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W2 Radiation effects on SiC-based PN junction diodes during in-core and ex-core irradiation campaigns

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Silicon Carbide (SiC)-based radiation detectors are promising candidates for neutron flux monitoring in extreme nuclear environments due to their high radiation resistance, wide bandgap energy, and excellent thermal stability. This study presents the results of irradiation campaigns conducted in different neutron fields to assess the performance and reliability of 4H-SiC P+N junction diodes under various experimental conditions.

Experimental Approach

The study was conducted in three neutron environments:
1. Fast neutron measurements at GENESIS platform at Grenoble LPSC: A 14.1 MeV mono-energetic D-T neutron generator was used to evaluate the acquisition chain and detector response under fast neutron flux up to few 10^7 cm^-2·s^-1
2. Ex-core irradiation at JSI TRIGA Mark II reactor (Slovenia): Characterization and comparison of the response of two wide bandgap semiconductor detectors (one single-crystalline CVD Diamond and one SiC-based diode) in the Tangential channel under neutron fluxes up to 10^10 cm^-2·s^-1
3. In-core irradiation at the JSI TRIGA reactor: high neutron flux exposure directly in the core of two SiC-based diodes with similar surfaces

The tested detectors included some SiC-based diodes with Boron-10 Neutron Conversion Layer (NCL) for thermal neutron detection and others without NCL for epithermal and fast neutron measurements. Pulse Height Distribution (PHD), Charge Collection Efficiency (CCE), and Pulse Shape Analysis (PSA) were analyzed to assess radiation effects on the detector response.

Key Results

1. Fast Neutron Response with D-T Generator Experiments at the LPSC Grenoble D-T neutron generator demonstrated the adaptability of SiC-based diodes for fast neutron measurements. Under a 14.1 MeV neutron flux of 3×10^7 cm^-2·s^-1, the detectors exhibited high-amplitude pulses and energy resolution comparable to existing literature. The PSA method successfully extracted neutron-induced signal characteristics, confirming the feasibility of SiC-based detection for fusion applications.

2. Ex-Core Measurements During ex-core irradiation in the tangential channel, the SiC-based diode showed a stable response up to fluences of 3×10^14 cm^-2, with a maximum CCE decrease of only 5.2%. Count rate and pulse amplitude exhibited predictable behavior with increasing reactor power, confirming the detectors'reliability in moderate neutron flux environments. Notably, the PHD revealed a clear separation between thermal neutron interactions (with NCL) and fast neutron-induced signals.

3. Radiation-Induced Degradation during In-Core measurements During this irradiation campaign, two SiC-based diodes, one with and the other without NCL were characterized with neutron flux and fluence up to 1×10^13 cm^-2·s^-1 and 1×10^17 cm^-2, respectively. With increasing fluence, a gradual decrease in charge collection was observed, primarily attributed to deep-level defects such as Z1/2 centers (Carbon vacancies), which trap charge carriers. Despite this degradation, the detectors retained stable rise and decay times, emphasizing their robustness for long-term neutron flux monitoring.

Conclusion
These results confirm the potential of SiC-based diodes for neutron flux monitoring in fission environments.

They demonstrate a high resistance to radiation damage under ex-core conditions, although a gradual CCE degradation was observed at higher fluences, attributed to defect accumulation in SiC lattice. The presentation will also discuss future perspectives, including defect characterization, potential annealing treatments, and improvements in acquisition electronics to further enhance performance under harsh conditions.

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