Online RADHARD SYMPOSIUM

Book of Abstracts

November 10th, 2020

www.radhard.eu

SEIBERSDORF LABORATORIES · FFG Promoting Innovation. · Federal Ministry Republic of Austria Transport, Innovation and Technology · AUSTROSPACE · TU Graz · FACHHOCHSCHULE WIENER NEUSTADT · RADECS

Imprint

Editor: Dr. Peter Beck, Seibersdorf Labor GmbH, 2444 Seibersdorf, Austria
Layout: Seibersdorf Labor GmbH, Marketing, 2444 Seibersdorf, Austria
Publisher: Seibersdorf Laboratories Publishing, Austria
Print: Seibersdorf Labor GmbH, 2444 Seibersdorf, Austria

ISBN (Print) 978-3-902780-18-8
ISBN (Ebook) 978-3-902780-19-5

www.seibersdorf-laboratories.at

Chairman's Invitation

On behalf of the organizing team of the RADHARD Symposium 2020, it is my great pleasure to report about the 5th edition of the RADHARD Symposium, which was held online for the first time.

The mission of the RADHARD Symposium is to provide you, in addition to the RADECS conference, with a forum for the exchange of practical experience in the field of radiation hardness assurance, which is important for both industrial applications as well as research and science. Our vision is that the RADHARD Symposium will provide a place with plenty of room for communication, initiate new joint projects and invite you to the upcoming RADECS Conference 2021 in Vienna, Austria.

Please register now - www.radecs2021.at

The focus of the RADHARD Symposium 2020 was

- Testing of SmallSats and COTS components
- Practical aspects of ensuring radiation hardness
- Radiation hardness testing with laser systems

The RADHARD Symposium is aimed at space system integrators, manufacturers of electrical and electronic equipment, industry, research and science as well as students interested in radiation and its effects on components and systems. International experts present new results and give a comprehensive overview of the current situation. We encourage students to present their early research work on radiation hardening effects and discuss with radiation hardening experts from research and industry.

Keynote speeches and educational presentations on space radiation and radiation effects are an integral part of the RADHARD Symposium. We are pleased and very proud that a RHA expert from the European Space Agency, ESA gave a keynote lecture on the topic „News and Outlook on COTS Test Standardization". Experts from Seibersdorf Laboratories gave training lectures on „Space Radiation Environments at LEO, MEO, GEO and their Effects on Components and Systems". This year the training session was complemented by a lecture on "Electronics Design for Space Applications" presented by RUAG Space, Vienna.

The practical aspect of ensuring radiation hardness particular for New Space applications is of particular importance. Three lectures were given on "Small Satellites" by Graz University of Technology, RUAG Space, and University of Applied Sciences Wiener Neustadt. In addition, five lectures on „Testing of COTS Components" on current space activities related to radiation and its effects on components and systems were given by Seibersdorf Laboratories, University Padova, Graz University of Technology, and FOTEC, Wiener Neustadt. New and innovative radiation testing is absolutely necessary in addition to proven methods. The team consisting of Seibersdorf Laboratories, RUAG Space and Vienna Technical University presented a current study on this topic in the session "Laser Testing". The session was opened by a recognized expert on this topic with a keynote and was complemented by an invited talk on „Insights into a Laser Radiation Inspection System".

The RADHARD Symposium 2020 was organized by Seibersdorf Laboratories and supported by the Austrian Research Promotion Agency (FFG), the Federal Ministry for Climat Action, Environment, Energy, Mobility, Innovation and Technology, AUSTROSPACE and in cooperation with the Graz University of Technology (TUG), the University of Applied Sciences Wiener Neustadt (FHWN) and the association RADECS.

Our special thanks go to our supporters, AUSTROSPACE and the Austrian Research Promotion Agency (FFG), who once again this year enable us to offer the RADHARD Symposium without participation fee.

The RADHARD-Symposium took place on November 10th, 2020 and was available on the internet until the end of the following month.

Even if no come-together dinner could take place this year, the event was organized for you with many innovative ideas, with new presentation possibilities, very integrative and as a joint event with lots of fun and heart.

We hope you all had an interesting RADHARD 2020 Online Symposium!

Peter Beck

On behalf of the organizing team of the RADHARD Symposium 2020

Table of Content

Program Tuesday, November 10th, 2020

09:30 **Welcome Notes by the General Manager**
Martina Schwaiger, Seibersdorf Laboratories, Austria

Welcome Notes by the Head of Austrian Aeronautics and Space Agency
Andreas Geisler, Austrian Aeronautics and Space Agency, Austria

Welcome Notes by the Technopol Manager Wiener Neustadt, Austria
Rainer Gotsbacher, ecoplus, Austria

Introduction and Scope of the RADHARD Symposium 2020
Peter Beck, Head Radiation Protection Dosimetry, Seibersdorf Laboratories, Austria

10:00 **Keynote- News and Outlook on COTS Test Standardization**
Marc Poizat, European Space Agency, ESA/ESTEC

Session: Training Lectures

Space Radiation Environments at LEO, MEO, GEO and their Effects on Components and Systems
Michael Wind, Seibersdorf Laboratories, Austria

Electronics Design for Space Applications
Thomas Panhofer, RUAG Space Vienna, Austria

Q&A Session
Moderated by Christoph Tscherne

12:00 **Lunch Break**

13:30 Session: Small Satellites - New Space

OPS-SAT - Small Satellite Mission Recently Launched
Otto Koudelka, Graz University of Technology, Austria

Approval of the Detailed PRETTY Design
Michael Moritsch, RUAG Space Vienna, Austria

Status of the radiation environment simulations for CLIMB
Carsten Scharlemann, University of Applied Sciences Wiener Neustadt, Austria

Q&A Session
Moderated by Christoph Tscherne

14:20 **Coffee Break**

 Program status at the editorial deadline.

