High Efficiency LED with Optimized Photonic Crystal Extractor
Tech ID: 22789 / UC Case 2005-198-0

BRIEF DESCRIPTION

New LED structures that provide increased light extraction efficiency while retaining a planar structure.

BACKGROUND

As semiconductor materials have improved, the efficiency of semiconductor devices has also improved and new wavelength ranges have been used. Gallium nitride (GaN) based light emitters are probably the most promising for a variety of applications. GaN provides efficient illumination in the ultraviolet (UV) to amber spectrum, when alloyed with varying concentrates of indium (In), for example. Unfortunately, most of the light emitted within a semiconductor LED material is lost due to total internal reflection at the semiconductor-air interface. Typical semiconductor materials have a high index of refraction, and thus, according to Snell's law, most of the light will remain trapped in the materials, thereby degrading efficiency. By choosing a suitable geometry for the LED, a higher extraction efficiency can be achieved.

DESCRIPTION

Researchers at the University of California, Santa Barbara have developed new LED structures that provide increased light extraction efficiency while retaining a planar structure. The new LED structures provide direct emissions outside the structure and, in addition, convert guided light into extracted light using a diffraction grating. This grating may be placed outside the current-injected region of the active layer, or current may be injected into the grating region. Moreover, the diffraction grating is comprised of an array of holes, which may be pierced into the emitting species of the active layer, or only in other layers of the LED. The diffraction grating is a two-dimensional photonic crystal extractor, and the present invention provides improvements over previous implementations of photonic crystal extractors. The efficiency of the new LED structure is due to the fact that guided light is only (or mostly) emitted into guided modes that will be interacting with the photonic crystal, so that the many guided modes that are usually lost are diffracted outside the device. This is especially important in the case of an LED that supports numerous guided modes, such as a nitride-materials-based LED (which usually has to be several microns thick due to material growth considerations). The new LED structure retains a planar single layer structure making it easily manufacturable at low cost.

ADVANTAGES

▶ Increased light extraction efficiency
▶ Lower manufacturing costs

APPLICATIONS

▶ LED manufacturing

This technology is available for licensing.

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>7,582,910</td>
<td>09/01/2009</td>
<td>2005-198</td>
</tr>
</tbody>
</table>
ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- Method for Improved Surface of (Ga,Al,In,B)N Films on Nonpolar or Semipolar Substrates
- Enhanced Optical Polarization of Nitride LEDs by Increased Indium Incorporation
- Vertical Cavity Surface-Emitting Lasers with Continuous Wave Operation
- Low-Cost Zinc Oxide for High-Power-Output, GaN-Based LEDs (UC Case 2010-183)
- 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
- Photonic Structures for Efficient Light Extraction and Conversion in Multi-Color LEDs
- Highly Efficient Blue-Violet III-Nitride Semipolar Laser Diodes
- Hybrid Growth Method for Improved III-Nitride Tunnel Junction Devices
- Volumetric Hole Injection with Intentional V-Defects
- Low Temperature Deposition of Magnesium Doped Nitride Films
- Transparent Mirrorless (TML) LEDs
- 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
- Size-Independent Forward Voltage Micro-LED with an Epitaxial Junction
- Method for Enhancing Growth of Semipolar Nitride Devices
- III-Nitride Tunnel Junction with Modified Interface
- Improved Fabrication of Nonpolar InGaN Thin Films, Heterostructures, and Devices
- Growth of High-Quality, Thick, Non-Polar M-Plane GaN Films
- 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
- Incorporating Temperature-Sensitive Layers in III-N Devices
- Oxyfluoride Phosphors for Use in White Light LEDs
- Technique for the Nitride Growth of Semipolar Thin Films, Heterostructures, and Semiconductor Devices
- (In,Ga,AI)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
- Heterogeneously Integrated GaN on Si Photonic Integrated Circuits
- Reduction in Leakage Current and Increase in Efficiency of III-Nitride MicroLEDS
- Methods for Fabricating III-Nitride Tunnel Junction Devices
- Low-Droop LED Structure on GaN Semi-polar Substrates
- Contact Architectures for Tunnel Junction Devices
- GaN Interlayer Design to Fully Eliminate V-Pits from InGaN Pseudo-Substrates
- Semi-polar LED/LD Devices on Relaxed Template with Misfit Dislocation at Hetero-interface
- Photoelectrochemical Etching Of P-Type Semiconductor Heterostructures
- Semipolar-Based Yellow, Green, Blue LEDs with Improved Performance
- Growth of Semipolar III-V Nitride Films with Lower Defect Density
- III-Nitride Tunnel Junction LED with High Wall Plug Efficiency
- Improved Manufacturing of Solid State Lasers via Patternning of Photonic Crystals
- Solid Solution Phosphors for Use in Solid State White Lighting Applications
- 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
- High Light Extraction Efficiency III-Nitride LED
- III-V Nitride Device Structures on Patterned Substrates
- Activation of P-Type Layers of Tunnel Junctions in Micro-LEDs
- Hexagonal Wurtzite Type Epitaxial Layer with a Low Alkali-Metal Concentration
- Method for Increasing GaN Substrate Area in Nitride Devices
Nitride Based Ultraviolet LED with an Ultraviolet Transparent Contact
Growth of Planar, Non-Polar, A-Plane GaN by Hydride Vapor Phase Epitaxy
Single or Multi-Color High Efficiency LED by Growth Over a Patterned Substrate
GaN-Based Thermoelectric Device for Micro-Power Generation
Limiting Strain-Relaxation in III-Nitride Heterostructures by Substrate Patterning
Improved Manufacturing of Semiconductor Lasers
LED Device Structures with Minimized Light Re-Absorption
Growth of Planar Semi-Polar Gallium Nitride
Nonpolar (Al, B, In, Ga)N Quantum Well Design
UV Optoelectronic Devices Based on Nonpolar and Semi-polar AlInN and AlInGaN Alloys
Defect Reduction of Non-Polar and Semi-Polar III-Nitrides
Low-Cost Zinc Oxide for High-Power-Output, GaN-Based LEDs (UC Case 2010-150)
Suppression of Defect Formation and Increase in Critical Thickness by Silicon Doping
Wafer Bonding for Embedding Active Regions with Relaxed Nanofeatures
Enhancing Growth of Semipolar (Al,In,Ga,B)N Films via MOCVD