A METHOD OF FABRICATING A SEMICONDUCTOR ON INSULATOR TYPE HETEROSTRUCTURE

The present invention relates to a method of fabricating a "semiconductor on insulator" type substrate known by the acronym "SeOI".

Said substrate or heterostructure is used in particular in the fields of optics, electronics, and optoelectronics.

A "SeOI" type substrate generally comprises at least one insulating layer interposed between two layers of semiconductor material.

Throughout the remainder of the description and claims, the term "insulator" is used to designate an electrically insulating material which may have high permittivity.

SeOI substrates are fabricated using a method comprising the following steps, for example:

- forming or depositing an insulating layer on a first substrate termed the "donor" substrate, so that a "connection" interface exists between them;
- implanting atomic species within said donor substrate using a method known commercially as "SmartCut™", to form a zone of weakness therein;
- bonding a second substrate termed the "receiver" substrate onto the free surface of the insulator by molecular bonding; and
- detaching the back portion of said donor substrate along the zone of weakness.

A heterostructure is thereby obtained comprising, in succession, a support, an insulating layer and an upper active layer derived from the donor substrate.

In the microelectronics field, the surface quality of the active layer of semiconductor material is of great importance. More precisely, the roughness and the absence of defects on the surface of said active layer are parameters that must be optimized so that future

components which are produced from said heterostructures are of good quality.

However, various types of surface defects may appear following transfer of the active layer onto the receiving substrate. They are in particular:

- non transferred zones (abbreviated to NTZ);
- blisters;
- voids;
- crystal orientated voids, abbreviated to "COV".

All such defects are due to poor transfer, to the presence of subjacent defects in the various layers of the heterostructure, to the bonding quality at the bonding interface or, merely to the methods employed in fabricating said heterostructures, such as atomic species implantation or heat treatment, for example.

The defects present at bonding interfaces or connection interfaces become locations where gas becomes trapped during the various steps in the method and then expand and form COV type blisters or voids.

Thus, for example, in the case of a heterostructure comprising, in succession, a silicon substrate support covered with a layer of thermal oxide, then with a layer of TEOS oxide obtained by LPCVD deposition, and finally with a layer of germanium, the gaseous elements may derive from several sources. The expression "LPCVD TEOS" designates a silicon oxide (SiO_2) obtained by low pressure chemical vapor deposition from a tetraethylorthosilicate (TEOS) type precursor.

Said gaseous elements may originate from:

- hydrogen or helium supplied during the atomic species implantation step which is intended to form the zone of weakness, the quantity of said gaseous elements depending on the type of implanter used and the implantation conditions (dose and energy);
- desorption of water molecules (H_2O) present at the bonding interface between the thermal oxide and the TEOS oxide;

· the TEOS oxide, if densification thereof has not been sufficient, due to diffusion of carbon-containing compounds.

Further, it should be noted that the thinner the useful layer, the larger the number of defects. When the active layer is thick, blister or void type defects are generally retained in the thickness of the active layer, and so fewer appear on the surface.

An illustrative example of such problems with defects is shown in the accompanying Figure 3.

The figure is a graph plotting the concentration **C** in H^+ ions/cm^2 [hydrogen ions/square centimeter] in a composite substrate as a function of the depth in nanometers (nm), which results were obtained by secondary ion mass spectroscopy (SIMS).

More precisely, said composite substrate is the result of bonding between a support substrate (Si) which has undergone thermal oxidation and a Ge donor substrate on which a layer of SiO_2 has been deposited. The bonding interface is thus made between two oxides, one belonging to the support substrate and the other belonging to the donor substrate. In Figure 3, the bonding interface between the two layers of SiO_2 is located at -200 nm. The support substrate is not shown in Figure 3; only its connection interface with the SiO_2 layer is shown and that interface is located at -400 nm.

