**Technique for the Nitride Growth of Semipolar Thin Films, Heterostructures, and Semiconductor Devices**

Tech ID: 25247 / UC Case 2005-668-0

**BRIEF DESCRIPTION**
A method to grow semipolar (Ga, Al, In, B)N thin films, heterostructures, and devices on suitable substrates or planar templates in which a large area of the semipolar film is parallel to the substrate surface.

**BACKGROUND**
The usefulness of gallium nitride (GaN) and its ternary and quaternary compounds incorporating aluminum and indium has been well established for fabrication of visible and ultraviolet optoelectronic devices. Current nitride technology for these devices uses nitride films grown along the polar c-direction; however, quantum-well active regions in devices suffer from the quantum-confined Stark effect (QCSE). One way to combat the issue is to grow films on semipolar planes of GaN in order to improve device performance by reduce polarization effects and increasing the efficiency of optical transitions.

**DESCRIPTION**
Researchers at UC Santa Barbara have developed a method to grow semipolar (Ga, Al, In, B)N thin films, heterostructures, and devices on suitable substrates or planar templates in which a large area of the semipolar film is parallel to the substrate surface.

The method uses vapor phase epitaxy, such as metalorganic chemical vapor deposition (MOCVD), in order to grow the semipolar structures. Additionally, this technique alters the crystal growth orientation in order to reduce polarization effects in nitride thin films.

This method is stable, energy efficient and cost-effective.

**ADVANTAGES**
- Reduces the negative impact of polarization
- Improved device efficiency
- Improved crystal growth orientation

**APPLICATIONS**
- LEDs and Laser Diodes (LDs)
- Semiconductors

**PATENT STATUS**

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<td>United States Of America</td>
<td>Issued Patent</td>
<td>9,793,435</td>
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**RELATED CASES**
2005-668-0

**CATEGORIZED AS**
- Optics and Photonics
  - All Optics and Photonics
  - Energy
    - Lighting
  - Semiconductors
    - Design and Fabrication

