SEIBERSDORF LABORATORIES

RADHARD 2016 - Symposium

June 7th - 8th, 2016, Seibersdorf, Austria

Book of Abstracts

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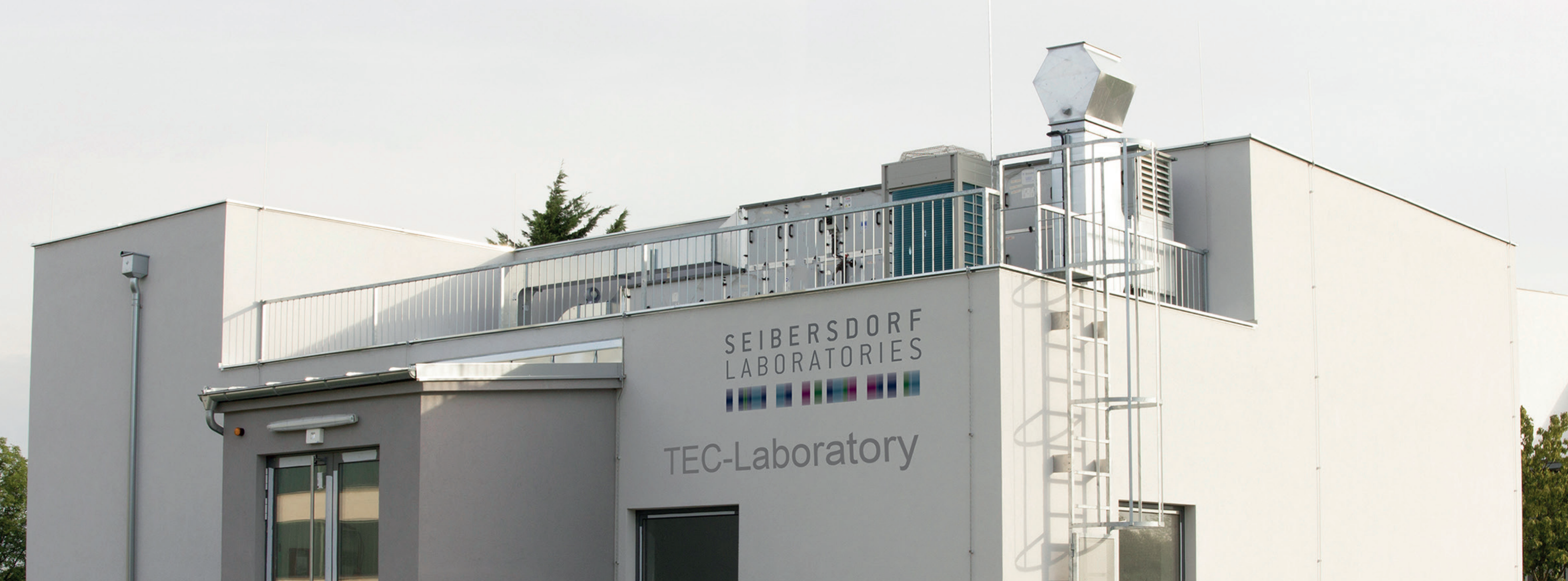

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Programme status at the editorial deadline.

Programme

2nd day: Wednesday, June 8th, 2016

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13:00	**Lunch Buffet** Visit of the TEC-Laboratory
14:00	**Closing**

Programme status at the editorial deadline.

Laboratory Accreditation (Keynote)

Raul Alarcon - European Space Agency, ESTEC, The Netherlands

Abstract

ESA/ESTEC laboratories frequently collaborate with top National Measurement Institutes to maintain state-of-the-art technical competence and know-how in addition to the developing several test and calibration methods suitable for third-party Accreditation according to the technical requirements of ISO/IEC 17025.

Laboratory Accreditation to ISO/IEC 17025 not only provides formal recognition that an organisation consistently operates an effective quality management system, but also demonstrates that the organisation has the required technical competence and can issue certificates of compliance or test reports in accordance with established technical standards and procedures.

