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Robert Weller received his doctorate in physics from the California Institute of Technology (Caltech) in 1978 following service as a naval officer during the Vietnam conflict. He joined the faculty of the Vanderbilt University School of Engineering in 1987 after seven years as an assistant and later associate professor of physics at Yale University.

Throughout his career, the theme of Professor Weller's research has been the study of the interaction of radiation with matter and the effects thereof. Motivated by his lifelong interest in astrophysics and spaceflight, his work has touched areas from ion-beam analysis of geological and lunar samples to basic studies in the physics of ion sputtering and secondary ion emission. A recurring theme has been the development and application of novel ion-beam analytical techniques. In recent years, his interests have evolved from laboratory investigation to scientific computing, emphasizing the interaction of radiation with semiconductor materials and devices. The intellectual contributions of this work, embodied in a computer program called MRED, have revolutionized the simulation of single event effects in microelectronics and are factors contributing to the international preeminence of Electrical Engineering's Radiation Effects and Reliability research group.

In 2001, he received an R&D 100 award with colleagues from Sandia National Laboratories for invention of the ion-induced electron emission microscope. The annual award established by the editors of *R&D Magazine* identifies the year's 100 most significant scientific advances across multiple disciplines. He is also a recipient of the Outstanding Conference Paper award at the 2007 and 2013 Nuclear and Space Radiation Effects Conferences and has received several other conference-presentation awards.

Professor Weller has authored or co-authored more than 240 scientific publications and holds five U.S. patents. He is a licensed amateur radio operator (AK4RO), a member of Tau Beta Pi (1969), Sigma Xi (1978), and the Böhmische Physikalische Gesellschaft (1989), a Senior Member of IEEE, and a fellow of the American Physical Society.

Curriculum Vitae

Education

- Ph.D., Physics, California Institute of Technology, Pasadena, California, 1978. Thesis Advisor: Thomas A. Tombrello. Thesis: The Energy Spectra of Uranium Atoms Sputtered from Uranium Metal and Uranium Dioxide Targets
- B.S. with Highest Honors, Engineering Physics, The University of Tennessee, Knoxville, 1971.

Appointments

5/03-present Professor of Electrical Engineering, Materials Science and Engineering, and Physics, Vanderbilt University

9/97-5/03 Associate Professor of Electrical Engineering, Vanderbilt University

9/88 -5/03 Associate Professor of Physics, Vanderbilt University.

9/87 -5/03 Associate Professor of Materials Science, Vanderbilt University.

7/85 - 7/87 Associate Professor of Physics, Yale University, assignment to Yale College and the Graduate School.

7/80 - 7/85 Assistant Professor of Physics, Yale University, assignment to Yale College.

2/79 - 6/80 Member of the Technical Staff, Systems Evaluation Division, The Institute for Defense Analyses, Arlington, Virginia.

3/78 - 2/79 Research Fellow, W. K. Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California.

9/73-2/78 Research Assistant, W. K. Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California.

6/71-7/73 U. S. Navy. Division Officer, Engineering Department, USS Constellation, CVA-64.

Research Narrative

The recurring theme of my research has been the interaction of radiation with matter and the application of radiation techniques — particularly those involving ion beams — to problems in areas outside mainstream nuclear physics, where most of the techniques were developed. Along with this, I have had a closely related and continuing interest in measurement instrumentation and scientific computing (for example, reference [147] or the last two patents in the list below). In my early career at Vanderbilt, these interests were combined and expressed through the development and application of time-of-flight medium energy backscattering spectrometry (ToF MEBS) for the analysis of ultra-thin films. More recently, I have been involved in the development of computational

techniques for predicting general radiation effects on materials and devices and the rate of single-event effects in devices both terrestrially and in space [6, 8, 40].

Before leaving Yale University, I was lead by considerations of scattering cross section and stopping power to experiment with 600 keV He^{2+} ions for backscattering spectrometry. When we encountered mass interference from H_2^+ molecular ions, we chose instead to use He^+ at 300 keV. The results were not particularly useful for surface analysis because of the relatively poor resolution of silicon surface-barrier detectors at that energy. However, the experiments highlighted the potential analytical power, especially in increased cross section, which a perfected medium energy technique might yield. The key to success was to replace the silicon surface barrier detector with a technology more appropriate to the energy range. Another technique then being developed for heavy-ion nuclear research, where intense radiation damage to Si detectors precluded their routine use, was time of flight. The development of time-of-flight medium energy backscattering spectrometry (ToF MEBS) is chronicled in a series of publications [176], [180], [186], [189], [191], [192], [199], [206], [208] culminating in a summary that appeared in a comprehensive surface analysis reference work [154, 155].

