Group III-nitride thin films grown using MBE and bismuth

Patent Number: US6139629
Publication date: 2000-10-31
Inventor(s): KISIELOWSKI CHRISTIAN K (US); RUBIN MICHAEL (US)
Applicant(s):: UNIV CALIFORNIA (US)
Requested Patent: ☐ US6139629
Application Number: US19980055064 19980403
Priority Number(s): US19980055064 19980403; US19970043042P 19970403
IPC Classification: C30B23/06
EC Classification:
Equivalents:

Abstract

The present invention comprises growing gallium nitride films in the presence of bismuth using MBE at temperatures of about 1000 K or less. The present invention further comprises the gallium nitride films fabricated using the inventive fabrication method. The inventive films may be doped with magnesium or other dopants. The gallium nitride films were grown on sapphire substrates using a hollow anode Constricted Glow Discharge nitrogen plasma source. When bismuth was used as a surfactant, two-dimensional gallium nitride crystal sizes ranging between 10 mu m and 20 mu m were observed. This is 20 to 40 times larger than crystal sizes observed when GaN films were grown under similar circumstances but without bismuth. It is thought that the observed increase in crystal size is due bismuth inducing an increased surface diffusion coefficient for gallium. The calculated value of 4.7x10-7 cm2/sec. reveals a virtual substrate temperature of 1258 K which is 260 degrees higher than the actual one.

Method of forming gallium nitride crystal

Patent Number: US6139628

Publication date: 2000-10-31

Inventor(s): YURI MASAAKI (JP); BABA TAKAAKI (US); UEDA TETSUZO (US)

Applicant(s):: MATSUSHITA ELECTRONICS CORP (JP)

Requested Patent: US6139628

Application Number: US19980056622 19980408

Priority Number(s): JP19970090673 19970409

IPC Classification: C30B25/04

EC Classification:

Equivalents: CN1201081, JP10287496

Abstract

The method of forming gallium nitride crystal comprises the following three steps: the first step of heating a silicon substrate 1 in gas atmosphere including gallium, the second step of forming the first gallium nitride 3 on the silicon substrate 1, the third step of forming the second gallium nitride 4 on the first gallium nitride 3 at the higher temperature than when the first gallium nitride 3 has been formed. The method including these three steps can produce a thick film crystal of gallium nitride having excellent flatness and crystallinity.

Method for the preparation and doping of highly insulating monocrystalline gallium nitride thin films

Patent Number: US6123768
Publication date: 2000-09-26
Inventor(s): MOUSTAKAS THEODORE D (US)
Applicant(s):: UNIV BOSTON (US)
Requested Patent: ☐ US6123768
Application Number: US19960644576 19960510
Priority Number(s): US19960644576 19960510; US19950372113 19950113; US19930113964 19930830; US19910670692 19910318
IPC Classification: C03B25/14
EC Classification:
Equivalents:

Abstract

This invention relates to a method of preparing highly insulating GaN single crystal films in a molecular beam epitaxial growth chamber. A single crystal substrate is provided with the appropriate lattice match for the desired crystal structure of GaN. A molecular beam source of Ga and source of activated atomic and ionic nitrogen are provided within the growth chamber. The desired film is deposited by exposing the substrate to Ga and nitrogen sources in a two step growth process using a low temperature nucleation step and a high temperature growth step. The low temperature process is carried out at 100-400 DEG C. and the high temperature process is carried out at 600-900 DEG C. The preferred source of activated nitrogen is an electron cyclotron resonance microwave plasma.

Method for manufacturing gallium nitride compound semiconductor

Patent Number: US6121121
Publication date: 2000-09-19
Inventor(s): KOIDE NORIKATSU (JP)
Applicant(s):: TOYODA GOSEI KK (JP)
Requested Patent: US6121121
Application Number: US19990361624 19990727
Priority Number(s): US19990361624 19990727
IPC Classification: H01L21/20
EC Classification:
Equivalents:

Abstract

An Al0.15Ga0.85N layer 2 is formed on a silicon substrate 1 in a striped or grid pattern. A GaN layer 3 is formed in regions A where the substrate 1 is exposed and in regions B which are defined above the layer 2. At this time, the GaN layer grows epitaxially and three-dimensionally (not only in a vertical direction but also in a lateral direction) on the Al0.15Ga0.85N layer 2. Since the GaN layer grows epitaxially in the lateral direction as well, a GaN compound semiconductor having a greatly reduced number of dislocations is obtained in lateral growth regions (regions A where the substrate 1 is exposed).

Method for fabricating semiconductor device having group III nitride

Patent Number: US6117700
Publication date: 2000-09-12
Inventor(s): ORITA KENJI (JP); ISHIDA MASAHIRO (JP); NAKAMURA SHINJI (JP); YURI MASAAKI (JP)
Applicant(s):: MATSUSHITA ELECTRONICS CORP (JP)
Requested Patent: ☐ US6117700
Application Number: US19990389024 19990902
Priority Number(s): JP19980254996 19980909; JP19980326352 19981117
IPC Classification: H01L21/00
EC Classification:
Equivalents:

Abstract

First, n-type contact layer of GaN, n-type cladding layer of AlGaN, active layer of InGaN, first Mg-doped layer of AlGaN and second Mg-doped layer of GaN are grown in this order over a sapphire substrate. Thereafter, the substrate, including the second Mg-doped layer, is exposed to nitrogen plasma for about 40 minutes. As a result, Mg, which has been introduced into the first and second Mg-doped layers, is activated as an acceptor. Thus, p-type cladding layer and p-type contact layer with low resistance and excellent crystallinity can be formed out of the first and second Mg-doped layers, respectively.

Method for manufacturing an epitaxial wafer with a group III metal nitride epitaxial layer

Patent Number: US6110809
Publication date: 2000-08-29
Inventor(s): GUO JAN-DAR (TW); LAI WEI-CHI (TW); SZE SIMON M (TW); CHAN SHIH-HSIUNG (TW); TSANG JIAN-SHIHN (TW)
Applicant(s)::
Requested Patent: US6110809
Application Number: US19980102675 19980623
Priority Number(s): TW19980104571 19980326
IPC Classification: H01L21/20
EC Classification:
Equivalents:

Abstract

A new method for manufacturing a Group III metal nitride epitaxial wafer comprises providing a first nitrogen-contained gas source, providing a second Group III metal trichloride-containing gas source, and causing said first gas to react with second gas in a heating region, thereby forming a Group III metal nitride epitaxial layer on a substrate. The formed epitaxial wafer can serve as a substrate of a laser diode.