The Accreditation process of the ESA/ESTEC Radiation Effects Laboratory for Total Ionising Dose and Dose Rates measurements using a Cobalt-60 source has increased the confidence in the laboratory's testing and calibration results, proven to support the advancement of technical competence of laboratory personnel, and ensured that world-class test services are maintained and independently assessed on an annual basis.

This presentation provides an overview of the key elements of ISO/IEC 17025:2005, the benefits and challenges of Laboratory Accreditation, and the lessons learned from the Accreditation process adopted by the ESA/ESTEC Radiation Effects Laboratory.

Radiation Hardness Assurance Testing at Seibersdorf Laboratories

Peter Beck, Michael Wind, Marcin Latocha - Seibersdorf Laboratories, Seibersdorf, Austria

Abstract

Seibersdorf Laboratories is responsible for operating standard calibration laboratories for ionizing radiation in Austria for more than 50 years. Seibersdorf Laboratories provides secondary standard laboratory services according to EN ISO/IEC 17025 standards for accredited testing and verifying of ionizing radiation systems and devices. In the 1990s Seibersdorf Laboratories extended their radiation expertise on space radiation environment for aerospace applications. Expertise in modelling of space radiation effects to humans have been established and measurement techniques for aviation and space have been developed. Together with an Austrian component manufacturer Seibersdorf Laboratories investigated total dose and single event effects on device level using TCAD modelling tools and Monte Carlo methods [1].

Experimental comparisons with microdosimetric measurements are a substantial part of all investigations. Seibersdorf Laboratories carried out an extensive campaign of comparing standard and accelerated ELDRS (Enhanced Low Dose Rate Radiation Sensitivity) testing for the European Space Agency [2]. This finally led to the extension of the existing radiation laboratory capabilities with a new Cobalt-60 facility for 24/7 testing of electronic components and devices regarding ionising radiation hardness assurance, called TEC-Laboratory (testing of EEE components).

The TEC-Laboratory offers testing services in accordance with requirements of the European Space Agency as well as Military Standards. The quality standards of the Seibersdorf Laboratories is EN ISO/IEC 17025 for accredited testing laboratories and EN ISO 9001:2008 certification for quality management system. The presentation gives an overview of radiation hardness assurance testing capabilities and expertise at Seibersdorf Laboratories.

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[1] Wind, M.; Beck, P.; Jaksic, A., Investigation of the Energy Response of RADFET for High Energy Photons, Electrons, Protons, and Neutrons, IEEE Transactions on Nuclear Science, Volume: 56 Issue: 6, Page(s): 3387 – 3392, 2009.
[2] Wind, M., Beck, P.; Boch, J.; Dusseau, L.; Latocha, M.; Poizat, M.; Zadeh, A., Applicability of the Accelerated Switching Test Method - A Comprehensive Survey, Radiation Effects Data Workshop (REDW), 2011. eldrs.net

Acknowledgements

The authors gratefully acknowledge the support of research projects by the Austrian Research Promotion Agency (FFG), the European Space Agency and the European Commission.

Radiation Protection Design of the TEC-Laboratory

Marcin Latocha, Michael Wind, Peter Beck - Seibersdorf Laboratories, Seibersdorf, Austria

Abstract

Radiation protection design of the TEC-Laboratory has been performed according to applicable legal requirements [1, 2, 3] that lay down the annual effective dose limits for both occupationally exposed workers (20 mSv/year) and public (1 mSv/year). The TEC-Laboratory is equipped with a 74 TBq (2kCi) Cobalt-60 source which is located in a large exposure room. The size of the exposure room allows realization of all dose rate ranges specified in the European Space Agency's standards [4]. For radiation protection purposes, the irradiation room is accessible through a radiation protection door (3 mm lead) and a labyrinth.

The controlled area is defined behind the radiation protection door that is in the labyrinth and irradiation room. The laboratory is designed in such a way that outside the controlled area (either outside or inside of the laboratory) ambient dose equivalent, $H^*(10)$, does not exceed the limit of 0.5 µSv/h (40 hours workweek). This specification has been achieved by constructing the concrete shielding walls with an appropriate thicknesses. The efficiency of the shielding was simulated with FLUKA [5, 6] Monte Carlo code. These simulations were part of the design phase of the TEC-Laboratory.

