SEE Bulletin

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TEST RESULTS FOR A NEW HIGH-DENSITY CONFORMAL RADIATION SHIELDING

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INTRODUCTION

Microelectronics' exposure to radiation is a major space flight challenge. Total absorbed dose may cause aging and linear energy transfer may cause single event effects. A new concept for materials radiation shielding is presented here and its performance is discussed. Two concepts for chip encapsulation are also briefly discussed.

A NEW MATERIALS CONFORMAL SHIELDING CONCEPT

Background

Electron and proton shielding materials work because they possess mass. As the particle traverses through the shield it transfers its energy to the material's atomic structure. If there is a sufficient amount of shield material then the particle's energy is either completely absorbed, in which case the particle does not exit, or the particle exits with so little remaining energy that it is not sufficient for concern. The higher is the shield material's atomic number, Z, the larger the energy transfer. Thus "Hi-Z" materials, such as tungsten and tantalum, are used as shield materials.

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One advantage of Hi-Z shielding materials is that they can provide required protection for a relatively low-volume cost. For a single device this low-volume application is termed "spot shielding". Compared to a thick-wall aluminum box that must provide protection based on the least durable interior device, spot shielding can provide significant mass savings. Spot shielding originally used pure tungsten or tantalum. But tungsten is difficult to machine and volume-efficient conformal shape is not always possible. In the early 1990's, a spot shielding called RAD-PAK® became available. It entailed a metallic shield as the top of the device encapsulation and required special device production lines. Later in the 1990's a conformal spot shield called RAD-COAT® was developed. RAD-COAT® was applied to the topside of COTS devices. It required special tools and skills for its application.

The New Conformal Radiation Shielding

The new material radiation shielding for spot and conformal shielding is called PolyRAD®. It has been produced at densities up to approximately 15 g/cc. Its service environment is from – 128 °C to + 142 °C. It may be applied to the top of COTS devices and is available as a cap that extends down on the four sides of a device just short of its leads. It has been developed with the support of a NASA SBIR contract.

PolyRAD® is fabricated using a proprietary compression molding process. Figure 1 is a 40-mm casting of 15.3 g/cc shielding that is 0.51 mm thick. Casting thickness for property performance measurements ranged from 0.95 mm to 0.254 mm with corresponding specimen-to-specimen standard deviations from 0.011 mm to 0.004 mm.

Figure 1. - PolyRAD® disk, 40-mm diameter, 0.51 mm thick

PROPERTY PERFORMANCE MEASURMENTS

Electron Beam Radiation Exposure Testing

The exposures used ESAPMOS4 radfets from National Microelectronics Research Centre, Republic of Ireland. The frontal view of the radfet arrangement, as seen by the electron beam, is shown in figure 2. The radfet's lids were removed. For each exposure the top radfet was not shielded and the other three, clockwise, were shielded with 4.0-, 10.0-, and 15.3-g/cc PolyRAD®. A Faraday Cup at the center monitored the electron fluence.

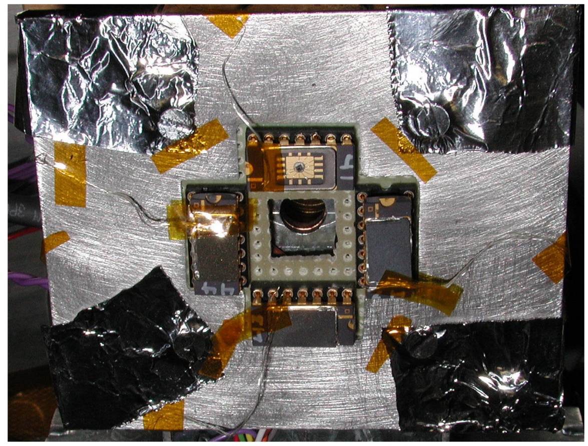

Figure 2. - Frontal view of the experimental arrangement for 1-MeV electron beam exposures

The shield thicknesses corresponded reciprocally to their densities so ideally the dose ratios should be the same. The prediction dose ratios, modeled with NOVICE, are shown in Figure 3. The purpose of the modeling was to predict the order of magnitude of dose reduction. The small lack of equality isn't significant. The experimental performance shown in figure 3 is slightly better than the modeled prediction. The lack of equal experimental performance for the three thicknesses is attributed to possible beam non-uniformity and to possible particle leakage around the shield. (Note in figure 2 that PolyRAD® shields covered only the central portion of each radfet.) The modeled and experimental performances are within less than a factor of 1.5 agreement. From this comparison NOVICE is expected to predict PolyRAD® performance in space within an order of magnitude.

