

Strained Channel on Insulator Device

TECHNICAL FIELD

[0001] The present invention relates generally to integrated circuits, and more particularly to a strained channel on insulator device and method for forming the same.

BACKGROUND

[0002] Typical commercial semiconductor devices are formed from silicon. In these devices, regions of the silicon are doped with impurities to vary the conductivity and form junctions, which can be used to form, for example, transistors. In most commercially available devices, these transistor devices are formed in a semiconductor substrate. For example, the devices may be formed within a lightly doped well within a monocrystalline silicon substrate. In other devices, known as silicon-on-insulator (SOI), a silicon layer is formed over an insulating layer, which is formed on the substrate. Transistor devices can then be formed in the upper silicon layer.

[0003] Enhanced electron mobility in silicon under tensile channel strain and enhanced hole mobility in silicon-germanium (SiGe) under compressive channel strain have been reported. See e.g., Ismail et al., "Electron transport properties of Si/SiGe heterostructures: Measurements and device implications," Applied Physics Letters Vol. 63, No. 5, 2 August 1993, pp. 660-662; and Nayak et al., "Enhancement-Mode Quantum-Well $\text{Ge}_x\text{Si}_{1-x}$ PMOS," IEEE Electron Device Letters, Vol. 12, No. 4, April 1991, pp. 154-156. Both of these papers are incorporated herein by reference.

[0004] Recent studies have shown the feasibility of strained Si/SiGe-on-Insulator (SiGe-OI) structure. For example, Gamiz et al. have shown by Monte Carlo simulation that electron mobility is greater when strained-silicon inversion layers are grown on SiGe-on-insulator substrates than when unstrained-silicon-on-insulator devices are employed. Gamiz et al., "Strained-Si/SiGe-on-insulator inversion layers: The role of strained-Si layer thickness on electron mobility," *Applied Physics Letters*, vol. 80, no. 22, 3 June 2002, pp. 4160-62; *see also* Gamiz et al., "Electron Transport in strained Si inversion layers grown on SiGe-on-insulator substrates," *Journal of Applied Physics*, vol. 92, no. 1, 1 July 2002, pp. 288-295. Both of these papers are incorporated herein by reference.

[0005] Mizuno et al. have studied p-channel advanced SOI MOSFETs using double SiGe heterostructures fabricated by the combination of SIMOX and high-quality strained-Si/SiGe regrowth technologies, in order to introduce higher strain in the silicon channel. Mizuno et al., "Novel SOI p-Channel MOSFETs With Higher Strain in Si Channel Using Double SiGe Heterostructures," *IEEE Transactions on Electron Devices*, vol. 49, no. 1, January 2002, pp. 7-14; *see also* Tezuka et al., "High-performance Strained Si-on-Insulator MOSFETs by Novel Fabrication Processes Utilizing Ge-Condensation Technique," 2002 Symposium on VLSI Technology Digest of Technical Papers, pp. 97-97. Both of these papers are incorporated herein by reference.

SUMMARY OF THE INVENTION

[0006] The present invention includes embodiments of semiconductor devices that have enhanced electron and hole mobility, for example in CMOS devices. With certain embodiments, both the NMOS and the PMOS devices can be formed in a single layer and both can experience the speed advantages of a properly stressed material.

[0007] In one embodiment, for example, a semiconductor device includes a substrate (e.g., a silicon substrate) with an insulating layer (e.g., an oxide such as silicon dioxide) disposed thereon. A first semiconducting material layer (e.g., SiGe) is disposed on the insulating layer and a second semiconducting material layer (e.g., Si) is disposed on the first semiconducting material layer. The first and second semiconducting material layers preferably have different lattice constants in the relaxed state such that, when adjacent, the first semiconducting material layer is compressive and the second semiconducting material layer is tensile.

[0008] A method of making an embodiment device of the present invention includes forming a first epitaxial $\text{Si}_{1-x}\text{Ge}_x$ layer over the SOI substrate. The $\text{Si}_{1-x}\text{Ge}_x$ layer is oxidized so that Ge atoms are driven from an upper surface of the $\text{Si}_{1-x}\text{Ge}_x$ layer into the remaining portion of the $\text{Si}_{1-x}\text{Ge}_x$ layer and the silicon layer of the SOI substrate. This process forms a relaxed $\text{Si}_{1-y}\text{Ge}_y$ layer (preferably y is greater than x). The oxide layer that was formed during oxidation is removed and a second silicon layer is formed over the $\text{Si}_{1-y}\text{Ge}_y$ layer. Preferably, the second silicon layer induces a compressive stress in the relaxed $\text{Si}_{1-y}\text{Ge}_y$ layer.

