Predicting, Characterizing, and Mitigating SEE in Advanced Semiconductor Technologies

Announcement for the 2019 IEEE NSREC Short Course

MONDAY
JULY 8, 2019
SAN ANTONIO, TEXAS

On behalf of the 2019 IEEE Nuclear and Space Radiation Effects Conference (NSREC) Committee, I invite you to attend the 40th IEEE NSREC Short Course. An outstanding group of technical experts will provide an overview of Single Event Effects including mechanisms and rates, advanced techniques for measuring SEE, and challenges posed by advanced technologies.

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COURSE DESCRIPTION

A one-day short course, *"Predicting, Characterizing, and Mitigating SEE in Advanced Semiconductor Technologies,"* will be presented at the 2019 IEEE Nuclear and Space Radiation Effects Conference (NSREC). The course will discuss single event effects (SEE) that occur in components used in space systems. The past four decades have seen our understanding of the range of SEE experienced by space systems expand substantially as more modern devices have been utilized in space systems and exposed to the space radiation environment. Vulnerabilities of devices today are much more complicated than in the past, and those vulnerabilities continue to threaten space systems as parts are scaled, new materials are used, devices become faster, and new mechanisms are discovered.

This short course is organized into four sections as shown below. The short course includes an up-to-date overview of SEE mechanisms and rates; discussions of various methods to test for SEE and isolate sensitive nodes; and a discussion of SEE in advanced components, and the challenges posed by some of these components for our test methodologies. All of the testing presentations will show case studies, indicate how the techniques are used to isolate susceptible nodes, discuss correlations between particle tests and photon tests, and indicate how the test methodologies point to strategies for mitigation.

This short course is intended for radiation effects engineers and scientists, component specialists, systems designers, and other technical and management personnel who are involved in developing reliable systems to operate in environments susceptible to SEE. It provides a unique opportunity for IEEE NSREC attendees to benefit from the expertise of the instructors, along with a critical review of state-of-the-art knowledge in the field. Electronic copies of detailed course notes will be provided at registration.

For those interested in Continuing Education Units (CEUs), an open book exam will be held at the end of the course. The course, endorsed by the IEEE and by the International Association for Continuing Education and Training (IACET), is valued at 0.6 CEUs.

PART I - BASICS OF SINGLE EVENT EFFECT MECHANISMS AND PREDICTIONS

Dr. Daisuke Kobayashi, ISAS/JAXA, will provide basic knowledge of SEE mechanisms and rates that will underlie this year's short course. More than three decades have passed since the term "single-event' appeared for the first time in the titles of NSREC short course presentations. In 1983, two lecturers used "single-event upsets". Since then this research topic has evolved to be very wide and complex, so that we are now collectively calling the field of investigation "single-event effects." This presentation will be useful, in particular for those who are new to this field, to see how SEE have evolved along with the diversity of processes and circuitry in semiconductor parts and their environments. Parts are now fabricated with various materials, such as tungsten and copper and soon cobalt, with complex circuits like radiation-hardened latches. They must withstand the bombardment of heavy ions, protons, electrons, neutrons, muons, photons, etc. The complexity of the mechanisms and predictions is expanding. This talk will provide a foundation for understanding SEE and a background for the remaining presentations in the short course.

PART II - SEE TESTING WITH BROAD AND FOCUSED PARTICLE BEAMS

Dr. Arto Javanainen, University of Jyväskylä, Department of Physics, will discuss issues related to SEE testing using accelerated particle beams, both broad and focused. Basic physics mechanisms governing the energy deposition and its relation with particle energy will be reviewed. Basic factors to be considered when testing with accelerators will be addressed. Some of the common pitfalls to avoid when performing SEE tests at particle accelerators will be identified. Modern technologies, with deep submicron feature sizes and low critical charge, may exhibit sensitivity to proton direct ionization which can lead to concerns about their susceptibility to muons; hence increased soft error rates in ground level applications. Also SEEs induced by high energy electrons may be a concern for some applications, for example those that are planned for Jupiter missions. The presentation will discuss the requirements that these issues set for the facilities and the SEE tests in general. Finally, the presentation will introduce different types of facilities available for SEE testing. A listing of both conventional broad beam and microbeam facilities and their general characteristics will be given.

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PART IIIA – LASER-BASED TESTING FOR SEE

Dr. Dale McMorrow, U.S. Naval Research Laboratory, will discuss application of pulsed-laser approaches to SEE testing and evaluation. Charge carrier generation induced by pulsed-laser excitation has become an essential tool for the investigation of SEE in micro- and nano-electronic structures. A primary advantage of laser-based approaches lies in their spatial selectivity: the ability to pinpoint and characterize sensitive nodes of circuits without the damage associated with particle-based radiation sources. This talk will address the fundamental physics associated with both linear- and nonlinear-optical approaches for charge generation in semiconductor materials, followed by examples that illustrate various aspects of the approach, including sensitive node identification, radiation hardened circuit verification (RHBD and RHBP), basic mechanism investigations, model validation and calibration, screening devices for space missions, and fault injection to understand error propagation in complex circuits. Finally, recent advances in putting laser SEE approaches on a more quantitative basis will be discussed, including progress toward correlating pulsed-laser and heavy-ion measurements.

PART IIIB - THE CURRENT STATUS AND POTENTIAL OF PULSED X-RAYS AS A HIGH-RESOLUTION PROBE FOR SINGLE EVENT EFFECTS TESTING

Mr. Stephen LaLumondiere, The Aerospace Corporation, will present an overview of the application of pulsed x-rays for SEE testing of microelectronic devices. A brief introduction to the properties of synchrotron generated x-rays will be given along with a description of how x-rays interact with relevant semiconductor materials. The technique for identifying SEE sensitive device nodes will be described in detail. Progress in development of the x-ray testing capability will be discussed and results from several recent case studies on both analog and digital SEEs will be presented. The status of efforts to establish a correlation between pulsed x-rays and energetic particles will also be discussed. The impact of future beamline upgrades and improvements in focusing optics will be included in the final part of the presentation.

PART IV - SEE TEST AND ANALYSIS OF COMPLEX DEVICES IN ADVANCED TECHNOLOGIES: FROM CELLS TO SYSTEMS

Mr. Manuel Cabanas-Holmen, Boeing Research & Technology, will discuss the challenges of SEE testing in modern complex devices in advanced semiconductor processing nodes. In modern technologies, standard and Radiation Hardened by Design (RHBD) logic gates, storage elements and macros exhibit strong angular sensitivity that should guide how we test complex devices to avoid naively optimistic results. Fault tolerant microprocessors often have multiple circuit cells and macros with starkly different angular sensitivity, and it is often necessary to perform extensive SEE test campaigns to acquire the data necessary to estimate their error rate. At-speed SEE testing of high performance mixed signal macros, such as Analog-to-Digital Converters (ADC) with high speed interfaces, requires complex instrumentation with continuous data capture and concurrent error detection algorithms. Frequently, it is preferable to synchronize the ADC data capture with the radiation source for a one-to-one correlation of a laser pulse or ion spill with the resulting effect. Advanced packaging solutions using 2.5D and 3D heterogeneous integration increase the complexity of SEE testing many fold by combining multiple complex devices in a single package, without access to the interfaces within the module. The presentation will conclude with a discussion of the challenges to be faced by those testing advanced technologies for susceptibility to SEE.