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A TCAD Simulation Framework for DLTS-based Defect Characterisation in Solid-State Particle Detectors

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The increasing radiation levels expected in future high-luminosity collider experiments demand robust predictive models for the design and optimisation of semiconductor particle detectors operating under extreme fluences (above $1 \cdot 10^{16}$ 1 MeV n_{eq}/cm^2). Although TCAD-based modelling of radiation damage has evolved over the past two decades, a general-purpose model capable of reliably simulating the macroscopic effects of deep-level defects is still lacking.

This work presents a TCAD simulation framework designed to reproduce Deep Level Transient Spectroscopy (DLTS) spectra and Arrhenius plots, enabling the extraction and refinement of trap characteristics –namely concentration, activation energy, and capture cross-section –and their direct implementation into numerical radiation damage models. In particular, the activities carried out so far include the reproduction of DLTS spectra based on current transient measurements (I-DLTS) following laser-induced charge carrier injection for CiOi and BiOi defects, using the developed TCAD framework. Additionally, the numerical strategies adopted to ensure convergence at cryogenic temperatures (below 250 K), as required by the operating conditions of the DLTS climate chamber, are presented. These include the tuning of mathematical parameters (e.g. number of Newton iterations, extended precision floating-point arithmetic, error criteria) and the implementation of specific workarounds, such as artificially increasing the charge carrier generation rate.

To evaluate the reliability of the proposed framework, a benchmark procedure is defined, using DLTS measurements as reference data to validate the simulated defect response. This enables a systematic assessment of the "effectiveness"of each trap in reproducing key device-level observables such as leakage current, depletion voltage, and charge collection efficiency.

By bridging the gap between microscopic defect spectroscopy and macroscopic device simulation,the framework lays the groundwork for general-purpose TCAD models applicable across semiconductor materials and fluence regimes. This approach enhances the predictive power of simulation tools and supports the development of radiation-hard detectors for future collider environments.

Type of presentation (in-person/online)

in-person presentation

Type of presentation (I. scientific results or II. project proposal)

I. Presentation on scientific results

Authors: CROCI, Tommaso (INFN, Perugia Unit); FONDACCI, Alessandro (Università and INFN Perugia (IT)); GURIMSKAYA, Yana; MOLL, Michael (CERN); MOROZZI, Arianna (INFN, Perugia (IT)); MOSCATELLI, Francesco (IOM-CNR and INFN, Perugia (IT)); Prof. PASSERI, Daniele (Universita e INFN Perugia (IT)); RIZWAN, Faiza (Cern); SORGENFREI, Niels (CERN / University of Freiburg (DE))

Presenter: CROCI, Tommaso (INFN, Perugia Unit)

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