[0009] In preferred embodiments, the present invention provides simple structures for adjusting the channel strain of an electronic device. As an example, embodiments of the present invention provide techniques that allow design engineers to use stress engineering to optimize NMOS/PMOS ratio to optimize device performance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] For a more complete following descriptions taken in conjunction with the accompanying drawings, in which understanding of the present invention, and the advantages thereof, reference is now made to the:

[0011] Figure 1 is a cross-sectional view of a first embodiment of the present invention;

[0012] Figure 2 is a cross-sectional view of a first embodiment of the present invention;

[0013] Figure 3 is a cross-sectional view of a first embodiment of the present invention; and

[0014] Figures 4a-4d are cross-sectional views during fabrication of an embodiment of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0015] The making and using of the presently preferred embodiments are discussed in detail below. It should be appreciated, however, that the present invention provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed are merely illustrative of specific ways to make and use the invention, and do not limit the scope of the invention.

[0016] A first embodiment of the present invention will be described with respect to Figure 1, which shows a semiconductor device 10. The semiconductor device 10 is preferably formed on a semiconductor-on-insulator (SOI) substrate. In this case, the SOI substrate includes a substrate 12 and an insulating layer 14 disposed on the substrate 12. In the preferred embodiment, the substrate 12 is a monocrystalline silicon substrate. This substrate can be lightly doped, although doping is not necessary. Other materials such as germanium, quartz, sapphire, and glass could alternatively be used as the substrate material.

[0017] In the preferred embodiment, the insulating layer 14 is an oxide such as silicon dioxide (SiO_2). This layer can be formed to a thickness of between about 100 nm and about 200 nm. The present invention does not limit the method in which the insulating layer is formed. For example, an oxide layer 14 can be deposited or thermally grown on the substrate 12. Alternatively, the oxide layer 14 can be formed by implanting an oxygen bearing species into the substrate, e.g., using a SIMOX process. Alternatively, other insulators such as nitrides or an air gap (e.g., SON or silicon on nothing) can be used.

[0018] A first semiconducting material layer 16 is disposed on the insulating layer. The first semiconducting material is characterized as having a compressive stress. A second semiconducting material layer 18 is disposed on the first semiconducting material layer 16. The

second semiconducting material 18 is characterized as having a tensile stress. In the preferred embodiment, the stresses are created due to the fact that semiconducting materials that form layers 16 and 18 have different lattice constants in the relaxed state. When these two materials are joined, the lattice constant at the interface will be forced to be the same, which causes the stresses in the layers.

[0019] The first and second semiconducting material layers 16 and 18 can comprises any of a large number of semiconductors, such as alloy semiconductors, elemental semiconductors, or compound semiconductors. In the preferred embodiment, the first semiconducting material 16 is silicon germanium (SiGe) and the second semiconducting material 18 is silicon (Si). Other combinations of materials are also envisioned.

[0020] In the preferred embodiment, the first and second semiconducting material layers 16 and 18 have a combined thickness of less than about 40 nm (400 Å). For example, the first layer 16 may be a SiGe layer with a thickness less than about 400 Å and the second layer 18 may be a Si layer with a thickness less than about 400 Å. This example is useful for semiconductor devices built with 90 nm minimum design features. The thicknesses can vary (e.g., get smaller) as the design features vary (e.g., get smaller). In the preferred embodiment, the ratio of the thickness of the second semiconducting material layer 18 to the thickness of the first semiconducting material is greater than about 0.3.

[0021] The thickness of second layer 18 preferably has a thickness that is less than the critical thickness. The critical thickness is the thickness at which it becomes energetically favorable for misfit dislocations to be made.

[0022] In the embodiment illustrated in Figure 1, a CMOS (complementary metal oxide semiconductor) pair of transistors has been formed in the semiconducting material layers 16 and

18. The CMOS pair includes a first transistor 20 and a second transistor 22. The first transistor 20 includes a source region 24 and a drain region 26, both of which extend within the first and second semiconducting material layers 16 and 18. The drain region 26 is spaced from the source region 24 by a channel region 30. The selection of which region 24 or 26 is the source and which is the drain is arbitrary and the labels could be reversed in a particular circuit (and as a result both the source and drain can be referred to as a source/drain region). A gate-insulating layer 32 (e.g., an oxide and/or nitride) overlies the channel region 30 and a conductive gate 34 (e.g., polysilicon and/or silicide) overlies the gate-insulating layer 32.

