additional layers of material may be formed and processed (*e.g.*, patterned) over the epitaxial layer of III-V type semiconductor material to form one or more semiconductor devices on the engineered substrate.

[0009] When a layer of semiconductor material is epitaxially grown at elevated temperatures upon an engineered substrate, lattice strain may be induced in the crystal lattice of the layer of semiconductor material. The strain in the semiconductor material may result from a lattice parameter mismatch between the crystal lattice of the underlying materials of the engineered substrate and that of the semiconductor material being formed thereon (*e.g.*, the underlying material has one or more lattice constants that differ from that of the semiconductor material).

[0010] In addition, a lattice strain may also be induced in the crystal lattice of the semiconductor material during epitaxial growth at elevated temperature due to a difference in the coefficients of thermal expansion (CTE) exhibited by the respective adjacent materials. For example, if the underlying engineered substrate has mean a CTE which is greater than that of the semiconductor material being grown upon the engineered substrate, the semiconductor material may be grown in a state of tensile strain. Such a state of tensile strain may increase during the growth of the semiconductor material, as the layer thickness increases, and may eventually result in the formation of defects in the semiconductor layer. Such defects may include, for example, dislocations and cracks.

BRIEF SUMMARY

[0011] Embodiments of the present invention may be used to provide layers of semiconductor material over engineered substrates having reduced lattice strain, which may enable the formation of relatively thicker layers of high quality semiconductor material using the engineered substrates. As a result, embodiments of the present invention may be used to provide improved semiconductor devices.

[0011a] An aspect of the present invention provides a semiconductor structure or device comprising: a carrier substrate; a non-glassy bonding layer deposited upon the carrier substrate; a plurality of seed structures bonded to the non-glassy bonding layer through a bonding interface, a mean coefficient of thermal expansion of the carrier substrate greater than a mean coefficient of thermal expansion of the plurality of seed structures; and at least one layer

of a semiconductor material grown upon a surface of the plurality of seed structures, a thickness of the at least one layer of the semiconductor material greater than two (2) microns, and the mean coefficient of thermal expansion of the carrier substrate greater than a mean coefficient of thermal expansion of the at least one layer of the semiconductor material.

[0011b] Another aspect of the present invention provides a semiconductor structure or device comprising: a carrier substrate; a non-glassy bonding layer deposited upon the carrier substrate; a plurality of seed structures bonded to the non-glassy bonding layer through a bonding interface and comprising compressively strained gallium nitride; and at least one layer of a semiconductor material grown upon a surface of the plurality of seed structures, a thickness of the at least one layer of the semiconductor material greater than two (2) microns.

[0012] The disclosure also relates to~~In some embodiments, the present invention includes~~ methods of fabricating semiconductor structures and devices in which at least one seed structure is bonded to a carrier substrate using a glass bonding layer. The at least one seed structure is at least substantially comprised by a single crystal of semiconductor material. At least one layer of semiconductor

material may be deposited over the at least one seed structure at a temperature above a glass transition temperature of a glass material of the glass bonding layer while the at least one seed structure is supported on the glass bonding layer.

[0013] The disclosure also relates to~~In additional embodiments, the present invention includes~~ methods of fabricating semiconductor structures and devices in which at least one seed structure is bonded to a first carrier substrate using a glass bonding layer. The at least one seed structure is at least substantially comprised by a single crystal of semiconductor material. A second carrier substrate is bonded to the at least one seed structure on a side thereof opposite the first carrier substrate using a non-glassy bonding layer. The first carrier substrate and the glass bonding layer may be removed from the at least one seed structure, and the single crystal of semiconductor material of the at least one seed structure may be expanded using the thermal expansion of the second carrier substrate while heating the at least one seed structure, the non-glassy bonding layer, and the second carrier substrate. At least one layer of semiconductor material may be deposited over the at least one seed structure on a side thereof opposite the second carrier substrate and the non-glassy bonding layer while the single crystal of semiconductor material is in an expanded state at least partially caused by the thermal expansion of the second carrier substrate.

[0014] The disclosure also relates to~~Additional embodiments of the present invention include~~ semiconductor structures and devices formed by the methods described herein. Such semiconductor structures and devices include, for example, integrated circuits (ICs) (*e.g.*, logic processors and memory devices), radiation emitting devices (*e.g.*, light emitting diodes (LEDs), resonant cavity light emitting diodes (RCLEDs), and vertical cavity surface emitting lasers (VCSELs)), radiation absorbing devices (*e.g.*, optical sensors and solar cells) and switching/rectifying devices (*e.g.*, power electronic devices). Such devices may comprise bipolar junction transistors (BJTs), power metal-oxide-field-effect-transistor (MOSFETS), thyristors, schottky diodes, junction field effect transistors (JFETs), insulated gate bipolar transistors (IGBTs) and PIN diodes.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0015] While the specification concludes with claims particularly pointing out and distinctly claiming what are regarded as embodiments of the present invention, the advantages of

