XV LATIN AMERICAN SYMPOSIUM ON NUCLEAR PHYSICS AND APPLICATIONS
São Paulo, BRAZIL
07 - 10 December 2026
Host institution: IPEN / SP

Machine Learning for Disentangling Bias and Geometry Effects in Irradiated Power MOSFETs

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This work focuses on the use of machine learning (ML) techniques to predict the effects of ionizing radiation on power MOS transistors of different geometries under various biasing modes. It is well known that total ionizing dose (TID) effects can cause malfunctions or even total failure in electronic devices. Consequently, it is essential to study device reliability for applications in harsh environments, such as avionics and aerospace. Traditional analytical models often struggle to fully characterize the non-linear and stochastic nature of radiation-induced degradation, making data-driven ML techniques critical for extrapolation, health monitoring, and component lifespan estimation.

Thus, this study explores the use of ML to predict the threshold voltage shift () for an integrated circuit intended for aerospace applications, featuring 0.6 µm SOI PMOS power transistors designed with both Enclosed Layout Transistor (ELT) and conventional Rectangular (RET) geometries. The devices were exposed to 10 keV X-ray irradiation up to an accumulated TID of 300 krad(Si) under two operational conditions: ON-mode (-5 V gate bias) and OFF-mode (grounded). Five ML models were evaluated, with the Gaussian Process Regression (GPR) demonstrating superior predictive performance and generalization.

A Critical Dose Analysis was performed to extrapolate the predicted degradation curves to a scenario where the maximum threshold voltage variation reaches a 1.0 V failure limit. The results indicate that degradation is heavily dependent on both layout and biasing, and the ON-state polarization significantly accelerates degradation due to intensified charge trapping.

Physically, the accelerated degradation observed under ON-state bias is driven by the electric field, which prevents recombination and promotes hole transport toward the Si/SiO interface, leading to trapped oxide charges. Crucially, the study highlights that conventional parameter analysis alone was insufficient to conclusively determine these potential improvements in TID tolerance. Therefore, integrating GPR-based forecasting with failure threshold analysis constitutes a highly robust methodology for qualifying radiation-tolerant microelectronics.

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