engineered substrate, 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.

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).

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.

DISCLOSURE

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.

~~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~~

According to an aspect of the present invention, there is provided a method of fabricating a semiconductor structure or device, comprising: bonding at least one seed structure at least substantially comprised by a single crystal of semiconductor material to a carrier substrate using a glass bonding layer; selecting the carrier substrate to comprise a material that exhibits a coefficient of thermal expansion higher than a coefficient of thermal expansion exhibited by the single crystal of semiconductor material of the at least one seed structure; depositing at least one layer of semiconductor material 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; cooling the at least one layer of semiconductor material, the at least one seed structure, the glass bonding layer, and the carrier substrate to room temperature after depositing the at least one layer of semiconductor material over the at least one seed structure; and compressively straining the single crystal of semiconductor material of the at least one seed structure using thermal contraction of the carrier substrate while cooling the at least one layer of semiconductor material, the at least one seed structure, the glass bonding layer, and the carrier substrate to room temperature from a temperature below the glass transition temperature of the glass material of the glass bonding layer.

~~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.~~

~~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.~~

According to another aspect of the present invention, there is provided a method of fabricating a semiconductor structure or device, comprising: bonding at least one seed structure at least substantially comprised by a single crystal of semiconductor material to a first carrier substrate using a glass bonding layer; bonding a second carrier substrate to the at least one seed structure on a side thereof opposite the first carrier substrate using a non-glassy bonding layer; removing the first carrier substrate and the glass bonding layer from the at least one seed structure; expanding the single crystal of semiconductor material of the at least one seed structure using 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; and depositing at least one layer of semiconductor material 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.

There are also disclosed~~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.

patterning an at least substantially continuous seed layer to form a plurality of seed structures; and

bonding the plurality of seed structures to the first carrier substrate using the glass bonding layer.

12. The method of claim 8, further comprising selecting the single crystal of semiconductor material of the at least one seed structure to comprise a III-V type semiconductor material.

13. The method of claim 12, wherein depositing the at least one layer of semiconductor material over the at least one seed structure comprises epitaxially growing a layer of III-V type semiconductor material on the at least one seed structure to a thickness of about two microns (2 μm) or more.

14. The method of claim 8, further comprising:

selecting the glass bonding layer to comprise a borophosphosilicate glass (BPSG); and

selecting the non-glassy bonding layer to comprise at least one of SiO_2, Si_3N_4, and SiO_xN_y, wherein x and y are any numbers having a sum approximately equal to two (2).

15. The method of claim 8, further comprising:

selecting the second carrier substrate to comprise an electrically and thermally conductive material; and

selecting the non-glassy bonding layer to comprise a metal or metal alloy material.

16. The method of claim 8, further comprising fabricating at least one of a light-emitting diode, a laser, an optical sensor, a power electronic device and a solar cell comprising the at least one layer of semiconductor material.

~~17. 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.~~

~~18. The semiconductor structure of claim 17, wherein the non-glassy bonding layer comprises at least one of SiO_2, Si_3N_4 and SiO_xN_y.~~

~~19. The semiconductor structure of claim 17, wherein the seed structures of the plurality of seed structures comprise compressively strained gallium nitride.~~

~~20. The semiconductor structure of claim 17, 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).~~

~~21. The semiconductor structure of claim 17, 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).~~

~~22. The semiconductor structure of claim 17, wherein the thickness of the at least one layer of the semiconductor material is greater than six microns (6 μm).~~

~~23. The semiconductor structure of claim 17, wherein the at least one layer of the semiconductor material comprises compressively strained gallium nitride.~~