[0023] Similarly, the second transistor 22 includes a source region 36 and a drain region 38, both of which extend within the first and second semiconducting material layers 16 and 18. The drain region 38 is spaced from the source region 36 by a channel region 40. As before, the selection of which region 36 or 38 is the source and which is the drain is arbitrary and the labels could be reversed in a particular circuit. A gate-insulating layer 42 (e.g., an oxide and/or nitride) overlies the channel region 40 and a conductive gate 43 (e.g., polysilicon and/or silicide) overlies the gate-insulating layer 42.

[0024] In this example, the first transistor 20 is a p-channel transistor and the second transistor 22 is an n-channel transistor. In this case, the source/drain regions 24 and 26 are preferably heavily doped with a p-type dopant such as boron and the channel 30 is more lightly doped with an n-type dopant such as arsenic or phosphorus. The source/drain regions 36 and 38 are preferably heavily doped with an n-type dopant such as arsenic or phosphorus and the channel 40 is more lightly doped with a p-type dopant such as boron.

[0025] An isolation region 28 can isolate the p-channel transistor 20 and the n-channel transistor 22. In the preferred embodiment, the isolation region 28 is formed from a dielectric

such as silicon dioxide (SiO_2). For example, region 28 could be formed by standard shallow trench isolation (STI) or local oxidation of silicon (LOCOS) processes. Alternatively, isolation region 28 could be formed from other materials such as silicon nitride (e.g., Si_3N_4) or nothing (mesa method). Although only one isolation region is shown, a typical device 10 would include a plurality of isolation regions.

[0026] In the preferred embodiment, the isolation region 28 is formed adjacent the first and second semiconducting material layer 16 and 18 so as to induce a compressive strain on the first semiconducting material layer 16 and/or a tensile strain on the second semiconducting material layer 18.

[0027] The isolation region 28 can induce strain in at least three ways. For example, when an isolation trench is used, a trench liner (not shown) can be formed in a manner that induces stress. As another example, when the trench is filled a stress is intrinsically induced. Likewise, in the case of thermal oxidation, a stress can be induced in the layer during the LOCOS process. As a final example, the volume of the trench filling material can be decreased (or increased) by thermal (or other) treatment.

[0028] In addition, source/drain regions 24, 26, 36 and 38 are preferably strained source/drain regions. A strained source/drain is a doped region formed adjacent to the gate in a strained region. The strained source/drain regions induce more tensile strain on the second semiconducting material layer 18 or more compressive strain on the first semiconducting material layer 16. The source/drain regions 24, 26, 36 and 38 can induce more stress due to the larger or smaller atom sizes of different implantation species. In addition, a silicide layer (not shown) can be formed over the source/drain regions. This silicide layer can induce additional stress.

[0029] Figure 2 shows an alternate embodiment that further includes a thin film layer 44 disposed over the source/drain regions 24, 26, 36 and/or 38. As examples, the thin layer 44 can be formed of an oxide (e.g., silicon dioxide), a nitride (e.g., silicon nitride), or a combination of nitride and oxide (e.g., SiON or a composite layer). Any other layer that induces stress could alternatively, or additionally, be used. In the preferred embodiment, the layer 44 is formed to a thickness of between about 200 Å and about 800 Å.

[0030] In one embodiment, the thin film layer 44 has a tensile stress that induces tensile strain on the second semiconducting material layer 18. In this embodiment, the preferred material is an insulator, such as one of the insulators discussed above. To understand properties of the materials that cause the inducement of a stress, reference can be made to the papers by Tiwari et al., International Electron Device Meeting 1997, pp. 939-941 and Ootsuka, et al., International Electron Device Meeting 2000, pp. 575-578.

[0031] In an alternate embodiment, the thin film layer 44 has a compressive stress and induces a compressive strain on the first semiconducting material layer 16. In this embodiment, the preferred material is an insulator, such as one of the insulators discussed above. The same film can be used for inducing a compressive stress as a tensile stress, e.g., with an additional process step such as a germanium implantation.

