CLAIMS

I/We claim:

1. A method for forming a light emitting diode (LED), comprising:

exposing a surface of a substrate to a nitrogen-containing composition, the substrate having a substrate material;

generating a nitrogen-rich environment at least proximate the surface of the substrate with the nitrogen-containing composition;

adjusting at least one operating parameter of exposing the surface of the substrate to the nitrogen-containing composition such that the nitrogen-containing composition does not react with the substrate material to form a nitrodizing product; and

forming an LED structure on the surface of the substrate with the nitrogen-rich environment, the LED structure having a nitrogen polarity.

2. The method of claim 1 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si);

exposing the surface of the substrate includes:

generating a nitrogen plasma;

directing the nitrogen plasma toward the surface of the silicon wafer;

generating the nitrogen-rich environment includes adsorbing nitrogen atoms from the nitrogen plasma onto the surface of the silicon wafer via Van der Waals forces;

adjusting the at least one operating parameter includes adjusting at least one of a plasma charge density and a plasma temperature such that the nitrogen plasma does not react with silicon at the surface of the silicon wafer to form silicon nitride (SiN); and

forming the LED structure includes sequentially depositing N-type gallium nitride (GaN), indium-gallium nitride (InGaN), and P-type GaN materials on the surface of the silicon wafer.

3. The method of claim 1 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si);

exposing the surface of the substrate includes depositing silicon nitride (SiN) on the surface of the silicon wafer, the deposited silicon nitride containing a plurality of nitrogen (N) atoms;

generating the nitrogen-rich environment includes causing at least some of the nitrogen (N) atoms to migrate into the surface of the silicon wafer via heating and/or radiation; and

adjusting the at least one operating parameter includes adjusting at least one of an amount of heat, a radiation intensity, a duration of radiation and/or heat such that the migrated nitrogen (N) atoms do not react with silicon at the surface of the silicon wafer to form silicon nitride (SiN); and

the method further includes removing the deposited silicon nitride (SiN) from the surface of the silicon wafer; and

forming the LED structure includes sequentially depositing N-type GaN, InGaN, and P-type GaN materials on the surface of the silicon wafer after the silicon nitride (SiN) is removed from the surface of the silicon wafer.

4. The method of claim 1 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si); and

adjusting the at least one operating parameter includes adjusting at least one operating parameter such that the nitrogen-containing composition does not react with silicon at the surface of the silicon wafer to form silicon nitride (SiN).

5. The method of claim 1 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si); and

generating the nitrogen-rich environment includes adsorbing a plurality of nitrogen (N) atoms onto the surface of the silicon wafer without forming silicon nitride (SiN) on the surface of the silicon wafer.

6. The method of claim 1 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si);

exposing the surface of the substrate includes:

generating a nitrogen plasma; and

directing the nitrogen plasma toward the surface of the silicon wafer; and

generating the nitrogen-rich environment includes adsorbing a plurality of nitrogen (N) atoms from the nitrogen plasma onto the surface of the silicon wafer without forming silicon nitride (SiN) on the surface of the silicon wafer.

7. The method of claim 1 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si);

exposing the surface of the substrate includes:

generating a nitrogen plasma; and

directing the nitrogen plasma toward the surface of the silicon wafer;

generating the nitrogen-rich environment includes adsorbing a plurality of nitrogen (N) atoms from the nitrogen plasma onto the surface of the silicon wafer; and

adjusting the at least one operating parameter includes adjusting at least one of a plasma charge density and a plasma temperature of the nitrogen plasma such that the nitrogen plasma does not react with silicon at the surface of the silicon wafer to form silicon nitride (SiN).

8. The method of claim 1 wherein:

the substrate includes a silicon wafer having a lattice structure;

the substrate material includes silicon (Si);

exposing the surface of the substrate includes depositing silicon nitride (SiN) on the surface of the silicon wafer, the deposited silicon nitride containing a plurality of nitrogen (N) atoms;

generating the nitrogen-rich environment includes causing at least some of the nitrogen (N) atoms to migrate into the surface of the silicon wafer, the migrated nitrogen (N) atoms being trapped in the lattice structure of the silicon wafer without

forming a silicon nitride (SiN) crystal structure with the silicon (Si) in the silicon wafer.

