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TCAD modeling of radiation induced defects in 4H-SiC diodes and LGADs

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The material properties of Silicon-Carbide (SiC) make it a promising candidate for application as a particle detector at high beam rates. Compared to Silicon (Si), the increase in charge carrier saturation velocity and breakdown voltage allow for high intrinsic time resolution while mitigating pile-ups. The larger band gap potentially improves radiation hardness, which, in combination with its good thermal conductivity, efficiently suppresses dark current after high levels of preceding irradiation as well as at high beam rates.
However, current manufacturing standards of epitaxial layers restrict the active thickness of high-quality SiC, thus limiting the signal amplitude. While literature indicates a strong correlation between the Si/C ratio present during epitaxial growth and intrinsic impurity levels, the formation of radiation-induced defects is still not sufficiently understood.

This work presents a bulk radiation damage model for TCAD simulations considering the major lifetime killers of 4HSiC ($Z_{1,2}$ & $Et_{6,7}$). Measurements on 50 µm 4H-SiC pad diodes that have been neutron-irradiated at various fluxes ranging from $5 \cdot 10^{14}\ n_{eq}/cm^2$ to $1 \cdot 10^{16}\ n_{eq}/cm^2$ are used for development and validation. Radiation-induced damage parameters, such as cross-sections and introduction rates, are determined using the optimizer tool of Synopsys TCAD. The model accurately predicts a low increase in dark current levels, flattening of the detector capacitance, degradation in charge collection efficiency (CCE), and signal detection capabilities under forward bias conditions up to high voltages.
Furthermore, model predictions on the detector performance of an irradiated 4H-SiC low gain avalanche detector (LGAD) will be shown. The employed structure is based on a recently developed design to increase the signal output via controllable intrinsic carrier amplification.

Collaboration

Role of Submitter

I am the presenter

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