Method of crystal growth of a GaN layer over a GaAs substrate

Patent Number: US6096130

Publication date: 2000-08-01

Inventor(s): KIMURA AKITAKA (JP); NIDO MASAAKI (JP); SUNAKAWA HARUO (JP)

Applicant(s):: NIPPON ELECTRIC CO (JP)

Requested Patent: ☐ US6096130

Application Number: US19970824017 19970321

Priority Number(s): JP19960065644 19960322

IPC Classification: C30B25/14

EC Classification:

Equivalents: JP2925004B2, ☐ JP9255496

Abstract

A method of crystal growth of a GaN layer with an extremely high surface planarity over a GaAs substrate is provided, wherein a GaAs substrate is heated to a temperature in the range of 600 DEG C. to 700 DEG C. without supplying any group-V element including arsenic to form a Ga-rich surface on the GaAs substrate, before a first source material including N and a second source material including Ga are supplied along with a carrier gas onto a surface of the GaAs substrate to form a GaN layer over the GaAs substrate.

Gallium nitride-based III-V group compound semiconductor

Patent Number: US6093965

Publication date: 2000-07-25

Inventor(s): BANDO KANJI (JP); NAKAMURA SHUJI (JP); SENOH MASAYUKI (JP); YAMADA MOTOKAZU (JP); YAMADA TAKAO (JP)

Applicant(s):: NICHIA KAGAKU KOGYO KK (JP)

Requested Patent: ☐ US6093965

Application Number: US19980209826 19981211

Priority Number(s): US19980209826 19981211; JP19930124890 19930428; JP19930129313 19930531; JP19930207274 19930728; JP19930234684 19930921; JP19930234685 19930921; JP19930253171 19931008; JP19940008726 19940128; JP19940008727 19940128; US19970995167 19971219; US19960670242 19960617; US19940234001 19940428

IPC Classification: H01L29/78

EC Classification: H01L33/00B4, H01L33/00B4B

Equivalents:

Abstract

A gallium nitride-based III-V Group compound semiconductor device has a gallium nitride-based III-V Group compound semiconductor layer provided over a substrate, and an ohmic electrode provided in contact with the semiconductor layer. The ohmic electrode is formed of a metallic material, and has been annealed.

Process for producing high-quality III-V nitride substrates

Patent Number: US6086673
Publication date: 2000-07-11
Inventor(s): MOLNAR RICHARD J (US)
Applicant(s):: MASSACHUSETTS INST TECHNOLOGY (US)
Requested Patent: ☐ US6086673
Application Number: US19980054097 19980402
Priority Number(s): US19980054097 19980402
IPC Classification: C30B25/16
EC Classification:
Equivalents:

Abstract

Provided is a method for producing a nitride layer on a growth substrate. First a pretreatment layer is formed on the growth substrate, and then the formed pretreatment layer is exposed to a gaseous environment that is thermochemically reactive with the pretreatment layer. After gaseous environment exposure of the pretreatment layer, there is carried out an epitaxial growing process to produce on the substrate a nitride layer material defined as InxGayAl1-x-yN, where 0 The growth substrate can include a plane of mechanical weakness that is parallel with a predominant nitride growth surface of the substrate, and that is either inherently exhibited by the substrate or that is produced by processing of the substrate. Similarly, an interlayer of material characterized by a plane of mechanical weakness parallel with the predominant nitride growth surface can be formed on the substrate, preferably after the pretreatment layer deposition and gaseous environment exposure steps.

Separation of thin films from transparent substrates by selective optical processing

Patent Number: US6071795
Publication date: 2000-06-06
Inventor(s): CHEUNG NATHAN W (US); SANDS TIMOTHY D (US); WONG WILLIAM S (US)
Applicant(s):: UNIV CALIFORNIA (US)
Requested Patent: ☐ US6071795
Application Number: US19980012829 19980123
Priority Number(s): US19980012829 19980123
IPC Classification: H01L21/302
EC Classification:
Equivalents:

Abstract

A method of separating a thin film of GaN epitaxially grown on a sapphire substrate. The thin film is bonded to an acceptor substrate, and the sapphire substrate is laser irradiated with a scanned beam at a wavelength at which sapphire is transparent but the GaN is strongly absorbing, e.g., 248 nm. After the laser irradiation, the sample is heated above the melting point of gallium, i.e., above 30 DEG C., and the acceptor substrate and attached GaN thin film are removed from the sapphire growth substrate. If the acceptor substrate is flexible, the GaN thin film can be scribed along cleavage planes of the GaN, and, when the flexible substrate is bent, the GaN film cleaves on those planes. Thereby, GaN lasers and other electronic and opto-electronic devices can be formed.

Method of growing group III nitride semiconductor crystal layer and semiconductor device incorporating group III nitride semiconductor crystal layer

Patent Number: US6069021

Publication date: 2000-05-30

Inventor(s): TSUZAKI TAKUJI (JP); UDAGAWA TAKASHI (JP); NISHIMURA SUZUKA (JP); TERASHIMA KAZUTAKA (JP)

Applicant(s):: SHOWA DENKO KK (JP)

Requested Patent: US6069021

Application Number: US19990270749 19990317

Priority Number(s): JP19980066769 19980317; JP19980180921 19980626; JP19980193125 19980708; JP19980232279 19980804; JP19990036830 19990216

IPC Classification: H01L21/20

EC Classification: H01L33/00G3B2, H01L21/20B6B6

Equivalents:

Abstract

A method of growing a group III nitride semiconductor crystal layer includes a step of growing a first buffer layer composed of boron phosphide on a silicon single crystal substrate by a vapor phase growth method at a temperature of not lower than 200 DEG C. and not higher than 700 DEG C., a step of growing a second buffer layer composed of boron phosphide on the first buffer layer by a vapor phase growth method at a temperature of not lower than 750 DEG C. and not higher than 1200 DEG C., and a step of growing a crystal layer composed of group III nitride semiconductor crystal represented by general formula AlpGaqInrN (where 0

Formation of group III-V nitride films on sapphire substrates with reduced dislocation densities

Patent Number: US6064078
Publication date: 2000-05-16
Inventor(s): BRINGANS ROSS D (US); NORTHRUP JOHN E (US); ROMANO LINDA T (US)
Applicant(s):: XEROX CORP (US)
Requested Patent: US6064078
Application Number: US19980083137 19980522
Priority Number(s): US19980083137 19980522
IPC Classification: H01L33/00 ; H01L21/20
EC Classification:
Equivalents:

Abstract

A single layer of atoms of a selected valence is deposited between a substrate and a group III-V nitride film to improve the quality of the nitride film and of subsequently deposited nitride films on the substrate. The interlayer provides local charge neutrality at the interface, thereby promoting two-dimensional growth of the nitride film and reduced dislocation densities. When the substrate is sapphire, the interlayer should include atoms of group II elements and possibly group III elements. The structure can include a group III-V nitride buffer layer on the interlayer to further enhance the quality of the group III-V nitride films. The structures can be used in blue light emitting optoelectronic devices.

