Improved Fabrication of Nonpolar InGaN Thin Films, Heterostructures, and Devices
Tech ID: 25014 / UC Case 2004-495-0

BRIEF DESCRIPTION
A method for fabricating high-quality indium-containing epitaxial layers, heterostructures, and devices based on InGaN growth on GaN substrates.

BACKGROUND
GaN and its alloys (AlGaN, InGaN, AlInGaN) have been established as effective for fabrication of visible and ultraviolet optoelectronic devices and high-power electronic devices. These devices are most often grown along the polar c-direction, using a variety of growth techniques, including molecular beam epitaxy (MBE), metalorganic chemical vapor deposition (MOCVD), or hydride vapor phase epitaxy (HVPE). Growing devices in the polar c-direction results in charge separation, spontaneous polarization, and degraded device performance. Growth of such devices along a nonpolar axis could significantly improve their performance, but InGaN-based devices have previously encountered problems with growth conditions and material quality.

DESCRIPTION
UC Santa Barbara researchers have developed a method for fabricating high-quality indium-containing epitaxial layers, heterostructures, and devices based on InGaN growth on GaN substrates. These InGaN films are grown along the nonpolar direction using a metalorganic chemical vapor deposition technique, and result in the successful creation of violet and near-ultraviolet LEDs and LDs. Previous issues related to the growth of InGaN-based devices, such as gross surface roughening, low indium incorporation, and indium desorption in InGaN heterostructures have been overcome with this technique.

ADVANTAGES
· Variability in layer thickness
· Violet and near-ultraviolet light emission
· Growth of nonpolar InGaN at a reduced temperature
· Growth of InGaN layers at or near atmospheric pressure

APPLICATIONS
· LEDs
· Laser diodes (LDs)

PATENT STATUS
<table>
<thead>
<tr>
<th>Country</th>
<th>Type</th>
<th>Number</th>
<th>Dated</th>
<th>Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States Of America</td>
<td>Issued Patent</td>
<td>8,502,246</td>
<td>08/06/2013</td>
<td>2004-495</td>
</tr>
<tr>
<td>United States Of America</td>
<td>Issued Patent</td>
<td>7,504,274</td>
<td>03/17/2009</td>
<td>2004-495</td>
</tr>
<tr>
<td>United States Of America</td>
<td>Issued Patent</td>
<td>7,186,302</td>
<td>03/06/2007</td>
<td>2004-495</td>
</tr>
</tbody>
</table>

INVENTORS
▶ Chakraborty, Arpan
▶ DenBaars, Steven P.
▶ Haskell, Benjamin A.
▶ Keller, Stacia
▶ Mishra, Umesh K.
▶ Nakamura, Shuji
▶ Speck, James S.

OTHER INFORMATION
KEYWORDS
indssl, indled, GaN, thin films

CATEGORIZED AS
▶ Energy
▶ Lighting
▶ Semiconductors
▶ Design and Fabrication

RELATED CASES
2004-495-0

ADDITIONAL TECHNOLOGIES BY THESE INVENTORS
Method for Improved Surface of (Ga,Al,In,B)N Films on Nonpolar or Semipolar Substrates
High Efficiency LED with Optimized Photonic Crystal Extractor
Enhanced Optical Polarization of Nitride LEDs by Increased Indium Incorporation
Edge-Emitting Laser Diode with Via-Activated Tunnel Junction Contact
Etching Technique for the Fabrication of Thin (Al, In, Ga)N Layers
Lateral Growth Method for Defect Reduction of Semipolar Nitride Films
Flexible Arrays of MicroLEDs using the Photoelectrochemical (PEC) Lift-off Technique
Vertical Cavity Surface-Emitting Lasers with Continuous Wave Operation
Achieving “Active P-Type Layer/Layers” In III-Nitride Epitaxial Or Device Structures Having Buried P-Type Layers
Gallium-containing MicroLEDs for Displays
High-Quality N-Face GaN, InN, AlN by MOCVD
High Speed Indium Gallium Nitride Multi-Quantum Well (InGaN MQW) Photodetector
Low-Cost Zinc Oxide for High-Power-Output, GaN-Based LEDs (UC Case 2010-183)
Internal Heating for Ammonothermal Growth of Group-III Nitride Crystals
Defect Reduction in GaN films using in-situ SiNx Nanomask
Enhanced Light Extraction LED with a Tunnel Junction Contact Wafer Bonded to a Conductive Oxide
Highly Efficient Blue-Violet III-Nitride Semipolar Laser Diodes
Hybrid Growth Method for Improved III-Nitride Tunnel Junction Devices
Phosphor-Free White Light Source
Volumetric Hole Injection with Intentional V-Defects
Control of Photoelectrochemical (PEC) Etching by Modification of the Local Electrochemical Potential of the Semiconductor Structure
Low Temperature Deposition of Magnesium Doped Nitride Films
Device Structures Utilizing Barrier Enhancement Conductive Materials on N-polar III-N
Transparent Mirrorless (TML) LEDs
Improved GaN Substrates Prepared with Ammonothermal Growth
Laser Diode With Tunnel Junction Contact Surface Grating
Optimization of Laser Bar Orientation for Nonpolar Laser Diodes
High Efficiency Semipolar AlGaN-Cladding-Free Laser Diodes
High Mobility Group-III Nitride Transistors with Strained Channels
Method for Growing Self-Assembled Quantum Dot Lattices
A Structure For Increasing Mobility In A High-Electron-Mobility Transistor
Method for Enhancing Growth of Semipolar Nitride Devices
III-Nitride Tunnel Junction with Modified Interface
Growth of Polyhedron-Shaped Gallium Nitride Bulk Crystals
Nonpolar III-Nitride LEDs With Long Wavelength Emission
Fabrication of Relaxed Semiconductor Films without Crystal Defects
Growth of High-Quality, Thick, Non-Polar M-Plane GaN Films
Methods for Locally Changing the Electric Field Distribution in Electron Devices
Increased Light Extraction with Multistep Deposition of ZnO on GaN
Method for Manufacturing Improved III-Nitride LEDs and Laser Diodes: Monolithic Integration of Optically Pumped and Electrically Injected III-Nitride LEDs
Selective-Area Mesoporous Semiconductors And Devices For Optoelectronic And Photonic Applications
High-Efficiency, Mirrorless Non-Polar and Semi-Polar Light Emitting Devices
Method for Growing High-Quality Group III-Nitride Crystals
Near-Infrared, Flip-Chip, TCO-Clad, InGaN Quantum Dot Laser Diode
Incorporating Temperature-Sensitive Layers in III-N Devices
Controlling Linearity in N-Polar GaN MISHEMTs
Oxyfluoride Phosphors for Use in White Light LEDs
Technique for the Nitride Growth of Semipolar Thin Films, Heterostructures, and Semiconductor Devices
Enabling Epitaxial Growth On Thin Substrates
(In,Ga,Al)N Optoelectronic Devices with Thicker Active Layers for Improved Performance
MOCVD Growth of Planar Non-Polar M-Plane Gallium Nitride
Reduced Dislocation Density of Non-Polar GaN Grown by Hydride Vapor Phase Epitaxy
N-polar III-N Semiconductor Device Structures Enabled by Wet Chemistry
Heterogeneously Integrated GaN on Si Photonic Integrated Circuits
Al, In, Ga, B)N Device Structures
Reduction in Leakage Current and Increase in Efficiency of III-Nitride MicroLEDs