A number of interesting and timely problems both in the theory and application of ToF MEBS arose during its development. These included measurements of ion beam effects on the stoichiometry of thin films that were potentially important for space-based optics [196], [204], [205], design of an original algorithm to compute small-angle multiple scattering based on the fast Fourier transform [187] (calculations needed to mathematically model ToF spectrometer efficiency), and development of another original algorithm to compute classical screened Rutherford scattering collision cross sections quickly and accurately [200]. Over the course of the project, I assembled these algorithms and others from the literature into a comprehensive set of computational tools for analysis of backscattering spectra and other routine, research-related ion-solid calculations [165]. This toolkit is distinguished in a number of ways, particularly in its focus on algorithms (ignoring to first approximation the capability of a particular generation of computer hardware) and its integration into a platform-independent symbolic computation environment.

With the transition of ToF MEBS from development to a routinely available analytical tool, I began to participate in larger collaborations, where I provided focused contributions consistent with my expertise and interests. These included a program on silicon carbide semiconductor electronics with L. C. Feldman and others, where my graduate student Kyle McDonald played a pivotal role, e.g. [157], and a rewarding collaboration with R. H. Magruder and R. A. Weeks studying ion beam effects in glass, e.g. ref. [141], where my computational tools were quite useful. I also worked with B. R.

Rogers applying ToF MEBS analyses to high-K dielectric films grown by CVD in her laboratory at Vanderbilt, and with L. C. Feldman, R. F. Haglund, R. H. Magruder and others in a nanoscience and engineering program [151].

Our nanoscience program, which later became one of the foundations of the Vanderbilt Institute for Nanoscale Science and Engineering, employed a focused ion beam (FIB) and pulsed laser deposition (PLD) system, which Profs. Feldman, Haglund, and I assembled beginning in 1998 with NSF support. My strongest interest was in the application of the FIB for engineering nanoscale structures. I created computer tools with which we were able to create very complex patterns for FIB implementation (including for amusement micron-size photographs with 20 nm features[1]). We applied these patterns to fabricating, among other things, nanocrystal arrays and a novel oxide semiconductor strain gauge that could be directly deposited on a surface using thin-film technology, and formed to net shape using FIB machining [130], [144]. The strain-gauge program had many interesting facets: the materials science of why the active component, oxygen-rich, indium-tin oxide, is strain sensitive, the issues associated with engineering the material in to a multilayer sensing structure, and the specifics of how to build and characterize a functioning strain gauge with maximum dimension less than 100 □m.

For the last several years, the singular focus of my efforts has been on developing software tools and methods for computing radiation effects, given information on device structure and composition and the physics of nuclear and ion-solid interactions. (See [40] and [8] and references therein.) Computing the rate of single event effects in semiconductor devices has been of particular interest. The most visible product of this work is a Monte Carlo radiation transport code optimized for microstructures called MRED, which is based on the high-energy physics detector simulation toolkit Geant4, from CERN (European Organization for Nuclear Research) in Switzerland.[2]

Using MRED we have been able to significantly advance the state of the art in single event rate prediction by rigorously adhering to a simple principle – treat all parts of the problem with the most detailed physics available, and let the computer manage the complexity. The details are provided in the review paper [40]. This review includes not only a description of the MRED software, but also a full mathematical analysis of exactly what it calculates. Using that mathematical analysis, it has been possible to connect Monte Carlo simulation of single event effects with the earlier method based on a rectangular parallelepiped that was in use by radiation effects engineers. The latter has

[1] One of these, a portrait of Vanderbilt's former Chancellor, E. Gordon Gee, approximately 6 × 8 μm in size imaged with atomic force microscopy by Damon Farmer, then a Vanderbilt undergraduate, graced the rear cover of the 2001 calendar distributed by Digital Instruments, a leading atomic force microscope vendor.