Gallium nitride semiconductor structures including a lateral gallium nitride layer that extends from an underlying gallium nitride layer

Patent Number: US6051849

Publication date: 2000-04-18

Inventor(s): NAM OK-HYUN (KR); BREMSER MICHAEL D (US); ZHELEVA TSVETANKA (US); DAVIS ROBERT F (US)

Applicant(s):: UNIV NORTH CAROLINA (US)

Requested Patent: ☐ US6051849

Application Number: US19980032190 19980227

Priority Number(s): US19980032190 19980227

IPC Classification: H01V33/00

EC Classification: H01L21/20B6B4, H01L33/00G3B2

Equivalents:

Abstract

A gallium nitride semiconductor layer is fabricated by masking an underlying gallium nitride layer with a mask that includes an array of openings therein, and growing the underlying gallium nitride layer through the array of openings and onto the mask, to thereby form an overgrown gallium nitride semiconductor layer. Although dislocation defects may propagate vertically from the underlying gallium nitride layer to the grown gallium nitride layer through the mask openings, the overgrown gallium nitride layer is relatively defect free. The overgrown gallium nitride semiconductor layer may be overgrown until the overgrown gallium nitride layer coalesces on the mask, to form a continuous overgrown monocrystalline gallium nitride semiconductor layer. The gallium nitride semiconductor layer may be grown using metalorganic vapor phase epitaxy. Microelectronic devices may be formed in the overgrown gallium nitride semiconductor layer.

Integrated heterostructures of group III-V nitride semiconductor materials including epitaxial ohmic contact comprising multiple quantum well

Patent Number: US6046464

Publication date: 2000-04-04

Inventor(s): SCHETZINA JAN FREDERICK (US)

Applicant(s):: UNIV NORTH CAROLINA (US)

Requested Patent: ☐ US6046464

Application Number: US19970910891 19970813

Priority Number(s): US19970910891 19970813; US19950412971 19950329

IPC Classification: H01L33/00 ; H01L31/0328 ; H01L31/0336 ; H01L31/072

EC Classification:

Equivalents:

Abstract

An integrated heterostructure of Group III-V nitride compound semiconductors is formed on a multicomponent platform which includes a substrate of monocrystalline silicon carbide and a non-nitride buffer layer of monocrystalline zinc oxide. The zinc oxide may be formed by molecular beam epitaxy (MBE) using an MBE effusion cell containing zinc, and a source of atomic oxygen, such as an MBE-compatible oxygen plasma source which converts molecular oxygen into atomic oxygen. An ohmic contact for a semiconductor device formed of Group III-V nitride compound semiconductor materials including a layer of aluminum nitride or aluminum gallium nitride, includes a continuously graded layer of aluminum gallium nitride and a layer of gallium nitride or an alloy thereof on the continuously graded layer. The continuously graded layer eliminates conduction or valence band offsets. A multiple quantum well may also be used instead of the continuously graded layer where the thickness of the layers of gallium nitride increase across the multiple quantum well. The ohmic contacts may be used for Group III-V nitride laser diodes, light emitting diodes, electron emitters, bipolar transistors and field effect transistors.

Group III-V type nitride semiconductor device

Patent Number: US6043514
Publication date: 2000-03-28
Inventor(s): TERAGUCHI NOBUAKI (JP)
Applicant(s):: SHARP KK (JP)
Requested Patent: ☐ US6043514
Application Number: US19980022642 19980212
Priority Number(s): JP19970043179 19970227
IPC Classification: H01L33/00
EC Classification: H01L33/00G3B2
Equivalents: ☐ JP10242579

Abstract

A group III-V type nitride semiconductor device includes a substrate with a crystal structure of rutile type, CaC2 type, rock salt type, spinel type, NaFeO2(II) type or LiAlO2(I) type, and a nitride semiconductor layer epitaxially grown thereon. The substrate is selected so that its lattice constant allows good lattice match with respect to the nitride semiconductor layer, or the substrate is adjusted in composition to have such a lattice constant.

Method for growing a nitride compound semiconductor

Patent Number: US6043140
Publication date: 2000-03-28
Inventor(s): NAKAMURA FUMIHIKO (JP); KAWAI HIROJI (JP); ASATSUMA TSUNENORI (JP)

Applicant(s):: SONY CORP (JP)
Requested Patent: ☐ US6043140
Application Number: US19970867964 19970603
Priority Number(s): JP19960177042 19960617
IPC Classification: H01L21/04
EC Classification:
Equivalents: ☐ JP10004211

Abstract

A new and improved method for growing a p-type nitride III-V compound semiconductor is provided which can produce a p-type nitride compound semiconductors having a high carrier concentration, without the need for annealing to activate impurities after growth. In a preferred embodiment, a p-type nitride compound semiconductor, such as p-type GaN, is grown by metal organic chemical vapor deposition methods using a nitrogen source material which does not release hydrogen during release of nitrogen and the semiconductor is grown in an inactive gas. The nitrogen source materials may be selected from nitrogen compounds that contain hydrogen radicals and alkyl radicals and/or phenyl radicals provided that the total amount of hydrogen radicals is less than or equal to the sum total of alkyl radicals and phenyl radicals present in the nitrogen compound used as the nitrogen source material.

Growth of GaN layers on quartz substrates

Patent Number: US6033490
Publication date: 2000-03-07
Inventor(s): IZUMI KOICHI (JP); KIMURA AKITAKA (JP); SASAOKA CHIAKI (JP)
Applicant(s):: NIPPON ELECTRIC CO (JP)
Requested Patent: US6033490
Application Number: US19980145465 19980902
Priority Number(s): JP19970237167 19970902
IPC Classification: H01L21/20
EC Classification: H01L21/20B4, C30B25/02, H01L21/205C3
Equivalents: JP11079897, JP3094965B2

Abstract

In a method of manufacturing a semiconductor device which includes a quartz substrate having a z-cut plane of (0001) plane on a surface, a GaN film is first deposited on the surface. Finally, the quartz substrate is removed from the GaN film. The removed GaN film is used as a real substrate for forming GaN based compound semiconductor layers thereon.