Solid curve **a** shows the results obtained in the germanium (Ge) donor substrate covered with SiO_2, before bonding of the two substrates and before SmartCut™ atomic species implantation to form the zone of weakness within the layer of germanium. The H^+ ions are principally found at the bonding interface between the first layer of SiO_2 and the germanium layer.

Bold curve **c** shows the results obtained in the same substrate following implantation to allow the formation of the zone of weakness and prior to bonding with the second layer of SiO_2. It should be noted that the

vertical line at -200 nm is an artifact. The values only begin close -200 nm as this corresponds to implantation carried out before bonding the second layer of SiO_2. In the particular case of germanium, detachment does not occur at the maximum implantation level but just a little later (about 550 nm), which explains the shape of curve **b** below.

Curve **b** in dotted lines shows the results obtained after bonding the two SiO_2 layers and after detachment and transfer of the active germanium layer. The hydrogen species distribution shows an accumulation at the SiO_2/Ge and SiO_2/support substrate connection interfaces. A very small peak at the SiO_2 layer appears at -200 nm: it corresponds to the bonding interface of the two layers of SiO_2.

A substantial increase in the quantity of gas in the insulating layer (SiO_2) can be seen after the step of detachment and transfer of the active germanium layer. This increase is the source of defects visible after transfer on the upper face of the transferred germanium layer.

United States document US-A-2002/0190269 describes a method of fabricating a heterostructure comprising a layer of germanium on silicon, said method being intended to reduce the formation of bubbles at the bonding interface. More precisely, said heterostructure is obtained by implanting hydrogen into a germanium donor substrate to form a zone of weakness therein, then bonding to a silicon receiver substrate, and finally heat treating to detach the back portion of the germanium substrate.

In a particular implementation, the author suggests disposing a layer termed an "anti-bubble" layer of amorphous silicon on the germanium substrate prior to bonding, to render the bonding interface hydrophilic and thereby reduce the formation of bubbles of hydrogen when

the germanium substrate is bonded to the silicon substrate.

In a further variation, it is suggested that the roughness of the transferred layer of germanium be improved by depositing thereon a buffer layer of germanium formed by epitaxial growth.

Those two solutions are aimed at improving the quality of the bonding interface between the two substrates, but they necessitate adding a supplemental layer, which complicates the method.

One also knows according to the United States document US-6 696 352 a method of manufacture of a multilayered substrate comprising a thin single crystalline layer and a sacrificial layer. In this method, it is proposed to form a zone of weakness inside a source substrate, in order to transfer later a part of this substrate, on a receiving substrate.

To do thus, a layer for trapping H^+ ions is formed by atomic species implantation inside the donor substrate. This latter is then bonded to the receiving substrate by using an adhesive able to release H^+ ions by heating. After thermal treatment of this substrate, the H^+ ions contained in the adhesive migrate towards the trapping layer and this one after curing becomes a zone of weakness.

However, this document does not apply to the formation of a SeOI substrate and does not suggest to realize in an insulating layer, a trapping layer which retain various gaseous species which are present at the various interfaces of the SeOI substrate.

Finally, one knows according to the United States document US-2004/0171196, a process for fabricating a SOI type substrate, which similarly to what was above-described, proposes to form an ions trapping layer in a donor substrate, in order to transform it later in a weakness zone.

The trapping layer according to embodiments of the invention differs from this trapping layer by its position and its utility. As a matter of fact, it is not intended to become a zone of weakness used during a layer transfer.

Embodiments of the present invention seek to avoid the formation of defects on the surface of the transferred active layer, more precisely defects due to the agglomeration of gaseous elements at the various bonding and/or connection interfaces.

Embodiments of the present invention also seek to avoid recourse to the deposition of intermediate layers (amorphous layers or buffer layers) deposited or interposed between the insulating layer and the active layer, as is the case with the prior art methods. Such layers tend to modify the electrical properties of the final structure.