Three scenarios has been investigated: (1) no scattering bodies – to test the thickness of the front wall, (2) several printed circuits boards as scattering bodies – for a typical operational case, and (3) seven steel plates (2 cm thick each) – for the worst case backscattering scenario. All scenarios showed that outside the laboratory the $H^*(10)$ does not exceed the limit of 0.5 µSv/h. Scenario (3) showed also that the radiation protection door with 3 mm lead efficiently shields the backscattered radiation so that $H^*(10)$ is below 0.1 µSv/h outside the door. Measurements in various positions inside and outside of the laboratory were conducted. Measurements confirmed the simulated results, showing that $H^*(10)$ outside the controlled area is below 0.1 µSv/h [7].

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[2] ÖNORM S 5265-2:2006-06-01, 2006.
[3] EU Directive 96/29/EURATOM, 1996
[4] ESA, ESCC Basic Specification No. 22900, Issue 4, 2010.
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[6] A. Ferrari et al., „FLUKA: a multi-particle transport code", CERN-2005-10, INFN/TC_05/11, SLAC-R-773, 2005.
[7] Accredited Testing Laboratory Nr.312, Laboratory Report Nr. LG-P998-1/15, 2015.

ELDRS - Low Dose Rate Testing

Michael Wind, Marcin Latocha, Peter Beck - Seibersdorf Laboratories, Seibersdorf, Austria

Abstract

The ELDRS effect (Enhanced Low Dose Rate Sensitivity) can cause functional failure of electronic devices that are operated in a low dose rate radiation environment (e.g. satellites) and thus might be a limiting factor for the applicability of ELDRS susceptible devices. Testing at low dose rates using high dose levels for the TID (Total Ionizing Dose) exposures requires long test times which is associated with high costs.

Seibersdorf Laboratories has experience in characterizing electronic devices with respect to ELDRS. Within the scope of a comprehensive study an accelerated ELDRS test method [1, 2] was investigated. The device selection for this study comprised five operational amplifiers, three comparators and a reference diode manufactured by various companies.

The design of the TEC-Laboratory allows the exposure of test samples within a wide dose rate range that covers both of the two dose rate windows as specified in the ESCC basic specifications by ESA [3]. Within the TEC-Laboratory it is possible to expose a significant amount of various electronic parts at the same time at a low dose rate for an extensive period of time on the one hand side, but also at standard dose rate on the other hand. Thus the TEC-Laboratory is perfectly suited also for ELDRS testing, particularly when considering technical and economical aspects.

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[1] J. Boch, F. Saigné, R.D. Schrimpf, J.-R. Vaillé, L. Dusseau, S. Ducret, M. Bernard, E. Lorfèvre, and C. Chatry, Estimation of Low-Dose-Rate Degradation on Bipolar Linear Integrated Circuits Using Switching Experiements, IEEE-TNS, vol. 52 (6), p. 2616, December 2005

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[3] ESCC Basic Specification No. 22900, Total Dose Steady-State Irradiation Test Method, Issue 4,ESA, 2010

Acknowledgements

The authors gratefully acknowledge the support by the European Space Agency (ESA) and the Austrian Promotion Agency, FFG.

Practical Aspects of Radiation Hardness Assurance

Practical Aspects of Radiation Hardness Assurance of EEE Components at AIRBUS D&S

Anne Samaras - Airbus Defence and Space, Toulouse, France

Abstract

AIRBUS Defense and Space Radiation Hardness Assurance (RHA) provide requirements to follow during any space program in order to prove that the system will continue to perform its function throughout program mission duration.

RHA requirements apply to all space systems contractors and equipment providers.

The aim of this presentation is to describe each of the Major tasks involved in the Radiation Spacecraft design.

In a first part methods to calculate the internal ionising and non ionising radiation environment and the resulting effects will be discussed.

Then EEE part test requirement from Airbus point of view will be described. Considering the test results radiation tolerance determination can be performed. The methodology to be used for this analysis will be described.

Finally the system level verification requirements that will allow equipment to be folded into higher-level reliability calculations will be provided.

