Thin Current Spreading Layers Improve Breakdown Performance (#8789)

For high-power III-nitride devices

This new approach to current spreading in quasi-vertical diodes avoids excessive current flow, field crowding, and premature breakdown at the mesa edges. It does this by improving electrical current uniformity in group III-nitride devices with thin current spreading layers (CSL). By sandwiching a thin gallium nitride (GaN):beryllium (Be) i-layer thin film inside the n-type GaN layer, the current uniformity dramatically increases from approximately 40% of the p-contact radii to nearly 100%, resulting in higher breakdown performance and reduced current leakage. This technology can be applied to any thickness drift layer and has been shown to be particularly effective for thicker drift layers needed for high voltage devices. It can be used for any Ga-containing alloy (e.g., aluminum-gallium-indium-nitride [AlGaInN]).

While demonstrated with Georgia Tech's new metal modulated epitaxy (MME) method, the high breakdown voltage and good forward voltage characteristics of these devices may enable comparatively high performance in group III-nitride high-power devices even when grown by other methods.

See also:
#8790, "Cascaded Nickel Hard Mask"
#8810/#8666/#8786, "Metal Modulated Epitaxy Grown Be-Doped AlN Films and Layered Films"

Benefits/Advantages

- **Increases current uniformity**: Improves cumulative current flow distribution from ~40% to ~100% of the p-type contact
- **Improves breakdown performance**: Avoids premature breakdown at the mesa edges making quasi-vertical devices comparable in performance to more expensive vertical devices.
- **Improves Immunity to Etch Variation**: Because current flow is no longer crowded along the mesa edges, process related variations in the mesa etching are less important to the diode performance.

Potential Commercial Applications

- Group III-nitride devices for electronic and optoelectronic applications (e.g, rectifying diodes for power, RF and communications, solar cells, light emitting diodes, photodetectors, and laser diodes)
- GaN-based deep ultraviolet, high-power and high-frequency devices capable of operation in

extreme radiation and heat environments

Background/Context for This Invention

To reduce costs, many power devices use a quasi-vertical instead of a fully vertical current path. While the fully vertical design is preferred, it requires a costly (and often unavailable) thick conductive substrate. The quasi-vertical design has an outer contact made on a recessed/etched region of the device, while a separate contact is made on the top of the mesa. Because of the background doping concentration and thickness of the achievable intrinsic/drift layer (a low-doped region), quasi-vertical high-power devices (and fully vertical devices) have limited breakdown performance. In quasi-vertical high-power devices, breakdown performance is limited by threading dislocations and surface defects introduced by plasma etching during the fabrication process. This surface damage can cause current to travel along the edges of the device instead of penetrating into the central regions of the device.

Georgia Tech's buried current spreading layer enabled by Be doping improves the current uniformity in these devices. The capability of these novel devices can be further extended by controlling the p-GaN:Be thickness, growth temperature, III/V ratio, excess metal-dose per MME shutter cycle, and Be doping, thereby advancing a wide range of future high-power electronic and optoelectronic device applications.

Dr. William Alan Doolittle
Professor and Director of Advanced Semiconductor Technology Facility (ASTF) - Georgia Tech School of Electrical and Computer

Zachary Engel
Graduate Research Assistant - Georgia Tech School of Electrical and Computer Engineering

Dr. Habib Ahmad
Former PhD Student - Georgia Institute of Technology

Patent/IP Information

U.S. Application Filed

Publications

Realization of homojunction PN AlN diodes, Journal of Applied Physics, May 2, 2022

Georgia Tech's New Aluminum Nitride-based Semiconductor is Posed to Transform the Industry
, Georgia Tech School of Electrical and Computer Engineering News, August 4, 2022

Substantial P-Type Conductivity of AlN Achieved via Beryllium Doping, Advanced Materials, September 2, 2021

For more information about this technology, please visit:
https://licensing.research.gatech.edu/technology/thin-current-spreading-layers-improve-breakdown-performance