14:25 Session: Small Satellites - New Space

ESA Study on Radiation Testing of COTS Components to Verify a COTS RHA Approach
Peter Beck, Seibersdorf Laboratories, Austria

Total Ionizing Tests on Non-volatile Memories For Small Satellites
Simone Gerardin, University Padova, Italy

Studies of High-K CMOS Process Nodes in the Context of Future IC Applications for Ionizing Environments
Alicja Michalowska-Forsyth, Graz University of Technology, Austria

Pre-Charge Analysis in Siedwall Spacer with Respect to Ionizing Radiation
Tommaso Vincenzi, Graz University of Technology, Austria

Latch-up Detection and Mitigation Strategies
Bernhard Seifert, FOTEC, Wiener Neustadt, Austria

Q&A Session
Moderated by Christoph Tscherne

15:40 Coffee Break

15:45 Session: Laser Testing

Keynote: Laser Testing for Single-Event Effects: Some Thoughts from a User Perspective
Gary Swift, Swift Engineering & Radiation Services, USA

Invited Talk: Insights into a Laser Radiation Inspection System
Sebastien Jonathas, PULSCAN, France

SEELAS - Comparison of Laser and Heavy Ion Radiation Testing
Christoph Tscherne, Seibersdorf Laboratories, Austria

Q&A Session
Moderated by Peter Beck

17:00 Closing

Keynote
COTS components in space projects: motivations and challenges

Marc Poizat[1]
[1] European Space Agency, ESA

Abstract

The use of COTS components in space projects is increasing for both cost and performance reasons. However, the use of COTS has its disadvantages such as traceability, obsolescence, cost increase due to up-screening etc.

In this lecture, the main motivations for using COTS in European space projects will be presented. The classifications of EEE parts and modules will be introduced. Some of the basics of radiation hardness assurance will be recalled. Lastly some of the challenges encountered during RHA activities for COTS will be presented. COTS components represent a great opportunity for space programs but their use can pose significant challenges in order to make radiation robust space systems.

References

- ECSS-Q-ST-60-15C: Radiation Hardness Assurance – EEE components
- ECSS-E-HB-10-12A: Calculation of radiation and its effects and margin policy handbook
- ECSS-Q-ST-60C: Electrical, Electronic, Electromechanical (EEE) components
- ESCC22900 (Iss5): Total dose steady-state irradiation test method
- ESCC25100 (Iss2): Single Event Effects Test Method and Guidelines
- NSREC conference 2017 Short Course
- ESCCON conference 2019
- MEWS 2019 & 2020
- NSREC 2019

Session:
Training Lectures

Space Radiation Environments at LEO, MEO, GEO and their Effects on Components and Systems

Michael Wind[1], Peter Beck[1], Lukas Huber[1], Marcin Latocha[1], Christoph Tscherne[1]
[1] Seibersdorf Labor GmbH, Austria

Abstract

Spacecraft in near-Earth orbits are exposed to a complex and harsh radiation environment that poses a great challenge to space mission design. Semiconductor devices are pervasively deployed in analogue and digital applications for earth and space due to being cheap, small, fast, light weighted, and offering high functionality. When exposed to ionizing radiation semiconductor devices are vulnerable to a variety of damaging mechanisms. Exemplarily, radiation accelerates the aging of EEE components, eventually leading to a decrease in performance or to a complete loss of functionality [1]. Effects due to radiation have been observed and investigated for many decades by now and a lot of insight into the phenomena has been gathered and documented in literature ([2], [3], [4], [5], [6], [7]). In order to face these challenges, it is necessary to understand both the nature and effects of space radiation as well as the damaging mechanism induce by radiation.

The space radiation environments at Low Earth Orbits (LEO), Medium Earth Orbits (MEO) and Geostationary Earth Orbits (GEO) compose of three main types of primary radiation: solar energetic particles (SEP), galactic cosmic radiation (GCR) and charged particles trapped in the Earth's magnetic field ([2], [8]). All three types are of different origin, vary greatly in energy and flux and underlie short-term and long-term variations modulated by the sun's activity [9]. The presentation discusses different types of orbits and the space radiation environments that are associated with these orbits. Characteristics of SEP, GCR and trapped particles are described and their influence on mission design and radiation hardness assurance (RHA) is outlined ([10], [11], [12]).

In addition to the relevant radiation environments in LEO, MEO and GEO an overview is given on the major types of radiation effects, i.e. Total Ionizing Dose (TID), Single Event Effects (SEE) and Total Non-Ionizing Dose (TNID) effects. The basic radiation effects are illustrated that occur in electronics when they are exposed to the different radiation sources. Semiconductor parts being scheduled for operation in a radiation environment, e.g. satellite's electronics, require a decent knowledge on their susceptibility to the present radiation environment which raises the need for radiation tests. To assure the significance of such test and the comparability of the results testing is typically performed according to standards ([13], [14], [15]). Basic information on test procedures and available test standards is given.

The present talk is intended to give an introduction into radiation environments and radiation effects - the focus is laid on giving a decent overview without going too much into detail.

References

[1] Poivey, Christian. „Total Ionizing and Non-Ionizing Dose Radiation Hardness Assurance." Short course of NSREC 2017, 17 July 2017, New Orleans. USA. Presentation.

[2] Holmes-Siedle, Andrew G., and Len Adams. Handbook of radiation effects. 2nd ed., Oxford University Press, 2002.

[3] Proceedings of the Nuclear and Space Radiation Effects Conference (NSREC) Conference, published yearly in the December issue of IEEE-Trans. Nucl. Sci

[4] Proceedings of the Radiation Effects on Components and Systems (RADECS) Conference, published yearly by IEEE.

[5] M. Wind, J. V. Bagalkote, P. Clemens, T. Kündgen, M. Latocha, W. Lennartz, S. Metzger, M. Poizat, Sven Ruge, M. Steffens, P. Beck, Comprehensive Radiation Characterization of Digital Isolators, 16th European Conference on Radiation Effects on Components and Systems (RADECS), Proceedings, 2016

[6] M. Wind, P. Beck, J. Boch, L. Dusseau, M. Latocha, M. Poizat, A. Zadeh, Applicability of the Accelerated Switching Test Method – A Comprehensive Survey, Radiation Effects Data Workshop (REDW), 2011

[7] M. Wind, J. V. Bagalkote, P. Beck, M. Latocha, M. Poizat, TID and SEGR Radiation Characterisation of European COTs Power MOSFETs with Respect to Space Application, 15th European Conference on Radiation Effects on Components and Systems (RADECS), Proceedings, 2015

[8] Santin, Giovanni. „Radiation Environments: Space, Avionics, Ground and Below." Short Course of RADECS 2017, 2 Oct. 2017, Geneva. Switzerland. Presentation.

[9] Viereck, Rodney. „Space Weather: What is it? How Will it Affect You?" NOAA Space Environment Center, 2007, Boulder Colorado. USA. Presentation.

