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PROCESS FOR THE TREATMENT OF SUBSTRATES FOR MICROELECTRONICS AND SUBSTRATES OBTAINED BY THIS PROCESS

The invention relates to the field of processes for the treatment of substrates intended for the manufacture of components for microelectronics and/or for optoelectronics. The invention also relates to the substrates obtained by this process.

More specifically, the invention relates to the field of processes for treating substrates which are wholly semiconducting (for example of silicon) or wholly insulating (for example of quartz) or else composed of a stack of semiconducting or insulating layers. They can be substrates on which a layer is deposited (for example an epitaxial layer) or substrates comprising nonhomogeneous structures, such as substrates comprising components or component parts at more or less advanced stages in their preparation.

There exists, over a certain depth from the surface of at least one face of these substrates, a layer of material which, at least partially, is a constituent of the components produced on this face. This layer will subsequently be denoted by the expression "working layer".

The quality of this working layer and in particular that of its surface, for example in terms of roughness, conditions that of the components.

Continual research is being carried out to improve the quality of this working layer. The document WO99/53528, for example, provides a polishing process by which the surface of the working layer is polished with a roller, the rotational axis of which is parallel to this surface. However, polishing results in defects, such as work hardening defects, in the layer of material underlying the polished surface.

An aim of the invention is to improve the quality of this working layer both in terms of roughness and in terms of concentration of defects.

This aim is achieved according to the invention by virtue of a process for the treatment of substrates for microelectronics or optoelectronics comprising a working layer at least partially composed of an oxidizable material on at least one of their faces, this process comprising:

- a first sacrificial oxidation stage for removing material constituting the working layer over a certain surface thickness of each substrate,
- a stage of polishing the face which has been subjected to the first sacrificial oxidation stage, and
- a second sacrificial oxidation stage for again removing material constituting the working layer on the polished face.

When a layer of material comprising defects exists over a certain thickness from the surface of a substrate with an unsatisfactory roughness, the first sacrificial oxidation stage makes it possible to remove said thickness of this defect-comprising layer.

However, this first sacrificial oxidation stage, which does not necessarily result in the complete removal of the defect-comprising layer, generally does not make it possible either to sufficiently reduce the roughness of the surface which has been subjected to it. The first sacrificial oxidation stage is then usefully complemented by a polishing stage which makes it possible to obtain the desired roughness.

The second sacrificial oxidation stage subsequently makes it possible, in a way analogous to the first, to remove in particular the layer into which the polishing stage has introduced defects and/or the remainder of the defect-comprising layer. However, starting this time from a polished surface, the roughness of the face of the substrate, after the second sacrificial oxidation stage, is satisfactory and compatible with the use of the working layer in micro- or optoelectronic applications.

The layer in which the majority of the defects generated by the polishing are found generally has a

thickness of greater than 100 Å. Consequently, a layer of material will advantageously be removed, by virtue of the second sacrificial oxidation stage, over a thickness of between 400 Å and 1000 Å.

It is thus understood that the invention consists of a combination of sacrificial oxidation and polishing stages. Each of these stages participates in the removal of the part of the working layer comprising an excessively high concentration of defects, the second sacrificial oxidation stage optionally participating more specifically in the repairing of the defects generated by the polishing stage.

This process is more advantageous than a polishing alone. Thus, as indicated above, the second sacrificial oxidation stage makes it possible to remove the region into which the polishing has introduced defects. However, furthermore, it makes it possible to limit other harmful effects of the polishing. This is because, if there is a relatively thick layer of defects at the start, a lengthy polishing is necessary in order to remove it. In point of fact, a lengthy polishing generally results in a lack of uniformity of thickness. This disadvantage becomes increasingly critical as the thickness of material to be removed increases and thus as the polishing stage becomes longer. This is in particular the case when the thickness to be removed reaches 150 to 200 nm. In addition, lengthy polishings slow down the execution of the process and result in a fall in productivity. The first sacrificial oxidation stage makes it possible to avoid these disadvantages by limiting the polishing essentially to that which is necessary to reduce the roughness, since this first sacrificial oxidation stage has contributed not insignificantly to removing the part of the working layer comprising a high concentration of defects. Furthermore, by reducing the polishing needed, the defects generated by the latter may be developed on a lesser scale.

