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>
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<tr>
<td>United States Of America</td>
<td>Issued Patent</td>
<td>7,582,910</td>
<td>09/01/2009</td>
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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
- 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
- Growth of Planar Semi-Polar Gallium Nitride
- Photonic Structures for Efficient Light Extraction and Conversion in Multi-Color LEDs
- Defect Reduction of Non-Polar and Semi-Polar III-Nitrides
- MOCVD Growth of Planar Non-Polar M-Plane Gallium Nitride
- Low Temperature Deposition of Magnesium Doped Nitride Films
- Improved Manufacturing of Solid State Lasers via Patterning of Photonic Crystals
- Single or Multi-Color High Efficiency LED by Growth Over a Patterned Substrate
- Packaging Technique for the Fabrication of Polarized Light Emitting Diodes
- LED Device Structures with Minimized Light Re-Absorption
- (In,Ga,AI)N Optoelectronic Devices with Thicker Active Layers for Improved 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
- 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
- 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)
- Method for Increasing GaN Substrate Area in Nitride Devices
- 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
- Technique for the Nitride Growth of Semipolar Thin Films, Heterostructures, and Semiconductor Devices
- 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,AI,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

Methods for Fabricating III-Nitride Tunnel Junction Devices

Reduction in Leakage Current and Increase in Efficiency of III-Nitride MicroLEDs

Vertical Cavity Surface-Emitting Lasers with Continuous Wave Operation

Wafer Bonding for Embedding Active Regions with Relaxed Nanostructures

Heterogeneously Integrated GaN on Si Photonic Integrated Circuits

Retaining Injection Efficiency and Optical Properties of Laser Diodes with Built-in Polarization Fields

Laser Diode With Tunnel Junction Contact Surface Grating

III-Nitride Tunnel Junction LED with High Wall Plug Efficiency