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Modeling the Effects of Surface Potential on Gallium Nitride Betavoltaic Cell Collection Efficiency

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The performance of Gallium Nitride (GaN) betavoltaic devices is strongly influenced by surface potential due to the shallow penetration depth of beta particles from Tritium (^3H). In this work, the effects of surface potential on charge collection efficiency in a PN, GaN betavoltaic cell are modeled using a Metal–Oxide–Semiconductor (MOS)-based field-plate approach implemented in Silvaco TCAD. The model incorporates incomplete dopant ionization and surface recombination to realistically capture carrier transport near the surface. By varying the surface potential and P-type doping concentration, the impact of surface-induced depletion on carrier collection is quantified. Simulation results indicate that at a surface potential of 1.5 eV, a P-type doping concentration of $1 \times 10^{19}/\text{cm}^3$ enables approximately 87% of the ideal (flat-band) collection efficiency, whereas a lower doping concentration of $1 \times 10^{18}/\text{cm}^3$ results in only 57% of the maximum achievable efficiency due to complete depletion of the P-layer. These findings demonstrate that surface potential is an unavoidable effect in GaN betavoltaic devices and that high P-type doping combined with ultra-thin junction design is essential for mitigating surface-induced carrier loss. The results provide design guidelines for optimizing shallow-junction GaN betavoltaic cells for long-lifetime, ultra-low-power nuclear energy harvesting applications.

Academic or Professional Status

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