Claims

1. A method of forming a p-type gallium nitride layer, the method comprising:

providing a substrate structure including an epitaxial gallium nitride layer;

sputtering a dopant source including magnesium onto the epitaxial gallium nitride layer;

patterning the dopant source to form patterned dopant source regions and one or more openings to the epitaxial gallium nitride layer;

depositing a dielectric capping structure over the patterned dopant source regions and the one or more openings;

thereafter, annealing the substrate structure at a temperature ranging from 1000 °C to 1400 °C to diffuse magnesium into the epitaxial gallium nitride layer;

removing the dielectric capping structure and the patterned dopant source regions; and

thereafter, activating the diffused magnesium to form the p-type gallium nitride layer.

2. The method of claim 1 wherein the dopant source comprises a layer of magnesium fluoride having a thickness ranging from 20 nm to 50 nm.

3. The method of claim 1 wherein the dopant source comprises a layer of an aluminum nitride magnesium composite material having a thickness ranging from 5 nm to 50 nm.

4. The method of claim 1 wherein the substrate structure comprises:

a polycrystalline ceramic core;

a barrier layer encapsulating the polycrystalline ceramic core;

a bonding layer coupled to the barrier layer; and

a substantially single crystalline layer coupled to the bonding layer.

5. A method of forming a doped gallium nitride layer, the method comprising:

providing a substrate structure including an epitaxial gallium nitride layer;

forming a dopant source layer over the epitaxial gallium nitride layer;

patterning the dopant source layer to form patterned dopant source regions and one or more openings to the epitaxial gallium nitride layer;

depositing a dielectric capping structure over the patterned dopant source regions and the one or more openings;

thereafter, annealing the substrate structure at a temperature ranging from 1000 °C to 1400 °C to diffuse dopants into the epitaxial gallium nitride layer;

removing the dielectric capping structure and the patterned dopant source regions; and

thereafter, activating the diffused dopants.

6. The method of claim 5 wherein forming the dopant source layer comprises sputtering the dopant source layer over the epitaxial gallium nitride layer.

7. The method of claim 5 further comprising, prior to forming the dopant source layer, performing a surface preparation process.

8. The method of claim 7 wherein the surface preparation process comprises an organic clean process or an oxide removal process.

9. The method of claim 7 wherein the surface preparation process comprises a metallic clean process.

10. The method of claim 1 wherein the dielectric capping structure comprises AlN and at least one of SiO_2 or SiN_X.

11. The method of claim 7 wherein the surface preparation process comprises an organic clean process, a metallic clean process, and an oxide removal process.

12. The method of claim 5 wherein the epitaxial gallium nitride layer is undoped.

13. The method of claim 5 wherein the dopant source layer comprises magnesium having a thickness ranging from 5 nm to 20 nm and the epitaxial gallium nitride layer comprises a p-type gallium nitride layer.

14. The method of claim 5 wherein the dopant source layer comprises magnesium fluoride having a thickness ranging from 20 nm to 50 nm.

15. The method of claim 5 wherein the dopant source layer comprises an aluminum nitride magnesium composite material having a thickness ranging from 5 nm to 50 nm.

16. The method of claim 15 wherein a magnesium concentration in the aluminum nitride magnesium composite material ranges from 1×10^{19} cm^3 to 10%.

17. The method of claim 5 wherein the dielectric capping structure comprises AlN and at least one of SiO_2 or SiN_X.

18. The method of claim 5 wherein the substrate structure comprises:

a polycrystalline ceramic core;

a barrier layer encapsulating the polycrystalline ceramic core;

a bonding layer coupled to the barrier layer; and

a substantially single crystalline layer coupled to the bonding layer.

19. The method of claim 5 wherein the dielectric capping structure is operable to anneal magnesium implant damage in the substrate structure.

20. The method of claim 5 further comprising, prior to forming the dopant source layer, forming a mask on the epitaxial gallium nitride layer, wherein the mask exposes one or more portions of a top surface of the epitaxial gallium nitride layer.