Radiation Hardness Assurance of Satellite Systems

Chiara Tran Thi - OHB System AG, Bremen, Germany

Abstract

OHB System AG is one of the leading independent forces in European space, since 35 years particularly in the core business comprising low-orbiting and geostationary satellites. OHB System is developing and executing some of the key projects of our times such as the Galileo navigation satellites, the SARah reconnaissance system, the MTG meteorological satellites, the EnMAP environment satellite, the TET-1 technology testing vehicle and the HispaSat, ELECTRA and EDRS-C telecommunications satellites.

In manned space flight, OHB has been materially involved in assembling and equipping the Columbus research laboratory fitted to the ISS and the ATV space freighter as well as numerous experiment systems used on board the ISS. For what concern exploration activities between different studies OHB System is working intensively on ESA's two-part flagship mission ExoMars.

The Current Programs are in the area of Human Spaceflight, Earth Observation, Exploration / Science, Communication, Navigation and Security

This presentation aims to show OHB Project portfolio and the Influence of RHA on the different Projects/Mission types and phases, from predevelopment to manufacturing.

The presentation also describes the RHA approach for the different product levels and provides results of the RHA implementation e.g. verification methods and test needs.

Space Radiation Environment Specification

Athina Varotsou - TRAD, Toulouse, France

Abstract

The space radiation environment specification for a specific mission is the first step to the radiation hardness assurance process. This specification includes the charged particle fluxes and fluences, as well as inputs for radiation effects analysis, i.e. the dose-depth curve, the LET spectrum and the displacement damage equivalent fluence. These inputs are then used for ionising dose, single event effects and non-ionizing dose analysis, respectively.

It is essential that all important quantities are well described so that interested industrial players understand which inputs they need to take into account for their radiation analysis. However, putting together such a specification is not an easy task as many important parameters intervene, like the mission definition, the solar cycle hypothesis as well the parameterisation of the engineering models used to describe the radiation environment.

In the radiation hardness assurance procedure, the specified radiation environment is then combined with heavy ion and proton radiation test results to estimate corresponding SEE rates for the selected EEE parts list. In addition, dose analysis is performed at component level using a 3D radiation model of the satellite and equipment and by inputting the specified radiation environment.

In this presentation, the contents of the space radiation environment specification will be described and the impact of important parameters will be highlighted with results obtained using the OMERE software [1] and the FASTRAD® 3D radiation tool [2].

References

[1] OMERE software, http://www.trad.fr/OMERE-Software.html
[2] FASTRAD® software, www.fastrad.net

Broadening of RHA-Testing Quality in Europe (Keynote)

Robert Ecoffet - RADECS Association

Abstract

The past decade has witnessed a large broadening of offer in terms of radiation test facilities. On top of “historical” test facilities, other facilities not necessarily interested in radiation tests in the first place now see this activity as a viable one, and new facilities have been set up. The offer covers now almost any type of particles and energies necessary to assess space and ground/atmospheric effects. Types of radiation used in the past for space qualification was Cobalt-60 (alternative X-rays), high energy protons (few 10-100 MeV) and medium energy heavy ions (few 1-10 MeV/nucleon). The emergence of direct ionization proton SEEs, electron SEEs (few 100 keV – few 10 MeVs), and radiation effects on materials now advocate also the use of low energy proton beams, electron beams of various energies, photons in various wavelength, in single or combined irradiation.

In the same period, the space sector has witnessed the apparition and development of new players and businesses (e.g. “new space”, nanosatellites). Depending on the radiation hardness policies that will be adopted, this new context may possibly lead to a larger volume of testing activity, and will surely demand cheaper tests.

In the past, few customers (agencies, prime contractors) used few historical facilities. In the future, a possibly large number of customers will meet a large offer in terms of test facilities. The new players will not have necessarily, or will not be willing to have, the expertise on how to choose and define test conditions. This gives a business way to specialized radiation engineering service companies able to make the interface.

There is to date no clear European normative documents defining minimum quality requirements, as such, for test facilities. We believe that a more developed normative and labelling system would be of great help in better structuring this new economy.

Radiation Hardness Assurance Testing

Practical Aspects of TID-Testing

Stefan Metzger - INT-Fraunhofer, Euskirchen, Germany

Abstract

Abstract was not available at the editorial deadline.