In accordance with a first aspect of the present invention, there is provided a method of fabricating a "semiconductor on insulator" type heterostructure comprising at least one insulating layer interposed between a substrate termed the "receiver" substrate and a layer termed the "active" layer, derived from a substrate termed the "donor" substrate, at least one of said insulating layers comprising a layer termed the "trapping layer" which can retain the gaseous species which may be present at the various interfaces of the heterostructure and limit the formation of defects on the surface of the active layer of said heterostructure, said method comprising the steps consisting in:

- forming or depositing at least one insulating layer on at least one of the two substrates, donor and receiver, both substrates being formed from semiconductor material ;
- bonding said donor substrate and said receiver substrate by molecular bonding such that the insulating layer or layers is (are) interposed between them and such that a bonding interface exists between one of the two substrates and one of the insulating layers or between the two insulating layers;

• withdrawing a portion of the donor substrate termed the "remainder" to retain only said active layer and to obtain said heterostructure,

the method being characterized in that prior to bonding, said trapping layer is formed by implanting at least one category of atomic species in at least one of said insulating layers, said category of atomic species being selected so as to be either identical to one of the atomic species constituting the insulating layer in which these species are implanted, or to belong to the same column of the periodic table as one of the atomic species constituting the insulating layer in which they are implanted.

Other advantageous non-limiting embodiments of the invention, taken alone or in combination, are as follows:

• after forming the trapping layer, a step of annealing the insulating layer containing said trapping layer is carried out at a temperature of at least 350°C for at least 30 minutes;

• the implantation parameters are selected so as to form said trapping layer either close to said bonding interface, preferably at a distance in the range 2 nanometers to 10 nanometers from the bonding interface, or close to a connection interface between the insulating layer and one of the two substrates;

• the trapping layer is constituted by a two-dimensional layer of nanocavities or nanoparticles;

• the insulator may be an oxide, for example silicon dioxide (SiO_2), and the implanted species are thus selected from silicon, germanium and oxygen atoms;

• the insulator may be a nitride, for example silicon nitride (Si_3N_4) and the implanted species are thus selected from silicon, germanium and nitrogen atoms;

• the back portion is withdrawn by chemical mechanical polishing;

• prior to bonding, a zone of weakness is formed in the source substrate, said zone of weakness defining the active layer from the remainder of said substrate destined to be lifted; said zone of weakness may be formed by atomic species implantation;

In accordance with a second aspect of the present invention, there is provided a "semiconductor on insulator" type heterostructure comprising at least "one insulating layer interposed between a substrate termed the "receiver" substrate formed from semiconductor material and a layer termed the "active" layer formed from semiconductor material,

characterized in that at least one of said insulating layers comprises a trapping layer constituted by a two-dimensional layer of nanocavities or nanoparticles, this trapping layer being able to retain the gaseous species which may be present at the various interfaces of the heterostructure and limit the formation of defects on the surface of the active layer of said heterostructure.

Other characteristics of the invention become apparent from the following description made with reference to the accompanying drawings which, by way of non-limiting indication, show possible implementations. In the drawings:

• Figures 1A to 1E are diagrams showing the various successive steps in a fabrication method in accordance with a first implementation of the invention;

• Figures 2A to 2F are diagrams showing the various successive steps in a fabrication method in accordance with a second implementation of the invention;

• Figure 3 is a graph plotting the concentration **C** in H^+ ions/cm^2 as a function of depth mentioned in nanometers, in a composite substrate resulting from bonding between a support substrate (Si) which has undergone thermal oxidation and a Ge donor substrate on which a layer of SiO_2 has been deposited. The results

were obtained by secondary ion mass spectroscopy (SIMS); and

· Figure 4 is a drawing made from a photograph of a section through part of an oxidized support substrate prior to SeOI bonding, including a trapping layer formed in the SiO_2 layer, where said photograph was obtained by transmission electron microscopy (TEM).

A first implementation of the invention is described below with reference to Figures 1A to 1E.

