Claims

1. A method of forming doped regions by diffusion in gallium nitride materials, the method comprising:

providing a substrate structure including a gallium nitride layer;

forming a mask on the gallium nitride layer, the mask exposing one or more portions of a top surface of the gallium nitride layer;

depositing a magnesium-containing gallium nitride layer on the one or more portions of the top surface of the gallium nitride layer at a temperature ranging from about 900° C. to about 1100° C;

concurrently with depositing the magnesium-containing gallium nitride layer, forming one or more magnesium-doped regions in the gallium nitride layer by diffusing magnesium into the gallium nitride layer through the one or more portions, wherein the magnesium-containing gallium nitride layer provides a source of magnesium dopants;

removing the magnesium-containing gallium nitride layer; and

removing the mask.

2. The method of claim 1 wherein depositing the magnesium-containing gallium nitride layer is performed in a thin film deposition chamber.

3. The method of claim 1 wherein depositing the magnesium-containing gallium nitride layer is performed at a temperature ranging from about 1000 °C to about 1100 °C.

4. The method of claim 1 wherein the magnesium-containing gallium nitride layer has a magnesium density ranging from about 1×10^{19} cm^{-3} to about 1×10^{20} cm^{-3}.

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

a buffer layer formed on a substrate;

a first epitaxial gallium nitride layer formed on the buffer layer; and

a second epitaxial gallium nitride layer formed on the first epitaxial gallium nitride layer;

wherein the one or more magnesium-doped regions are formed in the second epitaxial gallium nitride layer.

6. The method of claim 5 wherein the substrate 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.

7. The method of claim 5 wherein the second epitaxial gallium nitride layer is undoped before the magnesium-containing gallium nitride layer is deposited.

8. The method of claim 7 wherein the first epitaxial gallium nitride layer is N-type doped.

9. The method of claim 8 wherein each of the one or more magnesium-doped regions in the second epitaxial gallium nitride layer forms a p-n junction at an interface with the first epitaxial gallium nitride layer.

10. The method of claim 8 wherein the one or more magnesium-doped regions in the second epitaxial gallium nitride layer form portions of a merged p-i-n Schottky (MPS) diode.

11. The method of claim 10 wherein the one or more magnesium-doped regions in the second epitaxial gallium nitride layer form portions of a junction termination extension (JTE) for the MPS diode.

12. The method of claim 5 wherein two of the one or more magnesium-doped regions in the second epitaxial gallium nitride layer comprise a first edge termination region and a second edge termination region separated from each other by a portion of the second epitaxial gallium nitride layer, and the method further comprising:

forming a Schottky contact coupled to the portion of the second epitaxial gallium nitride layer, and to the first edge termination region and the second edge termination region.

13. The method of claim 1 wherein removing the magnesium-containing gallium nitride layer comprises removing an entirety of the magnesium-containing gallium nitride layer.

14. A method of forming doped regions in gallium nitride materials, the method comprising:

providing a gallium nitride substrate structure, the gallium nitride substrate structure including:

a buffer layer formed on a substrate;

a first epitaxial gallium nitride layer formed on the buffer layer;

a second epitaxial gallium nitride layer formed on the first epitaxial gallium nitride layer; and

an epitaxial aluminum gallium nitride layer formed on the second epitaxial gallium nitride layer;

forming a mask on the epitaxial aluminum gallium nitride layer, the mask exposing one or more portions of a top surface of the epitaxial aluminum gallium nitride layer;

depositing a magnesium-containing gallium nitride layer on the one or more portions of the top surface of the epitaxial aluminum gallium nitride layer;

concurrently with depositing the magnesium-containing gallium nitride layer, forming one or more magnesium-doped regions in the epitaxial aluminum gallium nitride layer by diffusing magnesium into the epitaxial aluminum gallium nitride layer through the one or more portions, wherein the magnesium-containing gallium nitride layer provides a source of magnesium dopants;

removing the magnesium-containing gallium nitride layer; and

removing the mask.

15. The method of claim 14 wherein depositing the magnesium-containing gallium nitride layer is performed in a thin film deposition chamber.

16. The method of claim 14 wherein depositing the magnesium-containing gallium nitride layer is performed at a temperature ranging from about 900 °C to about 1100 °C.

17. The method of claim 14 wherein the magnesium-containing gallium nitride layer has a magnesium density ranging from about 1×10^{19} cm^{-3} to about 1×10^{19} cm^{-3}.

18. The method of claim 14 wherein the substrate 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 14 wherein the second epitaxial gallium nitride layer is undoped.

20. The method of claim 19 wherein the first epitaxial gallium nitride layer is N-type doped.

21. The method of claim 20 wherein each of the one or more magnesium-doped regions in the epitaxial aluminum gallium nitride layer forms an interface with the second epitaxial gallium nitride layer, and wherein the interface controls a threshold voltage of a high-electron-mobility transistor (HEMT) power device.