Characterization of 4H-SiC Schottky Diodes for Potential Uses as Beta Voltaic Power Sources for Spent Fuel Storage Applications

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Introduction

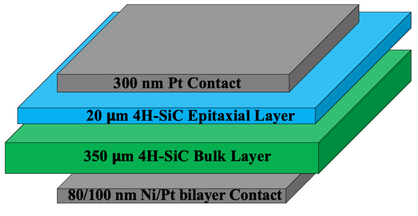
Monitoring of spent nuclear fuel (SNF) is a key element of nuclear waste management. However, storage conditions do not allow for wired sensors and the corresponding power supply, limiting possible options. Nuclear voltaic batteries offer an option for portable power to remote, in-situ units where power supply is a challenge. This study investigates the capabilities of 4H-SiC as a beta-voltaic energy transducer using secondary electrons from a ^{137}Cs Benchtop Irradiator

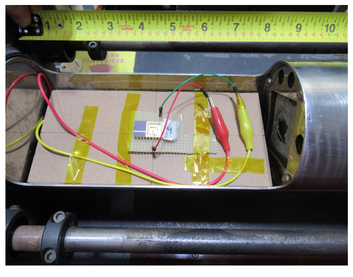
Goals and Objectives

- Evaluate the power output capabilities of 4H-SiC in a beta-rich environment
- Investigate damage caused to 4H-SiC Devices under high beta irradiation

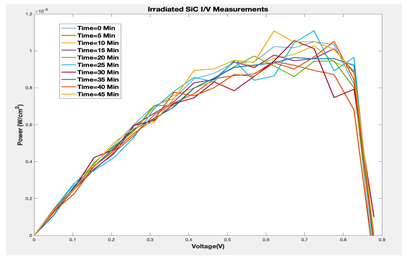
Methods

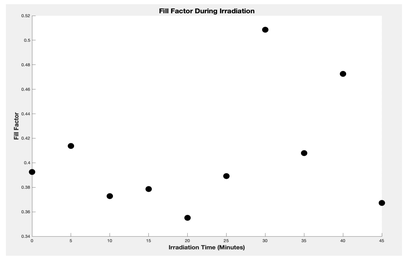
- 4H-SiC device was mounted inside of ^{137}Cs Irradiator (dose rate of 1200 rad/hr). The device then underwent periodic I/V sweeps to extract voltaic cell characteristics.
- Using the data from the I/V sweeps, the device would then be held at the voltage where the maximum power occurred to analyze the stability of the power output.
- Post-irradiation, the device's diode characteristics will be analyzed to investigate damage.

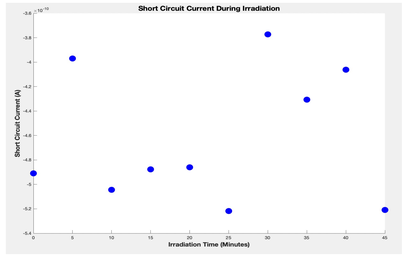


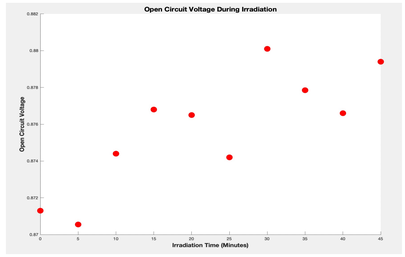


Results

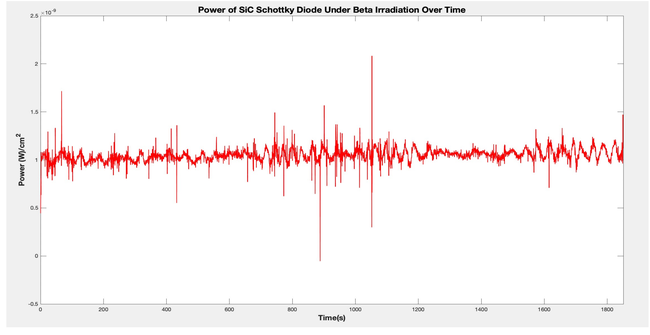




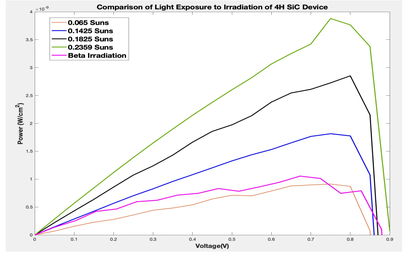


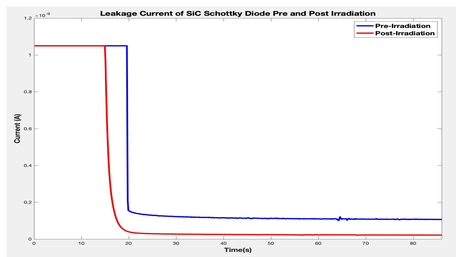


- Highest recorded fill factor was 50.86% .
- Increasing open circuit voltage may correspond to filling of charge trapping defects created from irradiation.
- The 4H SiC Schottky diode produced an average maximum power of 1.05nW/cm^2



- Diodes were also exposed to light prior to irradiation to compare the beta irradiation.
- Beta Irradiation was slightly higher than the diodes power output to 0.065 suns.





- 4H-SiC is known to exhibit charge trapping compensation under irradiation. This results in lower leakage current values. This device experienced an 80 pA drop post irradiation. This effect was also observed in other SiC Devices. [1,2]

Discussion and Future Work

- The power produced is low, however, the dose experienced in an environment inside a dry storage container(e.g., 23K rad/hr, PWR fuel 5 years discharged)[3], in close proximity to spent fuel assemblies would be much more than what was experienced in the ^{137}Cs irradiator (1.2 krad/hr).
- Displaying improved diode characteristics (lower leakage current after irradiation) creates the possibility for improved voltaic characteristics post-irradiation.
- Future work includes longer irradiations and monitoring of voltaic and diode characteristics with defect characterization by deep level transient spectroscopy (DLTS).

Conclusion and Relevance to Program Objective

The 4H SiC Schottky diode showed promising characteristics for application in a high gamma/beta irradiation field. Applying a new way to provide power for sensor to monitor the condition of spent fuel allows for more efficient management of SNF.

Acknowledgements

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