As can best be seen in Figures 1A and 1B, a substrate 1 is used. It is termed the "donor" substrate as this substrate produces the active layer in the future composite substrate or heterostructure obtained at the end of the method.

Said donor substrate 1 may be a monolayer or it may be multilayered, for example having two layers, as shown in Figure 1B. In this case, it is composed of a primary layer 11 covered with a secondary layer 12. The secondary layer is deposited on the primary layer by epitaxy, for example.

Further, a support substrate or receiver substrate 2 is used, on which or in which an insulating layer 3 is deposited or formed, as shown in Figure 1B, and as is described in more detail below.

A connection interface with reference number 20 exists between the insulating layer 3 and the receiver substrate 2.

As can be seen in Figure 1C, atomic species are then implanted in the donor substrate 1, for example within the secondary layer 12, to form a zone of weakness 13 therein. Said zone 13 defines an upper active layer 14 from the remainder 15 of the substrate.

In the embodiment of the substrate with two layers, shown in figure 1C, the remainder 15 comprises a part of the secondary layer 12 and the primary layer 11.

Further, in accordance with the invention, atomic species are implanted within the insulating layer 3 with a view to forming a trapping layer 31 therein.

As can be seen in Figure 1D, bonding of the two substrates, donor 1 and receiver 2, is then carried out by molecular bonding, by bringing the active layer 14 into intimate contact with the insulating layer 3. The bonding interface carries reference number 4.

As can be seen in Figure 1E, the back portion 15 is then withdrawn.

In the particular case in which a zone of weakness 13 exists, said withdrawal corresponds to detaching the back portion or remainder 15 of the substrate. Said detachment is achieved by applying mechanical, chemical or electrical stresses to the zone of weakness 13.

The heterostructure with reference number 5 is obtained.

Figures 2A to 2F illustrate a variation in the method described above.

The same elements carry the same reference numbers.

This variation differs from the preceding method on the one hand in that an insulating layer 6 is deposited or formed on the source substrate 1 prior to the step of atomic species implantation to form the zone of weakness 13 inside said substrate and on the other hand, in that the trapping layer, which has here the reference number 61, is formed by atomic species implantation carried out within the insulating layer 6, this last one being supported by the source substrate.

It is possible to form successively the zone of weakness 13, then the trapping layer 61, as further illustrated in Figures 2C and 2D.

However, preferably, the implantation allowing the formation of the trapping zone 61 is realized firstly, before the implantation to form the zone of weakness 13. while thus processing, the heavy contaminating elements, which may be present during the implantation aimed to

form the zone of weakness 13, are retained in the trapping layer 61, while the lighter elements, such as ions H^+ for example, cross the insulating layer 6 without being retained therein and form the zone of weakness 13.

It is to be noted that a connection interface 60 exists between the insulating layer 6 and the source substrate 1.

In the implementation shown in Figure 2D, the insulating layer 3 does not undergo the same treatment. However, it would also be possible to form a trapping layer 31 therein. In this case, the final composite substrate obtained would comprise two of them.

It would also be possible not to form the insulating layer 3 on the receiving substrate 2, since there is an insulating layer 6 on the donor substrate 1.

Finally, as can be seen in Figure 2E, the two substrates 1 and 2 are bonded by molecular bonding so that a bonding interface 7 exists between them.

After detaching the remainder 15 from the source substrate 1, the heterostructure 8 shown in figure 2F is obtained.

Said heterostructure 8 comprises two insulating layers 3, 6, interposed between two layers of semiconductor materials, 14 and 2 respectively.

In the two implementations described above, the remainder 15 is detached from the source substrate 1 after forming a zone of weakness by atomic species implantation.

However, said implantation step could also be dispensed with, the remainder 15 then being withdrawn by a chemical-mechanical polishing step, known to the skilled person as CMP.

The nature and characteristics of the materials constituting the source and receiver substrates and the insulating layer are described below in more detail.