[0032] Figure 3 shows alternate embodiment. In this embodiment, the first semiconducting material layer 16 is isolated from the substrate 12 by an air tunnel 46. As shown in the figure, the portion of the layer 16 that includes a transistor, e.g., the active area is the portion that overlies the air tunnel 46. Further information on device that includes an air tunnel can be found in Jurczak et al., "Silicon-on-Nothing (SON) – an Innovative Process for Advanced CMOS," IEEE Transactions on Electron Devices, Vol. 47, No. 11, Nov. 2000, pp. 2179-2187, which

paper is incorporated herein by reference. Also incorporated herein by reference is U.S. Patent Application Publication No. 2002/0076899, entitled "Process for fabricating a substrate of the silicon-on-insulator or silicon-on-nothing type and resulting device."

[0033] A preferred method of forming a semiconductor device will now be described with reference to Figures 4a-4d. Referring first to Figure 4a, a semiconductor-on-insulator (SOI) substrate includes a silicon layer 150 that overlies an insulating layer 114. The insulating layer 114 is disposed on a substrate 112. As labeled on the figure, the layer 150 is preferably silicon, the layer 114 is preferably silicon dioxide, and the layer 112 is preferably silicon. These labels are provided solely to help the reader understand the preferred embodiment. It is understood that other materials could be used in addition to or in replacement of the materials shown.

[0034] In the preferred embodiment, the silicon layer 150 is a monocrystalline silicon layer, preferably having a thickness less than about 400 Å. This layer is preferably doped for the n-well (e.g., arsenic or phosphorus) and the p-well (e.g., boron). The silicon layer 150 may be epitaxially deposited on insulator 114. Alternatively, the insulator 114 could have been formed by implantation into the substrate 112 with the top layer 150 having been recrystallized.

[0035] Referring now to Figure 4b, a $\text{Si}_{1-x}\text{Ge}_x$ layer 152 is formed over the SOI substrate 150/114/112. Preferably, the $\text{Si}_{1-x}\text{Ge}_x$ layer 152 is epitaxially grown as a substantially monocrystalline layer. For example, the epitaxial layer can be grown by ultra high vacuum chemical vapor deposition (UHVCVD) or molecular beam epitaxy (MBE). Polycrystalline and amorphous layers are also possible. This layer 152 is preferably grown to a thickness less than about 400 Å. The variable x is a number between 0 and 1 and is typically between about 0.05 and about 0.2.

[0036] Referring to Figure 4c, the $\text{Si}_{1-x}\text{Ge}_x$ layer is oxidized thereby forming an oxide layer 154. The oxide layer 154 is preferably formed by thermal oxidation to form a silicon dioxide layer using standard thermal oxidation processes. During the oxidation process Ge atoms are driven from an upper surface of the $\text{Si}_{1-x}\text{Ge}_x$ layer 152 into the remaining portion of the $\text{Si}_{1-x}\text{Ge}_x$ layer 152 and the silicon layer 150. This creates a relaxed (i.e., without stress) $\text{Si}_{1-y}\text{Ge}_y$ layer, where y is a number between 0 and 1. In the preferred embodiment, y is greater than x . The variable y is typically between about 0.1 and about 0.3, preferably about 0.2.

[0037] As shown in Figure 4d, the oxide layer 154 that was formed during the oxidizing step is removed. This removal can be done by standard wet or dry etching, e.g., with an HF etch. A second silicon layer 118 is then formed over the $\text{Si}_{1-y}\text{Ge}_y$ layer. Preferably, the second silicon layer 118 induces a compressive stress in the relaxed $\text{Si}_{1-y}\text{Ge}_y$ layer 116. For example, the silicon layer 118 can have a thickness that is less than the critical thickness but still thick enough to induce a compressive stress in the $\text{Si}_{1-y}\text{Ge}_y$ layer 116. In typical embodiments, the silicon layer 118 is typically less than about 400 Å thick.

[0038] In the preferred embodiment, the second silicon layer 118 and the $\text{Si}_{1-y}\text{Ge}_y$ layer 116 have a combined thickness of less than about 40 nm. In addition, the second silicon layer preferably has a thickness t_{Si} and the $\text{Si}_{1-y}\text{Ge}_y$ layer has a thickness t_{SiGe} , where the ratio of t_{Si} to t_{SiGe} is greater than about 0.3 (e.g., $t_{\text{Si}}/t_{\text{SiGe}} > 0.3$).

[0039] While not shown in these figures, the transistors 22 and 22 (see e.g., Figure 1) can be formed using standard processing. For example, a gate oxide layer can be formed followed by a gate layer. Either of these layers can be composite layers. These are then etched to form the gate regions. The source/drain regions can then be doped (using appropriate masking for a CMOS process). As shown in Figure 1, sidewall spacers can be included on the gates. Contacts

and metalization (which are not shown in any of the figures) can then be used to connect the transistors into the appropriate circuits.

