

WHAT IS CLAIMED IS:

- 1 1. A method of forming doped regions by diffusion in gallium nitride
2 materials, the method comprising:
3 providing a substrate structure including a gallium nitride layer;
4 forming a mask on the gallium nitride layer, the mask exposing one or more
5 portions of a top surface of the gallium nitride layer;
6 depositing a magnesium-containing gallium nitride layer on the one or more
7 portions of the top surface of the gallium nitride layer;
8 concurrently with depositing the magnesium-containing gallium nitride layer,
9 forming one or more magnesium-doped regions in the gallium nitride layer by diffusing
10 magnesium into the gallium nitride layer through the one or more portions, wherein the
11 magnesium-containing gallium nitride layer provides a source of magnesium dopants;
12 removing the magnesium-containing gallium nitride layer; and
13 removing the mask.
- 1 2. The method of claim 1 wherein depositing the magnesium-containing
2 gallium nitride layer is performed in a thin film deposition chamber.
- 1 3. The method of claim 1 wherein depositing the magnesium-containing
2 gallium nitride layer is performed at a temperature ranging from about 900 °C to about 1100
3 °C.
- 1 4. The method of claim 1 wherein the magnesium-containing gallium
2 nitride layer has a magnesium density ranging from about $1 \times 10^{19} \text{ cm}^{-3}$ to about $1 \times 10^{20} \text{ cm}^{-3}$.
- 1 5. The method of claim 1 wherein the substrate structure comprises:
2 a buffer layer formed on a substrate;
3 a first epitaxial gallium nitride layer formed on the buffer layer; and
4 a second epitaxial gallium nitride layer formed on the first epitaxial gallium
5 nitride layer;
6 wherein the one or more magnesium-doped regions are formed in the second
7 epitaxial gallium nitride layer.
- 1 6. The method of claim 5 wherein the substrate comprises:
2 a polycrystalline ceramic core;

3 a barrier layer encapsulating the polycrystalline ceramic core;
4 a bonding layer coupled to the barrier layer; and
5 a substantially single crystalline layer coupled to the bonding layer.

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

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

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

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

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

1 12. The method of claim 5 wherein two of the one or more magnesium-
2 doped regions in the second epitaxial gallium nitride layer comprise a first edge termination
3 region and a second edge termination region separated from each other by a portion of the
4 second epitaxial gallium nitride layer, and the method further comprising:
5 forming a Schottky contact coupled to the portion of the second epitaxial
6 gallium nitride layer, and to the first edge termination region and the second edge termination
7 region.

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

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

5 a buffer layer formed on a substrate;
6 a first epitaxial gallium nitride layer formed on the buffer layer;

7 a second epitaxial gallium nitride layer formed on the first epitaxial
8 gallium nitride layer; and
9 an epitaxial aluminum gallium nitride layer formed on the second
10 epitaxial gallium nitride layer;
11 forming a mask on the epitaxial aluminum gallium nitride layer, the mask
12 exposing one or more portions of a top surface of the epitaxial aluminum gallium nitride
13 layer;
14 depositing a magnesium-containing gallium nitride layer on the one or more
15 portions of the top surface of the epitaxial aluminum gallium nitride layer;
16 concurrently with depositing the magnesium-containing gallium nitride layer,
17 forming one or more magnesium-doped regions in the epitaxial aluminum gallium nitride
18 layer by diffusing magnesium into the epitaxial aluminum gallium nitride layer through the
19 one or more portions, wherein the magnesium-containing gallium nitride layer provides a
20 source of magnesium dopants;
21 removing the magnesium-containing gallium nitride layer; and
22 removing the mask.

1 14. The method of claim 13 wherein depositing the magnesium-containing
2 gallium nitride layer is performed in a thin film deposition chamber.

1 15. The method of claim 13 wherein depositing the magnesium-containing
2 gallium nitride layer is performed at a temperature ranging from about 900 °C to about 1100
3 °C.

1 16. The method of claim 13 wherein the magnesium-containing gallium
2 nitride layer has a magnesium density ranging from about $1 \times 10^{19} \text{ cm}^{-3}$ to about $1 \times 10^{19} \text{ cm}^{-3}$.

1 17. The method of claim 13 wherein the substrate comprises:
2 a polycrystalline ceramic core;
3 a barrier layer encapsulating the polycrystalline ceramic core;
4 a bonding layer coupled to the barrier layer; and
5 a substantially single crystalline layer coupled to the bonding layer.

1 18. The method of claim 13 wherein the second epitaxial gallium nitride
2 layer is undoped.

1 19. The method of claim 18 wherein the first epitaxial gallium nitride layer
2 is N-type doped.

1 20. The method of claim 19 wherein each of the one or more magnesium-
2 doped regions in the epitaxial aluminum gallium nitride layer forms an interface with the
3 second epitaxial gallium nitride layer, and wherein the interface controls a threshold voltage
4 of a high-electron-mobility transistor (HEMT) power device.