[2] http://wwwinfo.cern.ch/asd/geant4/geant4.html

now been shown [55], [40] to be a simplified, analytically tractable version of a general calculation that is more appropriately carried out by a Monte Carlo procedure for advanced semiconductor devices.

Looking forward, while we have made significant strides in the past few years in predicting semiconductor device response to radiation from first principles, there are still many details yet to be understood and worked out. I expect to be immersed in these details, both theoretical and experimental, for the next several years, circumstances permitting. The relevant topics range from the details of charge motion in the tens of picoseconds following an ion strike, to the construction and application of ground- and space-based assets to validate our computations. Certainly, there is no shortage of very interesting things to do.

Awards

Fellow of the American Physical Society, 2011, "For contributions to the understanding of the interactions of radiation with microelectronic materials and devices."

Outstanding Conference Paper and *Outstanding Student Paper awards at the Nuclear and Space Radiation Effects Conference (NSREC) 2013* for, M. P. King, R. A. Reed, R. A. Weller, M. H. Mendenhall, R. D. Schrimpf, B. D. Sierawski, *et al.*, "Electron-induced single-event upsets in static random access memory," *Nuclear Science, IEEE Transactions on*, vol. 60, pp. 4122-4129, 2013.

With graduate student Brian Sierawski, *Best Student Paper*, International Reliability Physics Symposium (IRPS), San Francisco, 2011, for "Effects of scaling on muon-induced soft errors," B. D. Sierawski, R. A. Reed, M. H. Mendenhall, R. A. Weller, R. D. Schrimpf, S. Wen, R. Wong, N. Tam, and R. C. Baumann, in *2011 IEEE International Reliability Physics Symposium (IRPS 2011), 10-14 April 2011*, Piscataway, NJ, USA, 2011, p. 3C.3 (6 pp.).

With graduate student Elizabeth Auden, *Best Student Paper*, at the Radiation Effects in Components and Systems Conference (RADECS), Längenfeld, Austria, September, 2010 for "High Energy Electron-induced Transients In a Shielded Focal Plane Array," E. C. Auden, R. A. Weller, M. H. Mendenhall, R. A. Reed, R. D. Schrimpf, M. P. King, N. A. Dodds, L. A. Arpin, and M. Asai, *IEEE Transactions on Nuclear Science*, vol. 58, pp. 899-905, 2011.

Outstanding Conference Paper Award at the Nuclear and Space Radiation Effects Conference (NSREC) 2007 for "Impact of Heavy Ion Energy and Nuclear Interactions on Single-Event Upset and Latchup in Integrated Circuits," P. E. Dodd, J. R. Schwank, M. R.

Shaneyfelt, J. A. Felix, P. Paillet, V. Ferlet-Cavrois, J. Baggio, R. A. Reed, K. M. Warren, R. A. Weller, R. D. Schrimpf, G. L. Hash, S. M. Dalton, K. Hirose, and H. Saito, *IEEE Trans. Nucl. Sci.*, vol. 54, pp. 2303-2311, 2007.

Best Paper Award at the Workshop on Frontiers in Electronics, WOFE-07, 15-Dec-2007 for "Single Event Effects in the Nano Era," M. L. Alles, L. W. Massengill, R. D. Schrimpf, R. A. Weller and K. F. Galloway, *International Journal of High Speed Electronics and Systems*, vol. 18, pp. 815-824, 2008.

Meritorious Conference Paper Award at the Hardened Electronics and Radiation Technology Conference (HEART) 2004 for "Modeling Semiconductor Device Response using Detailed Radiation Event Simulations," Robert A. Weller, Ronald D. Schrimpf, Robert A. Reed, Andrew L. Sternberg, Aaron S. Kobayashi, Marcus H. Mendenhall, Lloyd W. Massengill, and D. M. Fleetwood, *J. Rad. Effects: Research and Engineering*, 23, No. 1, 129-137 (2007).

R&D 100 Award, 2001, with B. L. Doyle, G. Vizkelethy, and B. Senftinger, for invention of the ion-induced electron emission microscope (IEEM), selected by R&D Magazine as one of the 100 most technologically significant inventions of the year 2001.

