices locatons on the board, as well as the use of the shielding provided by other internal components of the spacecraft.

Device packaging and printed circuit board (PCB) materials are also sources of shielding that, more frequently than not, are not considered in dose modeling. This report demonstrates that packaging and PCB materials can provide a reduction of the TID as large as two orders of magnitude.

An important aspect of a packaging material's dose reduction is its effect on the accuracy of dosimetry flight experiments that use packaged dose sensors. A recent modeling study of the exposure of a packaged radfet to accelerator protons implies that the packaging does have an effect on the dose measured by FETs on the die, [2]. We use the modeling data in this study to show that if the device we have modeled were a packaged radfet then the doses measured for a space flight mission may be one or more orders of magnitude in error.

DESCRIPTION OF THE DOSE MODELING

For this modeling study we use two spacecraft (S/C) designs. The first, 0.135-in S/C, was discussed earlier [1]. The second, 0.040-in S/C, is a thinner-wall modification of the first one.

An array of devices on a FR4 board array was studied. For column 1 the packaging material is plastic and for column 2 it is alumina and includes a kovar lid. For column 3 the packaging is also alumina but the kovar lid is absent. The top row was not shielded where as the succeeding four rows were, with 10-, 20-, 40-, and 80-mil thick PolyRAD®. This advanced radiation shielding material has been discussed in a recent publication of the NASA MSFC SEE Bulletin [3].

DISCUSSION OF RESULTS

A portion of the modeling data are in this summary. A complete discussion of the data will be made in the presentation. The doses for GSO and a solar synchronous orbit (SSO) environment are modeled. A portion of the modeled annual GSO TID values for no-copper PCB, near the –X battery, are shown in Table I for the 0.135" and 0.040" generic spacecraft. Only the data for the 0.01-in thick PolyRAD® are shown.

Inside the two S/C the PCB reduces the TID approximately 40 %, from 24.9 krad to 14.7 krad and from 916 krad to 505 krad. Inside the packaging the dose reduction is more significant. For the 0.135-in S/C, the plastic packaging reduces the dose-in-the-die (DID) to 23 % of that inside the S/C. The DID inside the alumina package, with kovar lid, is 4 % of the dose inside the S/C. For the 0.040-in S/C the dose reduction is an order of magnitude for the plastic package and two orders of magnitude for the combined alumina package and kovar lid. A device having a 50-krad(Si) TIDD rating would function approximately 8 years in plastic and 45 years in alumina for a 0.135-in S/C in GSO. These DID are one- to two-orders-of-magnitude smaller than would be predicted by conventional dose modeling that does not consider the PCB and encapsulate materials. Equally important, as shown in the last three rows of the table little supplemental shielding (thus little additional mass) is required to provide an engineering margin of safety that may be required for a 10-year mission. One important observation to be made is that the dose reduction provided by the supplementary shielding was achieved by a top-only application. Thus the popular assumption that 4-pi supplementary shielding is required is not necessarily correct. A comparison of the two board locations does however suggest that for the near-the-shear-plane position the supplemental shielding may be more effective on the rear of the device. Our work with several device manufacturers has demonstrated that there are viable alternate locations on devices for supplemental shielding.

Location **(No-copper PC Board near battery)**	**Annual Dose in GSO, kad(Si)**	
	0.135-in S/C	**0.040-in S/C**
Outside the Spacecraft	1240000.00	1240000.00
Inside the Spacecraft, adjacent to PC board	24.90	916.00
On front of PC board, at corner	14.70	505.00
In die, plastic packaging	5.72	84.00
In die, alumina packaging w kovar lid	1.10	5.97
In die, alumina packaging w/o kovar lid	10.4	296.00
In die, plastic packaging + 0.01-in PolyRAD®	0.72	3.17
In die, alumina packaging w lid + 0.01-in PolyRAD®	0.22	0.55
In die, alumina packaging w/o lid + 0.01- PolyRAD®	0.53	1.61

Table – Modeled doses for encapsulated devices on FR4 PCB with no copper

Implications of Device Packaging for Dosimeter Measurements

The potential for orders-of-magnitude difference of dose inside and outside a packaged device poses significant design issues for space flight dosimetry experiments that use packaged dose sensors. A dosimeter experiment that uses a sensor that is in a ceramic-package covered with a kovar lid could underestimate the dose inside an adjacent plastic-packaged COTS device by one or more orders of magnitude. We have evaluated packaged radfets for dosimetry for electron beam experiments and found dose-reduction effects due to the packaging. In a recent modeling study of a flight experiment for which we anticipate using these radfets to evaluate the performance of PolyRAD® we found the radfet's packaging reduces the dose in the die two orders of magnitude and thus compromises the interpreted performance of the shielding material. Therefore we plan to delid the commercial, ceramic packaged radfet devices that we will use as TID sensors. However, not all of the packaging effects are eliminated by delidding. The ceramic packaging limits the solid angle of exposure to less than 2π, as is suggested by the differences in the dose values in rows 3 and 6 in Table I. Thus we conclude that it may be that only relative dosimetry measurements are possible if packaged sensors, radfets or otherwise, are used.

REFERENCES

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