[0040] The scope of the present application is not intended to be limited to the particular embodiments of the circuit, process, machine, manufacture, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, circuits, components, processes, machines, manufacture, means, methods, or steps, presently existing or later to be developed, that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such circuits, components, processes, machines, manufacture, means, methods, or steps.

WHAT IS CLAIMED IS:

1. A semiconductor device comprising:
 - a substrate;
 - an insulating layer disposed on the substrate;
 - a first semiconducting material layer disposed on the insulating layer, the first semiconducting material having a compressive stress; and
 - a second semiconducting material layer disposed on the first semiconducting material layer, the second semiconducting material having a tensile stress;wherein the first and second semiconducting materials have different lattice constants in a relaxed state such that, when the second semiconducting material layer is disposed on the first semiconducting material layer, the first semiconducting material layer is compressive and the second semiconducting material layer is tensile.
2. The device of claim 1 wherein the substrate comprises a semiconductor substrate.
3. The device of claim 1 wherein the insulating layer comprises an oxide layer.
4. The device of claim 1 wherein the insulating layer comprises a buried oxide layer.
5. The device of claim 1 wherein at least one of the first and second semiconducting material layers comprises an alloy semiconductor.

6. The device of claim 1 wherein at least one of the first and second semiconducting material layers comprises an elemental semiconductor.
7. The device of claim 1 wherein at least one of the first and second semiconducting material layers comprises a compound semiconductor.
8. The device of claim 1 and further comprising a plurality of isolation regions formed adjacent the first semiconducting material layer so as to induce compressive strain on the first semiconducting material layer.
9. The device of claim 1 and further comprising a plurality of isolation regions formed adjacent the second semiconducting material layer so as to induce tensile strain on the second semiconducting material layer.
10. The device of claim 1 and a strained source/drain region extending between the first and second semiconducting material layers.
11. The device of claim 10 wherein the strained source/drain region induces tensile strain on the second semiconducting material layer or more compressive strain on the first semiconducting material layer.

12. The device of claim 10 and further comprising a thin film layer disposed over the source/drain region.
13. The device of claim 12 wherein the thin film layer has a tensile stress which induces tensile strain on the second semiconducting material layer.
14. The device of claim 10 and further comprising a thin film layer with compressive stress over the source/drain region, the thin film layer inducing a compressive strain on the first semiconducting material layer.
15. The device of claim 1 wherein the first and second semiconducting material layers have a combined thickness of less than about 40 nm.
16. The device of claim 1 wherein the first semiconducting material layer and the second semiconducting material layer each have a thickness and wherein the ratio of the thickness of the second semiconducting material layer to the thickness of the first semiconducting material layer is greater than about 0.3.
17. The device of claim 16 wherein the first and second semiconducting material layers have a combined thickness of less than about 40 nm.
18. The device of claim 1 wherein the first semiconducting material layer comprises a silicon germanium layer.

19. The device of claim 1 wherein the second semiconducting material layer comprises a silicon layer.

20. A semiconductor device comprising:
- a substrate;
 - a first semiconducting material layer with compressive stress over the substrate, the first semiconducting material layer being isolated from the substrate by an air tunnel;
 - a second semiconducting material layer with tensile stress abutting the first semiconducting material layer;
- wherein the first and second semiconducting materials have different lattice constants in a relaxed state such that when the second semiconducting material layer abuts the first semiconducting material layer, the first semiconducting material layer is compressive and the second semiconducting material layer is tensile.
21. The device of claim 20 wherein the substrate comprises a semiconductor substrate.
22. The device of claim 20 wherein at least one of the first and second semiconducting material layers comprises an alloy semiconductor.
23. The device of claim 20 wherein at least one of the first and second semiconducting material layers comprises an elemental semiconductor.
24. The device of claim 20 wherein at least one of the first and second semiconducting material layers comprises a compound semiconductor.

25. The device of claim 20 and further comprising a plurality of isolation regions formed adjacent the first semiconducting material layer so as to induce compressive strain on the first semiconducting material layer.
26. The device of claim 20 and further comprising a plurality of isolation regions formed adjacent the second semiconducting material layer so as to induce tensile strain on the second semiconducting material layer.
27. The device of claim 20 and a strained source/drain region extending between the first and second semiconducting material layers.
28. The device of claim 27 wherein the strained source/drain region induces tensile strain on the second semiconducting material layer or more compressive strain on the first semiconducting material layer.
29. The device of claim 27 and further comprising a thin film layer disposed over the source/drain region.
30. The device of claim 29 wherein the thin film layer has a tensile stress which induces tensile strain on the second semiconducting material layer.