The donor 1 and receiver 2 substrates are constituted at least in part by semiconductor materials,

in particular those in routine use in the electronics field. As an example, they may be silicon (Si), germanium (Ge), gallium nitride (GaN), gallium arsenide (AsGa) or silicon germanium (SiGe).

The insulating layers 3, 6 are preferably selected from oxides such as silicon oxide (SiO_2). A nitride may also be used, for example silicon nitride (Si_3N_4) or an oxynitride, for example germanium oxynitride ($Ge_xO_yN_z$).

It is also possible to use high permittivity dielectric materials ("high k" materials) such as hafnium dioxide (HfO_2), alumina (Al_2O_3), zirconium oxide (ZrO_2), tantalum pentoxide (Ta_2O_5), titanium dioxide (TiO_2), their nitrides and their silicides.

When the insulating layers 3 or 6 are constituted by an oxide, they may be obtained by thermal oxidation of the source substrate 1 or the support 2 on which they have to be formed.

Said insulating layers 3 or 6 may also be obtained by deposition, for example chemical vapor deposition.

By way of example, for silicon dioxide (SiO_2), it is possible to use low pressure chemical vapor deposition (LPCVD) or atomic layer deposition (ALD).

In the case of depositing a SiO_2 layer, it is also possible to carry out LPCVD deposition from a tetraethylorthosilicate (TEOS) type precursor.

Atomic species implantation to form a zone of weakness within the source substrate may, for example, be carried out using the method known commercially as "SmartCut™".

For more details regarding that method, reference could be made to the document *"Silicon on Insulator Technology"*; Materials to VLSI, 2nd edition, by J P Collinge, *Kluwer Academic Publishers*, pp 50-51.

The term "atomic species implantation" generally designates any type of treatment which can introduce atomic or ionic species into the implanted donor

substrate, with a maximum concentration of species located at a predetermined depth from the treated surface.

Atomic species implantation in the insulating layer 3, 6 to form therein a trapping layer 31 or 61 respectively is described below in more detail.

The layer 31, 61 is intended to trap diffusing gaseous species.

Forming the trapping layer consists of implanting at least one category of atomic species within the insulating layer, said atomic species being selected so that they are either identical or "isoelectric" with one of the atomic species constituting said insulator.

More precisely, it is possible to implant a single category of atomic species, or several in succession.

This step can either oversaturate the insulator with at least one category of the atoms or atomic species contained therein or introduce thereto an "isoelectric" atomic species. The term "isoelectric atomic species" designates any atomic species belonging to the same column of the periodic table as one of the atomic species constituting said insulator. However, the choice of atomic species in that column depends on its chemical reactivity towards the categories of atomic species constituting the insulator.

Purely by way of illustrative example, into a layer of silicon oxide (SiO_2), it is possible to implant oxygen, silicon and/or germanium (germanium belonging to the column 4a of the periodic table as silicon). It is possible to implant nitrogen, silicon and/or germanium into a layer of silicon nitride (Si_3N_4).

The trapping layer obtained may be constituted by two types of traps depending on the nature of the implanted element, namely:

· nanocavities (voids) when implanting atoms such as oxygen or nitrogen;

· nanoparticles, when implanting silicon or germanium.

The implantation parameters which may be adjusted are the implantation energy, which allows the depth at which the trapping layer is formed to be varied, and the implantation dose, which allows the size of the agglomerates of atoms and the density of the nanoparticles or nanocavities which are formed to be modified.

As an example, by implanting silicon in SiO_2, with an implantation energy in the range 0.65 keV to 3 keV and implantation doses in the range 5×10^{15} to 2×10^{16} Si^+/cm^2, a trapping layer is obtained located at a depth in the range -4 nm to -6 nm beneath the free surface of the SiO_2, said trapping layer being in the range 2 nm to 3 nm thick and having a very high nanoparticle surface density of more than $1 \times 10^{15}.cm^{-2}$.