Testing of Commercial Components of the Shelf

Michael Wind, Marcin Latocha, Peter Beck - Seibersdorf Laboratories, Seibersdorf, Austria

Abstract

Seibersdorf Laboratories contributed to ESA's European Component Initiative (ECI) [1]. The goal of this activity was to increase experimental radiation data available for commercial of the shelf (COTS) parts of European manufacturers. Looking explicitly at European products seems to be of severe importance since the majority of semiconductor manufacturers that are performing radiation hardness testing are located in the United States of America. Thus activities such as ECI are enhancing the European industrial base for critical technologies needed by Europe's space missions and reduce the dependence of Europe's space sector on non-European component suppliers.

Within the scope of this activity comparators, operational amplifier and power MOSFETs manufactured by Austriamicrosystems AG, STMicroelectronics and Infineon have been characterized with respect to their TID tolerance. The total ionising dose (TID) testing was performed in the radiation standard laboratory at Seibersdorf [2] according to ECSS Specification No. 22900 [3]. The power devices have also been investigated with respect to their tolerance against single event gate rupture (SEGR). Single event effect (SEE) testing was carried out at the heavy ion exposure facility of University of Jyväskylä (RADEF) [4]. SEGR tests were performed according to MIL-STD-750-1 test method 1080 [5].

The results indicate the potential applicability of the tested COTS parts for low dose space missions having a TID dose level less than 20 krad.

References

[1] ESA, http://www.esa.int/Our_Activities/Space_Engineering_Technology/European_Component_Initiative_ECI, 2015
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[4] University of Jyväskylä, https://www.jyu.fi/fysiikka/en/research/accelerator/radef, 2015
[5] MIL-STD-750-1: Test Method Standard; Environmental Test Methods for Semiconductor Devices, Part1; Department of Defense, 2012

Typical Facilities and Procedure for Single Event Effects Testing

Vasily S. Anashin, Aleksandr E. Koziukov, Pavel A. Chubunov - Branch of JSC URSC-ISDE, Moscow, Russia

Abstract

Single event effects (SEE) are the most critical impact of space radiation influences in onboard system based on electronic components (EC) which limits the lifetime of the spacecraft [1,2]. So it’s very important to know the features which characterize sensitivity of every EC to SEE. This data is needed to calculate hardness of spacecraft electronic systems. The Branch of Joint Stock Company «United Rocket and Space Corporation» – «Institute of Space Device Engineering» for several years working on the subject of hardness control and assurance of EC to the space ionizing radiation and on the development and operation of the relevant test facilities (by order of Roscosmos). Currently our test facilities provide test operations of all electronic components functional classes on hardness to all types of SEE.

A number of heavy ion test facilities [3] are created on the base of cyclotrons U400 and U400M (Flerov Laboratory of Nuclear Reactions (FLNR), Joint Institute for Nuclear Research (JINR), Dubna city, Moscow region) which have differential in the composition of output ions and their energy, the radiation area, range of temperatures, by changeover time from one ion to another, vacuum pumping time. The designation and technical characteristics of test facilities are presented in this report as well as some photos of these test facilities. All test facilities are available to carrying out tests (on request); there are no restrictions for foreign organizations. The main direction for the development of test subjects of EC on hardness to SEE from space ionizing radiation influence is to ensure the completeness and process of test optimization with increasing of their informational content, accuracy and the contemporary process of increasing availability, efficiency, productivity and decreasing of tests costs.

The accuracy of tests is provided through their realization by approved standard methods (taking into account the specific character of realization on concrete test facility) with control of all possible types of effects to which the devices are potentially sensitive (and under an elevated temperatures for latch-up), ensuring the completeness of electrical parameters control of test object, the application of metrological certified test facilities and achievement of special Roscosmos requirements to carrying out tests.

References

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Acknowledgments

We would like to express our deep appreciation to our colleagues from the Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research (Dubna, Russia) for their help and participation in testing, as well as highlight their qualification and excellent personal qualities

Radiation Testing of Thermal Control Thin Films

Christian Ranzenberger - RUAG Space GmbH, Vienna, Austria

Abstract

Multi-layer insulation (MLI) forms to a great extent the outer barrier of a satellite towards space. Thin Polymer foils, which are used in MLI blankets, have to endure the harsh space environment for mission duration often lasting well above ten years. Thermo-optical but also mechanical properties suffer or change because of radiation exposure.

