A Wafer-Scale, Low Defect Density Strain Relaxed Template for III-Nitride-Based High Efficiency and High-Power Devices

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BACKGROUND

The bandgap of InGaN-based III-nitride alloys span across a wide range, and they are promising for applications in electronic and optoelectronic devices. The wide spectrum from visible to NIR of InGaN-based emitters can serve as the light source for atomic clocks and atom cooling and trapping. Additionally, integration of III-Nitride LDs with photonic circuit platforms can enable chip-scale optics system, including optical clocks, imaging and sensing, quantum computing, and more. However, there is a large lattice mismatch in this material system. This mismatch causes high strain for InGaN grown on GaN, resulting in generation of dislocations and degradation of surface morphology. The high threading dislocation density (TDD) generated from the large lattice mismatch serves as non-radiative recombination center, causing a drastic degradation in quantum efficiency as well as device lifetime. All these issues hinder the development of InGaN-based emitters, and it is therefore critical to address the high strain issues.

DESCRIPTION

Researchers at the University of California, Santa Barbara have devised a novel method of producing a wafer-scale, low defect density, strain relaxed template (SRT) for III-nitride-based devices. By utilizing a thin, highly defective III-nitride decomposition layer beneath a strain relaxed layer, followed by patterned etching and regrowth via lateral overgrowth, this approach dramatically reduces threading dislocation density and strain across large wafer areas. The method uniformly relaxes strain while maintaining low defect densities, enabling high efficiency and longer lifetime for devices such as LEDs, laser diodes (LDs), field effect transistors (FETs), and heterostructure FETs. Compared to prior approaches, it offers uniform relaxation over an entire wafer without limiting usable device area, solving longstanding issues related to lattice mismatch and strain-induced defects in InGaN-based materials.

ADVANTAGES

- Uniform strain relaxation across wafer-scale substrates (2 inches or larger)
- Significantly reduced threading dislocation density to near substrate levels
- Enables growth of high indium composition InGaN layers with fewer compositional pulling effects
- Improved surface morphology and reduced cracks
- Full wafer usability due to uniform strain relaxation and lateral overgrowth coalescence
- Longer device lifetimes owing to reduced non-radiative recombination and carrier leakage

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OTHER INFORMATION

KEYWORDS

LEDs, LDs, laser diodes, light-emitting diodes, field effect transistors, FETs, strain relaxed template, SRTs, wafer-scale, III-nitride-based devices

CATEGORIZED AS

- **Optics and Photonics**
  - All Optics and Photonics
- **Semiconductors**
  - Other

RELATED CASES

2024-849-0

- Highly suitable for scalable, cost-effective industrial production

APPLICATIONS

- High efficiency and high power light-emitting diodes (LEDs) spanning visible to near-infrared spectrum
- Laser diodes (LDs) for blue, green, red, and near-infrared applications including displays and sensing
- Field effect transistors (FETs) and heterostructure FETs for high-power electronics
- Photonic integrated circuits enabling chip-scale optical systems such as optical clocks, quantum computing, and imaging
- Quantum technology devices requiring stable and efficient III-nitride light sources

PATENT STATUS

Country	Type	Number	Dated	Case
Patent Cooperation Treaty	Reference for National Filings	WO 2025/090893	05/01/2025	2024-849

Patent Pending

ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- Vertical Cavity Surface-Emitting Lasers with Continuous Wave Operation
- 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
- III-Nitride Tunnel Junction LED with High Wall Plug Efficiency
- Novel Multilayer Structure for High-Efficiency UV and Far-UV Light-Emitting Devices
- A Method To Lift-Off Nitride Materials With Electrochemical Etch
- Activation of P-Type Layers of Tunnel Junctions in Micro-LEDs
- 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
- 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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