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250 µm thick detectors for neutron detection: design, electrical characteristics, and detector performances

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Solid-state detectors (SSDs) are emerging as instruments for fast neutron detection and spectroscopy in tokamaks. Their robust solid structure, their ability to distinguish neutrons from gamma radiation, and their insensitivity to magnetic fields make them optimal as neutron detectors for the regions closest to the plasma. The above properties facilitate their deployment in arrays, enabling comprehensive surveys of tokamak volumes along multiple lines of sight. While diamond-based detectors, notably Single-Crystal Diamond (SCD), have demonstrated impressive performances, but they also have a very high cost of production and they're impractical to manufacture in high numbers or with large areas. On the other hand, Silicon Carbide (SiC) is an attractive alternative: in fact, they are easy to produce in wafers with comparably low costs and in different polytypes (like 4H or 6H) that feature different electrical properties. In the case of SiC, increasing the thickness of the low doped epitaxial layer of the device is crucial for containing the charged products due to fast neutron interactions. To address this challenge, a novel approach, involving the growth of a 250 µm epitaxial layer by chemical vapor deposition with a high growth rate process and low doping level, led to the creation of Schottky and PN junction diodes neutron detectors. The low doping concentration (1014 cm^{-3}) allows to achieve the full depletion of the detector at lower voltages, enhancing detector performance. The Schottky and pn junction diodes were characterized at voltages up to 1000 V in reverse bias, proving their low leakage and stability. The PN junction diodes show a better stability, having leakage currents on the order of 10-11 A up to 620 V. The required voltage to achieve the complete depletion of the 250 µm layer (1000 V) could be achieved reducing the doping of the epitaxy further to 1013 cm^{-3}. These aspects could be improved in the next generation of detectors with a different design of the junction termination extension (JTE) structure. Preliminary tests involving alpha particle irradiation on SiC Schottky diodes show promising results in terms of stability and energy resolution. By optimizing bias voltages, the detectors successfully demonstrate stability in detecting alpha particles, offering insights into future advancements in detector technology for tokamak applications. A preliminary test using DT neutron (14 MeV) irradiation was conducted on both Schottky and pn junction diodes to evaluate their suitability as neutron detectors. The detection achieved with the pn junction is better than the one achieved with Schottky devices, featuring more counts, albeit with a larger Full Width at Half Maximum (FWHM)