The process in accordance with the present invention thus makes it possible, by a specific combination of stages consisting in removing material by sacrificial oxidation and by polishing, to obtain a working layer of improved quality, that is to say with a reduced concentration of defects and, in addition, with an optimized surface roughness. This is achieved while retaining a uniform substrate thickness and an optimum efficiency.

The process according to the invention is advantageously employed to improve the quality of a working layer made of oxidizable material, such as silicon.

In this case, the first sacrificial oxidation stage comprises a stage of oxidation of the oxidizable material over at least a portion of the thickness of this defect-comprising material and a stage of deoxidation of the material thus oxidized.

The second sacrificial oxidation stage advantageously comprises a stage of oxidation of the oxidizable material over a certain thickness of material into which the polishing stage has introduced defects and a stage of deoxidation of the material thus oxidized.

Consequently, the process according to the invention advantageously comprises, in addition, before and/or after the polishing stage, a stage of annealing the substrate.

If a stage of annealing the substrate is carried out before the polishing stage, the oxidation stage of the first sacrificial oxidation stage is advantageously capable of forming, before the end of this annealing stage, an oxide layer which protects the remainder of the substrate during at least a portion of the annealing. In this case, the oxide layer protects the remainder of the substrate from certain harmful effects of the annealing, such as the pitting phenomenon observed at the surface of certain semiconductors when the latter are annealed under a

nonoxidizing atmosphere (nitrogen, argon, vacuum, and the like). This pitting phenomenon takes place in the case of silicon in particular when the latter is bare, that is to say when it is not covered with oxide at all.

However, conversely, the annealing makes it possible to repair defects brought about by the oxidation.

If a stage of annealing the substrate is carried out after the polishing stage, the oxidation stage of the second sacrificial oxidation stage is advantageously capable of forming, before the end of this annealing stage, an oxide layer which protects the remainder of the substrate in the same way as was described for the first sacrificial oxidation.

The process according to the invention is also advantageously employed to improve the quality of a working layer made of material which is not easily oxidizable. In the continuation and in particular in the claims, the description "oxidizable" will be used without distinction, whether the so-called oxidizable material is easily oxidizable or not easily oxidizable.

Other aspects, aims and advantages of the invention will become apparent on reading the detailed description which follows. The invention will also be better understood with reference to this description, considered in conjunction with the appended drawings, in which:

- Figures 1A to 1F represent the change in a substrate (seen in cross section) during its treatment by a first embodiment of the process according to the invention;

- Figure 2 is a diagram representing the densities of implanted atoms and of defects generated by the implantation in a substrate prepared by one of the alternative forms of the Smart-Cut® process, as a function of the distance with respect to the surface bombarded during the implantation;

- Figure 3 represents an organigram of the process illustrated by Figure 1;

- Figure 4 is a diagrammatic representation in cross section of a substrate 1 which has been subjected to an oxidation stage in the context of the process illustrated by Figure 3;

- Figure 5 is a diagrammatic representation of the change in a substrate (seen in perspective) during the second sacrificial oxidation stage of the process illustrated by Figure 3;

- Figure 6 represents the organigram of a second embodiment of the process according to the invention;

- Figure 7 is a diagrammatic representation of the production of a capacitive structure on a substrate (seen in cross section) which has or has not been subjected to the second sacrificial oxidation stage in accordance with the process illustrated by Figure 6;

- Figure 8 diagrammatically represents the change in a substrate, seen in cross section, during its treatment by the technique known as the Secco technique;

- Figure 9 is a diagram representing the surface density of defects revealed by the technique illustrated in Figure 8, as a function of the thickness of the layer remaining after the first stage of this technique; and

- Figure 10 is a diagrammatic representation of the change in the edge of a substrate during the second sacrificial oxidation stage of the process described by Figure 6.

The present invention is described in a detailed way below in the specific but non-limiting context of a process for the manufacture of substrates known as the Smart-Cut® process.

A specific way of carrying out the Smart-Cut® process is disclosed, for example, in the document FR 2,681,472.

It is a process for the manufacture of substrates comprising a layer or a thin film of semiconductor on one of their faces.

According to one of its alternative forms, the Smart-Cut® process comprises:

- a stage of implanting atoms in an implantation region under a face of a semiconductor wafer;

- a stage of bringing the face of the wafer which has been subjected to the implantation into intimate contact with a backing substrate, and;

- a stage of cleaving the wafer at the level of the implantation region in order to transfer, onto said backing substrate, the portion of the wafer situated between the surface which has been subjected to the implantation and the implantation region and in order to form a thin film or a layer of semiconductor on said backing substrate.