Epitaxial wafer and method of preparing the same

Patent Number: US6031252

Publication date: 2000-02-29

Inventor(s): MATSUSHIMA MASATO (JP); MIURA YOSHIKI (JP); KOUKITU AKINORI (JP); MOTOKI KENSAKU (JP); OKAHISA TAKUJI (JP); SEKI HISASHI (JP); SHIMAZU MITSURU (JP)

Applicant(s):: SUMITOMO ELECTRIC INDUSTRIES (JP)

Requested Patent: ☐ US6031252

Application Number: US19960705330 19960829

Priority Number(s): JP19950257070 19950908

IPC Classification: H01L33/00

EC Classification: H01L33/00G3C, H01L21/20B6B4

Equivalents: ☐ JP9083017, KR243623

Abstract

An epitaxial wafer enabling epitaxial growth at a high temperature includes a compound semiconductor substrate containing As or P, and a covering layer including GaN; or InN; or AlN; or a nitride mixed-crystalline material containing Al, Ga, In and N. The covering layer covers at least a front surface and a back surface of the substrate. A method of preparing such an epitaxial wafer including steps of growing the covering layer at a growth temperature of at least 300 DEG C. and less than 800 DEG C. so as to cover at least the front and back surfaces of the substrate, and then annealing the substrate having the covering thereon layer at a temperature of at least 700 DEG C. and less than 1200 DEG C.

Method for producing group III-V compound semiconductor and fabricating light emitting device using such semiconductor

Patent Number: US6017774
Publication date: 2000-01-25
Inventor(s): INOGUCHI KAZUHIKO (JP); YUASA TAKAYUKI (JP)
Applicant(s):: SHARP KK (JP)
Requested Patent: US6017774
Application Number: US19960774056 19961223
Priority Number(s): JP19950341880 19951227; JP19950344223 19951228
IPC Classification: H01L21/20
EC Classification: H01L21/205C, C30B25/02, H01L33/00G3B2
Equivalents:

Abstract

The present invention provides a method for producing a group III-V compound semiconductor including nitrogen as a group V element by an organometallic vapor phase growth method. An organometallic as a group III material, an amine type material or ammonia as a group V material and an organic compound which is decomposed by heating so as to generate radicals are used to perform crystal growth.

Method for making cleaved facets for lasers fabricated with gallium nitride and other noncubic materials

Patent Number: US5985687
Publication date: 1999-11-16
Inventor(s): DENBAARS STEVEN P (US); BOWERS JOHN E (US); SINK R KEHL (US)
Applicant(s):: UNIV CALIFORNIA (US)
Requested Patent: US5985687
Application Number: US19960630675 19960412
Priority Number(s): US19960630675 19960412
IPC Classification: H01L21/00
EC Classification:
Equivalents:

Abstract

Optically flat cleaved facet mirrors are fabricated in GaN epitaxial films grown on sapphire by wafer fusing a GaN film with a sapphire substrate to a cubic substrate such as an InP or GaAs substrate. The sapphire substrate may then partially or entirely removed by lapping, dry etching, or wet etching away a sacrificial layer disposed in the interface between the sapphire substrate and the GaN layer. Thereafter, the cubic InP or GaN substrate is cleaved to produce the cubic crystal facet parallel to the GaN layer in which active devices are fabricated for use in lasers, photodetectors, light emitting diodes and other optoelectronic devices.

Semiconductor laminating structure

Patent Number: US5981980
Publication date: 1999-11-09
Inventor(s): BELLEGO YANN LE (JP); KAWAI HIROJI (JP); MIYAJIMA TAKAO (JP)
Applicant(s):: SONY CORP (JP)
Requested Patent: ☐ US5981980
Application Number: US19970839903 19970418
Priority Number(s): JP19960100350 19960422
IPC Classification: H01L33/00
EC Classification: H01L33/00G3B2, H01L29/201, H01L29/812, H01L33/00C2
Equivalents:

Abstract

To provide a semiconductor laminating structure in which an epitaxial growth of a GaN system material is achieved on a substrate with an excellent matching property with the substrate. The semiconductor laminating structure includes the substrate having a perovskite structure and at least one GaN system chemical compound semiconductor layer formed on the substrate, wherein a major surface of the substrate is formed of a (111) crystal surface.

Semiconductor devices constructed from crystallites

Patent Number: US5977612

Publication date: 1999-11-02

Inventor(s): CONNELL G A NEVILLE (US); BOUR DAVID P (US); BRINGANS ROSS D (US); GOETZ WERNER K (US); JOHNSON NOBLE M (US); ROMANO LINDA T (US); PONCE FERNANDO A (US)

Applicant(s):: XEROX CORP (US)

Requested Patent: ☐ US5977612

Application Number: US19960770403 19961220

Priority Number(s): US19960770403 19961220

IPC Classification: H01L29/06

EC Classification:

Equivalents: ☐ JP10190135

Abstract

The present invention relates to electronic devices formed in crystallites of III-V nitride materials. Specifically, the present invention simplifies the processing technology required for the fabrication of high-performance electronic devices in III-V nitride materials.

Method for growth of crystal surfaces and growth of heteroepitaxial single crystal films thereon

Patent Number: US5915194

Publication date: 1999-06-22

Inventor(s): LARKIN DAVID J (US); MATUS LAWRENCE G (US); NEUDECK PHILIP G (US); POWELL J ANTHONY (US)

Applicant(s):: US OF AMERICA AS REPRESENTED B (US)

Requested Patent: ☐ US5915194

Application Number: US19970887804 19970703

Priority Number(s): US19970887804 19970703

IPC Classification: H01L21/306

EC Classification:

Equivalents:

Abstract

A method of growing atomically-flat surfaces and high-quality low-defect crystal films of polytypic compounds heteroepitaxially on polytypic compound substrates that are different than the crystal film. The method is particularly suited for the growth of 3C-SiC, 2H-AlN, and 2H-GaN on 6H-SiC.

