Activation of P-Type Layers of Tunnel Junctions in Micro-LEDs

Tech ID: 32270 / UC Case 2021-551-0

BACKGROUND

Current commercial III-nitride light emitting diodes (LEDs) and laser diodes (LDs) employ the use of an n-type region and a p-type region to form a diode. However, p-type gallium nitride (p-GaN) is difficult to contact electrically and has low hole concentration and mobility. As a result, p-GaN cannot be used as a current spreading layer, and traditional p-contacts will add significant voltage to devices. All commercial light emitting devices utilize traditional p-contacts and materials other than p-GaN for current spreading, which typically involves a high barrier for tunneling. Current methods to reduce the tunneling barrier are associated with losses, either in terms of voltage or resistance increases or optical losses in the final device performance.

DESCRIPTION

Researchers at the University of California, Santa Barbara have created a novel method for fabricating micro-LEDs with low forward voltage tunnel junctions enabling improved performance and integration of multicolor displays. This approach fabricates III-nitride μLEDs incorporating an epitaxial tunnel junction made of p+GaN, InxAlyGazN insertion layers, and n+GaN layers grown by MOCVD. The InxAlyGazN insertion layers possess a smaller bandgap than GaN, reducing depletion width and increasing tunneling probability, which leads to low and stable forward voltages across device sizes ranging from 25 to 10,000 μm^2. The approach also includes chemical treatment between growth steps to activate the p-type layer despite previously limiting hydrogen compensation challenges. These advancements enable better current spreading, simplified fabrication, higher output power, and facilitate cascaded integration of μLEDs emitting blue, green, and red light in a single device.

ADVANTAGES

- Low and stable forward voltage
- Simplified fabrication process using consistent MOCVD growth with minimal complexity
- Improved current spreading via tunnel junctions on both device sides
- Higher output power performance compared to traditional p-contact LEDs
- Enables cascaded μLEDs with integrated multicolor emission (blue, green, red)
- Stable voltage performance across varying device sizes, supporting commercialization

APPLICATIONS

- Next-generation micro-LED displays, including near-eye and head-up displays

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OTHER INFORMATION

KEYWORDS

p+GaN, n+GaN, MOCVD, micro-LED, tunnel junction, forward voltage, LED

CATEGORIZED AS

- **Energy**
  - Lighting
- **Semiconductors**
  - Design and Fabrication

RELATED CASES

2021-551-0

- High-brightness, low-power display panels for wearable and augmented reality devices
- Multicolor display integration in compact micro-scale lighting systems
- Advanced lighting applications requiring efficient, small-area light sources
- Commercial and industrial LED lighting solutions benefiting from improved device efficiency

PATENT STATUS

Country	Type	Number	Dated	Case
United States Of America	Published Application	20230307579	09/28/2023	2021-551

RELATED MATERIALS

- Fully transparent metal-organic chemical vapor deposition-grown cascaded InGaN micro-light-emitting diodes with independent junction control - 06/25/2021

ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- Eliminating Misfit Dislocations with In-Situ Compliant Substrate Formation
- III-Nitride-Based Vertical Cavity Surface Emitting Laser (VCSEL) with a Dielectric P-Side Lens
- Enhanced Light Extraction LED with a Tunnel Junction Contact Wafer Bonded to a Conductive Oxide
- Methods to Produce and Recycle Substates for III-Nitride Materials with Electrochemical Etching
- III-Nitride Tunnel Junction with Modified Interface
- Improved Reliability & Enhanced Performance of III-Nitride Tunnel Junction Optoelectronic Devices
- (In,Ga,Al)N Optoelectronic Devices with Thicker Active Layers for Improved Performance
- Thermally Stable, Laser-Driven White Lighting Device
- Novel Multilayer Structure for High-Efficiency UV and Far-UV Light-Emitting Devices
- A Method To Lift-Off Nitride Materials With Electrochemical Etch
- High-Intensity Solid State White Laser Diode
- Nitride Based Ultraviolet LED with an Ultraviolet Transparent Contact
- Epitaxial Light Control Features in Light Emitting Diodes
- High-Efficiency Vertical Cavity Surface Emitting Laser Fabrication
- A Wafer-Scale, Low Defect Density Strain Relaxed Template for III-Nitride-Based High Efficiency and High-Power Devices
- High-Efficiency and High-Power III-Nitride Devices Grown on or Above a Strain Relaxed Template
- III-Nitride Based VCSEL with Curved Mirror on P-Side of the Aperture

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