The term "implanting atoms" is understood to mean any bombardment of atomic or ionic species which is capable of introducing these species into material with a concentration maximum for these species in this material, this maximum being situated at a predetermined depth with respect to the bombarded surface. The atomic or ionic species is introduced into the material with an energy which is also distributed about a maximum. The implantation of the atomic species in the material can be carried out by virtue of an ion beam implanter, an implanter by immersion in a plasma, and the like. The term "cleaving" is understood to mean any fracture of the implanted material at the level of the concentration maximum, in this material, of the implanted species or in the vicinity of this maximum. This fracture does not necessarily occur along a crystallographic plane of the implanted material.

In a specific application of this process, a layer of silicon on insulator, also known as SOI, is prepared.

Several ways can be envisaged for preparing a layer of silicon on insulator according to the Smart-Cut® process.

According to a first way, it is possible, for example, to cover a silicon wafer on its implantation face with a layer of insulating oxide and to use a backing substrate, for example also made of silicon, for the transfer.

According to a second way, it is possible to have a completely semiconducting layer which is transferred either onto a backing substrate covered with an insulating layer or onto a completely insulating backing substrate (ex.: quartz).

According to a third way, it is possible to have an insulator on the semiconductor wafer and to transfer a layer of this wafer either onto a backing substrate itself also covered with insulator or onto a completely insulating substrate.

After cleavage and transfer, an SOI structure with a layer transferred onto a face of the backing substrate is obtained in all cases, the free surface of this layer corresponding to a cleavage surface. It is then advantageous to use the process in accordance with the present invention to reduce the roughness of this cleavage surface and the density of defects in the transferred layer.

These defects can be revealed by various techniques (known as the "Wright", "Secco" and "Schimmel" techniques and the like, from the names of their inventors). Only the defects revealed by the Secco technique will be considered subsequently.

Several embodiments of the process according to the invention will be described below in the specific but non-limiting context of the Smart-Cut® process applied to the preparation of an SOI structure.

Such an SOI structure is represented diagrammatically in Figure 1A. It consists of a substrate 1 which comprises a backing 2 made of silicon, an

insulating layer 4 made of silicon oxide and a thin layer 6 of silicon on the backing 2.

The insulating layer 4 is sandwiched between the backing 2 and the thin layer 6. This insulating layer 4 can originate from the oxidation of the backing 2 and/or of the thin layer 6. After cleavage and transfer of the thin layer 6 onto the backing 2, the free surface of this thin layer 6 corresponds to a cleavage surface 8 which exhibits a roughness which it is desired to reduce. Furthermore, over a certain thickness, the thin layer 6 exhibits, from this cleavage surface 8, a region of defects 12. These defects are defects created during the stage of implanting atoms and by the cleaving (tearing off of material, for example). These defects are represented in Figure 1 in the form of triangles. They will be referred to below as implantation and cleavage defects 21. The generation of implantation and cleavage defects 21 is illustrated diagrammatically by the diagram in Figure 2. The atoms, for example hydrogen atoms, implanted with a certain energy are distributed in the implanted material in the vicinity of a surface situated at a certain depth Rp with respect to the implantation face 10. This surface corresponds to the maximum in the profile of the concentration N(x) of atoms implanted in the material as a function of the distance x with respect to the implanted face 10. The distribution of the concentration N(x) of implanted atoms about this maximum, situated at a distance Rp from the face 10, gradually decreases from this surface over a certain distance on either side of the surface. For example, for an implantation of hydrogen at 300 nm, this distance is approximately 80 nm on either side of Rp. However, as illustrated by Figure 2, the maximum in the density of defects D(x) as a function of the depth x from the implanted face 10 is situated at a distance De, with respect to this implanted face 10, which is less than the distance Rp.

It should be noted that it will possibly be necessary, in the context of the invention, to implant the atoms with a greater energy during the Smart-Cut® process than in the context of those occasions when it is employed in conjunction with the processes of the prior art, so as to be able to remove the amount of material exhibiting a high concentration D(x) of defects while retaining a final thin layer 6 having the desired thickness.

