Claims

1. A layered structure, comprising:

a first germanium substrate layer having a first lattice constant and a first thickness; and

a second layer that has a second lattice constant, a second thickness and is epitaxially grown over the first germanium substrate layer, wherein the second layer is a composite of a first constituent and a second constituent, and has a first ratio of the first constituent to the second constituent;

a third layer that has a third lattice constant, a third thickness and is epitaxially grown over the second layer, wherein the third layer is a composite of a third constituent and a fourth constituent and has a second ratio of the third constituent to the fourth constituent,

wherein:

the first ratio and the second ratio are selected such that the first lattice constant is between the second lattice constant and the third lattice constant,

the second thickness and the third thickness are chosen such that a total strain in the layered structure is close to zero with respect to the substrate, as is defined at least in part by:

a) the second thickness;

b) the third thickness; and

c) lattice constant differences between the adjacent layers;

a first lattice mismatch between the first germanium substrate layer and the adjacent second layer is offset by a second lattice mismatch between the first germanium substrate layer and the third layer to thereby reduce the total strain on the layered structure, and

the layered structure has a single in-plane lattice spacing.

2. The layered structure of claim 1, wherein the first constituent is the same as the third constituent, and the second constituent is the same as the fourth constituent.

3. The layered structure of claim 1, wherein the first constituent is different from the third constituent.

4. The layered structure of claim 1, wherein the first, the second, the third or the fourth constituent is a III-V binary alloy selected from a group consisting of AlP, GaP, InP, AlAs, GaAs, InAs, AlSb, GaSb, and InSb.

5. The layered structure of claim 1, further comprising:
a repetition of the second layer and the third layer grown over the third layer.

6. The layered structure of claim 1, wherein the layered structure is implemented as a vertical-cavity surface-emitting laser (VCSEL) epitaxial wafer.

7. The layered structure of claim 6, wherein the VCSEL epitaxial wafer has a bow measurement less than 10 μm.

8. The layered structure of claim 1, wherein the first germanium substrate layer is a single germanium wafer, and a lattice constant of an upper surface of the single germanium wafer is equivalent to a bulk germanium substrate.

9. The layered structure of claim 1, wherein the first germanium substrate layer includes a germanium wafer on an oxide layer that is on a silicon layer, and wherein a lattice constant of an upper surface of the germanium wafer is equivalent to a bulk germanium substrate.

10. The layered structure of claim 1, wherein the first germanium substrate layer includes a germanium wafer on a silicon layer, and wherein a lattice constant of an upper surface of the germanium wafer is equivalent to a bulk germanium substrate.

11. The layered structure of claim 1, wherein the first germanium substrate layer includes one or more porous germanium sublayers between two germanium sublayers, and wherein a lattice constant of an upper surface of the first germanium substrate layer that is adjacent to the second layer is equivalent to a lattice constant of a bulk germanium substrate.

12. The layered structure of claim 1, wherein the first germanium substrate layer includes a patterned germanium wafer having a first germanium portion and a second germanium portion that is spatially non-overlapping from the first germanium portion, and wherein a lattice constant of an upper surface of the first region or the second region in the patterned germanium wafer is equivalent to a bulk germanium substrate.

13. The layered structure of claim 1, wherein the first germanium substrate layer includes a layered structure of a germanium tin (Ge_xSn_{1-x}, $0 \leq x \leq 1$) wafer that is grown over a germanium wafer.

14. The layered structure of claim 1, further comprising:

an epitaxial germanium layer grown over the first germanium substrate layer,

wherein the epitaxial germanium layer is used to host an embedded device, and wherein the embedded device is selected from a group consisted of a germanium APD, a GaAs PIN and a germanium transistor.

15. The layered structure of claim 1, further comprising:

a second germanium layer, having the first lattice constant, that is directly or indirectly above the third layer; and

a fourth layer having the first constituent and the second constituent epitaxially grown over the second germanium layer;

wherein:

a third ratio between the first constituent and the second constituent in the fourth layer is chosen to render a third lattice constant of the fourth layer that is used to offset a total strain from layers below the second germanium layer.

16. The layered structure of claim 1, wherein the layered structure has a bow measurement less than 10 μm.

17. The layered structure of claim 1, wherein the first germanium substrate layer eliminates slip line.

18. A method to grow a layered structure, comprising:

obtaining a first germanium substrate layer having a first lattice constant and a first thickness; and

configuring a second layer that has a second lattice constant, a second thickness and is epitaxially grown over the first germanium substrate layer, wherein the second layer is a composite of a first constituent and a second constituent, and has a first ratio of the first constituent to the second constituent;

configuring a third layer that has a third lattice constant, a third thickness and is epitaxially grown over the second layer, wherein the third layer is a composite of a third constituent and a fourth constituent, and has a second ratio of the third constituent to the fourth constituent;

wherein:

the first ratio and the second ratio are selected such that the first lattice constant is between the second lattice constant and the third lattice constant,

the second thickness and the third thickness are chosen such that a total strain in the layered structure is close to zero with respect to the substrate, as is defined at least in part by:

a) the second thickness;

b) the third thickness; and

c) lattice constant differences between the adjacent layers;

a first lattice mismatch between the first germanium substrate layer and the second layer is offset by a second lattice mismatch between the first germanium substrate layer and the third layer to thereby reduce the total strain on the layered structure; and

the layered structure has a single in-plane lattice spacing.

19. The method of claim 18, further comprising:

configuring a second germanium layer, having the first lattice constant, that is directly or indirectly above the third layer; and

configuring a fourth layer having the first constituent and the second constituent epitaxially grown over the second germanium layer;

wherein:

a third ratio between the first constituent and the second constituent in the fourth layer is chosen to render a third lattice constant of the fourth layer that is used to offset a total strain from layers below the second germanium layer.

20. The method of claim 18, wherein:

the first germanium substrate layer includes a patterned germanium wafer having a first germanium portion and a second germanium portion that is spatially non-overlapping from the first germanium portion; and

a lattice constant of an upper surface of the first region or the second region in the patterned germanium wafer is equivalent to a bulk germanium substrate.