Complete MLI stacks, which were composed of thicker outermost layers and up to seven thin internal layers separated by non-woven spacers, were irradiation tested.

After initial screening tests on individual foils, space environmental tests were performed. The campaign involved vacuum thermal-cycling and exposures to UV-radiation, electrons and protons simulating a 15 year GEO mission.

Outer layer test candidates were an alternative 25µm black Polyimide (PI), a white PI, 25µm Polyether-ether-ketone (PEEK) and Kapton HN as the reference material.

For materials composing the internal MLI stack 6µm aluminized (VDA) PET -i.e. Mylar®- foil and an 8g/m² polyester spacer were chosen. These two standard internal MLI materials were compared to their thinner derivatives consisting of 3µm VDA/PET/VDA and a 4g/m² polyester spacer as well as to novel thin films made of 3µm VDA/ Polyethylennaphthalat (PEN) /VDA and 6µm VDA/PEEK/VDA.

Solar Absorptance was measured at the beginning and end of test, as well as at various stages in-situ during the exposures. Thermal emittance was measured ex-situ. Out of the tested MLI stacks samples were tensile tested to determine exposure influence on foil mechanical properties by comparison to pristine and reference materials.

This presentation outlines the test campaign performed, the test results achieved and discusses the conclusions derived.

Shielding and Radiation Hardness by Design

Radiation Shielding of Energetic Electrons

Peter Beck, Michael Wind, Marcin Latocha - Seibersdorf Laboratories, Seibersdorf, Austria

Abstract

Seibersdorf Laboratories carried out experiments and numerical simulations studying the performance of a multilayer graded shielding in energetic electron-fields and compared with earlier ESA studies [1-2]. In this study box and plane shielding geometries composed of aluminium, lead and tantalum were used. Monte Carlo code simulations using FLUKA and GEANT4 are compared with experimental measurements for electron with an energy range of 6 MeV and 50 MeV.

The results obtained from both the experiments and the numerical studies indicate that for 6 MeV and 10 MeV electrons an increased shielding-performance (i.e. a decrease of dose) can be observed with an increase in high-Z material content. When lead or tantalum is used as a high-Z layer material the decrease in dose can be as high as ~60% (5 MeV electrons) or ~50% (10 MeV electrons). When titanium is used as a high-Z layer material the effect is much less distinct, i.e. ~25% decrease in dose in case of 5 MeV electrons and ~7% for 10 MeV electrons. It is found that for incident electron energies lower than 10 MeV the dose is more effectively reduced when the high-Z layer is on the inside of the shielding while for higher energies the dose is more effectively reduced when the high-Z material is on the outside of the shielding.

The results obtained from numerical simulations performed with an electron environment representative for the Ganymede mission phase are comparable with those obtained for isotropic mono-energetic electrons of 5 MeV when the high-Z layer is positioned on the outside. The presentation provides a summary of the ESA study e^2RAD - Energetic Electrons Radiation Assessment Study [3].

References

[1] Giovanni Santin and Marie Ansart, "Investigation on the effects of combinations of shielding materials on the total ionising dose for the LAPLACE mission", ESA Technical Note, TEC-EES/2010.613/GS/2.0, Issue 2, Rev 1, 30 May 2012.
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The authors gratefully acknowledge the support of research projects by the Austrian Research Promotion Agency (FFG), the European Space Agency and the European Commission.

Radiation Effects from the Perspective of Analog IC Designer – Radiation-Hard-by-Design

Alicja Michalowska-Forsyth, Varvara Bezhenova - Graz University of Technology, Institute of Electronics, Graz, Austria

Abstract

In space-borne, medical and high energy physics applications, the heart of a measurement system is usually an Integrated Circuit (IC). More and more often Application-Specific Integrated Circuits (ASICs) are used instead of from-the-shelve products: ASIC offers lower power consumption than a standard IC or a discrete solution; also, higher measurement precision can be achieved, thanks to small capacitances and high speed, combined with a customized architecture.