As the fracture occurs in the vicinity of the surface situated at the distance Rp from the implanted face 10, the majority of the defects 15, 21 are found in the thin layer 6 transferred onto the backing 2. It must be understood that the "vicinity" does not necessarily indicate a region distributed approximately equivalently on either side of the depth situated at the distance Rp. The fracture can instead occur in the main in the part situated between the implanted face 10 and the surface situated at the depth Rp from this implanted face 10. However, it can also instead occur in the main in the part situated beyond the surface situated at the depth Rp from the implanted face 10, with respect to this implanted face 10. As illustrated by Figure 1A, after cleavage and transfer, the implanted face 10 is found embedded and the cleavage surface 8 is free. The implantation and cleavage defects 21 are thus found in the region of defects 12 situated in the vicinity of this cleavage surface 8.

According to a first embodiment of the process in accordance with the present invention, this comprises the stages represented in the organigram in Figure 3. This process comprises a first sacrificial oxidation stage 100, followed by a polishing stage 200, itself followed by a second sacrificial oxidation stage 300. Each sacrificial oxidation stage 100, 300 is divided up into an oxidation stage 110, 310, followed by a deoxidation stage 120, 320.

Each oxidation stage 110, 310 is preferably carried out at a temperature of between 700°C and

1100°C. The oxidation 110, 310 can be carried out by the dry route or by the wet route. By the dry route, the oxidation 110, 310 is carried out, for example, by heating the substrate under oxygen gas. By the wet route, the oxidation 310, 320 is carried out by heating the substrate 1 in an atmosphere charged with water vapor. By the dry route or by the wet route, the oxidation atmosphere can also be charged with hydrochloric acid according to conventional methods known to a person skilled in the art.

The wet route is preferred as it introduces, into the crystalline structure, fewer defects such as stacking faults, "HF" defects (an "HF" defect is the name given to a defect whose presence is revealed by a decorative halo in the embedded oxide of the SOI structure after treatment of this structure in a bath of hydrofluoric acid), and the like.

Each deoxidation stage 120, 320 is preferably carried out in solution. This solution is, for example, a 10 or 20% hydrofluoric acid solution. To remove a thousand to several thousand angströms of oxide, the substrate 1 is immersed in such a solution for several minutes.

The substrate 1 is then subjected to the polishing stage 200. This polishing 200 is carried out by the chemical-mechanical route according to techniques known to a person skilled in the art.

After the polishing 200, the substrate 1 is subjected to the second sacrificial oxidation 300. This is analogous to the first sacrificial oxidation 100. The polishing 200 contributes, with each sacrificial oxidation stage 100, 300, to removing material and in particular defect-comprising material.

The change in the substrate 1 during this process is represented diagrammatically in Figures 1A to 1F.

After the first oxidation stage 110, described above, an oxide layer 14 is formed in the vicinity of the cleavage surface 8 (Fig. 1B). This oxide layer 14

is represented diagrammatically in a more detailed way in Figure 4. This oxide layer 14, with a thickness E_0, has a greater volume than that corresponding to the oxidized silicon. The "ghost" of the position of the cleavage surface 8 is represented in Figure 4 by dotted lines. It should be pointed out that the sum of the thickness E_1 of the thin layer 6 of silicon remaining between the insulating layer 4 and the oxide layer 14 and of the thickness E_0 of said oxide layer 14 is greater than the thickness E_2 of the thin layer 6 of silicon before oxidation.

After the first oxidation stage 110, the substrate 1 is subjected to a deoxidation stage 120 targeted at removing the oxide layer 14.

On conclusion of the first sacrificial oxidation 100, the region of defects 12 is largely but generally not completely removed. Furthermore, the initial roughness of the cleavage surface 8, although reduced by this first sacrificial oxidation 100, still remains too high (Fig. 1C).

The substrate 1 is thus subjected to the polishing stage 200.

As represented diagrammatically in Figure 1D, the polishing 200 makes it possible to further reduce the roughness of the free surface of the thin layer 6. On conclusion of this polishing stage 200, the roughness is very low. Measured with an atomic force microscope, this roughness is of the order of 1 Å rms (rms is the acronym for the expression "root mean square").

However, a chemical-mechanical polishing produces work hardening defects 15 under the polished surface 17 over a certain depth of material.

The work hardening is dependent on changing parameters, such as the pressure of the polishing pad on the substrate 1, the wear of this pad, and the like. The work hardening defects 15 are visible at the surface by microscopy (atomic force microscopy, for example) in the form of scratches which are in fact composed of alignments of crystal defects which can be

displayed by the method of displaying of Secco type. However, in addition to these work hardening defects 15 generated by the polishing, there still mainly remain implantation and cleavage defects 21. These combined defects are illustrated diagrammatically by Figure 5. The work hardening defects 15 generated by the polishing are represented by dotted lines and the implantation and cleavage defects 21, remaining after the first sacrificial oxidation 100 and the polishing 200, are represented by triangles.