[10] ECSS-Q-ST-60-15C. "Radiation hardness assurance – EEE components", October 2012

[11] ECSS-E-ST-10-04C. "Space Environment", November 2008

[12] SPENVIS - The European Space Agency (ESA) Space Environment Information System (SPENVIS), available online at http://swe.ssa.esa.int/; https://www.spenvis.oma.be/

[13] European Space Component Coordination, Total Dose Steady-State Irradiation Test Method, ESCC Basic Specification No. 22900, issue 5, 2016

[14] MIL-STD-750-F Test Method Standard, Method 1019.5, Steady-State Total Dose Irradiation Procedure, Department of Defense, 2016

[15] European Space Component Coordination, Single Event Effects Test Method and Guidelines, ESCC Basic Specification No. 25100, issue 2, 2014

Acknowledgments

We acknowledge the insightful talks and presentations of the lecturers of the RADECS and NSREC short courses and the information provided by SPENVIS, ESA's Space Environment Information System (http://swe.ssa.esa.int/; https://www.spenvis.oma.be/).

Electronics Design for Space Applications

Thomas Panhofer[1]
[1] RUAG Space GmbH, Austria

Abstract

Satellites and their on-board electronics must operate reliably for many years in harsh environments without any possibility for repair. Therefore, it is very important to consider the environmental conditions the electronics is exposed to during the mission, and to implement appropriate failure handling techniques.

Designing robust electronics is not only limited to the circuit design as such, but already starts with the selection of suitable parts, materials and processes that need to be compatible to the operating environment. Apart from mission-specific requirements, the following conditions are always relevant and need particular treatment:

- Mechanical vibration & shock occurring during launch and deployments
- Large temperature variation depending on the sun-exposure
- Radiation environment

As a consequence, the mounting of each individual electrical parts needs to be qualified, as well as all processes that are applied for assembling a board or unit. Extensive analysis and simulations of the circuits are performed before a H/W is built, which is then tested under very harsh conditions to verify the compatibility to the mission. And all of that needs to be accurately documented to guarantee traceability even years after a unit was delivered.

This presentation illustrates the most important influences on the design of space-electronics and gives an overview about how they are handled.

Author

Thomas Panhofer has been working in the space industry for more than 22 years in various disciplines related to electronics H/W development. In recent years he was working as systems and project engineer for on-board motor drive electronics, where he was also responsible for the radiation and reliability analyzes. Since 2018 he is leading the “electronics design and layout” team at RUAG Space GmbH in Vienna, which is responsible for designs in the product areas of power supplies, motor drivers and data-handing electronics.

Session:
Small Satellites - New Space

OPS-SAT - Small Satellite Mission Recently Launched

O. Koudelka, R. Zeif, M. Kubicka, M. Henkel, A. Hörmer, M. Wenger, R. Finsterbusch, F. Teschl
Graz University of Technology

D. Evans, T. Mladenov, D. Marszk, A. Lofaldli, V. Shiradhonkar, V. Zelenevskiy, G. Labrèche, J. Feiteirinha, R. Majchrzak
ESA/ESOC

Abstract

OPS-SAT is an innovative triple CubeSat initiated by the European Space Operations Centre with the main objective to stimulate “innovation via experimentation” in the area of mission operations. OPS-SAT is the first in-orbit demonstration of a spacecraft with fully MO (Mission Operations)-based on-board software and ground implementations. The spacecraft is fully compatible with the relevant CCSDS standards and hence ESA’s ground infrastructure, thus OPS-SAT looks like an advanced ESA satellite. The purpose is to verify new operational concepts and to carry out a variety of hardware and software experiments in the field of radio and optical communications, attitude control, remote sensing and on-board autonomy. OPS-SAT was developed by an international consortium led by TU Graz and was successfully launched in December 2019. After intensive tests and validation of the spacecraft and the complex ground infrastructure, OPS-SAT entered the experimental phase.

Core of the satellite is a powerful processor based on a Cyclone V system-on-chip with a large Field Programmable Array which was developed by TU Graz. This unit and other COTS components on board of OPS-SAT were radiation tested at ESTEC for total dose and at the Paul Scherrer Institute for SEU effects.

The presentation outlines the design of the satellite and provides information on the operational experience.

Approval of the detailed PRETTY Design

M. Moritsch[1], C. Tscherne[2], A. Dielacher[1], H. Fragner[1], M. Wind[2], P. Beck[2], A. Hörmer[3], O. Koudelka[3]
[1] RUAG Space GmbH, Austria
[2] Seibersdorf Labor GmbH, Seibersdorf, Austria
[3] Graz University of Technology, IKS, Austria

Abstract

The consortium RUAG Space GmbH, TU Graz and Seibersdorf Laboratories have recently finalized the Critical Design Review (CDR) of the PRETTY (Passive REflecTometry and dosimeTrY) space mission together with ESA. While the instrument concepts have been presented in the frame of the RADHARD Symposium 2019 [RD1], the final design including all internal ICDs has now been approved for implementation.
The CDR was held on basis of several breadboarding activities that showed the viability of selected instrument concepts. While the satellite bus was a reuse from the OPSat mission relying heavily on commercial off the shelf (COTS) components from different vendors, the payloads rely on specific hard- and software based implementations. Within this presentation we will provide some insight on the most relevant breadboarding results for the passive reflectometer and the dosimeter.
The reflectometer hardware is provided by TU Graz and requires an antenna that was specifically designed for this mission. The active patch antenna provides within the L1 Band a gain of 15 dBi on a small footprint of only 10 cm x 20 cm. TU Graz has built a first prototype, measured the antenna pattern and compared it to the simulated results during the phase B study.

The signal processing core, which will run on an Altera Cyclon V has been developed by RUAG Space (RSA) and was recently validated by using test data obtained within the CyGNSS mission. RSA is also part of the extended US mission science team and was thus in the lucky position to obtain raw data from this mission in order to use it for the PRETTY signal processing core validation.

The reference dosimeter payload is designed and developed by Seibersdorf Laboratories. Its objectives are to assess the radiation mission dose during the whole CubeSat space mission and in particular at geographic regions of interest with elevated radiation levels, such as the South Atlantic Anomaly (SAA), North Pole and the South Pole. The proposed dosimeter system is based on RADFET and FGDOS which are made of silicon and therefore their response can be used as reference dose for total ionizing dose (TID) effects. Further, the dosimeter payload will feature a single event upset (SEU) assessment system. The SEU assessment system will be based on COTS SRAM memories and is carried out as collaboration with CERN. The measurements are representative for other silicon-based electronic systems e.g. during reliability testing of electronic components, in particular for COTS on-board CubeSat.

