oxygen precipitates are then sufficiently big and numerous to, in the same way as the interstitial oxygen, block the propagation of the dislocations.

However, such a configuration does not make possible the control and the maintenance of the resistivity of the support substrate at a value which is stable and sufficiently high for applications in the radiofrequency range. In addition, if the oxygen precipitates are too numerous and too big, they locally generate mechanical stresses at the core of the material which can cause an overall deformation of the substrate. The deformation of the substrate can also be the cause of problems of alignment of the lithography patterns.

BRIEF DESCRIPTION OF THE INVENTION

Embodiments of the invention seek to design a structure of semiconductor-on-insulator type such that the support substrate may exhibit a good resistance to the subsequent development of slip lines while exhibiting a high and controlled electrical resistivity, and without, however, generating significant mechanical stresses within said support substrate which might cause its overall deformation.

The term “high electrical resistivity” is understood to mean, in the present text, an electrical resistivity of greater than or equal to 500 Ω.cm.

Embodiments of the invention also seek to design a structure of semiconductor-on-insulator type which may not generate, during subsequent functionalization stages, the overlay problems known to a person skilled in the art, even for the manufacture of components applied in the field of high frequencies, the gate lengths of which are less than 65 nm, for example less than or of the order of 22 nm.

An aspect of the invention provides a process for the manufacture of a multilayer structure of semiconductor-on-insulator type, comprising the following stages:

- assembling of a support substrate made of a semiconductor material exhibiting an electrical resistivity of greater than or equal to 500 Ω.cm and containing interstitial nitrogen and interstitial oxygen, the initial concentration of interstitial oxygen in the support substrate being between 15 old ppma and 25 old ppma (measured according to Standard ASTM79), and of a donor substrate for a semiconductor layer to be transferred, an electrically insulating layer being at the interface between the support substrate and the donor substrate,
- transfer of said semiconductor layer onto the support substrate,

the process additionally comprising a nucleation stage comprising a heat treatment for precipitating, in a controlled way, at least a part of the interstitial oxygen and at least a part of the interstitial nitrogen, so as to form seeds of oxygen and nitrogen precipitates, and a stabilization stage comprising a heat treatment for causing said seeds of oxygen and nitrogen precipitates to grow to a size of between 10 nm and 50 nm.

The addition of interstitial nitrogen contributes a resistance to propagation of the dislocations without, however, degrading the resistivity of the support substrate. In addition, due to its affinity with oxygen, it helps in the precipitation of interstitial oxygen.

The addition of interstitial oxygen, in a controlled concentration intermediate between the concentrations of the “low Oi” and “high Oi” substrates, in conjunction with the addition to interstitial nitrogen, makes it possible to further improve the resistance to the subsequent development of slip lines, including for substrates having very slight thicknesses for which the overlay problems become critical.

The control of the size and of the concentration of the oxygen and nitrogen precipitates during the nucleation and growth stages also makes it possible to control the resistance to the subsequent development of slip lines by limiting the propagation of dislocations within the support substrate. In addition, by more or less fixing the interstitial nitrogen and the interstitial oxygen, said stages make it possible to control the resistivity of the support substrate, including the resistivity of highly resistive support substrates for applications in the range of high frequencies.

According to other characteristics of the invention, taken alone or in combination when this is technically possible:

- the process additionally comprises, before the assembling stage, the formation of a trap-rich layer on the support substrate, said trap-rich layer being arranged between the support substrate and the electrically insulating layer,
- the formation of said trap-rich layer comprises the deposition of a layer of polycrystalline silicon on the support substrate,
- the deposition of said layer of polycrystalline silicon is carried out after the stage of stabilization of the oxygen and nitrogen precipitates,
- the initial concentration of interstitial nitrogen in the support substrate is between 10^{14} atoms/cm^3 and 10^{15} atoms/cm^3,
- on conclusion of the stabilization stage, the support substrate comprises a concentration of oxygen and nitrogen precipitates of between 10^7 precipitates.cm^{-3} and 10^{10} precipitates. cm^{-3}, preferentially a concentration of between 10^8 precipitates.cm^{-3} and 10^9 precipitates.cm^{-3},

- the nucleation stage and the stabilization stage each comprise a heat treatment, the temperature applied during the nucleation heat treatment being lower than the temperature applied during the stabilization heat treatment and the duration of the nucleation heat treatment being less than the duration of the stabilization heat treatment,
- the nucleation stage comprises the application of a temperature of between 650°C and 800°C, preferentially a temperature of between 700°C and 750°C, for a period of time of greater than one hour, preferentially a period of time of two hours,
- the stabilization stage comprises the application of a temperature of greater than 900°C, preferentially a temperature of 950°C, for a period of time of greater than two hours, preferentially a period of time of four hours,
- the nucleation and stabilization stages are carried out directly the one following the other before the assembling stage.

Another aspect of the invention provides a multilayer structure of semiconductor-on-insulator type comprising, from its rear face to its front face, a support substrate, an electrically insulating layer and a semiconductor layer, characterized in that the support substrate is made of a semiconductor material exhibiting an electrical resistivity of greater than or equal to 500 Ω.cm and comprising oxygen and nitrogen precipitates exhibiting a size of between 10 nm and 50 nm, in a concentration of between 10^7 precipitates.cm^{-3} and 10^{10} precipitates.cm^{-3}.