Memberships

Fellow of the American Physical Society
Senior Member of the IEEE
Böhmische Physical Society
Sigma Xi
Tau Beta Pi (elected 1969)
Sigma Pi Sigma
American Radio Relay League (AK4RO)

Professional Activities

Member, Council of Sponsoring Institutions, Oak Ridge Associated Universities (ORAU) representing Vanderbilt University, 1992-2015.

Organizing Committee, Geant4 Space Users Workshop, Hiroshima, Japan, August, 2015.

Organizing Committee, Geant4 Space Users Workshop, Huntsville, AL, May, 2014.

Short Course Lecturer, Radiation Effects on Components and Systems Conference (RADECS), 2012.

Nominating Committee, Oak Ridge Associated Universities, 2005-2011.

Session Chair, Radiation Effects on Components and Systems Conference (RADECS), 2010.

Summer School Lecturer, Single Event Effects in Microelectronics, University of Jyväskylä, Finland, August 9-13, 2010.

Awards Committee, Radiation Effects on Components and Systems Conference (RADECS), 2009.

Awards Committee, Nuclear and Space Radiation Effects Conference (NSREC), 2009.

Short Course Lecturer, Hardened Electronics and Radiation Technology Conference (HEART), 2009.

Short Course Lecturer, Radiation Effects on Components and Systems Conference (RADECS), 2009.

Session Chair, Nuclear and Space Radiation Effects Conference (NSREC), 2008.

Organizing Committee, Geant4 Space Users Workshop, Pasadena, CA, November, 2006.

Faculty Senate, Vanderbilt University, 2006-2009.

Organizing Committee, Tutorial on the use of Geant4 for Space Radiation Applications, Vanderbilt University, January, 2004.

Organizing Committee, Geant4 Space Users Workshop, Sponsored by NASA, the European Space Agency, and the Standford Linear Accelerator Laboratory, Vanderbilt, University, May 2004.

Co-organizer, with T. Feltner, N. Halas, and Kai Liu, of an American Physical Scoiety Symposium on Asymmetric Nanostrcutures for the March APS Meeting, 2003.

Organizer, ARO/Vanderbilt Rapid Manufacturing Workshop, 1998. Author, with Robert R. Reeber, U. S. Army Research Office, of the workshop final report.

Coordinated reviews for Oak Ridge Associated Universities Junior Faculty enhancement awards in applied science 1995.

Steering committee of the Introductory University Physics Project (IUPP) of the American Physical Society and the American Association of Physics Teachers, 1987-1994.

Organizer, Workshop on medium energy ion beam analysis of materials as the Thirteenth Conference on the Application of Accelerators in Research and Industry, University of North Texas, November 1994.

Member, Oak Ridge Associated Universities Science and Technology Policy Committee, 1993-1994, Frank T. Avignone, University of South Carolina, Chair.

Co-organizer with J. Tesmer, Los Alamos National Laboratory, of a Workshop on Resources for Ion Beam Analysis, at the Twelfth Conference on the Application of Accelerators in Research and Industry, University of North Texas, November, 1992.

Session Chair, Analysis of Hydrogen at Surfaces, Twelfth Conference on the Application of Accelerators in Research and Industry, University of North Texas, November, 1992.

Organized and taught nationally advertised summer workshops for university faculty in *Mathematica* programming for classroom applications at Vanderbilt in 1992 and 1993 as part of a program funded by the Pew Charitable Trusts.

United States Patents

1. G. Y. Chung, C. C. Tin, J. R. Williams, K. McDonald, M. Di Ventra, R. A. Weller, S. T. Pantelides, and L. C. Feldman, "Inclusion of Nitrogen at the Silicon Dioxide - Silicon Carbide Interface for Passivation of Interface Defects," United States Patent 7,727,340, June 1, 2010.
2. G. Y. Chung, C. C. Tin, J. R. Williams, K. McDonald, M. Di Ventra, R. A. Weller, S. T. Pantelides, and L. C. Feldman, "Inclusion of Nitrogen at the Silicon Dioxide - Silicon Carbide Interface for Passivation of Interface Defects," United States Patent 7,235,438, June 26, 2007.
3. G. Y. Chung, C. C. Tin, J. R. Williams, K. McDonald, M. Di Ventra, R. A. Weller, S. T. Pantelides, and L. C. Feldman, "Inclusion of Nitrogen at the Silicon Dioxide - Silicon Carbide Interface for Passivation of Interface Defects," United States Patent 6,939,756, September 6, 2005.
4. B. L. Doyle, G. Vizkelethy, and R. A. Weller, "Ion-induced electron emission microscopy," United States Patent 6,291,823, September 18, 2001.
5. M. H. Mendenhall and R. A. Weller, "Method and apparatus for time of flight medium energy particle scattering," United States Patent 5,026,988, June 25, 1991.