9. The method of claim 1 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si);

exposing the surface of the substrate includes depositing silicon nitride (SiN) on the surface of the silicon wafer, the deposited silicon nitride containing a plurality of nitrogen (N) atoms; and

generating the nitrogen-rich environment includes causing at least some of the nitrogen (N) atoms to migrate into the surface of the silicon wafer; and

the method further includes removing the deposited silicon nitride (SiN) from the surface of the silicon wafer before forming the LED structure.

10. The method of claim 1 wherein:

the substrate includes a silicon wafer having a lattice structure;

the substrate material includes silicon (Si);

exposing the surface of the substrate includes depositing silicon nitride (SiN) on the surface of the silicon wafer, the deposited silicon nitride containing a plurality of nitrogen (N) atoms; and

generating the nitrogen-rich environment includes causing at least some of the nitrogen (N) atoms to migrate into the surface of the silicon wafer, the migrated nitrogen (N) atoms being trapped in the lattice structure of the silicon wafer without forming a silicon nitride (SiN) crystal structure with the silicon (Si) in the silicon wafer; and

the method further includes removing the deposited silicon nitride (SiN) from the surface of the silicon wafer before forming the LED structure.

11. A method for forming an LED, comprising:

exposing a surface of a substrate to a nitrogen-containing composition, the substrate having a substrate material;

increasing a nitrogen (N) concentration in the substrate material at least proximate the surface of the substrate with the nitrogen-containing composition without forming a nitrodizing product of the substrate material; and

forming an LED structure on the surface of the substrate with a nitrogen-rich environment, the LED structure having a nitrogen polarity.

12. The method of claim 11 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si); and

increasing the nitrogen (N) concentration includes adsorbing a plurality of nitrogen (N) atoms onto the surface of the silicon wafer without forming silicon nitride (SiN) on the surface of the silicon wafer.

13. The method of claim 11 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si); and

increasing the nitrogen (N) concentration includes:

contacting the surface of the silicon wafer with a nitrogen plasma; and

adsorbing a plurality of nitrogen (N) atoms from the nitrogen plasma onto the surface of the silicon wafer without forming silicon nitride (SiN) on the surface of the silicon wafer.

14. The method of claim 11 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si); and

increasing the nitrogen (N) concentration includes:

applying a nitrogen plasma to the surface of the silicon wafer;

adsorbing a plurality of nitrogen (N) atoms from the nitrogen plasma onto the surface of the silicon wafer; and

controlling the energy of the applied nitrogen plasma such that the nitrogen plasma does not react with silicon (Si) in the silicon wafer to form silicon nitride (SiN) on the surface of the silicon wafer.

15. The method of claim 11 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si); and

increasing the nitrogen (N) concentration includes:

applying a nitrogen plasma to the surface of the silicon wafer;

adsorbing a plurality of nitrogen (N) atoms from the nitrogen plasma onto the surface of the silicon wafer; and

controlling the energy of the applied nitrogen plasma such that the adsorbed nitrogen atoms are adsorbed on the surface of the silicon wafer via a molecular interaction having an interaction energy less than about 10 kcal/mol.

16. The method of claim 11 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si); and

increasing the nitrogen (N) concentration includes:

applying a nitrogen plasma to the surface of the silicon wafer;

attaching a plurality of nitrogen (N) atoms from the nitrogen plasma onto the surface of the silicon wafer; and

controlling the energy of the applied nitrogen plasma such that the nitrogen atoms are attached on the surface of the silicon wafer not via a molecular interaction having an interaction energy greater than about 50 kcal/mol.

17. The method of claim 11 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si); and

increasing the nitrogen (N) concentration includes migrating a plurality of nitrogen (N) atoms into the surface of the silicon wafer without forming silicon nitride (SiN) on the surface of the silicon wafer.

18. The method of claim 11 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si);

the method further includes depositing silicon nitride (SiN) onto the surface of the silicon wafer; and

increasing the nitrogen (N) concentration includes migrating a plurality of nitrogen (N) atoms from the deposited silicon nitride (SiN) into the surface of the silicon wafer without forming silicon nitride (SiN) on the surface of the silicon wafer.