The trapping layer may however be formed at any depth in the insulating layer.

In a first variation, it is formed as close as possible to the bonding interface, which is the source of the gas accumulation. It then acts as a chemical pump. In this case, it is also much more effective.

The trapping layer may also be formed as close as possible to the connection interface between the insulating layer and the substrate. This is particularly advantageous in the case of a deposited oxide where the connection interface may be a large zone for the accumulation of gaseous atomic species. The trapping zone then helps to reduce the concentration of gas accumulated at the connection interface.

When there are two insulating layers 3 and 6, as in the implementation shown in Figure 2, it may also be advantageous to produce a trapping layer in each of the two insulating layers. Preferably, these trapping layers are then formed at various depths so that one is close to a connection interface and the other is close to the bonding interface.

Finally, it may be advantageous, once the heterostructure 5 or 8 has been formed, to carry out thermal annealing. This is intended to strengthen the bonding and to change the trapping layer. However, this annealing method is limited by the maximum applicable thermal balance, as is explained below.

A plurality of physico-chemical phenomena cause traps to form, then capture gaseous species.

When the traps are nanoparticles, they are formed in the insulator during implantation, and some of them partially coalesce to form small agglomerates of particles.

Said coalescence results in the formation of a two-dimensional layer of nanoparticles and small agglomerates which trap gaseous species, in particular hydrogen, by a mechanical and by a chemical effect.

The term "coalescence" in this case designates the distribution and reorganization of nanoparticles in the same plane as implantation.

The trapping layer is two-dimensional because it extends over the whole surface of the structure, at a depth controlled by the implantation energy. It traps diffusing species and prevents them from reaching the neighboring bonding or connection interfaces.

The chemical trapping effect corresponds to the formation of bonds between the elements present. Thus, for example, atoms of silicon or germanium introduced into a layer of SiO_2 form Si-H or Ge-H bonds when hydrogen is released close by. The chemical hydrogen trapping reaction is particularly favored in the case of germanium implantation as the formation energy for the Ge-H bond is much lower.

The mechanical trapping effect corresponds to establishing a concentration gradient between the bonding or connection interface and the trapping zone. Coalescence of nanoparticles allows the trap density to be increased. The concentration of atoms imprisoned on

these traps increases. Thus, a gradient of atoms of free gas is set up between the bonding or connection interface and the trapping layer. The phenomenon of diffusion of gaseous species towards the traps is thus increased until the traps become saturated.

Finally, it should be noted that even when annealing is carried out after the trapping layer is formed (see Figures 1C and 2D), the agglomerates of particles obtained remain small. In fact, said anneal must be carried out at a temperature below that of the subsequent detachment step, carried out after bonding (see Figures 1E and 2F respectively).

There are thus a multitude of small agglomerates of a few angstroms which start to coalesce in the form of nanoparticles. Trapping is principally ensured by said small agglomerates, produced at a low thermal balance.

When the traps are nanocavities, free gas particles become trapped therein. The species accumulate in said voids buried in the insulator. A concentration gradient is set up between the free gas species and the gas species "retained" in the defects created in the oxide. Said concentration gradient is the driving force for trapping until the nanocavities are saturated.

Several implementations are described below in more detail.

EXAMPLE 1

A donor substrate was prepared by growing a layer of germanium on silicon by epitaxy. Hydrogen and/or helium was then implanted in the germanium to create a zone of weakness.

A silicon receiver substrate was also prepared by depositing therein an insulating layer of silicon oxide (SiO_2) 250 nm to 300 nm thick.

Silicon was then implanted in the SiO_2 layer to create therein a two-dimensional trapping layer. Said

implantation was carried out at an energy of 0.5 to 5 keV, at a dose of 5×10^{15} to 5×10^{16} Si^+ ions /cm^2.

This resulted in the formation of a layer of nanoparticles located between 1.5 nm and 4 nm (nanometers) beneath the surface of the SiO_2 layer with a thickness in the range 2 nm to 3 nm.