Method for growing p-type gallium nitride based compound semiconductors by vapor phase epitaxy

Patent Number: US5902393
Publication date: 1999-05-11
Inventor(s): NIDO MASAAKI (JP); USUI AKIRA (JP); MOCHIZUKI YASUNORI (JP)
Applicant(s):: NIPPON ELECTRIC CO (JP)
Requested Patent: ☐ US5902393
Application Number: US19970785654 19970117
Priority Number(s): JP19960007298 19960119
IPC Classification: C30B1/02
EC Classification: C30B25/02, H01L33/00C4D8B, H01L33/00G3B2
Equivalents: JP2872096B2, ☐ JP9199758

Abstract

Disclosed is a method of growing 4 gallium nitride-based crystal by vapor phase epitaxy, suitable for mass production, without the necessity of thermal processing after completion of the crystal growth. The temperature of the substrate crystal immediately after completion of the crystal growth is 700 DEG C. or higher, and cooling of the substrate crystal at 700 DEG C. or lower after completion of the crystal growth is performed in an atmosphere of a hydrogen-fee carrier gas.

Method for the growth of P-type gallium nitride and its alloys

Patent Number: US5891790
Publication date: 1999-04-06
Inventor(s): DENBAARS STEVEN P (US); KELLER STACIA (US); KOZODOY PETER (US); MISHRA UMESH K (US)
Applicant(s):: UNIV CALIFORNIA (US)
Requested Patent: ☐ US5891790
Application Number: US19970877254 19970617
Priority Number(s): US19970877254 19970617
IPC Classification: H01L33/00
EC Classification: H01L33/00C4D8B, H01L33/00G3B2, H01L33/00G3C
Equivalents:

Abstract

Growth of doped gallium nitride, especially p-type gallium nitride, without using post-growth processing is achieved by eliminating hydrogen containing molecules from the growth process before cooling down the substrate. Rapid cooling of the substrate with nitrogen gas prevents the reaction of p-type dopant atoms with hydrogen, and the use of the nitrogen gas also keeps the nitrogen intact within the crystalline structure.

Method for forming P-type gallium nitride

Patent Number: US5874320
Publication date: 1999-02-23
Inventor(s): LEE BIING-JYE (TW); CHEN CHIN-YUAN (TW); HONG MING-HUANG (TW); HUANG CHAO-NIEN (TW); SHIH KWANG-KUO (TW)
Applicant(s):: IND TECH RES INST (TW)
Requested Patent: ☐ US5874320
Application Number: US19970893385 19970711
Priority Number(s): TW19970103516 19970320
IPC Classification: H01L21/22
EC Classification: H01L21/326, H01L21/205C6, H01L21/223B, H01L21/324P, H01L33/00C4D8B
Equivalents:

Abstract

A method for forming P-type gallium nitride is disclosed in the invention. In this method, Mg-H can be completly discomposed by use of an annealing process, thereby entirely dissociating the hydrogen atoms from the gallium nitride, while the nitrogen atoms are not dissociated from the gallium nitride. Therefore, the P-type gallium nitride having high conductivity is obtained and VN gap defects created in the gallium nitride do not occur. During the annealing process, nitrogen flux is added around the gallium nitride to prevent decomposition of the gallium nitride. The above-mentioned nitrogen flux can be generated by use of RF plasma, electron cyclotron resonance (ECR) or ion beam. Furthermore, since a forward current is provided across the P-N junction of the gallium nitride, the Mg-H inside the magnesium-doped gallium nitride can be decomposed by just increasing the temperature to 175 DEG C. Therefore, in the invention, when a diode structure is manufactured with gallium nitride, the hydrogen atoms can be dissociated from the gallium nitride in a low-temperature process, thereby activating the magnesium (acceptor), such that the conductivity of the P-type gallium nitride is further increased and VN gap defects caused by a high-temperature process are prevented.

Method for growing single crystal III-V compound semiconductor layers on non single crystal III-V Compound semiconductor buffer layers

Patent Number: US5863811

Publication date: 1999-01-26

Inventor(s): FUNATO KENJI (JP); KAWAI HIROJI (JP); ASATSUMA TSUNENORI (JP)

Applicant(s):: SONY CORP (JP)

Requested Patent: ☐ US5863811

Application Number: US19960672042 19960626

Priority Number(s): JP19950184740 19950628

IPC Classification: H01L21/20

EC Classification: H01L21/205C, H01L21/20B6B2, H01L21/20B6B4

Equivalents: ☐ JP9018092

Abstract

A method for growing a single crystal III-V compound semiconductor layer, in which grown by vapor deposition on a first single crystal III-V compound semiconductor layer including at least Ga and N is a second single crystal III-V compound semiconductor layer different from the first layer and including at least Ga and N, comprises the steps of: growing a buffer layer other than single crystal and having substantially the same composition as that of the second layer by vapor deposition on the first layer; and growing the second layer on the buffer layer. A method for growing a single crystal AlGaN layer on a single crystal GaN layer by vapor deposition, comprises the steps of: growing a buffer layer of a III-V compound semiconductor including at least Ga and N on the single crystal GaN layer by vapor deposition; and growing the single crystal AlGaN layer on the buffer layer by vapor deposition. A method for growing single crystal III-V compound semiconductor layers, in which a first single crystal III-V compound semiconductor layer including at least Ga and N and a second single crystal III-V compound semiconductor layer different from the first layer and including at least Ga and N are grown on a substrate by vapor deposition, comprises the step of: growing a buffer layer of a III-V compound semiconductor including at least Ga and N between the first layer and the second layer.

Crystal growth method for gallium nitride films

Patent Number: US5843227

Publication date: 1998-12-01

Inventor(s): YAMAGUCHI ATSUSHI (JP); KIMURA AKITAKA (JP); NIDO MASAAKI (JP); SUNAKAWA HARUO (JP)

Applicant(s):: NIPPON ELECTRIC CO (JP)

Requested Patent: US5843227

Application Number: US19970782075 19970113

Priority Number(s): JP19960020623 19960112

IPC Classification: C30B25/18

EC Classification: C30B25/02, C30B25/18

Equivalents: JP2743901B2, JP9194299

Abstract

A crystal growth method for growing on a gallium arsenide (GaAs) substrate a gallium nitride (GaN) film which is good in surface flatness and superior in crystallinity. According to the method, a GaAs substrate having a surface which is inclined with respect to the GaAs(100) face is used. The inclination angle of the substrate surface is larger than 0 degree but smaller than 35 degrees with respect to the GaAs(100) face. The inclination direction of the substrate surface is within a range of an angular range from the [0,0,1] direction of GaAs to the [0,-1,0] direction past the [0,-1,1] direction and angles less than 5 degrees on opposite sides of the angular range around an [1,0,0] direction of gallium arsenide taken as an axis, or within another range crystallographically equivalent to the range. The GaN layer is formed on the surface of the GaAs substrate preferably by hydride vapor deposition method.

