STRESS CONTROL FOR HETEROEPITAXY

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims benefit of priority to U.S. Non-Provisional Patent Application No. 14/729,741, entitled "Stress Control for Heteroepitaxy," and filed on June 03, 2015, which is specifically incorporated by reference herein for all that it discloses or teaches. For the U.S., this application is a continuation application of U.S. Non-Provisional Patent Application No. 14/729,741.

TECHNICAL FIELD

This invention relates generally to semiconductor materials that include a multilayer superlattice structure.

SUMMARY

According to an aspect of the present invention, there is provided a semiconductor material comprising:

a substrate;

a seed layer on the substrate;

a superlattice structure comprising a plurality of superlattice layers (a) gallium nitride (GaN) and (b) layers selected from the group consisting of aluminum nitride (AlN), AlyGa1-yN, where 0<y<1, and mixtures thereof, the superlattice layers arranged in any order;

a buffer structure between the seed layer and the superlattice structure, the buffer structure compositionally different than the seed layer and compositionally different than the superlattice structure and comprising three or more distinct layers of AlxGa1-xN, where 0<x<1; and

a cap layer formed on the superlattice structure.

This disclosure is directed to stress control in silicon (Si) wafer based semiconductor materials using a superlattice structure that includes alternating layers of materials that include one or more of aluminum (Al), gallium (Ga), and/or nitrogen (N). The semiconductor materials include a seed layer that includes one or more of Al, Ga, and/or N on a substrate, an optional buffer structure that includes one or more of Al, Ga, and/or N on

the seed layer, the superlattice structure, and a cap layer that includes one or more of Al, Ga, and/or N. The buffer structure can be composed of three or more distinct layers comprising $Al_xGa_{1-x}N$, where $0 \leq x \leq 1$ in some implementations, and where $0 < x < 1$ in other implementations.

In one implementation, the stress control is via an AlN/GaN superlattice structure (SL) for epitaxy of GaN on silicon (Si) {111} substrates. A superlattice structure having at least one pair of AlN/GaN SL layers is provided on the Si substrate, on which is positioned a GaN layer. The superlattice structure can have 50 to 100 pairs of the AlN and GaN layers, where the AlN layers are 3-5 nm thick and the GaN layers are 10-30 nm thick. The thick GaN layer can be, e.g., greater than 1 micrometer thick, e.g., 2 micrometers thick.

In another implementation, the superlattice structure can have 50 to 100 pairs of the AlN and GaN, plus one additional GaN layer.

CLAIMS

1. A semiconductor material comprising:

a substrate;

a seed layer on the substrate;

a superlattice structure comprising a plurality of superlattice layers (a) gallium nitride (GaN) and (b) layers selected from the group consisting of aluminum nitride (AlN), $Al_yGa_{1-y}N$, where $0<y<1$, and mixtures thereof, the superlattice layers arranged in any order;

a buffer structure between the seed layer and the superlattice structure, the buffer structure compositionally different than the seed layer and compositionally different than the superlattice structure and comprising three or more distinct layers of $Al_xGa_{1-x}N$, where $0\leq x\leq 1$; and

a cap layer formed on the superlattice structure.

2. The semiconductor material of claim 1, wherein the buffer structure comprises three or more compositionally distinct layers of $Al_xGa_{1-x}N$, where $0\leq x\leq 1$, with a layer closer to the seed layer having greater Al and less Ga than a layer closer to the superlattice structure.

3. The semiconductor material of any of the preceding claims, wherein the superlattice structure comprises alternating layers of GaN and AlN.

4. The semiconductor material of claim 3, wherein the AlN layer of the superlattice structure is in contact with the buffer structure.

5. The semiconductor material of claim 3, wherein the GaN layer of the superlattice structure is in contact with the buffer structure.

6. The semiconductor material of claim 3, wherein the GaN layer of the superlattice structure is in contact with the cap layer.

7. The semiconductor material of any of claims 1-6, wherein the superlattice structure comprises 50 to 100 pairs of layers.

8. The semiconductor material of claim 3, wherein the AlN layer of the superlattice structure has a thickness of about 3 to 5 nm and the GaN layer of the superlattice structure has a thickness of about 10 to 30 nm.

9. The semiconductor material of claim 8, wherein a ratio of the thickness of the AlN layer of the superlattice structure to the GaN layer of the superlattice structure is 1:2 to 1:10.

10. The semiconductor material of claim 1 consisting essentially of:

a silicon (Si) substrate;

an AlN seed layer on the Si substrate;

a buffer structure on the seed layer, wherein the buffer structure comprises three or more distinct layers of $Al_xGa_{1-x}N$, where $0<x<1$;

a superlattice structure on the buffer structure, wherein the superlattice structure comprises a plurality of layers in any order of (a) gallium nitride (GaN) and (b) layers selected from the group consisting of aluminum nitride (AlN), $Al_yGa_{1-y}N$, where $0<y<1$, and mixtures thereof; and

a cap layer formed on the superlattice structure.

11. The semiconductor material of claim 10, wherein the superlattice structure comprises alternating layers of GaN and AlN.

12. The semiconductor material of claim 11, wherein the superlattice structure comprises at least three layers in any order of (a) GaN and (b) layers selected from the group consisting of AlN, $Al_yGa_{1-y}N$, where $0<y<1$, and mixtures thereof.

13. The semiconductor material of claim 1 comprising:

each of the superlattice layers comprising one or more of Al, Ga, N, with at least one of the plurality of superlattice layers providing compressive stress and at least one of the plurality of superlattice layers providing tensile stress; and

the cap layer comprising one or more of Al, Ga, N, and being lattice matched with the superlattice structure.

14. The semiconductor material of claim 13, wherein the plurality of superlattice layers is a pair of superlattice layers.

15. The semiconductor material of claim 14, wherein one of the superlattice layers of the pair has a lattice constant that is larger than a lattice constant of the other of the superlattice layers.

16. The semiconductor material of claim 15, wherein one of the superlattice layers of the pair has a lattice constant at least 0.01 Å larger than the lattice constant of the other of the superlattice layers.