Methods to Produce and Recycle Substates for III-Nitride Materials with Electrochemical Etching

Tech ID: 34554 / UC Case 2025-357-0

BACKGROUND

The substrate market for the III-N material system has been expanding for decades across optoelectronic and power electronics for both research and industry, and there is a need for new methods of producing high-quality III-nitride substrate and for ways to recycle III-nitride substrates for direct regrowth. Single crystal bulk GaN is mainly grown with three methods: liquid phase, metal-organic chemical vapor deposition, and hydride vapor phase epitaxy (HVPE). Because the growth rate of HVPE is almost 10 times faster than MOCVD and 50 times faster than the liquid phase method, HVPE grown bulk GaN substrates dominate the current market. Most bulk GaN growth techniques rely on foreign substrates, such as sapphire, GaAs, and SiC. Due to the lattice mismatch between these substrates and free-standing GaN, direct HVPE deposition can introduce a high density of defects, resulting in increased threading dislocation density (TDD) and exacerbating wafer bowing when the GaN crystal thickness exceeds a few millimeters. To address these challenges, methods like epitaxial lateral overgrowth (ELOG) and the development of free-standing GaN layers are commonly used to reduce TDD and relieve accumulated stress in GaN layers.

However, bulk GaN substrate fabricated by ELOG techniques has limitations. Since III-N materials do not readily grow on SiO2 or SiN hard masks used in ELOG, this technique promotes lateral growth over the mask regions, allowing partial relaxation of the bulk GaN and effectively reducing TDD during this phase. Although the enhanced crystal quality by ELOG strengthens the market appeal of bulk GaN substrates, this growth process requires extra time and expenses on fabrication. Additionally, crystal bowing is a persistent challenge, primarily due to the off-angle distribution during the GaN coalescence process using ELOG, which limits the crystal's achievable thickness due to accumulated stress and the potential for microcracks after laser lift-off.

DESCRIPTION

Researchers at the University of California, Santa Barbara have combined electrochemical etching with hydride vapor phase epitaxy (HVPE) growth, enabling high-quality production and recycling of III-nitride substrates with minimized wafer bowing and off-angle distribution. This innovative technology introduces advanced methods for producing and recycling III-nitride substrates by integrating electrochemical etching of highly doped n-type sacrificial layers with fast (HVPE). It addresses critical issues in substrate fabrication, such as wafer bowing, off-angle distribution, and costly polishing steps. By enabling 100% detachment in selected regions and producing a smooth, epi-ready surface for direct regrowth, these methods enhance crystal quality and allow for thicker, defect-reduced substrates. The approach

CONTACT

Pasquale S. Ferrari
ferrari@tia.ucsb.edu
tel: .

INVENTORS

- Bi, Hanyu
- DenBaars, Steven P.
- Iza, Michael
- Nakamura, Shuji
- Yao, Yifan

OTHER INFORMATION

KEYWORDS

LEDs, light-emitting diodes, LDs, laser diodes, hydride vapor phase epitaxy, III-nitride substrates

CATEGORIZED AS

- Optics and Photonics
- All Optics and Photonics

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also offers substrate recycling solutions that significantly reduce costs by reusing expensive buffer and mask materials while maintaining surface quality suitable for immediate device fabrication.

ADVANTAGES

• Enables complete and selective substrate detachment, reducing wafer bowing and structural stress

• Produces smooth, epi-ready surfaces that eliminate additional polishing, lowering processing time and costs

• Facilitates recycling of high-cost substrates and buffer layers, improving economic efficiency

• Minimizes material loss from slicing and polishing, saving resources and expenses

• Supports bonding of fully relaxed III-nitride materials onto foreign substrates for heterogeneous integration

• Improves crystal quality through reduction of threading dislocation density and off-angle variation

APPLICATIONS

• Production of high-quality III-nitride substrates for optoelectronic devices including LEDs and laser diodes

• Power electronics manufacturing requiring thick, low-defect GaN substrates

• Recycling and reuse of substrates and buffer layers to reduce semiconductor fabrication costs

• Heterogeneous integration of III-nitride materials on diverse foreign substrates for new device platforms

• Research and development in semiconductor material growth and epitaxial layer optimization

PATENT STATUS

Country	Type	Number	Dated	Case
Patent Cooperation Treaty	Published Application	2023/168139	09/07/2023	2025-357

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

University of California, Santa Barbara
Office of Technology & Industry Alliances
342 Lagoon Road, ,Santa Barbara,CA 93106-2055 |
https://www.tia.ucsb.edu
Tel: 805-893-2073 | Fax: 805.893.5236 | padilla@tia.ucsb.edu