Process for synthesis of cubic GaN on GaAs using NH3 in an RF plasma process

Patent Number: US5834379
Publication date: 1998-11-10
Inventor(s): LO YU-HWA (US); SHEALY JAMES R (US); ENGSTROM JAMES R (US)
Applicant(s):: CORNELL RES FOUNDATION INC (US)
Requested Patent: US5834379
Application Number: US19960680874 19960716
Priority Number(s): US19960680874 19960716
IPC Classification: C23C11/08
EC Classification: C23C8/36
Equivalents:

Abstract

A process for synthesizing wide band gap materials, specifically, GaN, employs plasma-assisted and thermal nitridation with NH3 to convert GaAs to GaN. Thermal assisted nitridation with NH3 can be employed for forming layers of substantial thickness (on the order of 1 micron) of cubic and hexagonal GaN on a GaAs substrate. Plasma-assisted nitridation of NH3 results in formation of predominantly cubic GaN, a form particularly useful in optoelectronic devices. Preferably, very thin GaAs membranes are employed to permit formation thereon of GaN layers of any desired thickness without concern for critical thickness constraints. The thin membranes are preferably formed either with an epitaxial bonding technique, or by undercut etching.

Methods of forming electrodes on gallium nitride group compound semiconductors

Patent Number: US5811319

Publication date: 1998-09-22

Inventor(s): ISHIKAWA HIDENORI (JP); MURAKAMI MASANORI (JP); NAGAI SEIJI (JP); KOIKE MASAYOSHI (JP); YAMASAKI SHIRO (JP); TSUKUI KATSUYUKI (JP)

Applicant(s):: TOYODA GOSEI KK (JP)

Requested Patent: ☐ US5811319

Application Number: US19960622045 19960326

Priority Number(s): JP19950094484 19950327

IPC Classification: H01L21/28

EC Classification: H01L21/285B6, H01L33/00B4, H01L33/00G3B2

Equivalents: ☐ JP8264478

Abstract

A surface of a compound semiconductor having at least gallium (Ga) and nitride (N) forms a target for sputtering with inert gas, so that oxide and other attachments are removed therefrom. The sputtering the surface is carried out until a disruption layer is formed which has atomically disordered and bumpy arrangement. Following the sputtering process, metal deposition by sputtering and alloying are carried out under vacuum in the same chamber used for the sputtering processes. As a result, the contact resistance between the surface layer and the deposited electrode layer is decreased.

GaN single crystal

Patent Number: US5810925

Publication date: 1998-09-22

Inventor(s): TADATOMO KAZUYUKI (JP); OKAGAWA HIROAKI (JP); WATABE SHINICHI (JP); HIRAMATSU KAZUMASA (JP)

Applicant(s):: MITSUBISHI CABLE IND LTD (JP)

Requested Patent: ☐ US5810925

Application Number: US19960649492 19960517

Priority Number(s): US19960649492 19960517; JP19930253098 19931008; JP19940062813 19940331; JP19940062815 19940331; US19940320263 19941011

IPC Classification: C30B25/02

EC Classification: H01L33/00G3C

Equivalents:

Abstract

A GaN single crystal having a full width at half-maximum of the double-crystal X-ray rocking curve of 5-250 sec and a thickness of not less than 80 mu m, a method for producing the GaN single crystal having superior quality and sufficient thickness permitting its use as a substrate and a semiconductor light emitting element having high luminance and high reliability, comprising, as a substrate, the GaN single crystal having superior quality and/or sufficient thickness permitting its use as a substrate.

UV assisted gallium nitride growth

Patent Number: US5780355

Publication date: 1998-07-14

Inventor(s): DENBAARS STEVEN P (US); KELLER STACIA (US); MISHRA UMESH KUMAR (US)

Applicant(s):: UNIV CALIFORNIA (US)

Requested Patent: ☐ US5780355

Application Number: US19960757873 19961127

Priority Number(s): US19960757873 19961127

IPC Classification: H01L21/205

EC Classification: H01L21/205, H01L33/00G3B2

Equivalents:

Abstract

A method for producing Group III nitride films with high indium content and superior optical quality. The Group III nitride film will produce light in the ultraviolet, blue, green, yellow, and red spectral regions. This will enable fabrication of full-color displays and produce a reliable white light source. A metal organic chemical vapor deposition (MOCVD) process in combination with a photochemical process reduces the growth temperature required to produce optical quality Group III nitride films.

Device and method for epitaxially growing gallium nitride layers

Patent Number: US5725674
Publication date: 1998-03-10
Inventor(s): MOLNAR RICHARD J (US); MOUSTAKAS THEODORE D (US)
Applicant(s):: UNIV BOSTON (US)
Requested Patent: US5725674
Application Number: US19950560498 19951117
Priority Number(s): US19950560498 19951117; US19950371708 19950113; US19930113964 19930830; US19910670692 19910318; WO1992US02242 19920318
IPC Classification: C23C16/00
EC Classification: C30B23/02, H01L21/203C, H01L33/00C4D4B, H01L33/00C4D8B, H01L33/00G3B2
Equivalents:

Abstract

An epitaxial growth system comprises a housing around an epitaxial growth chamber. A substrate support is located within the growth chamber. A gallium source introduces gallium into the growth chamber and directs the gallium towards the substrate. An activated nitrogen source introduces activated nitrogen into the growth chamber and directs the activated nitrogen towards the substrate. The activated nitrogen comprises ionic nitrogen species and atomic nitrogen species. An external magnet and/or an exit aperture control the amount of atomic nitrogen species and ionic nitrogen species reaching the substrate.