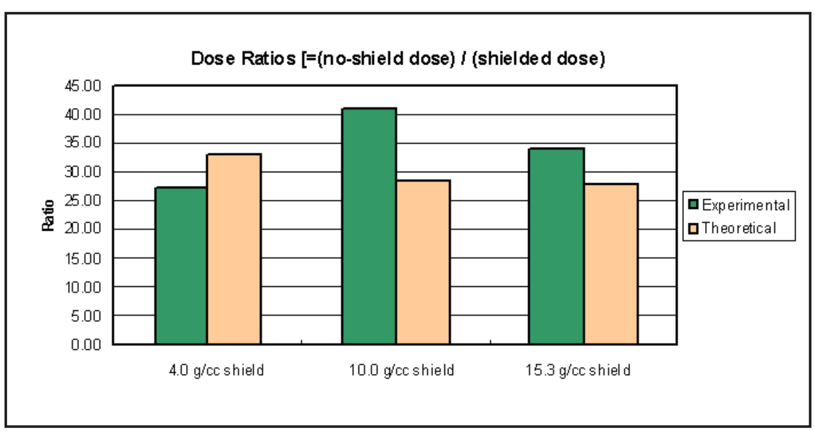

Figure 3. - PolyRAD® experimental and NOVICE modeled dose ratios for 1-MeV electron beam

Test Results For A New High-Density Conformal Radiation Shielding Cont'd.

NOVICE's modeled predictions of 12.5 g/cc and 15 g/cc PolyRADâ's shielding in MEO are shown in figure 4. The former is based on the filler tap density and the latter on a sintering-like process. For comparison, the modeled performance of tungsten, 19.3 g/cc, has been included. The advantage of W is remarkably insignificant.

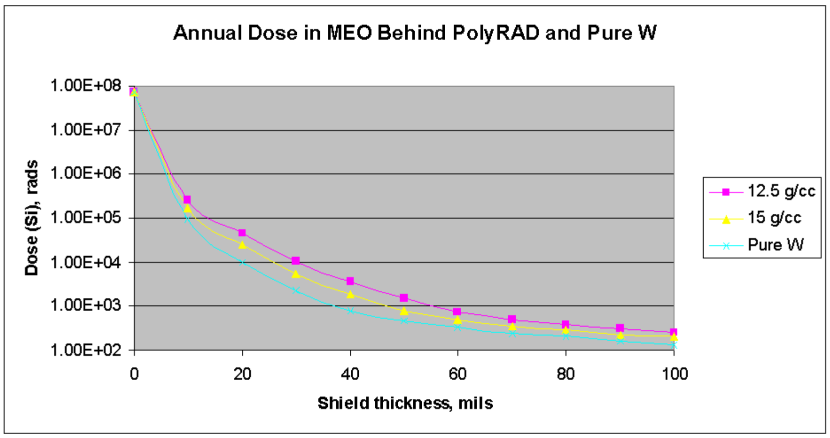

Figure 4. – NOVICE modeled shield performance of PolyRAD® and tungsten in MEO

Mechanical and Outgassing Data

The flexural strengths were from 25 ksi to 3 ksi. Flexural moduli were from 0.03 Msi to 0.3 Msi. For comparison, the flexural properties of polycarbonate, a tough material for eyeglass lenses, are 12 ksi and 0.3 Msi respectively.

The outgassing's Total Mass Loss was less than 0.015 % and Collected Volatile Condensable Material less than 0.011 %. Upper acceptable limit for TML is 1.0 % and for CVCM 0.1 %.