Research Sponsors

I am now, or have been, a principal investigator, co-principal investigator, or named senior collaborator on grants from the following agencies and companies, which are listed in alphabetical order.

DARPA
Defense Threat Reduction Agency (DTRA)
Electric Power Research Institute
Intel, Inc.
Motorola, Inc.
NASA
National Reconnaissance Office
National Science Foundation

Oak Ridge National Laboratory
Sandia National Laboratories
Texas Instruments, Inc.
U. S. Army Research Office
Research Corporation
SEMATECH
U. S. Air Force
U. S. Department of Energy

Publications[3]

[1] S. Bhandaru, E. X. Zhang, D. M. Fleetwood, R. A. Reed, R. A. Weller, R. R. Harl, *et al.*, "Ultra-thin oxide growth on silicon during 10 keV x-ray irradiation," *Surface Science*, vol. 635, pp. 49-54, 2015.

[2] S. L. Weeden-Wright, W. G. Bennett, N. C. Hooten, E. X. Zhang, M. W. McCurdy, M. P. King, *et al.*, "TID and displacement damage resilience of 1T1R HfO2 Resistive Memories," *IEEE Transactions on Nuclear Science*, vol. 61, pp. 2972-2978, 2014.

[3] P. Roche, G. Gasiot, J. L. Autran, D. Munteanu, R. A. Reed, and R. A. Weller, "Application of the TIARA radiation transport tool to single event effects simulation," *IEEE Transactions on Nuclear Science*, vol. 61, pp. 1498-1500, Jun 2014.

[4] T. Holman, B. D. Sierawski, R. Reed, R. A. Weller, A. L. Sternberg, R. Austin, *et al.*, "The small satellite (CubeSat) program as a pedagogical framework for the undergraduate EE curriculum," in *121st ASEE Annual Conference and Exposition: 360 Degrees of Engineering Education, June 15, 2014 - June 18, 2014*, Indianapolis, IN, United states, 2014, p. Dassault Systemes (DS); et al.; Kaplan; National Instruments; NCEES; Quanser.

[5] Z. J. Diggins, N. Mahadevan, D. Herbison, G. Karsai, B. D. Sierawski, E. Barth, *et al.*, "Total-ionizing-dose induced timing window violations in CMOS microcontrollers," *IEEE Transactions on Nuclear Science*, vol. 61, pp. 2979-2984, 2014.

[6] R. A. Weller, "Monte Carlo Simulation of Radiation Effects," in *Extreme Environment Electronics*, J. D. Cressler and H. A. Mantooth, Eds., ed Boca Raton, Florida: CRC Press, Taylor and Francis Group, 2013, pp. 123-136.

[7] I. K. Samsel, Z. En Xia, N. C. Hooten, E. D. Funkhouser, W. G. Bennett, R. A. Reed, *et al.*, "Charge Collection Mechanisms in AlGaN/GaN MOS High Electron Mobility Transistors," *Nuclear Science, IEEE Transactions on*, vol. 60, pp. 4439-4445, 2013.

[3] This is a comprehensive list of works in print ordered by publication date, beginning with the most recent. Most, although not all, are refereed. Generally, although not without exception, when essentially similar versions of a paper exist as both a journal article and a conference proceedings, only the former is listed. This list was compiled electronically and may contain a small number of unintentional duplications.

[8] R. A. Reed, R. A. Weller, A. Akkerman, J. Barak, W. Culpepper, S. Duzellier, *et al.*, "Anthology of the development of radiation transport tools as applied to single event effects," *Nuclear Science, IEEE Transactions on*, vol. 60, pp. 1876-1911, 2013.

[9] M. P. King, R. A. Reed, R. A. Weller, M. H. Mendenhall, R. D. Schrimpf, B. D. Sierawski, *et al.*, "Electron-induced single-event upsets in static random access memory," *Nuclear Science, IEEE Transactions on*, vol. 60, pp. 4122-4129, 2013.

