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Performance and Breakdown Characteristics of Irradiated Vertical Power GaN *P-i-N* Diodes

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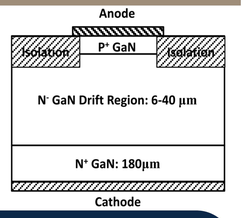
Abstract – Electrical performance and defect characterization of state-of-the-art vertical GaN *P-i-N* diodes before and after irradiation with 2.5 MeV protons and neutrons is investigated. Devices exhibit increase in specific on resistance following irradiation with protons and neutrons, indicating displacement damage introduces defects into the *p*-GaN and n^- drift regions of the device that impact on-state device performance. The breakdown voltage of these devices, initially above 1700 V, is observed to decrease only slightly for particle fluence < 10^{13} cm^{-2}. The unipolar figure of merit for power devices indicates that while the on-state resistance and breakdown voltage degrade with irradiation, vertical GaN *P-i-Ns* remain superior to the performance of the best available silicon devices and on-par with *unirradiated* modern SiC-based power devices.

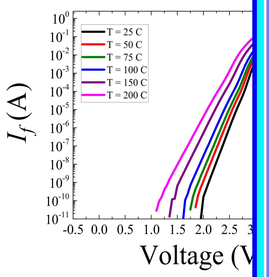
Advantages of Vertical GaN

- Silicon power devices are pushing fundamental material limits
- Use of GaN would enable improvements in size, weight, and power efficiency over Si- and SiC-based power devices
- Vertical devices exhibit smaller device area, higher device yield, increased breakdown voltage, and larger current drive



Electrical Performance

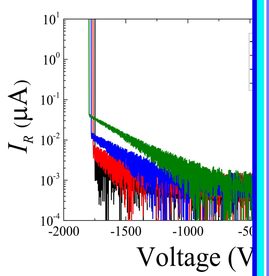
ON-state Characteristics



- Current density of 161 A/cm² at 4 V, 297 K
- Analysis of *I-V* curves suggests τ_p = 5 ns

- Low $R_{on,sp}$ shows excellent on-state performance
- Improved p-contact resistance with temperature

OFF-state Characteristics



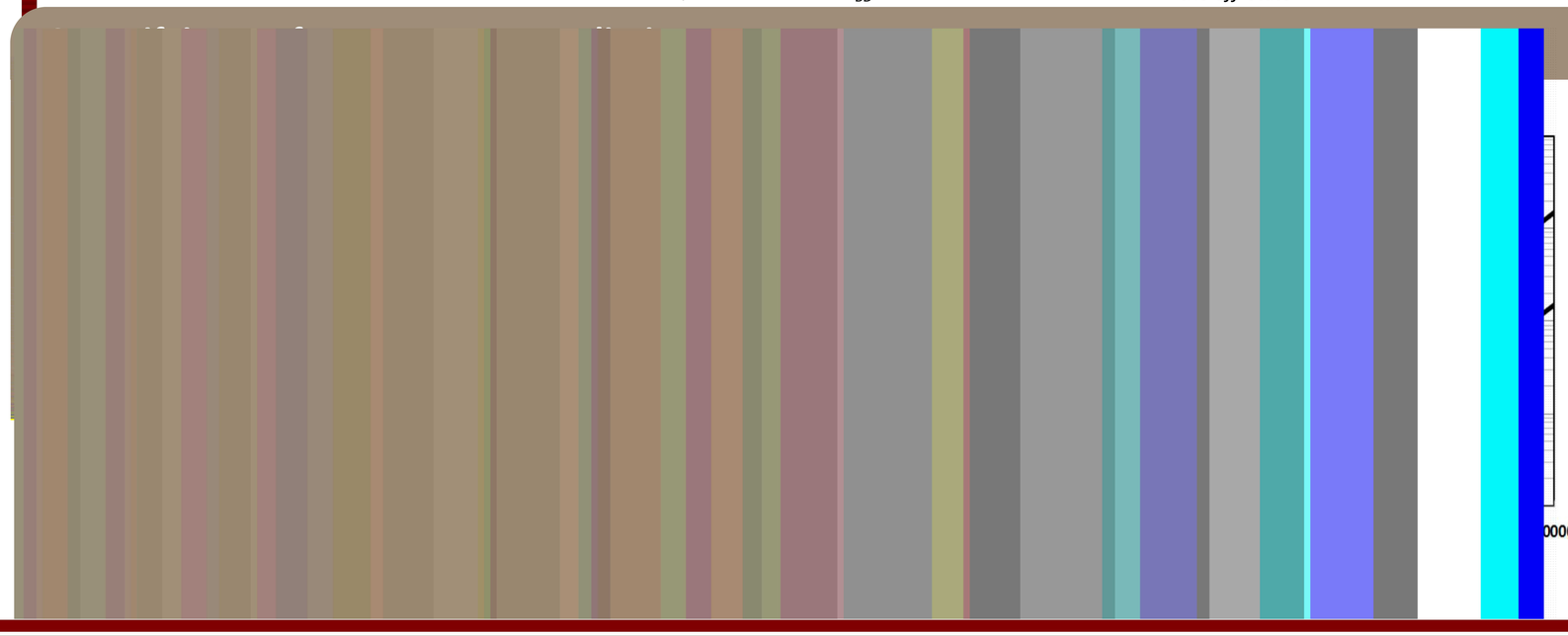
- Repeatable, *non-destructive* breakdown in GaN!

- Temperature dependence consistent with phonon-limited scattering processes
- Avalanche breakdown!

Impact of Displacement Damage on Electrical Performance

- Irradiation with protons leads to increase in generation current and higher resistivity in *on*-state characteristics
- Irradiation leads to increased leakage and decreased V_{BD}
- Softer reverse breakdown characteristics
- Three prominent defect levels in as-grown material
- Distribution of defect levels following irradiation with protons

- Increase in $R_{on,sp}$ results from higher series resistance from scattering centers in the n^- drift region and *p*-GaN layers
- V_{BD} trends following exposure to protons and neutrons show similar trends
- Compensation of holes in *p*-GaN field rings likely causes reduced V_{BD}
- Deep-levels act as compensating, scattering, and recombination centers
- Impacting $R_{on,sp}$ in the *on*-state and V_{BD} in the *off*-state



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