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Investigation of Neutron Radiation Damage in 4H-SiC PiN Diodes

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Silicon Carbide (SiC) is a wide-bandgap semiconductor that has recently become a topic of intensified interest in the HEP instrumentation community due to the availability of high-quality wafers from the power electronics industry. SiC features multiple advantageous material properties over silicon. It is insensitive to visible light, hypothesized to be more radiation hard, and has much lower leakage currents, even after irradiation. Especially for future high-luminosity experiments, the radiation hardness is an essential parameter. One of the most important metrics associated with radiation hardness is the charge collection efficiency (CCE), which typically decreases with irradiation due to the formation of traps and defects. A thorough understanding of these traps and defects is crucial for estimating the performance of a detector over its lifetime and can open to the door to techniques such as defect engineering.

We present the current status of characterization and simulations for 50 µm thick 4H SiC PiN diodes together with radiation hardness studies. The characterization work includes the determination of material parameters of 4H-SiC (ionization energy and Fano factor) and comparisons to TCAD and Monte-Carlo simulations. Recently, significantly increased signals (with respect to unirradiated samples) were reported for neutron-irradiated SiC diodes in forward bias using UV-TPA-TCT, hinting at charge multiplication. We re-investigate neutron irradiated 4H-SiC PiN diodes (fluences between 5×10^{14} and 1×10^{16} cm^{-2} 1 MeV neutron equivalent n_{eq}) which have been previously characterized using UV-TCT and alpha spectroscopic measurements. The CCE and transient waveforms were measured in forward and reverse bias using alpha and UV-TCT measurements. Furthermore, I-V and C-V measurements for forward as well as reverse bias voltages of up to 3kV were performed to serve as additional input in understanding observed radiation damage. For samples irradiated to 5×10^{14} and 5×10^{14} n_{eq} cm^{-2}, the CCE in the forward direction grows exponentially, surpassing 100% and coinciding with an increase in the leakage current. At the highest irradiation fluence, no exponential behavior was observed. However, the CCE in the forward direction was found to be larger than for reverse bias. For this fluence, the leakage current remained below 1 nA.

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