[10] N. C. Hooten, W. G. Bennett, L. D. Edmonds, J. A. Kozub, R. A. Reed, R. D. Schrimpf, *et al.*, "The Impact of Depletion Region Potential Modulation on Ion-Induced Current Transient Response," *Nuclear Science, IEEE Transactions on*, vol. 60, pp. 4150-4158, 2013.

[11] G. Gaur, D. Koktysh, D. M. Fleetwood, R. A. Reed, R. A. Weller, and S. M. Weiss, "Effects of X-ray and gamma-ray irradiation on the optical properties of quantum dots immobilized in porous silicon," *Proceedings of SPIE - The International Society for Optical Engineering*, vol. 8725D, p. 8 pages, 2013.

[12] J. S. Bi, Z. S. Han, E. X. Zhang, M. W. McCurdy, R. A. Reed, R. D. Schrimpf, *et al.*, "The Impact of X-Ray and Proton Irradiation on HfO_2/Hf-Based Bipolar Resistive Memories," *Nuclear Science, IEEE Transactions on*, vol. 60, pp. 4540-4546, 2013.

[13] W. G. Bennett, N. C. Hooten, R. D. Schrimpf, R. A. Reed, R. A. Weller, M. H. Mendenhall, *et al.*, "Experimental Characterization of Radiation-Induced Charge Sharing," *Nuclear Science, IEEE Transactions on*, vol. 60, pp. 4159-4165, 2013.

[14] E. C. Auden, R. A. Weller, R. D. Schrimpf, M. H. Mendenhall, R. A. Reed, N. C. Hooten, *et al.*, "Effects of high electric fields on the magnitudes of current steps produced by single particle displacement damage," *Nuclear Science, IEEE Transactions on*, vol. 60, pp. 4094-4102, 2013.

[15] R. D. Schrimpf, M. A. Alles, F. E. Mamouni, D. M. Fleetwood, R. A. Weller, and R. A. Reed, "Soft errors in advanced CMOS technologies," presented at the 2012 IEEE 11th International Conference on Solid-State and Integrated Circuit Technology (ICSICT), 29 Oct.-1 Nov. 2012, Piscataway, NJ, USA, 2012.

[16] M. H. Mendenhall and R. A. Weller, "A probability-conserving cross-section biasing mechanism for variance reduction in Monte Carlo particle transport calculations," *Nuclear Instruments & Methods in Physics Research, Section A (Accelerators, Spectrometers, Detectors and Associated Equipment)*, vol. 667, pp. 38-43, 2012.

[17] M. P. King, R. A. Reed, R. A. Weller, M. H. Mendenhall, R. D. Schrimpf, N. D. Pate, *et al.*, "Radial characteristics of heavy-ion track structure and implications of delta-ray events for microelectronics," *Applied Physics Letters*, vol. 101, p. 053509 (3 pp.), 2012.

[18] N. C. Hooten, L. D. Edmonds, W. G. Bennett, J. R. Ahlbin, N. A. Dodds, R. A. Reed, *et al.*, "The significance of high-level carrier generation conditions for charge collection in irradiated devices," *IEEE Transactions on Nuclear Science*, vol. 59, pp. 2710-2721, 2012.

[19] S. Bhandaru, E. X. Zhang, D. M. Fleetwood, R. A. Reed, R. A. Weller, R. R. Harl, *et al.*, "Accelerated oxidation of silicon due to X-ray irradiation," *IEEE Transactions on Nuclear Science*, vol. 59, pp. 781-785, 2012.

[20] W. G. Bennett, R. D. Schrimpf, N. C. Hooten, R. A. Reed, J. S. Kauppila, R. A. Weller, *et al.*, "Efficient method for estimating the characteristics of radiation-induced current transients," *IEEE Transactions on Nuclear Science*, vol. 59, pp. 2704-2709, 2012.

[21] E. C. Auden, R. A. Weller, M. H. Mendenhall, R. A. Reed, R. D. Schrimpf, N. C. Hooten, *et al.*, "Single particle displacement damage in silicon," *IEEE Transactions on Nuclear Science*, vol. 59, pp. 3054-61, 2012.

