Skysong Innovations
Advancing the Arizona State University Knowledge Enterprise

1475 N. Scottsdale Road, Suite 200
Scottsdale, AZ 85287-3538
Phone: 480 884 1996 Fax: 480 884 1984

Case ID:M20-007P^
Published: 7/16/2020

# Low-Leakage Regrown GaN P-N Junctions for GaN Power Devices

## Inventors

**Yuji Zhao**

**Kai Fu**

**Houqiang Fu**

## Contact

Shen Yan
shen.yan@skysonginnovations.com

Background

The wide-bandgap (WBG) semiconductor gallium nitride (GaN) has attracted considerable attention for efficient power conversion applications due to its large bandgap (3.4 eV), high breakdown electric field (~3.0 MV/cm) and high Baliga's figure of merit (~1000 times larger than that of Si). Previously, due to the lack of native GaN substrates, GaN power devices were usually heteroepitaxially grown on lattice-mismatched foreign substrates (e.g., sapphire) with large defect densities (>1e9 cm-2) which limited device performance. Recently, advancements in GaN crystal growth by hydride vapor phase epitaxy (HVPE) and the ammonothermal method have made free-standing bulk GaN substrates commercially available. Homoepitaxial growth of GaN power devices on these substrates can significantly reduce defect densities and improve device performance.

Due to the availability of heavily doped GaN substrates, vertical power devices have been developed for high-voltage and high-power applications. In contrast to lateral devices such as high electron mobility transistors (HEMTs), in vertical devices, the currents flow vertically through the devices, and the reverse voltages are held vertically. The advantages of the vertical structure over the lateral structure are multifold: smaller chip area, larger current, less sensitivity to surface states, better scalability, and smaller current dispersion, which is a challenging issue for HEMTs. Currently, vertical GaN-on-GaN power diodes such as p-n diodes and Schottky barrier diodes have been demonstrated. However, meaningful competition with traditional Si-based power electronics requires advancement in GaN power device structures, such as vertical junction field-effect transistors (VJFETs), junction barrier Schottky (JBS) diodes, and superjunctions (SJs). The realization of these devices depends critically on reliable regrown p-n junctions with low current leakages.

Invention Description

Researchers at Arizona State University have developed a method for fabricating low-leakage regrown GaN p-n junctions by metalorganic chemical vapor deposition (MOCVD) in combination with low-damage etching techniques and surface treatments. The regrown p-n junctions show low current leakage on the order of 10 nA at -600 V and breakdown voltages over 1.2 kV.

Potential Applications

- Power electronics
- High-frequency electronics

Benefits and Advantages

- Regrowth technique employs MOCVD, a standard industrial tool for mass production
- A four-stage, low-damage inductively coupled plasma (ICP) etching method reduces regrowth surface damages: The first two stages are high-RF to achieve reasonable removal rates for thick epilayers, and the remaining stages are low-RF for recovering surface damage
- Combines UV ozone and hydrofluoric (HF) acid treatments to recover regrowth surface
- Regrown p-n junctions achieved ultra-low leakage currents and record-high breakdown voltages
- Wide-ranging application as building blocks in various advanced power electronics such as VJFETs, SJs, and JBS diodes

Related Publication

Research Homepage of Professor Yuji Zhao