With the provided CDR data the consortium has successfully demonstrated the viability of the instrument designs by use of representative breadboard results. The flight implementation can now be started and is expected to be finalized within 2021.

References

RD1: RADHARD 2019, Book of Abstracts, Concluding the preliminary design Phase: PRETTY results from the Phase B study

Acknowledgments

The phase C and B study for the PRETTY mission has been funded by ESA GSTP Programme. The according Phase A study was funded by ASAP/FFG.

Status of the radiation environment simulations for CLIMB

Wolfgang Treberspurg[1], Carlo Girardello[1], Robert Kralovsky[2], Christof Obertscheider[1], Andreas Sinn[3], Carsten Scharlemann[1]
[1] University of Applied Sciences Wiener Neustadt
[2] RKOS IT Consulting
[3] TU-Wien

Abstract

The main objective of the CLIMB 3-U CubeSat mission of the FHWN is to reach the inner Van-Allen-Belt by increasing the apogee height of its orbit from 500 km to about 1000 km, by performing maneuvers with a FEEP [1] thruster. Beside of challenges concerning the thermal loads, the available energy budget and the required attitude control of the satellite, this mission demands special precautions with regard to the radiation hardness of the satellite. In order to take those environmental impacts into account during the development of the mission, several simulations and tests were performed. The effect of the propulsive maneuvers is numerically simulated with the system tool kit [2] allowing to determine the various orbit options. Those orbits are then used to estimate the total and time dependent radiation dose e.g. with the omere package [3]. The environmental specifications are further coupled via the FastRad software [4] with the CAD design files of the satellite to consider and optimize shielding effects for the specification of the total dose at sensitive components inside the structure. The microprocessor of the on-board computer (OBC) is a typical example for a sensitive and mission critical component. To ensure its radiation hardness up to the preliminary estimated worst case of 50 krad, irradiation tests have been performed with the 60Co source at the Seibersdorf Laboratories. The analysis of these results shows that the microprocessor itself could withstand the irradiated dose, although some components like temperature sensors and dosimeter are more likely to fail under the radiation effects of the harsh environment CLIMB will face.

References

[1] Krejci, David. "Demonstration of the IFM nano FEEP thruster in low Earth orbit". ResearchGate (Report). Retrieved 27 March 2019
[2] https://www.agi.com/products/stk
[3] https://www.trad.fr/en/space/omere-software/
[4] https://www.fastrad.net/

Session:
Testing of COTS Components

ESA Study on Radiation Testing of COTS Components to Verify a COTS RHA Approach

Peter Beck[1], Marta Bagatin[2], Simone Gerardin[2], Marcin Latocha[1], Alessandro Paccagnella[2], Christoph Tscherne[1], Michael Wind[1], Marc Poizat[3]
[1] Seibersdorf Labor GmbH, Austria
[2] University of Padova, Italy
[3] European Space Agency, ESA

Abstract

Small satellites, such as CubeSat, have become a popular and cost effective manner of accessing space [1]. The increased interest in flying small satellite missions and initiation of the European Space Agency, ESA projects to improve reliability of CubeSat has resulted in an increased utilization of COTS components. Besides, COTS are not only used for small satellite applications, but there is an increase in the use of COTS also on mainstream missions. Therefore, ESA initiated a study on radiation screening of COTS components and verification of COTS Radiation Hardness Assurance (RHA) approach (CORHA). The CORHA project is coordinated by the Seibersdorf Laboratories (SL) and is performed in collaboration with the University of Padova (UPD). ESA is making use of COTS components and popular examples are, amongst others, FPGAs and memory devices (FLASH, SDRAMs, DDR2, etc.) [1]. This increase in the use of COTS components is owed to the fact that COTS often have superior performance compared to space qualified components and might work with lower resource requirements (e.g. power consumption). Although COTS components performance capabilities often outperform traditional space qualified components, there are limitations strongly complicating their use for space applications. Limitations inlcude lack of traceability, packaging constraints, radiation sensitivity and questions regarding board level and component level testing, rapid obsolescence, cost increase due to up-screening and others.

According to the ECSS Radiation Hardness Assurance standard ECSS-Q-ST-60-15C standard [2] Radiation Hardness Assurance consists of all activities undertaken to ensure that the electronics of a space system perform within their design specifications after exposure to the space environment. In this context, RHA deals with the environment assessment, the part selection, the part testing, the spacecraft layout, the radiation tolerant design as well as with the mission, system, and subsystem requirements. In principle the ECSS-Q-ST-60-15C [2] that is embedded in the product assurance standard for Commercial EEE Components ECSS-Q-ST-60-13C [3] as an applicable document does also apply to COTS devices. However, the application of ECSS-Q-ST-60-15C to small satellites that are flying COTS devices may not be practical for technical and/or financial reasons. The RHA process for such missions is therefore often defined on a case-by-case basis. Hereby the RHA for COTS is commonly based on risk management in terms of acceptance of a given risk and not on risk avoidance [1].

As a first baseline, knowledge of the radiation environment is of crucial importance for a tailored RHA-approach. Various software tools are existing (e.g. SPENVIS [4], OMERE [5], etc.) that provide engineers with meaningful radiation environment data. These data are used to perform model calculations to determine TID and TNID dose levels inside the satellite at the location of the EEE components. With a well-known radiation environment, relevant hazards are identified. A detailed evaluation of the hazards serves as a good baseline for part selection and also for the definition of the radiation tests that need to be performed. A number of radiation effects may be mitigated by design. However, these mitigation techniques need to be fully understood as they may create additional problems [1].

Again, to achieve and implement effective mitigation a good knowledge of the radiation environment and associated potential radiation effects is necessary. There are numerous mitigation techniques that may be applied to increase the radiation performance of an equipment or system. Mitigation techniques comprise methods such as single event latch-up protection, soft error rate mitigation, use of extra shielding or positioning of sensitive parts in more shielded areas of the spacecraft. Within the RHA process, the design is critically assessed to identify risks and to decide what devices need to be tested.