[22] J. H. Adams, Jr., A. F. Barghouty, M. H. Mendenhall, R. A. Reed, B. D. Sierawski, K. M. Warren, *et al.*, "CRÈME: The 2011 revision of the cosmic ray effects on micro-electronics code," *IEEE Transactions on Nuclear Science*, vol. 59, pp. 3141-7, 2012.

[23] J. H. Adams, Jr., A. F. Barghouty, M. H. Mendenhall, R. A. Reed, B. D. Sierawski, K. M. Warren, *et al.* (2012). *CREME*. Available: https://creme.isde.vanderbilt.edu

[24] E. X. Zhang, A. K. M. Newaz, W. Bin, S. Bhandaru, C. X. Zhang, D. M. Fleetwood, *et al.*, "Low-energy X-ray and ozone-exposure induced defect formation in graphene materials and devices," *IEEE Transactions on Nuclear Science*, vol. 58, pp. 2961-2967, 2011.

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[26] M. S. Sabra, R. A. Weller, M. H. Mendenhall, R. A. Reed, M. A. Clemens, and A. F. Barghouty, "Validation of Nuclear Reaction Codes for Proton-Induced Radiation Effects: The Case for CEM03," *IEEE Transactions on Nuclear Science*, vol. 58, pp. 3134-8, 2011.

[27] M. S. Sabra, M. A. Clemens, R. A. Weller, M. H. Mendenhall, A. F. Barghouty, and F. B. Malik, "Validation of nuclear reaction models of 180MeV proton-induced fragmentation of 27Al," *Nuclear Instruments & Methods in Physics Research, Section B (Beam Interactions with Materials and Atoms)*, vol. 269, pp. 2463-8, 2011.

[28] R. H. Magruder, III, R. A. Weeks, and R. A. Weller, "New intrinsic oxygen related defect bands in oxygen implanted silica," *Journal of Non-Crystalline Solids*, vol. 357, pp. 1615-20, 2011.

[29] N. F. Haddad, A. T. Kelly, R. K. Lawrence, L. Bin, J. C. Rodgers, J. F. Ross, *et al.*, "Incremental Enhancement of SEU Hardened 90 nm CMOS Memory Cell," *IEEE Transactions on Nuclear Science*, vol. 58, pp. 975-80, 2011.

[30] P. M. Gouker, B. Tyrrell, M. Renzi, C. Chenson, P. Wyatt, J. R. Ahlbin, *et al.*, "SET Characterization in Logic Circuits Fabricated in a 3DIC Technology," *IEEE Transactions on Nuclear Science*, vol. 58, pp. 2555-62, 2011.

[31] Z. En Xia, A. K. M. Newaz, W. Bin, S. Bhandaru, C. X. Zhang, D. M. Fleetwood, *et al.*, "Low-energy X-ray and ozone-exposure induced defect formation in graphene materials and devices," *IEEE Transactions on Nuclear Science*, vol. 58, pp. 2961-7, 2011.

[32] A. Dasgupta, D. M. Fleetwood, R. A. Reed, R. A. Weller, and M. H. Mendenhall, "Effects of metal gates and back-end-of-line materials on x-ray dose in HfO_2 gate oxide," *IEEE Transactions on Nuclear Science*, vol. 58, pp. 3139-44, 2011.

[33] M. A. Clemens, B. D. Sierawski, K. M. Warren, M. H. Mendenhall, N. A. Dodds, R. A. Weller, *et al.*, "The Effects of Neutron Energy and High-Z Materials on Single Event Upsets and Multiple Cell Upsets," *IEEE Transactions on Nuclear Science*, vol. 58, pp. 2591-8, 2011.

[34] S. Bhandaru, E. X. Zhang, D. M. Fleetwood, R. A. Reed, R. A. Weller, and S. M. Weiss, "Accelerated oxidation of silicon due to x-ray irradiation," presented at the 2011 12th European Conference on Radiation and Its Effects on Components and Systems (RADECS), 19-23 Sept. 2011, Piscataway, NJ, USA, 2011.

[35] E. C. Auden, R. A. Weller, M. H. Mendenhall, R. A. Reed, R. D. Schrimpf, M. P. King, *et al.*, "High energy electron-induced transients in a shielded focal plane array," *IEEE Transactions on Nuclear Science*, vol. 58, pp. 899-905, 2011.

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