CLAIMS:

1. A semiconductor structure or device comprising:

a carrier substrate;

a non-glassy bonding layer deposited upon the carrier substrate;

a plurality of seed structures bonded to the non-glassy bonding layer through a bonding interface, a mean coefficient of thermal expansion of the carrier substrate greater than a mean coefficient of thermal expansion of the plurality of seed structures; and

at least one layer of a semiconductor material grown upon a surface of the plurality of seed structures, a thickness of the at least one layer of the semiconductor material greater than two (2) microns, and the mean coefficient of thermal expansion of the carrier substrate greater than a mean coefficient of thermal expansion of the at least one layer of the semiconductor material.

2. The semiconductor structure of claim 1, wherein the non-glassy bonding layer comprises at least one of SiO_2, Si_3N_4 and SiO_xN_y.

3. The semiconductor structure of claim 1, wherein the seed structures of the plurality of seed structures comprise compressively strained gallium nitride.

4. The semiconductor structure of claim 1, wherein each seed structure of the plurality of seed structures has lateral dimensions *X* and *Y* of between about five microns (5 μm) and about one millimeter (1 mm).

5. The semiconductor structure of claim 1, wherein each of the plurality of seed structures is spaced from adjacent seed structures by a distance of between about one micron (1 μm) and about one hundred microns (100 μm).

6. The semiconductor structure of claim 1, wherein the thickness of the at least one layer of the semiconductor material is greater than six microns (6 μm).

7. The semiconductor structure of claim 1, wherein the at least one layer of the semiconductor material comprises compressively strained gallium nitride.

CLAIMS:

1. A semiconductor structure or device comprising:

a carrier substrate;

a non-glassy bonding layer deposited upon the carrier substrate;

a plurality of seed structures bonded to the non-glassy bonding layer through a bonding interface, a mean coefficient of thermal expansion of the carrier substrate greater than a mean coefficient of thermal expansion of the plurality of seed structures; and

at least one layer of a semiconductor material grown upon a surface of the plurality of seed structures, a thickness of the at least one layer of the semiconductor material greater than two (2) microns, and the mean coefficient of thermal expansion of the carrier substrate greater than a mean coefficient of thermal expansion of the at least one layer of the semiconductor material.

2. The semiconductor structure of claim 1, wherein the non-glassy bonding layer comprises at least one of SiO_2, Si_3N_4 and SiO_xN_y.

3. The semiconductor structure of claim 1, wherein the seed structures of the plurality of seed structures comprise compressively strained gallium nitride.

4. The semiconductor structure of claim 1, wherein each seed structure of the plurality of seed structures has lateral dimensions X and Y of between about five microns (5 μm) and about one millimeter (1 mm).

5. The semiconductor structure of claim 1, wherein each of the plurality of seed structures is spaced from adjacent seed structures by a distance of between about one micron (1 μm) and about one hundred microns (100 μm).

6. The semiconductor structure of claim 1, wherein the thickness of the at least one layer of the semiconductor material is greater than six microns (6 μm).

7. The semiconductor structure of claim 1, wherein the at least one layer of the semiconductor material comprises compressively strained gallium nitride.

8. A semiconductor structure or device comprising:

a carrier substrate;

a non-glassy bonding layer deposited upon the carrier substrate;

a plurality of seed structures bonded to the non-glassy bonding layer through a bonding interface and comprising compressively strained gallium nitride; and

at least one layer of a semiconductor material grown upon a surface of the plurality of seed structures, a thickness of the at least one layer of the semiconductor material greater than two (2) microns.

9. The semiconductor structure of claim 8, wherein the a mean coefficient of thermal expansion of the carrier substrate is greater than a mean coefficient of thermal expansion of the plurality of seed structures and a mean coefficient of thermal expansion of the at least one layer of a semiconductor material.

10. The semiconductor structure of claim 8, wherein the non-glassy bonding layer comprises at least one of SiO_2, Si_3N_4 and SiO_xN_y.

11. The semiconductor structure of claim 8, wherein each seed structure of the plurality of seed structures has lateral dimensions X and Y of between about five microns (5 μm) and about one millimeter (1 mm).

12. The semiconductor structure of claim 8, wherein each of the plurality of seed structures is spaced from adjacent seed structures by a distance of between about one micron (1 μm) and about one hundred microns (100 μm).

13. The semiconductor structure of claim 8, wherein the thickness of the at least one layer of the semiconductor material is greater than six microns (6 μm).

14. The semiconductor structure of claim 8, wherein the at least one layer of the semiconductor material comprises compressively strained gallium nitride.