Bonding and detachment were carried out as described above in connection with Figures 1 and 2.

EXAMPLE 2

Figure 4 is a drawing produced from a photograph obtained by transmission electron microscopy (TEM) which shows a trapping layer formed in a layer of SiO_2 by implanting silicon at an energy of 1 keV and a dose of 1×10^{16} Si^+/cm^2. Said trapping layer 31 appears as a darker line in the middle of the oxide 3.

Further, tests were carried out to determine the range of energies and implantation dose to use in producing the trapping layer when the insulator was respectively silicon dioxide (SiO_2) or silicon nitride (Si_3N_4). The values are given below.

When the insulator was silicon dioxide (SiO_2), the implanted species were selected from silicon, germanium and oxygen.

In this case, either only one of the categories of atomic species mentioned below or several of them in succession may be implanted:

· silicon atoms with an implantation energy in the range 0.5 keV to 5 keV and an implantation dose in the range 5×10^{15} to 5×10^{16} Si^+/cm^2. Under these conditions, the layer of nanoparticles is located 15 nm to 40 nm beneath the bonding interface. Increasing the implantation dose allows to increase the surface density of the traps and thus modulate the total quantity of atoms of gas imprisoned on said traps.

· germanium atoms with an implantation energy in the range 0.7 keV to 10 keV and an implantation dose in the

range 5×10^{15} to 1×10^{17} Ge^+/cm^2. Since germanium is heavier, the implantation energy range is broader to position the plane of nanoparticles in the same depth range.

· oxygen atoms with an implantation energy in the range 0.5 keV to 3 keV and an implantation dose in the range 1×10^{15} to 1×10^{17} O^+/cm^2. To position the trapping zone at the same depth as before, the implantation energy window is reduced in this case with respect to silicon implantation as oxygen is lighter.

When the insulator is silicon nitride (Si_3N_4), the implanted species are selected from silicon, germanium and nitrogen atoms.

In this case, either only one of the atomic species categories mentioned below or several thereof in succession may be implanted:

· silicon atoms with an implantation energy in the range 0.5 keV to 5 keV and an implantation dose in the range 5×10^{15} to 5×10^{16} Si^+/cm^2;

· germanium atoms with an implantation energy in the range 0.7 keV to 10 keV and an implantation dose in the range 5×10^{15} to 1×10^{17} Ge^+/cm^2;

· nitrogen atoms with an implantation energy in the range 0.5 keV to 3 keV and an implantation dose in the range 1×10^{15} to 1×10^{17} N^+/cm^2.

The SeOI fabrication method of the invention can do away with all defects due to the accumulation of gas at the bonding or connection interfaces of a heterostructure.

The method of the invention is applicable to the fabrication of semiconductor on insulator substrates with any type of semiconductor material since the trapping layer is formed in the insulator. The advantages are clearly more marked in the case of GeOI, since SIMS profiles show that a large quantity of hydrogen is present in the oxide.

CLAIMS

1. A method of fabricating a "semiconductor on insulator" type heterostructure comprising at least one insulating layer interposed between a substrate termed the "receiver" substrate and a layer termed the "active" layer, derived from a substrate termed the "donor" substrate, at least one of said insulating layers comprising a layer termed the "trapping layer", which can retain the gaseous species which may be present at the various interfaces of the heterostructure and limit the formation of defects on the surface of the active layer of said heterostructure, said method comprising the steps consisting in:

• forming or depositing at least one insulating layer on at least one of the two substrates, donor and receiver, both substrates being formed from semi conductor material ;

• bonding said donor substrate and said receiver substrate by molecular bonding such that the insulating layer or layers is (are) interposed between them and such that a bonding interface exists between one of the two substrates and one of the insulating layers or between the two insulating layers;

• withdrawing a portion of the donor substrate termed the "remainder" to retain only said active layer and to obtain said heterostructure,

the method being characterized in that prior to bonding, said trapping layer is formed by implanting at least one category of atomic species in at least one of said insulating layers, said category of atomic species being selected so as to be either identical to one of the atomic species constituting the insulating layer in which these species are implanted, or to belong to the same column of the periodic table as one of the atomic species constituting the insulating layer in which they are implanted.