This talk focuses on Total Ionizing Dose (TID) effects on integrated circuits (IC) and prospects for their mitigation through Radiation-Hard-by-Design (RHBD) techniques. It also discusses the radiation-hardened ASIC design flow, in particular emphasizing the issues of efficient irradiation tests and characterization of the integrated test structures.

References

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European Dimension and Future Requirements for Testing Qualifications

European Components Initiative

Keith Miller - European Space Agency, ESTEC, The Netherlands

Abstract

In 1990's ESA, National Space Agencies, and the European Space Industry observed a rapidly decreasing European market share of Electrical, Electronic and Electromechanical (EEE) components suitable for space applications. Europe was becoming increasingly dependent on the non-European export regulated sources for space components. Consequently, Europe's competitiveness in the global market was impacted, as the best technology for a given mission was not necessarily accessible.

In 2004, to reduce the dependence of Europe's space sector on non-European component suppliers an EEE-components action plan was put in place called the European Component Initiative (ECI). Since then, ESA has launched four phases of the ECI, each phase focusing on the business needs in the next 3 to 5 years. In total, 98 ESA contracts actions have been placed. Recent surveys have shown that the ratio of European to non-European EEE-components used in a typical European built commercial satellite has increased from just 15% in 2000 to 50% in 2015 and significant improvements have been achieved in securing a European supply chain for EEE components for space.

The presentation will outline the objectives of the ECI, how it is being implemented and the problems facing the European EEE space component supply chain.

Update of ESCC22900 Total Dose Steady State Irradiation Test Method

Christian Poivey, Marc Poizat - European Space Agency, ESTEC, The Netherlands

Abstract

ESCC 22900 is the Total ionizing Dose (TID) test standard used in European projects. The current issue is issue 4. The Radiation Working Group (RWG) of the ESCC Component Technology Board (CTB) has recently drafted an update (issue 5). CTB RWG members are experts from European national and international public space organizations, the component manufacturers and the user industries.

Major changes have been made in the new issue. These changes will be presented in this talk: Criteria for Enhanced Low Dose Rate Sensitivity (ELDRS) characterization for ESCC evaluation, dose rate requirements, and TID testing outside the frame of ESCC evaluation or qualification.

References

ESCC2900 issue 4 (https://escies.org)

Future Requirements on Radiation Quantities and Testing Environment

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Abstract

In the past, testing requirements were expressed in terms of ionizing dose (rad(Si)), non-ionizing dose, heavy ion LET (dE/dx) and proton energy. Except for proton energy, all those quantities are radiation – matter interaction quantities supposed to be descriptive of the effect under consideration. Are they still representative today? Two trends may limit this representativity and advocate for the definition of alternative radiation quantities.

First trend is the miniaturization of electronic technologies and their diving into the submicronic – nanometric world. "Dose" is basically a macroscopic value, how much is it representative at the micrometer or nanometer scale ? LET is a one-dimension value, how much is it representative when the target size is smaller than the ion track radius? Another consequence of the diving into the "small world" is that a larger number of particle types may be susceptible to produce effects because typical charges on the circuit are smaller and easier to disturb (today electrons can induce SEEs, tomorrow maybe photons, the day after tomorrow…?). Much more physical interactions will have to be taken into account.

Second trend is the multiplication of the number of atomic elements in electronic technologies. In the past, only a handful of elements was to take into consideration (silicon, oxygen, aluminium, phosphorus, boron…), today, almost the entire Mendeleiev table is used. One given example is the use of tungsten and copper: recoil products from proton nuclear reactions with those elements will have much larger energy deposition properties than products from silicon – proton reactions. Other examples are various types of III-V semiconductors. Laser diodes could have optical elements made of KTiOPO4 with surface treatment MgF2, etc. Stacked technologies could integrate very different active and passive materials.

It is thus essential to continue and promote research activities on the definition of more representative quantities for the description of effects (and thus definition of test conditions), and to continue and promote research activities on the characterization of the multiple interaction types susceptible to be responsible of radiation effects.

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Radiation Protection Design of the TEC-Laboratory

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Practical Aspects of TID Testing

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Radiation Effects from the Perspective of Analog IC Designer – Radiation-Hard-by-Design

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