

THIS SHEET HAS BEEN
REPLACED

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The present invention relates to a semiconductor material particularly intended for use in manufacturing bipolar semiconductor devices such as high voltage fast switching rectifiers and an all epitaxial method for making same.

5 The production of material for use in manufacturing semiconductor devices by epitaxial techniques and diffusion is well known. A process which employs an all epitaxial method is disclosed in copending European Patent Application 94301701.2 filed 10th March, 1994 and entitled Multilayer Epitaxial
10 Structure and Method for Fabricating Same. Moreover, it is known to employ epitaxial techniques to form depletion layers with silicon/silicon-germanium interfaces under conditions which result in regions of misfit dislocations to control the switching speed of the power semiconductor devices. In this
15 regard, the reader is referred to U.S. Patent No. 5,097,308 and U.S. Patent No. 5,102,810, both issued to Ali Salih and entitled Method for Controlling The Switching Speed of Bipolar Power Devices.

The present invention is particularly concerned with
20 providing an improved process for making a semiconductor material using all epitaxial techniques, similar to that disclosed in the abovementioned Application No. 94301701.2 to form regions of misfit dislocations similar to those disclosed in the above patents. The material is economical to produce and
25 particularly well suited for fabrication of high voltage, fast switching rectifiers rated over 1000 volts with high yields and high reliability.

By combining several techniques in which a method is



achieved in which the epitaxial material is inverted after formation such that what started as the substrate becomes the structure in which the base of the device is formed.

The process starts with a high resistivity substrate.

5 The substrate is preferably Neutron Transmutation Doped silicon or Float Zone silicon. The surface of the high resistivity layer is prepared by slicing, diamond grinding and, if necessary etching. Alternating layers of substantially germanium free silicon and silicon containing

10 germanium are epitaxially grown under conditions suitable to create regions of misfit dislocations. The misfit dislocations function to control switching speed of the device to be formed. A low resistivity layer is grown over the misfit dislocation region. The material is then

15 inverted so that the low resistivity layer takes the place of the substrate and the high resistivity layer takes the place of the epi layer that is used to form the base of the semiconductor.

The present invention particularly enables us to

20 provide an epitaxial process for making material useful in the fabrication of high voltage fast switching bipolar power semiconductor devices.

The practice of the present invention enables us to provide an epitaxial process in which the material is

25 inverted so as to interchange the position of the high resistivity and low resistivity layers.

It also enables us to provide a method for making a material useful in fabricating high voltage rectifiers

rated over 1000 volts, in which defect engineering is utilized to control switching speed, while avoiding the difficulty of growing very high resistivity, very thick epi layers.

5 In accordance with one aspect of the present invention, a method is provided of making material useful in fabricating a semiconductor device of the type having a high resistivity, thick base. The method begins by preparing the surface of a relatively high resistivity
10 silicon layer. A multilayer silicon region is grown by vapor deposition adjacent the prepared surface under conditions which result in misfit dislocation regions. A relatively low resistivity silicon layer is grown adjacent the multilayer region. The material is then inverted. The
15 thickness of the high resistivity layer is reduced to a thickness adequate for the width of the base of the device to be formed. The device can thereafter be formed in the material using the high resistivity silicon layer as the base. The method preferably includes the following steps:

20 The step of preparing the surface preferably comprises the step of slicing the high resistivity silicon and diamond grinding the surface. The ground surface is then gas etched in an epitaxial reactor or chemically mechanically polished.

25 The step of forming the multilayer region comprises the steps of forming a first substantially germanium free silicon layer and forming a first silicon, layer containing a few percent germanium, so as to create two

silicon/silicon-germanium interface planes.

The step of forming the multilayer region further comprises the steps of forming a second substantially germanium free silicon layer and forming a second silicon layer, containing a few percent germanium, so as to create two more silicon/silicon-germanium interface planes.

A third substantially germanium free silicon layer is formed in two steps. The surface of this third layer is partially removed to form the surface of the multilayer region.

The method further comprises the step of forming a silicon buffer layer adjacent the multilayer region. The low resistivity layer is formed adjacent the buffer layer.

The step of reducing the thickness of the high resistivity layer comprises the step of grinding the surface of the low resistivity layer.

