Ill-Nitride Based Tunnel Junction with P-Type Superlattice

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OTHER INFORMATION
KEYWORDS
LED, VCSEL, EELD, Laser, Tunnel Junction, III-Nitride, GaN, TCO, long-wavelength

CATEGORIZED AS
- Semiconductors
- Assembly and Packaging
- Design and Fabrication
- Processing and Production

RELATED CASES
2022-777-0
BACKGROUND
MOCVD-grown III-N tunnel junctions (TJs) have received significant attention as an alternative to transparent conducting oxides (TCOs) in devices such as LEDs, edge-emitting laser diodes (EELDs), and vertical-cavity surface-emitting laser diodes (VCSELs) because they provide a current spreading solution without the same level of optical and electrical loss as a TCO. A significant obstacle remains, however, caused by incomplete activation, where the magnesium (most commonly used p-type dopant) at the center of these devices remains passivated, impacting device performance and light uniformity. This is a significant problem for large-area LEDs but is also a problem at high current densities in VCSELs and EELDs. Current solutions to this problem increase the performance of small, micron-scale LED devices, but there is a demand for improving p-GaN carrier concentration uniformity for larger LEDs, VCSELs, and EELDs in addition to longer wavelength devices that don't need to be thermally activated at all.

DESCRIPTION
Researchers at the University of California, Santa Barbara have circumvented the device performance consequences of incomplete activation by using p-InGaN/p-AlGaN/p-GaN superlattices (SLs) instead of a conventional bulk p-GaN layer to achieve high hole concentration without the need for hydrogen sidewall diffusion via thermal activation. The hole concentration within the p-type layer is increased with or without post-activation thermal treatments of Mg acceptors, and the TJ interface can benefit from greater tunneling probability. Additionally, under the right band bending conditions, the p-type layer can have sufficiently generated holes entirely from the polarization-induced charges, removing the need for thermal activation or Mg-doping entirely. For TJ devices, this will improve the turn-on voltage, output power, and efficiency, as well as reduce thermal effects related to highly resistive p-type layers. This is especially useful for laser architectures with a TJ that operate at high current densities. This technology will improve the performance of all TJ devices that are currently limited by the p-GaN layer, namely large area LEDs, VCSELs, EELDs, and long wavelength devices that are damaged by thermal activation.

ADVANTAGES
▶ Improved device efficiency
▶ Reduced energy consumption
▶ Longer device lifetimes
▶ Removes the need for thermal activation or Mg-doping entirely

APPLICATIONS
▶ III-Nitride devices
▶ LEDs
▶ EELDs
▶ VCSELs
▶ Long wavelength devices

PATENT STATUS
Patent Pending
- Lateral Growth Method for Defect Reduction of Semipolar Nitride Films
- Vertical Cavity Surface-Emitting Lasers with Continuous Wave Operation
- Eliminating Misfit Dislocations with In-Situ Compliant Substrate Formation
- III-Nitride-Based Vertical Cavity Surface Emitting Laser (VCSEL) with a Dielectric P-Side Lens
- Aluminum-cladding-free Nonpolar III-Nitride LEDs and LDs
- Low-Cost Zinc Oxide for High-Power-Output, GaN-Based LEDs (UC Case 2010-183)
- Highly Efficient Blue-Violet III-Nitride Semipolar Laser Diodes
- Low Temperature Deposition of Magnesium Doped Nitride Films
- Transparent Mirrorless (TML) LEDs
- Improved GaN Substrates Prepared with Ammonothermal Growth
- Optimization of Laser Bar Orientation for Nonpolar Laser Diodes
- Method for Enhancing Growth of Semipolar Nitride Devices
- Ultraviolet Laser Diode on Nano-Porous AlGaN template
- Growth of Polyhedron-Shaped Gallium Nitride Bulk Crystals
- Nonpolar III-Nitride LEDs With Long Wavelength Emission
- Improved Fabrication of Nonpolar InGaN Thin Films, Heterostructures, and Devices
- Growth of High-Quality, Thick, Non-Polar M-Plane GaN Films
- High-Efficiency, Mirrorless Non-Polar and Semi-Polar Light Emitting Devices
- Method for Growing High-Quality Group III-Nitride Crystals
- Controlled Photoelectrochemical (PEC) Etching by Modification of Local Electrochemical Potential of Semiconductor Structure
- Technique for the Nitride Growth of Semipolar Thin Films, Heterostructures, and Semiconductor Devices
- MOCVD Growth of Planar Non-Polar M-Plane Gallium Nitride
- Reduced Dislocation Density of Non-Polar GaN Grown by Hydride Vapor Phase Epitaxy
- Methods for Fabricating III-Nitride Tunnel Junction Devices
- Low-Droop LED Structure on GaN Semi-polar Substrates
- Contact Architectures for Tunnel Junction Devices
- Semi-polar LED/LD Devices on Relaxed Template with Misfit Dislocation at Hetero-interface
- Semipolar-Based Yellow, Green, Blue LEDs with Improved Performance
- III-Nitride-Based Devices Grown On Thin Template On Thermally Decomposed Material
- Growth of Semipolar III-V Nitride Films with Lower Defect Density
- III-Nitride Tunnel Junction LED with High Wall Plug Efficiency
- III-Nitride-Based Vertical Cavity Surface Emitting Laser (VCSEL) with an Activated Tunnel Junction
- Tunable White Light Based on Polarization-Sensitive LEDs
- Cleaved Facet Edge-Emitting Laser Diodes Grown on Semipolar GaN
- Growth of High-Performance M-plane GaN Optical Devices
- Packaging Technique for the Fabrication of Polarized Light Emitting Diodes
- Improved Anisotropic Strain Control in Semipolar Nitride Devices
- Novel Multilayer Structure for High-Efficiency UV and Far-UV Light-Emitting Devices
- III-V Nitride Device Structures on Patterned Substrates
- Method for Increasing GaN Substrate Area in Nitride Devices
- High-Intensity Solid State White Laser Diode
- Nitride Based Ultraviolet LED with an Ultraviolet Transparent Contact
- Growth of Planar, Non-Polar, A-Plane GaN by Hydride Vapor Phase Epitaxy
- GaN-Based Thermoelectric Device for Micro-Power Generation
- Limiting Strain-Relaxation in III-Nitride Heterostructures by Substrate Patterning
- LED Device Structures with Minimized Light Re-Absorption
III-Nitride Based-Tunnel Junction with Interlayer

Growth of Planar Semi-Polar Gallium Nitride

High-Efficiency and High-Power III-Nitride Devices Grown on or Above a Strain Relaxed Template

UV Optoelectronic Devices Based on Nonpolar and Semi-polar AlInN and AlInGaN Alloys

III-Nitride Based VCSEL with Curved Mirror on P-Side of the Aperture

Enhancing Growth of Semipolar (Al,In,Ga,B)N Films via MOCVD