31. The device of claim 27 and further comprising a thin film layer with compressive stress over the source/drain region, the thin film layer inducing a compressive strain on the first semiconducting material layer.
32. The device of claim 20 wherein the first and second semiconducting material layers have a combined thickness of less than about 40 nm.
33. The device of claim 20 wherein the first semiconducting material layer and the second semiconducting material layer each have a thickness and wherein the ratio of the thickness of the second semiconducting material layer to the thickness of the first semiconducting material layer is greater than about 0.3.
34. The device of claim 33 wherein the first and second semiconducting material layers have a combined thickness of less than about 40 nm.

35. A semiconductor device comprising:
- a substrate;
 - an insulating layer formed over the substrate;
 - a compressive strained silicon germanium layer over the insulating layer; and
 - a tensile strained silicon layer over the compressive strained silicon germanium layer.
36. The device of claim 35 where the substrate comprises a silicon substrate.
37. The device of claim 35 and further comprising a field effect transistor, the field effect transistor comprising:
- a source region extending within the silicon germanium layer and the silicon layer;
 - a drain region extending within the silicon germanium layer and the silicon layer, the drain region spaced from the source region by a channel region;
 - a gate insulating layer overlying the channel region; and
 - a conductive gate overlying the gate insulating layer.
38. The device of claim 37 and further comprising a second field effect transistor formed within the silicon germanium layer and the silicon layer and spaced from the first field effect transistor, wherein the first field effect transistor comprises an n-channel transistor and the second field effect transistor comprises a p-channel transistor.
39. The device of claim 35 wherein the insulating layer comprises a silicon dioxide layer.

40. The device of claim 35 wherein the first and second semiconducting material layers have a combined thickness of less than about 40 nm.

41. The device of claim 35 wherein the silicon germanium layer and the silicon layer each have a thickness and wherein the ratio of the thickness of the silicon layer to the thickness of the silicon germanium layer is greater than about 0.3.

42. The device of claim 41 wherein the first and second semiconducting material layers have a combined thickness of less than about 40 nm.

43. A method of making an electron device, the method comprising:
 - providing a semiconductor-on-insulator (SOI) substrate having a silicon layer overlying an insulating layer, the insulating layer disposed on a substrate;
 - forming a first epitaxial $\text{Si}_{1-x}\text{Ge}_x$ layer over the SOI substrate;
 - oxidizing the $\text{Si}_{1-x}\text{Ge}_x$ layer so that Ge atoms are driven from an upper surface of the $\text{Si}_{1-x}\text{Ge}_x$ layer into a remaining portion of the $\text{Si}_{1-x}\text{Ge}_x$ layer and the silicon layer of the SOI substrate thereby forming a relaxed $\text{Si}_{1-y}\text{Ge}_y$ layer, wherein y is greater than x ;
 - removing an oxide layer formed during the oxidizing;
 - forming a second silicon layer over the $\text{Si}_{1-y}\text{Ge}_y$ layer.
44. The method of claim 43 wherein the second silicon layer induces a compressive stress in the relaxed $\text{Si}_{1-y}\text{Ge}_y$ layer.
45. The method of claim 44 wherein the second silicon layer has a thickness less than a critical thickness.
46. The method of claim 43 wherein the second silicon layer has a thickness t_{Si} and the $\text{Si}_{1-y}\text{Ge}_y$ layer has a thickness t_{SiGe} and wherein the ratio of t_{Si} to t_{SiGe} is greater than about 0.3.
47. The method of claim 43 wherein the second silicon layer and the $\text{Si}_{1-y}\text{Ge}_y$ layer have a combined thickness of less than about 40 nm.

48. The method of claim 47 wherein the $\text{Si}_{1-y}\text{Ge}_y$ layer has a thickness that is less than about three times a thickness of the second silicon layer.

49. A method of forming a semiconductor device, the method comprising:
- providing a substrate with an insulating layer disposed on a surface thereof;
 - forming a first semiconducting material layer on the insulating layer, the first semiconducting material having a compressive stress; and
 - a forming a second semiconducting material layer on the first semiconducting material layer, the second semiconducting material having a tensile stress.
50. The method of claim 49 wherein the first and second semiconducting material layers have different lattice constants such that the first semiconducting material layer is compressive and the second semiconducting material layer is tensile.