The method further comprises the step of etching the ground surface of the high resistivity layer. The high resistivity silicon layer for example comprises 100 ohm-cm N type Float Zone or Neutron Transmutation Doped silicon.

The silicon layer, containing a few percent germanium, is grown to a thickness of approximately 2 microns. Each of the layers containing no germanium is also grown to a thickness of approximately 2 microns. The step of forming the third layer, again containing no Ge, comprises the steps of growing a first portion approximately two microns thick and growing a second portion, which next is partially etched away, to form the surface of the third layer.

The low resistivity silicon layer has a resistivity of less than .005 ohm-cm. The low resistivity silicon layer is grown to a thickness of 100 microns.

The practice of the invention both as regards material
5 for use in manufacturing semiconductors and an all-epitaxial method for making same, is set forth in detail in the following description taken together with the annexed drawings, in which like numerals relate to like parts and in which:

10 Fig. 1 is a schematic cross-sectional view of the material of the present invention after it has been formed but prior to inversion; and

Fig. 2 is a schematic cross-sectional of the material of the present invention ready for device fabrication.

15 As seen in the figures, the starting material is a layer 10 of either Float Zone or Neutron Transmutated Doped silicon with a relatively high resistivity (100 ohm-cm) oriented at 1-1-1 or 1-0-0. In this example, it is N type, with a thickness of approximately 10 mils.

20 The surface 12 of layer 10 is prepared by slicing and chemical mechanical polishing or an equivalent two step diamond grinding process which is disclosed in the copending European Patent Application 94301627.9 filed March 8, 1994.

25 After obtaining a mirror finish on surface 12, a two step high temperature HCl gas etch is employed. Thereafter, a multilayer region including two silicon/silicon-germanium interfaces, is grown under

conditions which result in the formation of misfit dislocations. Preferably, this region includes six separate N-type layers formed by vapor deposition techniques.

5 The first substantially germanium free silicon layer 14 has a resistivity of 10 ohm cm and a thickness of about 5 microns. Adjacent silicon layer 14, a first silicon layer 16, containing a few percent germanium is grown. Layer 16 has a resistivity of 10 ohm cm, contains 10 approximately 3% germanium and has a thickness of about two microns.

Adjacent layer 16 is a second substantially germanium free silicon layer 18 having a resistivity of 10 ohm cm and a thickness of about two microns. Next to layer 18 is 15 grown a second germanium containing layer 20. Layer 20 has a resistivity of 10 ohm cm, contains approximately 3% germanium and has a thickness of about two microns.

Adjacent layer 20 is formed a third germanium free silicon layer including a first silicon sublayer 22 of 10 20 ohm-cm resistivity, about 2 microns thick and a second silicon sublayer 24 also of 10 ohm-cm resistivity and 2 micron thickness.

The surface of sublayer 24 is subject to a HCl gas etch to remove a portion of the sublayer. This step also 25 cleans up the deposition of germanium from the chamber, preventing it from acting as a future unwanted source.

Adjacent the etched surface of sublayer 24 is grown an N-type silicon buffer layer 26 of 10 ohm-cm resistivity.

Layer 26 is in the range of 5 to 15 microns thick. Thereafter a relatively low resistivity (less than .005 ohm-cm) N+ layer 28 is grown to a thickness of 100 microns.

The resulting material generally has an N+/SiGe/N- structure. The material is then inverted as shown in Fig. 2 such that high resistivity N- layer 10 is situated on top and low resistivity N+ layer 28 is located below. The surface 30 of layer 10 is ground to remove a portion thereof such that it has the predetermined thickness 10 required to support the desired voltage. That is, layer 10 will be thick enough so that after additional diffusions enough is left to serve as the high resistivity layer of the device. The surface of layer 10, surface 30, is subjected to a HCl gas etch, or to another damage removing 15 etch, to further minimize damage from the grinding process.

The material is removed from the reactor. It is now ready for device processing. It has a N-/SiGe/N+ structure.