CHIP ENCAPSULATION METHODS

Two candidate methods for PolyRAD® chip encapsulation are shown in figure 5. On the left is a two-piece 29.8-mm OD molding with a 7.7-mm tall, 1.27-mm thick wall. Two-piece molding is necessary for mold-production of 3-D enclosures that have tall walls. A rectangular 19.1-mm x 8.3-mm x 5.5-mm, with a 1.9-mm wall thickness, hollow box example of one-piece molding, using post machining is also shown in figure 5. For both methods, the assembly would be on a chip-support base of PolyRAD® using a method similar to that employed for metallic encapsulates.

CONCLUDING REMARKS

PolyRAD® was developed with the support of a Phase I SBIR sponsored by the Marshall Space Flight Center. The work continues under a Phase II SBIR, also sponsored by MSFC. Six-inch moldings are being fabricated. Performance measurements include electrical and thermal properties as well as additional outgassing and mechanical data. PolyRAD® shields are currently commercially available. Additional information is available by phone, (540) 363-0104, or by E-mail (Sales@PolyRAD.net).

Figure 5. – Examples of PolyRAD™ castings for encapsulating microelectronic chips

Modeling Charge Collection in Detector Arrays

by

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The Radiation Environment Array Charge Transport (REACT) model is an engineering tool that predicts charge collection in space-based infrared detector arrays due to ionizing particle radiation. The modeling uses a combination of analytical and Monte Carlo techniques to capture the essential features of energetic ion-induced charge collection to detector pixels in a two-dimensional array. The model addresses several aspects that are necessary for high-fidelity simulation of complex focal plane array(FPA) structures including multiple layers, subregions within layers, variation of linear energy transfer with range, secondary electron scattering, free-field diffusion, and field-assisted diffusion.

This work is of specific significance for design of sensor missions that are concerned with noise levels of FPAs operated in the space environment, and of general significance for studying particle-induced charge collection in two-dimensional arrays of integrated circuits. The array modeling and engineering software tools that were developed can be used to plan mitigation schemes for ionizing particle radiation on space missions before the sensors are designed, built and launched. In addition, the Monte Carlo model of transport of ionizing radiation created carriers in integrated circuits with varying electric fields and varying lifetime regions will have broader application to all charge collection problems associated with single event effects (SEE).

This model will soon be available for distribution from the SEE Program website.

NOTE:

Continue to check the SEE Program website concerning a potential NRA release in August 2004.

Information will be released as it becomes available.

Coming Soon

Electrostatic Return Flux (ESRF) Model

The ESRF model is an engineering tool for calculating return flux of ionized contaminants to spacecraft surfaces. The tool will have the ability to address spheres, plates, and cylinders used in all ambient environments. It has application to large solar sails, thermal control surfaces, optics and solar array surfaces. The model also has the capability to address deposition on and sputtering of spacecraft surfaces by return of the ionized contaminants.

(Please check the SEE website in the coming months.)

8th Spacecraft Charging Technology Conference

October 20-24, 2003

Huntsville, Alabama, USA

Hosted by: NASA's Space Environments and Effects (SEE) Program

SECOND CALL FOR PAPERS

Technical papers and poster presentations are sought for the 8th Spacecraft Charging Technology Conference. This conference seeks to examine various mitigation techniques in the areas of:

Models & Computer Simulations

Ground Testing Techniques

On-Orbit Investigations

Environment Specifications

Plasma Propulsion & Tethers

Materials Characterizations

New Sessions Added!

Current Collection and Plasmas Probes in Space Plasmas

Interactions of Spacecraft and Systems with the Natural and Induced Plasma Environment

Abstracts Due: June 27, 2003

Notification of Acceptance: July 25, 2003

Registration is limited.

For more information on paper submission, registration and other conference information, please see:

http://see.msfc.nasa.gov/sctc

Chairman Jody Minor: 256-544-4041 or jody.minor@nasa.gov

Co-Sponsored by NASA, US Air Force Research Lab (AFRL) and the European Space Agency's (ESA) ESTEC Division

Upcoming Events

National Space and Missle Materials Symposium, San Diego, CA, June 2003

IEEE Nuclear and Space Radiation Effects Conference, Monterey, CA, July 21-25, 2003

8th Spacecraft Charging Technology Conference, Huntsville, AL, October 20-24, 2003

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In The Next Issue:

- **Electro-static Return of Contaminants**
- **Savant Code**

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