A definition of dose level limits for TID and LET thresholds for SEE may be used as a criterion whether to perform testing of a specific device or not. The criteria for part selection should comprise the use of technologies that are less sensitive and the selection of components being testable. Available test data and flight heritage should be considered for part selection. Board-level testing might be an effective tool. The major advantages of board level testing are the reduced test time and the fact that tested parts are exposed in application conditions. The advantages come at the cost of reduced observability; i.e. the test can be considered as go / no go tests. Also, the results cannot be reused for another application. Board level proton testing allows for SEE testing on entire boards as large-area beams are available. Also, high energy protons have a good penetration depth. However, proton SEE testing has major limitations that are small sample sizes, difficulties in identifying the SEE error mode, complicated test sequence and that testing is only applicable for the specific application. Also, the fluence needed to get sufficient SEE statistics may result in high TID and TNID dose levels.

Using COTS offers great benefits, however they come also with some serious disadvantages. Thus, the use of COTS components requires a solid understanding of the relevant processes and must be based on a comprehensive risk management. In this context it is of crucial importance that RHA for COTS is implemented already in the early phases of the project development and that there is an awareness for the need of a suitable risk management strategy. Within the scope of a critical system analysis, a large number of radiation effects may be avoided by effective mitigation techniques. Nevertheless, irradiation testing of COTS devices is important in particular for critical devices that need to be properly identified. Currently no universal RHA standards are available that are dedicated to COTS. For this reason, RHA for COTS is handled on a case-to-case base and thus is realized as tailored RHA solution for each specific application. The unfavorable situation of lacking dedicated RHA standards for COTS needs to be addressed promptly by providing standards that regulate testing of COTS components to facilitate the achievement of significant test results.

The objectives of the CORHA study are to (1) screen COTS components, (2) prepare and execute radiation test campaigns, (3) and propose an ad-hoc RHA approach for COTS components. The CORHA team will evaluate COTS technologies available on the market with respect to their TID response and to their susceptibility for SEE. During the presentation, we show a set of proposed candidates for further radiation hardness investigations. Further, based on the gathered data, review of existing standards and the most recent scientific and technical literature, we outline an ad-hoc RHA approach for COTS components, which will be investigated in more detail in the CORHA study.

References

[1] M. Poizat, A. Zadeh, C. Poivey, R. Walker, Radiation Hardness Assurance for Commercial-Off-The-Shelf (COTS) components for Small Satellites, RADHARD Symposium 2018, https://www.seibersdorf-laboratories.at/en/radhard/archive/2018-radhard-symposium, ISBN (Print) 978-3-902780-12-6, ISBN (Ebook) 978-3-902780-13-3, Editor: Peter Beck, Seibersdorf Labor GmbH, 2444 Seibersdorf, Austria, Publisher: Seibersdorf Laboratories Publishing, Austria, April 2018.

[2] ECSS-Q-ST-60-15C, Radiation Hardness Assurance – EEE Components, ECSS, Oct 2012

[3] ECSS, ECSS-Q-ST-60-13C, Space product assurance – Commercial electrical, electronic and electromechanical (EEE) components

[4] SPENVIS, The Space Environment Information System, software, accessible via http://swe.ssa.esa.int/; https://www.spenvis.oma.be/

[5] TRAD, Omere, software, accessible via http://www.trad.fr/en/space/omere-software

Acknowledgments

We acknowledge the support by the European Space Agency, ESA under the ESA contract – Contract No. 4000126049/18/NL/KML.

Total Ionizing Tests on Non-volatile Memories For Small Satellites

Simone Gerardin[1], Marta Bagatin[1], Alessandro Paccagnella[1], Peter Beck[2], Christoph Tscherne[2], Michael Wind[2], Marc Poizat[3]
[1] University of Padova – Department of Information Engineering, Italy
[2] Seibersdorf Labor GmbH, Austria
[3] European Space Agency, ESA

Abstract

Microcontrollers and FPGAs used in small satellites require low-footprint non-volatile memories (NVM) for configuration, code, and data storage purposes. The Serial Peripheral Interface (SPI) is a standard low-pin count interface that allows for simplified routing and small board area occupation and it is therefore well suited for this kind of application. On the other side, the Flash NOR interface has a larger pin-count and footprint, but provides faster random access.

In this talk we will show the results of Total Ionizing Dose (TID) tests performed on NVMs at the Seibersdorf Laboratories with a Co60 source, in the frame of the project CORHA (COTS Radiation Hardness Assurance), funded by the European Space Agency. We will present TID data on three SPI memories and one NOR Flash memory, to address the needs of small satellites. The SPI NVMs are manufactured with two different technologies, charge trap and ferroelectric RAM. The NOR Flash memory employs the floating gate technology.

Parametric degradation and failure modes will be illustrated up to 100 krad(Si).

References

[1] M. Poizat, A. Zadeh, C. Poivey, R. Walker, “Radiation Hardness Assurance for Commercial-Off-The-Shelf (COTS) components for Small Satellites”, RADHARD Symposium 2018, https://www.seibersdorf-laboratories.at/en/radhard/archive/2018-radhard-symposium, ISBN (Print) 978-3-902780-12-6, ISBN (Ebook) 978-3-902780-13-3, Editor: Peter Beck, Seibersdorf Labor GmbH, 2444 Seibersdorf, Austria, Publisher: Seibersdorf Laboratories Publishing, Austria, April 2018.
[2] P. Beck, M. Bagatin, S. Gerardin, M. Latocha, Alessandro Paccagnella, C. Tscherne, M. Wind, M. Poizat, “CORHA - Radiation Screening of COTS Components and Verification of COTS RHA Approach”, Symposium 2019

Author

Simone Gerardin is an Associate Professor of Electronics at the University of Padova - Italy. His research is focused on ionizing radiation effects in advanced CMOS technologies and on their interplay with device aging and electrostatic discharges, in the space, terrestrial, and high-energy physics environments. In recent years, his interests have been on innovative non-volatile memories and total dose effects at ultra-high levels. Simone has authored or co-authored more than 200 peer-reviewed journals, book chapters, and conference presentations, twelve of which were recognized with international awards. He co-edited a book about radiation effects and was an associate editor for the IEEE Transactions on Nuclear Science, in addition to serving as short course chair and technical chair for the IEEE Nuclear Space Radiation Effects Conference.