The substrate 1 is then subjected to a second sacrificial oxidation 300 targeted at removing the material comprising the defects 15 generated under the effect of the polishing 200 and the remaining implantation and cleavage defects 21 of the thin layer 6 after cleavage (Figs. 1D and 1F).

This second sacrificial oxidation 300 is analogous to the first. However, starting from a polished surface, the free surface of the thin layer 6, after the deoxidation stage 320 (Fig. 1F), exhibits a satisfactory roughness.

On conclusion of this first embodiment of the process in accordance with the present invention, a substrate 1 is obtained with an SOI structure in which the concentration of defects in the thin layer 6 has been greatly reduced.

According to a second embodiment of the process according to the invention, illustrated by Figure 6, each sacrificial oxidation comprises a stage of annealing (130, 330) of the substrate 1.

As with the first embodiment of the process according to the invention, this second embodiment is described below in combination with the Smart-Cut® process applied to the manufacture of SOI structures.

The term "annealing" denotes any thermal operation intended to improve the qualities of the material of the working layer 6. This annealing 130, 330 can be a heat treatment carried out at a constant temperature or at a variable temperature. In the latter case, the

annealing 130, 330 can be carried out, for example, with a gradual increase in the temperature between two values or with a cyclic oscillation between two temperatures, and the like.

The annealing 130, 330 is preferably carried out, at least in part, at a temperature of greater than 1000°C and more particularly at approximately 1100-1200°C.

The annealing 130, 330 is preferably carried out under a nonoxidizing atmosphere. This atmosphere can comprise argon, nitrogen, hydrogen and the like or a mixture of these gases. The annealing 130, 330 can also be carried out under vacuum. Consequently, in order to protect the remainder of the thin layer 6 during the annealing 130, 330 and to avoid the pitting phenomenon described above, the oxidation stage 110, 310 of each sacrificial oxidation 100, 300 is preferably carried out before the annealing stage 130, 330. According to an advantageous alternative form of the process according to the invention, the oxidation begins with the beginning of the rise in temperature of the annealing 130, 330 and terminates before the end of the latter.

The stage of annealing 130, 330 the substrate 1 makes it possible to repair the defects generated in the thin layer 6 during the preceding stages of the process for the manufacture and preparation of this substrate 1. More particularly, the annealing stage 130, 330 can be carried out for a time and at a temperature such that crystal defects, such as stacking faults, HF defects, and the like, generated in the thin layer 6 during the stage of formation of each oxide layer 14 are repaired by this annealing.

This annealing stage 130, 330 additionally exhibits the advantage of strengthening the bonding interface between the thin layer 6 transferred during the Smart-Cut® process and its backing 2.

The density of defects remaining in the thin layer 6 is here again greatly decreased after the

treatment of the substrate 1 by the alternative form of the process according to the invention illustrated by Figure 6.

Electrical measurements were carried out in order to compare in particular the improvement in the electrical properties contributed by the second sacrificial oxidation 300. To this end and as represented diagrammatically in Figure 7, capacitive structures were produced on the free surface of the thin layer 6 of substrates 1 which have or have not been subjected to the second sacrificial oxidation 300.

In both cases, the capacitive structure simulates a gate oxide. It is composed of a layer of insulating oxide 11 formed on the free surface of the thin layer 6 and of an electrode 13 positioned on this layer of insulating oxide 11.

The breakdown voltage measured on these capacitive structures is then compared with that measured on capacitive structures produced on a "defect-free" material, that is to say a material which has not been subjected either to implantation or to cleavage. It is then found that the capacitive structures produced on the SOI structures which have not been subjected to a second sacrificial oxidation 300 or which have been subjected to a second sacrificial oxidation 300 which forms and removes 50 nm of oxide exhibit a higher frequency of failure (breakdown) than capacitive structures produced on a "defect-free" material; whereas the capacitive structures produced on the SOI structures which have been subjected to a second sacrificial oxidation 300 which forms and removes 200 nm of oxide exhibit a frequency of failure (breakdown) which is comparable with that of the capacitive structures produced on a "defect-free" material. The notion of frequency of failure covers the fact that there is observed, unpredictably, during the tests on the capacitive structures described above, a breakdown, under the same conditions as the conventional conditions of use, with a certain frequency. In other

words, there are virtually no more failing capacitive structures produced on a material which has been subjected to a second sacrificial oxidation 300 which forms and removes 200 nm of oxide than failing capacitive structures produced on a "defect-free" material.

