Control of Photoelectrochemical (PEC) Etching by Modification of the Local Electrochemical Potential of the Semiconductor Structure

Tech ID: 22656 / UC Case 2005-207-0

BRIEF DESCRIPTION

A method for locally controlling an electrical potential of a semiconductor structure or device, and thus locally controlling lateral and/or vertical photoelectrochemical (PEC) etch rates.

BACKGROUND

PEC etching uses above-bandgap illumination to generate carriers (specifically holes) needed to etch III-nitrides. The electrochemical potential of the semiconductor material surface relative to the electrolyte causes holes to be drawn toward the semiconductor-electrolyte interface in n-type (unintentionally-doped or doped) material, allowing them to participate in the electrochemical reactions necessary for material removal. Because the etching mechanism relies heavily on the absorption of incident light and the electrochemical potential of the semiconductor material relative to the electrolyte, PEC etching can be defect-selective, dopant-selective, and bandgap-selective. Most applications of PEC etching have pertained to vertical etching of the material, either through direct illumination of the material surface, or by illumination through a masking layer. However, specific descriptions of local control of the etch process through modifications of the electrochemical component of etching have not been presented. Previously published and patented techniques that apply to III-nitride PEC etching suffer from certain limitations.

DESCRIPTION

This invention describes a scheme for fabricating III-nitride semiconductor structures wherein a highly selective photo-induced etch is achieved through strategic modification of the local electrochemical potential of the semiconductor structure relative to the electrolyte. This is accomplished through:

- The suitable placement of electrically resistive (unintentionally-doped, doped, alloyed) or electron-blocking layers in the semiconductor structure.
- The selective placement of the cathode in PEC etching, wherein the cathode acts as a "channel" for the controlled collection of photo-generated electrons from the semiconductor layers with which it is in contact.
- The use of a suitable light source during PEC etching, which enables the photo-generation of electrons and holes in layers with bandgap energies lower than the energy of the incident light. The etch will not proceed without photo-induced carriers. The light source may be a laser or a broad-spectrum source with/without a filter.
- The use of a suitable electrolyte solution during PEC etching, wherein the concentration and type of electrolyte determines the etch rate and etch selectivity.

ADVANTAGES

PEC etching is a viable method for producing specific geometries in the III-nitride material system, forming three-dimensional structures that would be extremely challenging to produce with gas-phase etching processes or more standard wet chemical etching. The existence of a controlled three-dimensional etch process can give rise to numerous useful device geometries. Specifically, an undercut geometry is desirable in several applications including but not limited to microdisk resonators, air-gap DBRs, semiconductor membranes and cantilevers, electrical and optical apertures, and in substrate removal.

APPLICATIONS

- Bandgap-selective lateral etching

PATENT STATUS

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<th>Country</th>
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ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- Backside-Illuminated Photoelectrochemical (Bipec) Etching
- 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
- Improved Manufacturing of Semiconductor Lasers
- Cleaved Facet Edge-Emitting Laser Diodes Grown on Semipolar GaN
- Enhancing Growth of Sempoliar (Al,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
Method for Growing High-Quality Group III-Nitride Crystals
Growth of Planar Semi-Polar Gallium Nitride
MOCVD Growth of Planar Non-Polar M-Plane Gallium Nitride
Lateral Growth Method for Defect Reduction of Semipolar Nitride Films
Low Temperature Deposition of Magnesium Doped Nitride Films
Growth of Polyhedron-Shaped Gallium Nitride Bulk Crystals
Phosphor-Free White Light Source
Packaging Technique for the Fabrication of Polarized Light Emitting Diodes
LED Device Structures with Minimized Light Re-Absorption
III-V Nitride Device Structures on Patterned Substrates
Growth of Semipolar III-V Nitride Films with Lower Defect Density
Improved GaN Substrates Prepared with Ammonothermal Growth
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
Photoelectrochemical Etching for Chip Shaping Of LEDs
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
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)
Nonpolar III-Nitride LEDs With Long Wavelength Emission
Method for Increasing GaN Substrate Area in Nitride Devices
Flexible Arrays of MicroLEDs using the Photoelectrochemical (PEC) Liftoff 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
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,Al,In,Ni,B)N Films on Nonpolar or Semipolar Substrates
Improved Anisotropic Strain Control in Semipolar Nitride Devices
III-Nitride Tunnel Junction with Modified Interface
Hybrid Growth Method for Improved III-Nitride Tunnel Junction Devices
Contact Architectures for Tunnel Junction Devices
Internal Heating for Ammonothermal Growth of Group-III Nitride Crystals
Methods for Fabricating III-Nitride Tunnel Junction Devices
Multifaceted III-Nitride Surface-Emitting Laser
Vertical Cavity Surface-Emitting Lasers with Continuous Wave Operation
Efficient Implementation of a Tunnel Junction Contact on a Nitride-Based Edge-Emitting Laser Diode
Heterogeneously Integrated GaN on Si Photonic Integrated Circuits
Distributed Feedback Laser with Transparent Conducting Oxide Grating