Studies of high-K CMOS process nodes in the context of future IC applications for ionizing environments

Alicja Michalowska-Forsyth[1]
[1] Institute of Electronics, Graz University of Technology

Abstract

With down-scaling of CMOS technologies the silicon dioxide gate in MOSFET has to be replaced with high dielectric constant (high-K) material. The insulator is thinner, resulting in lower density of gate leakage current. High-K materials are used in CMOS process nodes below 65 nm. Specifically the planar bulk processes 28 nm and 40 nm, relatively cheap comparing to FinFET or FDSOI, inevitably will gain on maturity over the coming years and will become more important in the future standard and custom integrated circuit solutions. Also applications designed for ionizing environments will want to benefit from the ultra-high speed offered by scaled processes. Consequently there is a great interest to better understand the effects of ionizing radiation on these IC fabrication processes. The results presented here as well as those found in the literature [1][2] point so far to a superior performance in terms of the total ionizing dose (TID) tolerance. Still, at high TID levels one can expect new effects in the electrical characteristics due to new wafer processing techniques during fabrication, changed doping profile and concentration [2], geometry constraints imposed by photolithography or device size shrinking that is not uniformly scaled vertically and horizontally [3]. Also related to novel material composition the previously neglected electron trapping has been reported in high-K gate stack devices [4][5]. This talk gives an outlook on the SIRENS (Studies of Ionizing Radiation Effects in NanoScale CMOS Technology Nodes) project, the first measurements, the scientific questions and on the future activities.

References

[1] Zhang, Chun-Min, et al. „Characterization and Modeling of Gigarad-TID-Induced Drain Leakage Current of 28-nm bulk MOSFETs.“ IEEE Transactions on Nuclear Science 2018, pp. 38-47.

[2] Bonaldo, Stefano, et al. „Influence of Halo Implantations on the Total Ionizing Dose Response of 28 nm pMOSFETs Irradiated to Ultrahigh Doses.“ IEEE Trans. on Nuclear Science 2018, pp. 82-90.

[3] Faccio, Federico, et al. „Influence of LDD Spacers and H+ Transport on the Total-Ionizing-Dose Response of 65-nm MOSFETs Irradiated to Ultrahigh Doses.“ IEEE Trans. Nucl. Sc. 2017, pp. 164-174.

[4] Zhou, X. J., et al. „Effects of Switched-Bias Annealing on Charge Trapping in HfO2 Gate Dielectrics.“ IEEE Transactions on Nuclear Science 53.6 (2006): 3636-3643.

[5] Dixit, Sriram K., et al. „Radiation Induced Charge Trapping in Ultrathin HfO2-Based MOSFETs.“ IEEE Transactions on Nuclear Science 54.6 (2007): 1883-1890.

Acknowledgments

The author gratefully acknowledges the contributions to the successful start of SIRENS project from Varvara Bezhenova and Nikolaus Czepl from Graz University of Technology. She is also thankful to Federico Faccio and Giulio Borghello from CERN for welcoming the team to join the experiments and for sharing the measurement data. The author is also grateful for the support of this research project by Field of Expertise “Advanced Materials Science” at Graz University of Technology as well as by Austrian Science Fund (FWF): P 33387-N.

Pre-charge analysis in Sidewall Spacer with respect to Ionizing Radiation

Tommaso Vincenzi[1,2], Gregor Schatzberger[1], Alicja Michalowska-Forsyth[2]
[1] ams AG
[2] Graz University of Technology

Abstract

Non-Volatile Memories (NVM) suffer from radiation damage in the same way regular MOS devices do, having to withstand Total Ionizing Dose (TID) and Single Events (SE). Nowadays, most of the commercially available solutions for NVMs are charge based. This means that the information is stored as either positive or negative charge within a certain storage element, either it being a conductive layer, such as in Floating Gate (FG) devices [1], or a non-conductive one, as in Charge Trapping devices [2-3].

The presentation analyzes the Sidewall Spacer (SwSpc) Memory BitCell [4], compliant with standard CMOS process, and expands the works performed in [5]. This type of device is more robust compared to standard FG because it uses a charge-trapping mechanism rather than a conductive layer to preserve the charge. In particular, due to the cost benefit and the high-reliability to TID, the SwSpc is particularly suitable both for medical and consumer applications, normally separate and independent. This work analyzes how the charging conditions, i.e. the amount of charge in the nitride spacer after a program operation, influences the tolerance of the BitCell to ionizing radiation. Multiple chips have been tested under a tungsten X-ray tube up to 500krad to sample the response of the cells.

References

[1] D. Frohman-Bentchkowsky, “Famos-A new semiconductor charge storage device,” Solid-State Electron., vol. 17, pp. 517–528, 1974, IN1-IN2, 529.
[2] M. H. White, et al., „On the go with SONOS,“ in IEEE Circuits and Devices Magazine, vol. 16, no. 4, pp. 22-31, July 2000.
[3] S. Gerardin, A. Paccagnella, “Present and Future Non-Volatile Memories for Space”, IEEE Transactions on Nuclear Science, vol. 57, pp. 3016-3039, December 2010.
[4] Breitwisch, Matthew J., inventor et al. International Business Machines Corp, assignee; U.S. Patent 6518614B1. February 11, 2003.
[5] T. Vincenzi, G. Schatzberger and A. Michalowska-Forsyth, „Program Time Effects on Total Ionizing Dose Tolerance of Sidewall Spacer Memory Bit Cell,“ 2019 Austrochip Workshop on Microelectronics (Austrochip), Vienna, Austria, 2019, pp. 55-58

Acknowledgments

The authors thank Alex Costa, Heinz Pernegger, Johannes Fellner and Bernd Deutschmann for the support on the project. A special thanks to MedAustron research center for the support on the irradiation of devices.

Latch-up Detection and Mitigation Strategies

B. Seifert[1], T. Hörbe[1], E. Ceribas[1]
[1] FOTEC Forschungs- und Technologietransfer GmbH, Wiener Neustadt, Austria

Abstract

FOTEC has been developing COTS-based (Commercial Off the Shelf) electronics for space application for more than 10 years. As space is a harsh environment, extensive qualification testing is required during the development process. This includes environmental testing, such as thermal-vacuum, vibration and shock, as well as EMI (Electromagnetic Interference) and radiation testing. The latter is again split into TID (Total Ionizing Dose) and SEE (Single Event Effect) test cases.

