TITLE

Plasma-Assisted Atomic Layer Epitaxy of Cubic and Hexagonal InN Films and its alloys with A1N at Low Temperatures

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This Application claims the benefit of U.S. Provisional Application 61/661,016 filed on June 18, 2012.

BACKGROUND

[0002] Among III-nitride semiconductors, indium nitride (InN) has the smallest direct band gap, largest electron saturation velocity and mobility, and smallest electron effective mass. It has long been an attractive semiconductor material for application in optical, electrical, and optoelectronic device technologies such as solar-cells and high electron mobility and high frequency devices. The most thermodynamically stable phase of the InN is a wurtzite structure (a hexagonal phase), however, the growth of zincblende (a cubic phase) InN on InAs/GaAs has been demonstrated at 450 °C by plasma assisted molecular beam epitaxy (MBE) . Cubic InN has a smaller band gap and superior electronic properties as its lattice is isotropic and possesses lower phonon scattering.

BRIEF SUMMARY

[0003] ~~In a first aspect of t~~The present disclosure~~, there is provided~~ provides a method for growing indium nitride (InN) materials, comprising growing hexagonal and/or cubic InN using a pulsed growth method at a temperature lower than 300 °C.

[0003a] In a first aspect of the present disclosure, there is provided a method for growing indium nitride (InN) materials, comprising growing hexagonal and/or cubic InN using a pulsed growth method at a temperature lower than 300 °C, wherein the pulsed growth method is characterized by plasma-assisted atomic layer epitaxy involving alternate pulses of (1) nitrogen precursor and (2) either an indium precursor or an aluminum precursor, with purging to remove unreacted precursor between pulses.

[~~0003a~~0003b] In a second aspect of the present disclosure, there is provided a material comprising ~~InN~~ indium nitride in a face-centered cubic lattice crystalline structure having an NaCl type phase, produced by the method as described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1 shows variation of growth rate (GR) and In/N ratio with a trimethylindium (TMI) pulse of 0.06 seconds.

[0005] FIG. 2 depicts the x-ray diffraction (XRD) peaks from three of the samples - namely InN (60nm) on GaN/$A1_2O_3$ template with T_g=183°C (top) and on a-plane $A1_2O_3$ with T_g= 240°C (middle) and 183°C (bottom)).

CLAIMS

What is claimed is:

1. A method for growing indium nitride (InN) materials, comprising growing hexagonal and/or cubic InN using a pulsed growth method at a temperature lower than 300 °C, wherein the pulsed growth method is characterized by plasma-assisted atomic layer epitaxy involving alternate pulses of (1) nitrogen precursor and (2) either an indium precursor or an aluminum precursor, with purging to remove unreacted precursor between pulses.

2. The method of Claim 1, using N_2 plasma as a nitrogen precursor.

3. The method of Claim 1, using trimethylindium as an indium precursor.

4. The method of Claim 1, wherein said hexagonal and/or cubic InN consists of a homogenous phase of either hexagonal or cubic InN.

5. The method of Claim 1, wherein said temperature is intentionally varied during said growing in order to control conductivity of said hexagonal and/or cubic InN.

6. The method of Claim 1, further comprising in situ surface treatment with atomic hydrogen, nitrogen, a mixture of hydrogen and nitrogen, and/or ammonia plasma.

7. The method of Claim 1, further comprising variation of purge time with the pumping speed, thereby controlling formation of carbon impurities.

8. The method of Claim 1, wherein said temperature is lower than 200 °C.

9. The method of Claim 8, using N_2 plasma as a nitrogen precursor.

10. The method of Claim 8, wherein said hexagonal and/or cubic InN consists of a homogenous phase of either hexagonal or cubic InN.

11. The method of Claim 8, wherein said temperature is intentionally varied during said growing in order to control conductivity of said hexagonal and/or cubic InN.

12. The method of Claim 8, further comprising in situ surface treatment with atomic hydrogen, nitrogen, a mixture of hydrogen and nitrogen, and/or ammonia plasma.

13. The method of Claim 8, further comprising variation of purge time with the pumping speed, thereby controlling formation of carbon impurities.

14. The method of Claim 1, wherein said pulsed growth method comprises pulsed growth of an $Al_xIn_{1-x}N$ film at a temperature lower than 300 °C by via alternate pulses of indium precursor and nitrogen precursor.

15. The method of Claim 14, using N_2 plasma as said nitrogen precursor.

16. The method of Claim 14, wherein said film has a homogenous phase.

17. The method of Claim 14, further comprising in situ surface treatment with atomic hydrogen, nitrogen, a mixture of hydrogen and nitrogen, and/or ammonia plasma.

18. The method of Claim 14, further comprising variation of purge time with the pumping speed, thereby controlling formation of carbon impurities.

19 A material comprising ~~InN~~ indium nitride in a face-centered cubic lattice crystalline structure having an NaCl type phase, produced by the method of any one of claims 1 to 18.