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Towards High-Fidelity Simulations of Radiation Effects in Complex Systems

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Scientific evidence increasingly indicates that using an average approach (e.g. Linear Energy Transfer or LET) to approximate the energy deposition process due to a radiation event such as a heavy ion strike, is inadequate and/or erroneous. It is important to capture the complex microstructure of the energy deposition, and consequent charged species generation profile, to accurately model the system response in the spatial and temporal scales.

This paper primarily focuses on high-fidelity, three-dimensional (3D) simulations of radiation effects in modern, deep submicron electronic devices and circuits. We perform these simulations using an in-house, advanced, Technology Computer Aided Design (TCAD) solver called NanoTCAD. Recently, this solver has been enhanced with an interface to an external Monte Carlo (Geant4) based code to receive inputs of complex energy deposition microstructure (multi-track), efficiently filter in only the high energy tracks of interest, and perform adaptive mesh generation in an automated manner, to enable full-3D simulations of charge transport and resulting device response. NanoTCAD's overall capabilities have been further enhanced by means of a coupling with the Cadence Spectre circuit/system solver that permits the direct use of "as-designed" layouts and circuits and foundry process design kits (PDKs) in a mixed-mode manner (3D TCAD + external circuit netlist), to calculate the radiation response of real-world circuits. With appropriate enhancements to device physics and circuit compact models, these simulation tools have been utilized to characterize radiation effects in extreme (e.g., space) environment electronics.

Accurate analysis of the response of biological systems, such as cells and tissues, to incident high-energy radiation continues to be an important area of research in the scientific community. A related multi-scale computational framework developed for studies of the origin and progression of primary (bio-mechanical) and secondary (complex physico-chemical) injury mechanisms, will be briefly presented. The objective is to adapt current understanding of radiation events, and simulation capabilities from other related areas, to calculations of radiation response of biological systems.

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