This shows that the thin layer 6 after having been subjected to the process according to the invention, with a second sacrificial oxidation 300 comprising an annealing 330 which removes a sufficient thickness of material, exhibits virtually no more defects.

The concentration of defects can be determined by displaying them by virtue of a solution of Secco type, the composition of which is known to a person skilled in the art. Thus, starting from an SOI substrate 1 composed of 2000 Å of silicon on 4000 Å of silicon oxide, a standard technique for displaying defects by virtue of a solution of Secco type is illustrated in Figure 8. It comprises:

- a Stage A which consists in immersing the substrate 1 for 12 to 23 seconds in a solution of Secco type in order to etch 1100 to 1900 Å of silicon from the thin layer 6 and more rapidly to selectively etch this thin layer 6 at the crystal defects in the material (comprising, inter alia, those generated by the polishing 200), until holes 19 corresponding to the sites of these defects open onto the insulating layer 4;

- a Stage B which consists in immersing the substrate 1 in a hydrofluoric acid solution in order to etch, by widening them in the insulating layer 4, the holes 19 produced in the preceding stage;

- a Stage C which consists in again immersing the substrate 1 in a solution of Secco type in order to remove the remainder of the thin layer 6 and to propagate the holes 19 in the backing 2; and

- a Stage D which consists in again immersing the substrate 1 in a hydrofluoric acid solution in order to completely remove the insulating layer 4.

The holes 19 remaining in the backing 2 are sufficiently large to be able to be counted under a microscope.

It should be noted that the thin layer 6 thickness remaining after Stage A has to be particularly well controlled as the determination of the density of defects by the technique described above is very sensitive thereto.

Figure 9 represents counts of holes 19 thus displayed as a function of the thin layer 6 thickness remaining after Stage A on substrates 1 which have or have not been subjected to a second sacrificial oxidation 300 accompanied by an annealing 330 in accordance with the process according to the invention. More specifically, as each point corresponds to a density of defects determined under a microscope for a thin layer 6 thickness remaining after Stage A, it should be understood that the thinner the thickness of this remaining thin layer 6, the more defects are displayed. Thus, for a concentration by volume of defects which will be constant over the entire thickness of the thin layer 6, the corresponding curve ought to be decreasing toward the high values for thin layer 6 thicknesses remaining after Stage A.

The upper curve corresponds to measurements carried out on a substrate 1 with 3650 Å of transferred thin layer 6 which has been subjected to a sacrificial oxidation with annealing (removing 650 Å of thin layer 6), followed by a polishing (removing 950 Å of thin layer 6) in order to result in a thin layer 6 of 2050 Å, before treatment by the Secco technique set out above. A strong rise toward the low values for thin layer 6 thicknesses remaining after Stage A is observed in this curve. It is representative of the surface defects induced by the polishing 200.

The lower curve corresponds to measurements carried out on a substrate 1 with 4300 Å of transferred thin layer 6 which has been subjected, before treatment by the Secco treatment set out above, to the process according to the invention comprising a first sacrificial oxidation 100 with annealing (removing 650 Å of thin layer 6), followed by a polishing 200 (removing 950 Å of thin layer 6) and by a second sacrificial oxidation with annealing 300 (removing 650 Å of thin layer 6) in order also to result in a thin layer 6 of 2050 Å. It is found that the strong rise toward the low values for thin layer 6 thicknesses remaining after Stage A which appears in the upper curve has disappeared. There are therefore virtually no more defects 15 induced by the polishing 200 in the working layer 6 after the substrate 1 has been subjected to the process according to the invention. It is also noticed that the base level of the lower curve lies approximately one order of magnitude below the base level of the upper curve. This can be attributed to the fact that better removal of the residual defects originating from the implantation and from the cleaving has been achieved by virtue of the process in accordance with the present invention.

The surface density of Secco defects measured on the substrate 1 which has been subjected to the process according to the invention is less than 5×10^2 cm^{-2} over the entire range of remaining thin layer 6 thickness.