According to other characteristics of the invention, taken alone or in combination when this is technically possible:
- the substrate additionally comprises a trap-rich layer between the support substrate and the electrically insulating layer,
- the residual concentration of interstitial oxygen in the support substrate is less than 15 old ppma, preferentially less than 12 old ppma (measured according to Standard ASTM 79).

BRIEF DESCRIPTION OF THE FIGURES

Other characteristics and advantages of the invention will emerge from the detailed description which will follow, with reference to the appended drawings, in which:

- Figure 1 represents a multilayer structure of semiconductor-on-insulator type according to the invention, the support substrate comprising oxygen and nitrogen precipitates (white circles), residual interstitial nitrogen (black crosses) and residual interstitial oxygen (black spots),

- Figures 2A to 2F represent an embodiment of the process according to the invention in which, starting from a support substrate comprising interstitial nitrogen and interstitial oxygen (Figure 2A), a nucleation stage for the formation of seeds of oxygen and nitrogen

CLAIMS

1. A process for the manufacture of a multilayer structure of semiconductor-on-insulator type, comprising the following stages:

(a) assembling of a support substrate made of a semiconductor material exhibiting an electrical resistivity of greater than or equal to 500 Ω.cm and containing interstitial nitrogen and interstitial oxygen, the initial concentration of interstitial oxygen in the support substrate being between 15 old ppma and 25 old ppma (measured according to Standard ASTM79), and of a donor substrate for a semiconductor layer to be transferred, an electrically insulating layer being at the interface between the support substrate and the donor substrate,

(b) transfer of said semiconductor layer onto the support substrate,

the process additionally comprising a nucleation stage (c) comprising a heat treatment for precipitating, in a controlled way, at least a part of the interstitial oxygen and at least a part of the interstitial nitrogen, so as to form seeds of oxygen and nitrogen precipitates, and a stabilization stage (d) comprising a heat treatment for causing said seeds of oxygen and nitrogen precipitates to grow to a size of between 10 nm and 50 nm.

2. The process according to Claim 1, additionally comprising, before the assembling stage (a), the formation of a trap-rich layer on the support substrate, said trap-rich layer being arranged between the support substrate and the electrically insulating layer.

3. The process according to Claim 2, in which the formation of said trap-rich layer comprises the deposition of a layer of polycrystalline silicon on the support substrate.

4. The process according to Claim 3, in which the deposition of said layer of polycrystalline silicon is carried out after stage (d) of stabilization of the oxygen and nitrogen precipitates.

5. The process according to any one of Claims 1 to 4, characterized in that the initial concentration of interstitial nitrogen in the support substrate is between 10^{14} atoms/cm^3 and 10^{15} atoms/cm^3.

6. The process according to any one of Claims 1 to 5, in which, on conclusion of the stabilization stage (d), the support substrate comprises a concentration of oxygen and nitrogen precipitates of between 10^7 precipitates.cm^{-3} and 10^{10} precipitates.cm^{-3}, preferentially a concentration of between 10^8 precipitates.cm^{-3} and 10^9 precipitates.cm^{-3}.

7. The process according to any one of Claims 1 to 6, characterized in that the nucleation stage (c) and the stabilization stage (d) each comprise a heat treatment, the temperature applied during the nucleation heat treatment (c) being lower than the temperature applied during the stabilization heat treatment (d) and the duration of the nucleation heat treatment (c) being less than the duration of the stabilization heat treatment (d).

8. The process according to any one of Claims 1 to 7, in which the nucleation stage (c) comprises the application of a temperature of between 650°C and 800°C, preferentially a temperature of between 700°C and 750°C, for a period of time of greater than one hour, preferentially a period of time of two hours.

9. The process according to any one of Claims 1 to 8, in which the stabilization stage (d) comprises the application of a temperature of greater than 900°C, preferentially a temperature of 950°C, for a period of time of greater than two hours, preferentially a period of time of four hours.

10. The process according to any one of Claims 1 to 9, in which the nucleation stage (c) and the stabilization stage (d) are carried out directly the one following the other before the assembling stage (a).

11. A multilayer structure of semiconductor-on-insulator type comprising, from its rear face to its front face, a support substrate, an electrically insulating layer and a semiconductor layer, characterized in that the support substrate is made of a semiconductor material exhibiting an electrical resistivity of greater than or equal to 500 Ω.cm and comprising oxygen and nitrogen precipitates exhibiting a size of between 10 nm and 50 nm, in a concentration of between 10^7 precipitates.cm^{-3} and 10^{10} precipitates.cm^{-3}.

12. The structure according to Claim 11, additionally comprising a trap-rich layer between the support substrate and the electrically insulating layer.

13. The structure according to either one of Claims 11 and 12, characterized in that the residual concentration of interstitial oxygen in the support substrate is less than 15 old ppma, preferentially less than 12 old ppma (measured according to Standard ASTM 79).