Highly insulating monocrystalline gallium nitride thin films

Patent Number: US5686738

Publication date: 1997-11-11

Inventor(s): MOUSTAKAS THEODORE D (US)

Applicant(s):: UNIV BOSTON (US)

Requested Patent: ☐ US5686738

Application Number: US19950372113 19950113

Priority Number(s): US19950372113 19950113; US19930113964 19930830; US19910670692 19910318

IPC Classification: H01L33/00 ; H01L29/20

EC Classification: H01L33/00G3C, C30B23/02, H01L33/00G3B2

Equivalents:

Abstract

This invention relates to a method of preparing highly insulating GaN single crystal films in a molecular beam epitaxial growth chamber. A single crystal substrate is provided with the appropriate lattice match for the desired crystal structure of GaN. A molecular beam source of Ga and source of activated atomic and ionic nitrogen are provided within the growth chamber. The desired film is deposited by exposing the substrate to Ga and nitrogen sources in a two step growth process using a low temperature nucleation step and a high temperature growth step. The low temperature process is carried out at 100-400 DEG C. and the high temperature process is carried out at 600-900 DEG C. The preferred source of activated nitrogen is an electron cyclotron resonance microwave plasma.

Integrated heterostructures of Group III-V nitride semiconductor materials including epitaxial ohmic contact non-nitride buffer layer and methods of fabricating same

Patent Number: US5670798

Publication date: 1997-09-23

Inventor(s): SCHETZINA JAN FREDERICK (US)

Applicant(s):: UNIV NORTH CAROLINA (US)

Requested Patent: ☐ US5670798

Application Number: US19950412971 19950329

Priority Number(s): US19950412971 19950329

IPC Classification: H01L33/00 ; H01L31/075 ; H01L31/105 ; H01L31/117

EC Classification: H01L29/205, H01L29/267, H01L33/00C4D6C2, H01L33/00G3B2

Equivalents:

Abstract

An integrated heterostructure of Group III-V nitride compound semiconductors is formed on a multicomponent platform which includes a substrate of monocrystalline silicon carbide and a non-nitride buffer layer of monocrystalline zinc oxide. The zinc oxide may be formed by molecular beam epitaxy (MBE) using an MBE effusion cell containing zinc, and a source of atomic oxygen, such as an MBE-compatible oxygen plasma source which converts molecular oxygen into atomic oxygen. An ohmic contact for a semiconductor device formed of Group III-V nitride compound semiconductor materials including a layer of aluminum nitride or aluminum gallium nitride, includes a continuously graded layer of aluminum gallium nitride and a layer of gallium nitride or an alloy thereof on the continuously graded layer. The continuously graded layer eliminates conduction or valence band offsets. A multiple quantum well may also be used instead of the continuously graded layer where the thickness of the layers of gallium nitride increase across the multiple quantum well. The ohmic contacts may be used for Group III-V nitride laser diodes, light emitting diodes, electron emitters, bipolar transistors and field effect transistors.

P-type gallium nitride

Patent Number: US5657335
Publication date: 1997-08-12
Inventor(s): RUBIN MICHAEL (US); NEWMAN NATHAN (US); FU TRACY (US); ROSS JENNIFER (US); CHAN JAMES (US)
Applicant(s):: UNIV CALIFORNIA (US)
Requested Patent: ☐ US5657335
Application Number: US19930146502 19931101
Priority Number(s): US19930146502 19931101
IPC Classification: H01L33/00
EC Classification: H01L33/00C4D8B, H01L33/00C4D4B, H01L33/00G3B2
Equivalents:

Abstract

Several methods have been found to make p-type gallium nitride. P-type gallium nitride has long been sought for electronic devices. N-type gallium nitride is readily available. Discovery of p-type gallium nitride and the methods for making it will enable its use in ultraviolet and blue light-emitting diodes and lasers. pGaN will further enable blue photocathode elements to be made. Molecular beam epitaxy on substrates held at the proper temperatures, assisted by a nitrogen beam of the proper energy produced several types of p-type GaN with hole concentrations of about 5x1011/cm3 and hole mobilities of about 500 cm2/V-sec, measured at 250 DEG K. P-type GaN can be formed of unintentionally-doped material or can be doped with magnesium by diffusion, ion implantation, or co-evaporation. When applicable, the nitrogen can be substituted with other group III elements such as Al.

Gallium nitride-based III-V group compound semiconductor

Patent Number: US5652434

Publication date: 1997-07-29

Inventor(s): BANDO KANJI (JP); NAKAMURA SHUJI (JP); SENOH MASAYUKI (JP); YAMADA MOTOKAZU (JP); YAMADA TAKAO (JP)

Applicant(s):: NICHIA KAGAKU KOGYO KK (JP)

Requested Patent: ☐ US5652434

Application Number: US19960665759 19960617

Priority Number(s): US19960665759 19960617; JP19930124890 19930428; JP19930129313 19930531; JP19930207274 19930728; JP19930234684 19930921; JP19930234685 19930921; JP19930253171 19931008; JP19940008726 19940128; JP19940008727 19940128; US19940234001 19940428

IPC Classification: H01L29/06

EC Classification: H01L21/285B6, H01L33/00B4B, H01L33/00C4D4B, H01L33/00C4D6C, H01L33/00C4D6C2, H01L33/00C4D8B

Equivalents:

Abstract

A gallium nitride-based III-V Group compound semiconductor device has a gallium nitride-based III-V Group compound semiconductor layer provided over a substrate, and an ohmic electrode provided in contact with the semiconductor layer. The ohmic electrode is formed of a metallic material, and has been annealed.

Method for epitaxially growing gallium nitride layers

Patent Number: US5633192

Publication date: 1997-05-27

Inventor(s): MOLNAR RICHARD J (US); MOUSTAKAS THEODORE D (US)

Applicant(s):: UNIV BOSTON (US)

Requested Patent: ☐ US5633192

Application Number: US19950371708 19950113

Priority Number(s): US19950371708 19950113; US19930113964 19930830; US19910670692 19910318

IPC Classification: H01L21/20

EC Classification: C30B23/02, H01L33/00C4D4B, H01L33/00G3B2

Equivalents:

Abstract

An epitaxial growth system comprises a housing around an epitaxial growth chamber. A substrate support is located within the growth chamber. A gallium source introduces gallium into the growth chamber and directs the gallium towards the substrate. An activated nitrogen source introduces activated nitrogen into the growth chamber and directs the activated nitrogen towards the substrate. The activated nitrogen comprises ionic nitrogen species and atomic nitrogen species. An external magnet and/or an exit aperture control the amount of atomic nitrogen species and ionic nitrogen species reaching the substrate.