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**OTHER INFORMATION**

**KEYWORDS**
indssl, indled, MOCVD, thin films

**ADDITIONAL TECHNOLOGIES BY THESE INVENTORS**
- Reduced Dislocation Density of Non-Polar GaN Grown by Hydride Vapor Phase Epitaxy
- Growth of Planar, Non-Polar, A-Plane GaN by Hydride Vapor Phase Epitaxy
- Nonpolar (Al, B, In, Ga)N Quantum Well Design
- Improved Manufacturing of Semiconductor Lasers
- Cleaved Facet Edge-Emitting Laser Diodes Grown on Semipolar GaN
Etching Technique for the Fabrication of Thin (Al, In, Ga)N Layers
Enhancing Growth of Semipolar (Al,In,Ga,B)N Films via MOCVD
GaN-Based Thermoelectric Device for Micro-Power Generation
Growth of High-Quality, Thick, Non-Polar M-Plane GaN Films
Method for Growing High-Quality Group III-Nitride Crystals
Growth of Planar Semi-Polar Gallium Nitride
Defect Reduction of Non-Polar and Semi-Polar III-Nitrides
MOCVD Growth of Planar Non-Polar M-Plane Gallium Nitride
Lateral Growth Method for Defect Reduction of Semipolar Nitride Films
Low Temperature Deposition of Magnesium Doped Nitride Films
Growth of Polyhedron-Shaped Gallium Nitride Bulk Crystals
Improved Manufacturing of Solid State Lasers via Patterning of Photonic Crystals
Novel Current-Blocking Layer in High-Power Current Aperture Vertical Electron Transistors (CAVETs)
Control of Photoelectrochemical (PEC) Etching by Modification of the Local Electrochemical Potential of the Semiconductor Structure
Phosphor-Free White Light Source
Single or Multi-Color High Efficiency LED by Growth Over a Patterned Substrate
High Efficiency LED with Optimized Photonic Crystal Extractor
Packaging Technique for the Fabrication of Polarized Light Emitting Diodes
LED Device Structures with Minimized Light Re-Absorption
(In,Ga,Al)N Optoelectronic Devices with Thicker Active Layers for Improved Performance
Polarization-Doped Field Effect Transistors with Increased Performance
Oxyfluoride Phosphors for Use in White Light LEDs
III-V Nitride Device Structures on Patterned Substrates
Growth of Semipolar III-V Nitride Films with Lower Defect Density
Improved GaN Substrates Prepared with Ammonothermal Growth
High-Quality N-Face GaN, InN, AIN by MOCVD
Enhanced Optical Polarization of Nitride LEDs by Increased Indium Incorporation
Semipolar-Based Yellow, Green, Blue LEDs with Improved Performance
Hexagonal Wurtzite Type Epitaxial Layer with a Low Alkali-Metal Concentration
Photoelectrochemical Etching Of P-Type Semiconductor Heterostructures
Photoelectrochemical Etching for Chip Shaping Of LEDs
Highly Efficient Blue-Violet III-Nitride Semipolar Laser Diodes
Method for Manufacturing Improved III-Nitride LEDs and Laser Diodes: Monolithic Integration of Optically Pumped and Electrically Injected III-Nitride LEDs
Defect Reduction in GaN films using in-situ SiNx Nanomask
Semi-polar LED/LD Devices on Relaxed Template with Misfit Dislocation at Hetero-interface
Limiting Strain-Relaxation in III-Nitride Heterostructures by Substrate Patterning
Suppression of Defect Formation and Increase in Critical Thickness by Silicon Doping
High Efficiency Semipolar AlGaN-Cladding-Free Laser Diodes
Low-Cost Zinc Oxide for High-Power-Output, GaN-Based LEDs (UC Case 2010-183)
Low-Cost Zinc Oxide for High-Power-Output, GaN-Based LEDs (UC Case 2010-150)
Nonpolar III-Nitride LEDs With Long Wavelength Emission
Method for Growing Self-Assembled Quantum Dot Lattices
Method for Increasing GaN Substrate Area in Nitride Devices
GaN-based Vertical Metal Oxide Semiconductor and Junction Field Effect Transistors
Flexible Arrays of MicroLEDs using the Photoelectrochemical (PEC) Lift-off Technique
Optimization of Laser Bar Orientation for Nonpolar Laser Diodes
UV Optoelectronic Devices Based on Nonpolar and Semi-polar AlInN and AlInGaN Alloys
Low-Droop LED Structure on GaN Semi-polar Substrates
Improved Fabrication of Nonpolar InGaN Thin Films, Heterostructures, and Devices
Growth of High-Performance M-plane GaN Optical Devices
Method for Enhancing Growth of Semipolar Nitride Devices
Transparent Mirrorless (TML) LEDs
Solid Solution Phosphors for Use in Solid State White Lighting Applications
Planar, Nonpolar M-Plane III-Nitride Films Grown on Miscut Substrates
High-Efficiency, Mirrorless Non-Polar and Semi-Polar Light Emitting Devices
High Light Extraction Efficiency III-Nitride LED
- Tunable White Light Based on Polarization-Sensitive LEDs
- Method for Improved Surface of (Ga,Al,In,B)N Films on Nonpolar or Semipolar Substrates
- Improved Anisotropic Strain Control in Semipolar Nitride Devices
- III-Nitride Tunnel Junction with Modified Interface
- Enhanced Light Extraction LED with a Tunnel Junction Contact Wafer Bonded to a Conductive Oxide
- Increased Light Extraction with Multistep Deposition of ZnO on GaN
- Hybrid Growth Method for Improved III-Nitride Tunnel Junction Devices
- Contact Architectures for Tunnel Junction Devices
- A Structure For Increasing Mobility In A High-Electron-Mobility Transistor
- Internal Heating for Ammonothermal Growth of Group-III Nitride Crystals
- III-N Based Material Structures and Circuit Modules Based on Strain Management
- Methods for Fabricating III-Nitride Tunnel Junction Devices
- Achieving "Active P-Type Layer/Layers" In III-Nitride Epitaxial Or Device Structures Having Buried P-Type Layers
- Multifaceted III-Nitride Surface-Emitting Laser
- Reduction in Leakage Current and Increase in Efficiency of III-Nitride MicroLEDs
- Vertical Cavity Surface-Emitting Lasers with Continuous Wave Operation
- Gated Electrodes For Electrolysis And Electrosynthesis
- Methods for Locally Changing the Electric Field Distribution in Electron Devices
- Continuous Fluidic Printing Of MicroLEDs
- Creating and Releasing Nanoscale Light Emitting Devices from Their Growth Substrates
- Colloidal Lithography-Enabled Creation of Metasurface-Integrated MicroLEDs and Devices
- Efficient Implementation of a Tunnel Junction Contact on a Nitride-Based Edge-Emitting Laser Diode
- Wafer Bonding for Embedding Active Regions with Relaxed Nanostructures
- Heterogeneously Integrated GaN on Si Photonic Integrated Circuits
- Fabrication of Relaxed Semiconductor Films without Crystal Defects
- Enhancement of Semi-Polar Gallium Nitride Surface Morphology in Photo-Electrochemical Undercut Etching
- Transparent Vertical Cavity Surface Emitting Laser for Augmented and Mixed Reality Displays
- Control Of Photoelectrochemical Etch Parameters For Minimization of Interfacial Roughness of Light Emitting Device Structures
- High Speed Indium Gallium Nitride Multi-Quantum Well (InGaN MQW) Photodetector
- Distributed Feedback Laser with Transparent Conducting Oxide Grating
- III-N Transistor With Stepped Cap Layers
- Eliminating Plasma Damage for Beta-Phase Gallium Oxide Transistors
- Retaining Injection Efficiency and Optical Properties of Laser Diodes with Built-in Polarization Fields