EEE (Electrical, Electronic and Electromechanical) components are qualified for commercial, industrial, automotive, military or space application with increasing reliability and costs but decreasing availability. Therefore, FOTEC attempts to utilize mostly automotive and military parts. Also, up-screening is possible to qualify components for higher reliability classes. This presentation will focus on different approaches regarding circuit design to increase the reliability of the total system without the necessity to use space-qualified components. The focus is laid on transient latch-up hazards, where fast (charged) particles can trigger the parasitic thyristor structure of semiconductors which leads to high current draw. This in turn, can overheat the die itself or permanently break thin tracks in it.

It is possible to use current-limiting resistors or PTC (Positive Temperature Coefficient) thermistors to reduce the current draw by a component, even when it is in latch-up condition. For power components, such MOSFETs in half- or full-bridge configuration, different approaches have to be taken to avoid a significant decrease in efficiency. In this scenario, fast-acting temperature surveillance in the near vicinity of the critical components is implemented.

Session:
Laser Testing

Laser Testing for Single-Event Effects: Some Thoughts from a User Perspective

Gary M. Swift[1]
[1] Swift Engineering and Radiation Services, LLC, San Jose, Calif. USA

Abstract

Whoa, Nellie Belle! The physics of charge deposition, collection, and circuit response is super complicated and the holy grail of matching- and eventually superseding- heavy ion testing with laser testing for single-event effects (SEE) purposes is, if not an impossible quest, very near so. Or maybe recent breakthroughs in modeling deposition [1] & [2] make this a solved problem.

Shoot, laser testing itself is extremely sophisticated, delicate, and difficult. As a long-time experienced ion beam tester who has admired several laser labs from afar and, more recently, dabbled in using a couple of laser facilities, my hat is off to those brave- or foolhardy- enough to attempt to provision and support laser SEE testing.

But not to worry, there are a fair number of tractable problems to solve and practical issues to research, particularly with regards to large die devices and two-photon absorption (TPA) testing. These include: single shot use and reproducibility, efficiently moving the target or spot [3], back-and-forth upsets, collection and categorization of SEE signatures, TID-like damage, avoiding killer damage, TPA tradeoffs, auto focus depth, user interfaces and more.

Mostly these leverage the complementary aspects of focused laser testing rather than the “competitive.” IMHO, the real goal is to use the right tool at the right time and in the right way and the real holy grail for laser SEE testing is localization. This is a “needle-in-the-haystack’ problem and means developing tools and techniques to efficiently find a particular and rare example SEE site on complicated, large-area, flip-chip devices, including precise timing signal exchange between the laser system and DUT board and detailed automated logging. Localization best practice likely includes ion-beam testing in conjunction with laser testing [4].

Another worthy aim of laser testing on large, complicated devices is to define the logical to physical map, a key step in SEE mitigation for memory arrays. This mapping can be done using heavy ion irradiation only in a statistical way [5], but doing this with a laser seems much more clear and direct. However, to be usable, a lot of automation is needed and will likely be obstructed by some of the unsolved problems listed above.

References

[1] J. M. Hales, A. Khachatrian, S. Buchner, N. Roche, J. Warner and D. McMorrow, „A Simplified Approach for Predicting Pulsed-Laser-Induced Carrier Generation in Semiconductor,“ in IEEE Transactions on Nuclear Science, vol. 64, no. 3, pp. 1006-1013, March 2017, doi: 10.1109/TNS.2017.2665546.

[2] J. M. Hales, A. Khachatrian, S. Buchner, N. Roche, J. Warner, Z. E. Fleetwood, A. Ildefonso, J. D. Cressler, V. Ferlet-Cavrois and D. McMorrow, „Experimental Validation of an Equivalent LET Approach for Correlating Heavy-Ion and Laser-Induced Charge Deposition,“ in IEEE Transactions on Nuclear Science, vol. 65, no. 8, pp. 1724-1733, Aug. 2018, doi: 10.1109/TNS.2018.2828332.

[3] M. Cannon, A. Pérez-Celis, G. Swift, R. Wong, S. Wen and M. Wirthlin, „Move the Laser Spot, Not the DUT: Investigating the New Micro-mirror Capability and Challenges for Localizing SEE Sites on Large Modern ICs,“ 2017 17th European Conference on Radiation and Its Effects on Components and Systems (RADECS), Geneva, Switzerland, 2017, pp. 1-4, doi: 10.1109/RADECS.2017.8696180.
[4] W. Rudge, C. Dinkins, W. Boesch, D. Vail, J. Bruckmeyer and G. Swift, „SEL Site Localization Using Masking and PEM Imaging Techniques: A Case Study on Xilinx 28nm 7-Series FPGAs,“ 2016 IEEE Radiation Effects Data Workshop (REDW), Portland, OR, USA, 2016, pp. 1-6, doi: 10.1109/NSREC.2016.7891736.
[5] M. Wirthlin, D. Lee, G. Swift and H. Quinn, „A Method and Case Study on Identifying Physically Adjacent Multiple-Cell Upsets Using 28-nm, Interleaved and SECDED-Protected Arrays,“ in IEEE Transactions on Nuclear Science, vol. 61, no. 6, pp. 3080-3087, Dec. 2014, doi: 10.1109/TNS.2014.2366913.
[6] For XRTC current activites, see: http://xrtc.groups.et.byu.net/wiki

Acknowledgments

Gary would like to thank and acknowledge the Xilinx Radiation Test Consortium [6] and, in particular, some key members who shared in both vain and fruitful attempts to use laser testing on a large-die: Harris (now L3Harris), NASA/Jet Propulsion Laboratory, NASA/Goddard, Boeing, and especially Brigham Young University. Also, a big “Thank You!” to the remarkably welcoming and smart researchers at the two laser facilities that hosted our efforts: the US. Naval Research Lab and Canada’s University of Saskatchewan.

Insights into a Laser Radiation Inspection System

Sebastien JONATHAS[1]
[1] PULSCAN

Abstract

The pulsed laser technique [1] has become a common way to test Integrated Circuits (ICs) for single-event effects (SEEs) as a complementary approach to the standard particle-beam testing method. The increasing use of the pulsed laser technique for SEE testing is motivated by its ease of use and access in a laboratory environment, when compared to the cost and availability constraints of particle accelerator testing, and by its unique ability to provide spatial and temporal information about the SEE sensitivity of ICs. The development of the laser technique can also be explained by the availability of industrial turn-key systems that make this technique accessible to non-experts.

