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Performance of neutron-irradiated 4H-Silicon Carbide pad diodes subjected to Alpha Particles, UV Laser Pulses, and proton beams

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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. In comparison to Silicon (Si), the increase in charge carrier saturation velocity and breakdown voltage allows for high intrinsic time resolution while mitigating pile-ups. A larger bandgap and higher atomic displacement threshold energy suppresses dark current and potentially improve radiation hardness, respectively. In addition to the lower susceptibility to temperature variations, it allows the operation of irradiated devices at room temperature and daylight illumination. On the contrary, current TCAD and Monte-Carlo simulation tools are challenged regarding SiC due to its low carrier density, anisotropic effects, and insufficient knowledge of material parameters. Furthermore, limitations of the epitaxial growth process restrict the active layer thickness of SiC samples to a maximum of 100-150 µm, limiting the number of charge carriers generated by traversing particles, especially when approaching minimum ionizing particles (MIP) energies.
We present selected experiments carried out on 50 µm thick SiC p-in-n pad sensors. In-lab measurements providing high signal amplitudes and stable conditions, such as an Alpha-source and a UV-TCT-Laser setup, deliver insight into intrinsic material properties, while detector performance under high rate particle accelerator conditions was studied at the medical ion beam facility MedAustron, exploiting proton beams at a wide range of particle energies up to several hundred MeV. Samples exposed to neutron fluences of up to 1016 neq cm-2 were included in all experiments to extend our studies regarding the potential radiation hardness of SiC. Setup simulations based on GEANT4 were used for output comparison to ensure proper data evaluation.

Studies using UV-TCT and protons from particle beams to determine the charge collection efficiency of the irradiated samples will be shown. For all fluence levels, measured dark current at room temperature remains in the nA-range. To overcome the decrease in signal-to-noise-ratio (SNR) in the MIP region, efforts are taken to implement SiC into an LGAD design for prototype production. To take full advantage of the fast charge collection of potential SiC-LGADs, we are developing advanced single-channel readout electronics to be used in beam tests and to study the material properties further. Moreover, progress towards the development of a multi-channel ASIC, capable to switch between single particle detection and charge integration over larger time periods, for using SiC as high-rate beam intensity and position monitor will be shown.

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