2. A method according to claim 1, characterized in that after forming the trapping layer, a step of annealing the insulating layer containing said trapping layer is carried out at a temperature of at least 350°C for at least 30 minutes.

3. A method according to claim 1 or claim 2, characterized in that the implantation parameters are selected so as to form said trapping layer close to said bonding interface.

4. A method according to claim 3, characterized in that the trapping layer is formed at a distance in the range 2 nanometers to 10 nanometers from the bonding interface.

5. A method according to claim 1 or claim 2, characterized in that the implantation parameters are selected so as to form said trapping layer close to a connection interface between the insulating layer and one of the two substrates.

6. A method according to any preceding claim, characterized in that the trapping layer is constituted by a two-dimensional layer of nanocavities or nanoparticles.

7. A method according to any preceding claim, characterized in that the insulator is an oxide.

8. A method according to any one of claims 1 to 6, characterized in that the insulator is a nitride.

9. A method according to claim 7, characterized in that the insulator is silicon dioxide (SiO_2) and in that the implanted species are selected from silicon, germanium and oxygen atoms.

10. A method according to claim 9, characterized in that silicon atoms are implanted with an implantation energy in the range 0.5 keV to 5 keV with an implantation dose in the range 5 x 10^{15} to 5 x 10^{16} Si^+/cm^2.

11. A method according to claim 9, characterized in that germanium atoms are implanted with an implantation energy in the range 0.7 keV to 10 keV with an implantation dose in the range 5 x 10^{15} to 1 x 10^{17} Ge^+/cm^2.

12. A method according to claim 9, characterized in that oxygen atoms are implanted with an implantation energy in the range 0.5 keV to 3 keV with an implantation dose in the range 1 x 10^{15} to 1 x 10^{17} O^+/cm^2.

13. A method according to claim 8, characterized in that the insulator is silicon nitride (Si_3N_4) and in that the implanted species are selected from silicon, germanium and nitrogen atoms.

14. A method according to claim 13, characterized in that silicon atoms are implanted with an implantation energy in the range 0.5 keV to 5 keV with an implantation dose in the range 5 x 10^{15} to 5 x 10^{16} Si^+/cm^2.

15. A method according to claim 13, characterized in that germanium atoms are implanted with an implantation energy in the range 0.7 keV to 10 keV with an implantation dose in the range 5 x 10^{15} to 1 x 10^{17} Ge^+/cm^2.

16. A method according to claim 13, characterized in that nitrogen atoms are implanted with an implantation energy in the range 0.5 keV to 3 keV with an implantation dose in the range 1 x 10^{15} to 1 x 10^{17} N^+/cm^2.

17. A method according to any preceding claim, characterized in that the back portion is withdrawn by chemical-mechanical polishing.

18. A method according to any one of claims 1 to 16, characterized in that prior to bonding, a zone of weakness is formed in the source substrate, said zone of weakness defining the active layer from the remainder of said substrate destined to be withdrawn.

19. A method according to claim 18, characterized in that the zone of weakness is formed by atomic species implantation.

20. A "semiconductor on insulator" type heterostructure comprising at least one insulating layer interposed between a substrate termed the "receiver" substrate formed from semiconductor material, and a layer termed the "active" layer formed from semiconductor material, characterized in that at least one of said insulating layers comprises a trapping layer constituted by a two-dimensional layer of nanocavities or nanoparticles, this trapping layer being able to retain the gaseous species which may be present at the various interfaces of the heterostructure and limit the formation of defects on the surface of the active layer of said heterostructure.