19. The method of claim 11 wherein:

the substrate includes a silicon wafer; and

the substrate material includes silicon (Si);

the method further includes depositing silicon nitride (SiN) onto the surface of the silicon wafer; and

increasing the nitrogen (N) concentration includes migrating a plurality of nitrogen (N) atoms from the deposited silicon nitride (SiN) into the surface of the silicon wafer without forming silicon nitride (SiN) on the surface of the silicon wafer; and

the method further includes removing the deposited silicon nitride (SiN) from the surface of the silicon wafer before forming the LED structure.

20. A method for forming an LED on a substrate having a substrate material, comprising:

forming a nitrogen-rich environment at least proximate a surface of the substrate without forming a nitrodizing product with the substrate material on the surface of the substrate; and

forming an LED structure with a nitrogen polarity on the surface of the substrate with the nitrogen-rich environment.

21. The method of claim 20 wherein forming the nitrogen-rich environment includes adsorbing a plurality of nitrogen (N) atoms onto the surface of the substrate without nitrodizing the substrate material on the surface of the substrate.

22. The method of claim 20 wherein forming the nitrogen-rich environment includes adsorbing nitrogen atoms on the surface of the silicon wafer via a molecular interaction having an interaction energy less than about 10 kcal/mol.

23. The method of claim 20 wherein forming the nitrogen-rich environment includes adsorbing nitrogen atoms on the surface of the silicon wafer without forming ionic or covalent bonds with the substrate material.

24. The method of claim 20 wherein forming the nitrogen-rich environment includes causing nitrogen atoms to migrate into the surface of the silicon wafer without forming ionic or covalent bonds with the substrate material.

25. A light emitting diode, comprising:

a substrate having a substrate material;

a first semiconductor material directly on a surface of the substrate;

an active region on the first semiconductor material, the active region having a nitrogen-polarity crystal structure;

a second semiconductor material on the active region; and

wherein the light emitting diode does not include a nitrodizing product of the substrate material at an interface between the surface of the substrate and the first semiconductor material.

26. The light emitting diode of claim 25 wherein:

the substrate includes a silicon wafer having a lattice structure;

the substrate material includes silicon (Si);

the first semiconductor material includes an N-type gallium nitride (GaN) material;

the active region includes an indium gallium nitride (InGaN) material;

the second semiconductor material includes a P-type GaN material; and

the silicon wafer includes a nitrogen-rich environment at least proximate the surface of the silicon wafer, the nitrogen-rich environment having a plurality of nitrogen (N) atoms trapped in the lattice structure of the silicon wafer without forming a silicon nitride (SiN) crystal structure with the silicon (Si) in the silicon wafer.

27. The light emitting diode of claim 25 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si);

the first semiconductor material includes an N-type gallium nitride (GaN) material;

the active region includes an indium gallium nitride (InGaN) material;

the second semiconductor material includes a P-type GaN material; and

the light emitting diode does not include crystalline silicon nitride (SiN) at the interface between the surface of the silicon wafer and the N-type GaN material.

28. The light emitting diode of claim 25 wherein:

the substrate includes a silicon wafer;

the substrate material includes silicon (Si); and

the light emitting diode does not include crystalline silicon nitride (SiN) at the interface between the surface of the silicon wafer and the first semiconductor material.

29. A method for forming a light emitting diode (LED), comprising:

forming a gallium nitride (GaN) material on a substrate with a dopant;

adjusting a concentration of the dopant such that the formed GaN material has substantially nitrogen polarity; and

forming an LED structure on the formed GaN material with the nitrogen polarity, the LED structure also having a nitrogen polarity.

30. The method of claim 29 wherein:

forming a GaN material includes depositing the GaN material with a magnesium dopant, the magnesium dopant having a concentration of at least about $1xE^{20}/cm^{-3}$ in the GaN material; and

adjusting a concentration of the dopant includes adjusting a concentration of the magnesium dopant such that the formed GaN material has substantially nitrogen polarity.

CLAIMS

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1. A method for forming a light emitting diode (LED), comprising:

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adjusting a concentration of the dopant such that the formed GaN material has substantially nitrogen polarity; and

forming an LED structure on the formed GaN material with the nitrogen polarity, the LED structure also having a nitrogen polarity.