Modified wurtzite structure oxide compounds as substrates for III-V nitride compound semiconductor epitaxial thin film growth

Patent Number: US5625202

Publication date: 1997-04-29

Inventor(s): CHAI BRUCE H T (US)

Applicant(s):: UNIV CENTRAL FLORIDA (US)

Requested Patent: ☐ US5625202

Application Number: US19950488741 19950608

Priority Number(s): US19950488741 19950608

IPC Classification: H01L33/00

EC Classification: H01L33/00G3B2, H01S3/19A1D2

Equivalents: CN1159251, ☐ WO9642114

Abstract

Semiconductor light emitting and sensing devices are comprised of a lattice matching wurtzite structure oxide substrate and a III-V nitride compound semiconductor single crystal film epitaxially grown on the substrate. Single crystals of these oxides are grown and the substrates are produced. The lattice matching substrates include Lithium Aluminum Oxide (LiAlO2), Lithium Gallium Oxide (LiGaO2), Lithium Silicon Oxide (Li2SiO3), Lithium Germanium Oxide (Li2GeO3), Sodium Aluminum Oxide (NaAlO2), Sodium Gallium Oxide (NaGaO2), Sodium Germanium Oxide (Na2GeO3), Sodium Silicon Oxide (Na2SiO3), Lithium Phosphor Oxide (Li3PO4), Lithium Arsenic Oxide (Li3AsO4), Lithium Vanadium Oxide (Li3VO4), Lithium Magnesium Germanium Oxide (Li2MgGeO4), Lithium Zinc Germanium Oxide (Li2ZnGeO4), Lithium Cadmium Germanium Oxide (Li2CdGeO4), Lithium Magnesium Silicon Oxide (Li2MgSiO4), Lithium Zinc Silicon Oxide (Li2ZnSiO4), Lithium Cadmium Silicon Oxide (Li2CdSiO4), Sodium Magnesium Germanium Oxide (Na2MgGeO4), Sodium Zinc Germanium Oxide (Na2ZnGeO4) and Sodium Zinc Silicon Oxide (Na2ZnSiO4). These substrates are used to grow single crystal epitaxial films of III-V nitride compound semiconductors with the composition AlxInyGa1-x-yN 0 With the exception of N which can partially replaces oxygen only, all the rest elements are able to replace partially the cations of the above mentioned wurtzite structure oxide compounds. The types of semiconductor light devices that use this invention include light emitting devices, laser diodes, optical pumped laser diodes and optical detectors such as photoluminescence sensors and photo detectors. The laser diode devices can include a lateral or vertical Fabry-Perot resonant cavity, with or without metal electrodes.

Method of depositing a gallium nitride-based III-V group compound semiconductor crystal layer

Patent Number: US5433169

Publication date: 1995-07-18

Inventor(s): NAKAMURA SHUJI (JP)

Applicant(s):: NICHIA KAGAKU KOGYO KK (JP)

Requested Patent: ☐ US5433169

Application Number: US19940223739 19940406

Priority Number(s): US19940223739 19940406; JP19900288665 19901025; JP19910074822 19910313; US19910780469 19911022

IPC Classification: C30B25/14

EC Classification: C30B25/02, C30B25/14

Equivalents:

Abstract

A method of depositing a gallium nitride-based III-V Group compound semiconductor crystal layer over a substrate by a metalorganic chemical vapor deposition technique. A reaction gas is supplied to a surface of a heated substrate in a direction parallel or oblique to the substrate. The gallium nitride-based III-V Group compound semiconductor crystal layer is grown on the heated substrate, while introducing a pressing gas substantially in a vertical direction toward the substrate to press the reaction gas against the entire surface of the substrate, under atmospheric pressure or a higher pressure.

Method for the preparation and doping of highly insulating monocrystalline gallium nitride thin films

Patent Number: US5385862

Publication date: 1995-01-31

Inventor(s): MOUSTAKAS THEODORE D (US)

Applicant(s):: UNIV BOSTON (US)

Requested Patent: ☐ US5385862

Application Number: US19930113964 19930830

Priority Number(s): US19930113964 19930830; US19910670692 19910318

IPC Classification: H01L21/00 ; H01L21/02 ; H01L21/203

EC Classification: C30B23/02, H01L21/203C, H01L33/00C4D4B, H01L33/00G3B2

Equivalents:

Abstract

This invention relates to a method of preparing highly insulating GaN single crystal films in a molecular beam epitaxial growth chamber. A single crystal substrate is provided with the appropriate lattice match for the desired crystal structure of GaN. A molecular beam source of Ga and source of activated atomic and ionic nitrogen are provided within the growth chamber. The desired film is deposited by exposing the substrate to Ga and nitrogen sources in a two step growth process using a low temperature nucleation step and a high temperature growth step. The low temperature process is carried out at 100 DEG -400 DEG C. and the high temperature process is carried out at 600 DEG -900 DEG C. The preferred source of activated nitrogen is an electron cyclotron resonance microwave plasma.

Crystal growth method for gallium nitride-based compound semiconductor

Patent Number: US5290393

Publication date: 1994-03-01

Inventor(s): NAKAMURA SHUJI (JP)

Applicant(s):: NICHIA KAGAKU KOGYO KK (JP)

Requested Patent: ☐ US5290393

Application Number: US19920826997 19920128

Priority Number(s): JP19910032259 19910131; JP19910089840 19910327; JP19910089841 19910327

IPC Classification: C30B25/22

EC Classification: C30B25/02, H01L21/20B4, H01L33/00C4D8B, H01L33/00G3B2

Equivalents: KR9506968

Abstract

Crystals of a gallium nitride-based compound semiconductor are grown on the surface of a buffer layer represented by formula GaXAl1-XN (0

Method for vapor phase deposition of gallium nitride film

Patent Number: US4792467
Publication date: 1988-12-20
Inventor(s): BRAUNAGEL NORBERT (DE); MELAS ANDREAS A (US)
Applicant(s):: THIOKOL MORTON INC (US)
Requested Patent: ☐ US4792467
Application Number: US19870086748 19870817
Priority Number(s): US19870086748 19870817
IPC Classification:
EC Classification: B05D5/00, B05D7/14, C23C16/30B2
Equivalents:

Abstract

A process for depositing a gallium nitride film on a substrate. A source compound is provided which has the formula: H3GaNR3 Each R is independently selected from alkyl groups having from 1 to about 4 carbon atoms. The source compound is conveyed into a deposition chamber containing a substrate. The source compound, maintained in the gaseous phase, decomposes in the deposition chamber and optionally reacts with other materals in the deposition chamber. Gallium nitride is deposited on the substrate as a result.