It will now be appreciated that there has been 20 described a material particularly adapted for use in manufacturing bipolar power semiconductor devices such as a high voltage fast switching rectifier rated at over 1000 volts and to a unique method for making same. The material starts with an N layer of high resistivity. A SiGe 25 multilayer region containing misfit dislocations for switching speed control is grown. Then a low resistivity N-layer is formed. The material is then inverted and the thickness of the high resistivity layer adjusted such that

the high resistivity layer becomes the base of the device.

While only a single preferred embodiment has been disclosed for purposes of illustration, many variations and modifications could be made thereto. It is intended to
5 cover all of these variations and modifications which fall within the scope of the present invention as defined by the following claims:



Claims

1. A method for making material useful in fabricating a semiconductor device of the type having a base with a given base width, the method comprising the steps of preparing
5 the surface of a relatively high resistivity silicon layer; growing a multilayer silicon region by vapor deposition adjacent the prepared surface, under conditions which result in localized misfit dislocations; growing a relatively low resistivity silicon layer adjacent the
10 multilayer region; inverting the material; and reducing the thickness of the high resistivity layer to a thickness, such that part of the device can be formed in the material using the high resistivity silicon layer and enough is left to serve as the base of the device.
- 15 2. The method of Claim 1 wherein the step of preparing the surface comprises the step of slicing the high resistivity silicon and diamond grinding the surface.
3. The method of Claim 2 wherein the step of preparing the surface further comprises the step of etching the
20 ground surface.
4. The method of Claim 1 wherein the step of forming the multilayer region comprises the steps of forming a first substantially germanium free silicon layer and forming a first silicon layer, containing a few percent germanium, so
25 as to create a first silicon/silicon-germanium interface.
5. The method of Claim 4 wherein the step of forming the multilayer region further comprises the steps of forming a second substantially germanium free silicon layer and



forming a second silicon layer, containing a few percent germanium, so as to create a second silicon/silicon-germanium interface.

6. The method of Claim 5 wherein the step of forming the
5 multilayer region further comprises the step of forming a third substantially germanium free silicon layer and partially removing the surface thereof to form the surface of the multilayer region.

7. The method of Claim 1 further comprising the step of
10 forming a silicon buffer layer adjacent the multilayer region.

8. The method of Claim 7 wherein the low resistivity layer is formed adjacent the buffer layer.

9. The method of Claim 1 further comprising the step of
15 reducing the thickness of the high resistivity layer comprises the step of diamond grinding the surface of the high resistivity layer.

10. The method of Claim 9 further comprising the step of etching the ground surface of the high resistivity layer.

20 11. The method of Claim 1 wherein the high resistivity silicon layer comprises 100 ohm cm N type Float Zone or Neutron Transmutation Doped silicon.

12. The method of Claim 4 wherein the silicon layer, containing a few percent germanium is grown to a thickness
25 of approximately 2 microns.

13. The method of Claim 5 wherein each of the layers is grown to a thickness of approximately 2 microns.

14. The method of Claim 6 wherein the step of forming the



third layer comprises the steps of growing a first sublayer approximately two microns thick and growing a second sublayer to form the surface of the third layer.

15. The method of Claim 1 wherein the low resistivity silicon layer has a resistivity of less than .005 ohm-cm.

16. The method of Claim 1 wherein the low resistivity silicon layer is grown to a thickness of 100 microns.

17. A material useful in manufacturing semiconductor devices of the type having a base with a given base width, the material comprising a relatively high resistivity silicon layer having a thickness equal to said given width, said high resistivity layer being situated above a region comprising a silicon/silicon germanium interface formed under conditions which result in misfit dislocations, a relatively low resistivity epitaxial layer, said low resistivity layer being situated below said region, such that the high resistivity layer is adapted to form the base of the semiconductor device.

18. The material of Claim 17 wherein said region further comprises a second silicon/silicon-germanium interface formed under conditions which result in misfit dislocations.

19. The material of Claim 17 wherein said region comprises a first layer of substantially germanium free silicon and a first layer of silicon layer, containing a few percent germanium.

20. The material of Claim 19 wherein said region comprises a second layer of substantially germanium free silicon and



a second layer of silicon layer, containing a few percent germanium.

21. The material of Claim 20 wherein said region further comprises a third layer of substantially germanium free 5 silicon.

22. The material of Claim 17 further comprising a buffer layer situated between said region and said low resistivity silicon layer.