This talk presents our PULSYS-RAD system for pulsed laser SEE testing. The system design results from our long experience in SEE laser testing and its capabilities have been field-proven on many different IC technologies [2-7]. The main elements and specifications of the all-fiber optical chain and the microscope are presented. The system includes the PULSBOX-PICO and/or PULSBOX-2P smart laser sources, respectively for Single-Photon Absorption (SPA) and Two-Photon Absorption (TPA) testing. Pros and cons of each of those approaches are discussed. The main features of the PULSWORKS software, which provides a complete user interface to control the system as well as for data acquisition and visualization, are described and its many laser-scanning possibilities are reviewed through different use cases.

Finally, the long-standing question of laser to heavy ion equivalence is discussed and the equivalent LET calculation [8] now embedded in our PULSYS-RAD system is presented.

References

[1] S. P. Buchner, F. Miller, V. Pouget, and D. P. McMorrow, “Pulsed-laser testing for single-event effects investigations,” IEEE Trans. Nucl. Sci., vol. 60, no. 3, pp. 1852–1875, 2013.
[2] K. Takeuchi et al., „Single-Event Effects Induced on Atom Switch-based Field-Programmable Gate Array,“ in IEEE Transactions on Nuclear Science, vol. 66, no. 7, pp. 1355-1360, July 2019
[3] S. M. Mahmood, “Investigation of Single Event Latch-up effects in the ALICE SAMPA ASIC”, TWEPP 2018, Antwerpen, Belgium
[4] G. Allen et al., « SEE Test Results and Community Efforts”, Nasa NEPP Electronics Technology Workshop, 2019
[5] A. Watkins et al, « Single Event Effects Characterization Using a Single Photon Absorption Laser”, 2018 IEEE AUTOTESTCON, National Harbor, MD, 2018
[6] G. S. Rodrigues et al., „Exploring the inherent fault tolerance of successive approximation algorithms under laser fault injection,“ IEEE 19th Latin-American Test Symposium (LATS), Sao Paulo, 2018, pp. 1-6
[7] J. Prinzie, J. Christiansen, P. Moreira, M. Steyaert and P. Leroux, „A 2.56-GHz SEU Radiation Hard LC -Tank VCO for High-Speed Communication Links in 65-nm CMOS Technology,“ in IEEE Transactions on Nuclear Science, vol. 65, no. 1, pp. 407-412, Jan. 2018
[8] V. Pouget, “Single-photon and two-photon absorption induced charge model calibration”, RADLAS 2017

SEELAS - Comparison of Laser and Heavy Ion Radiation Testing

Christoph Tscherne[1], Patrick Schmidt[2], Michael Hofbauer[3], Christian Laa[2], Andreas Dielacher[2], Michael Wind[1], Thomas Panhofer[1], Heinz Fragner[2], Horst Zimmermann[1], Peter Beck[1]

[1] Seibersdorf Labor GmbH, Austria,

[2] RUAG Space GmbH, Austria,

[3] Vienna University of Technology, Institute of Electrodynamics, Microwave and Circuit Engineering, Austria

Abstract

Single event effects (SEE) are a major threat to space missions since individual charged particles of the space radiation environment, such as protons or heavy ions, can irretrievably damage electronic devices. The introduction of modern technologies in space demands for new and innovative testing services, especially since many new players operating small satellites fear the high costs and efforts that accompany heavy ion testing. Although some US and European laboratories and industry look towards laser testing as an economic alternative, the current standards only accept heavy ion testing. SEELAS (Exploration of Single Event Effect Radiation Testing of COTS Components with Laser and Heavy Ions), a nationally funded and ESA supported activity investigates the applicability of laser testing as a modern approach to radiation hardness assurance by carrying out both, laser testing and traditional heavy ion testing for the same commercial off-the-shelf (COTS) components. A thorough analysis of the results using statistical methods, TCAD and Monte Carlo simulations allows for an objective evaluation of the method and positive results may support the industry's push to alter existing standards to allow laser testing.

Acknowledgments

We acknowledge the support by the Austrian Research Promotion Agency (FFG) under the FFG project No. 873705.

List of Lecturers

Beck Peter, Seibersdorf Laboratories, Austria
ESA Study on Radiation Testing of COTS Components to Verify a COTS RHA Approach

Gerardin Simone, University Padova, Italy
Total Ionizing Tests on Non-volatile Memories For Small Satellites

Jonathas Sebastien, PULSCAN, France
Invited Talk: Insights into a Laser Radiation Inspection System

Koudelka Otto, Graz University of Technology, Austria
OPS-SAT - Small Satellite Mission Recently Launched

Michalowska-Forsyth Alicja, Graz University of Technology, Austria
Studies of High-K CMOS Process Nodes in the Context of Future IC Applications for Ionizing Environments

Moritsch Michael, RUAG Space Vienna, Austria
Approval of the Detailed PRETTY Design

Panhofer Thomas, RUAG Space Vienna, Austria
Electronics Design for Space Applications

Poizat Marc, European Space Agency, ESA
Keynote - News and Outlook on COTS Test Standardization

Scharlemann Carsten, University of Applied Sciences Wiener Neustadt, Austria
Status of the radiation environment simulations for CLIMB

Seifert Bernhard, FOTEC, Wiener Neustadt, Austria
Latch-up Detection and Mitigation Strategies

Swift Gary, Swift Engineering & Radiation Services, USA
Keynote: Laser Testing for Single-Event Effects: Some Thoughts from a User Perspective

Tscherne Christoph, Seibersdorf Laboratories, Austria
SEELAS - Comparison of Laser and Heavy Ion Radiation Testing

Vincenzi Tommaso, Graz University of Technology, Austria
Pre-Charge Analysis in Siedwall Spacer with Respect to Ionizing Radiation

Wind Michael, Seibersdorf Laboratories, Austria
Space Radiation Environments at LEO, MEO, GEO and their Effects on Components and Systems

CONTACT

Seibersdorf Labor GmbH
2444 Seibersdorf, Austria

www.seibersdorf-laboratories.at
Fax: +43 50550 - 2502

Secretary
+43 50550 - 2500
office@seibersdorf-laboratories.at

Content & Prubt: Seibersdorf Labor GmbH, 2444 Seibersdorf · v06102020 · © 2020