Thus, in the case of the preparation of an SOI substrate 1 by the Smart-Cut® process, a layer of silicon comprising defects generated by the polishing 200 comprising a concentration of defects corresponding to surface densities of Secco defects of greater than 5×10^2 cm^{-2} will advantageously be removed, by virtue of the second sacrificial oxidation 300, when the thin layer 6 results from a substrate with, for example, a thin layer of silicon with a low defect density.

Analogous results would be obtained with, for example, a thin layer of epitaxied silicon, of silicon annealed under hydrogen or of so-called "low COPs" silicon, that is to say with a low density of "COPs" defects (from the acronym of the expression "Crystal Originated Particles"), or of FZ or CZ silicon with a low level of "COPs" defects.

Surprisingly, it has additionally be found that the second embodiment of the process according to the invention described above makes it possible to eliminate the so-called "edge falls" phenomenon of the embedded oxide forming the insulator 4 and of the thin layer 6. This edge falls phenomenon arises with SOI substrates 1 prepared with the processes of Smart-Cut® type of the prior art not comprising a second sacrificial oxidation 300 by the detachment of debris and particles originating from the embedded oxide and from the thin layer 6. This is because, as illustrated diagrammatically in Figure 10A, the layer of embedded oxide forming the insulator 4 and the thin layer 6 exhibit, after the first sacrificial oxidation 100, a beveled appearance close to the edge of the substrate 1. The tip of each of these layers 4, 6 and more particularly that of the transferred thin layer 6 is capable of separating from the substrate 1 during the various technological stages in the manufacture of electronic or optoelectronic components on these substrates 1.

However, as illustrated in Figure 10B, after the second sacrificial oxidation 300, oxide is formed, in particular on the tip of the thin layer 6, as a continuation of the layer of embedded oxide forming the insulator 4. This basically makes it possible to avoid the presence of a tip at the edge of the thin layer 6 which is brittle and easily detachable from the embedded oxide forming the underlying insulator 4.

The first and second embodiments of the process according to the invention which are described above relate to applications targeted at improving the

quality of thin layers 6 of silicon on insulator which are obtained by the "Smart-Cut®" process. A description has more particularly been given of the second embodiment of the process according to the invention in the context of its application to an SOI structure composed of a thin layer 6 of approximately 2000 Å of silicon on an insulating layer 4 of 4000 Å of silicon oxide. In order to obtain a thin layer 6 of this thickness, it is necessary to implant hydrogen atoms with an energy of between 70 and 100 keV. In order to obtain thicker layers 6, it will be necessary to implant these atoms more deeply, that is to say with a higher energy. However, the more deeply the atoms are implanted, the more spread out will be the distribution of the concentration of these atoms in the layer 6 and the more spread out also will be the concentration of defects relating to the implantation. The thickness of defect-comprising material to be removed by the process according to the present invention will then be greater. The thicknesses mentioned above are therefore in no way limiting.

It will also be understood that the process according to the invention can be employed in the context of other applications. Generally, the process according to the invention is of use each time that it is desired to remove a surface layer while retaining the quality of the underlying material. As mentioned above in the embodiment of the process comprising an annealing stage 130, 330, the annealing can have a repairing effect which can even make it possible to improve the quality of this underlying material.

The process according to the invention has been described above by taking the case of silicon as illustrative example but it must be understood that that which has been set out above is entirely applicable to materials other than silicon, in particular other semiconducting materials.

An example of an embodiment of the process according to the invention has been described above in

which each sacrificial oxidation comprises a stage of annealing the substrate. However, it must be understood that it would not be departing from the scope of the invention if only one of the sacrificial oxidations comprises an annealing stage. Thus, according to other implementational examples of the process according to the invention, only the first or the second sacrificial oxidation comprises an annealing stage analogous to that described above.

CLAIMS

1. A process for improving the structural quality of a substrate (1) for microelectronics or optoelectronics, the substrate comprising a working layer (6) intended especially for the production of circuits and at least partly composed of an oxidizable semiconductor material, said layer being exposed on one face of the substrate and possessing first defects (21) near said face, the process comprising:

- a first sacrificial oxidation step (100) for removing from the surface of the working layer (6) a certain thickness of the constituent material of the latter and at least some of the first defects (21);
- a step (200) of polishing that face of the working layer which has undergone the first sacrificial oxidation step (100), the said step generating second defects (15), especially work-induced defects, in the working layer near said face; and
- a second sacrificial oxidation step (300) for again removing from the surface of the working layer (6) a certain thickness of the constituent material of the latter and at least some of the second defects (15).

2. The process as claimed in claim 1, characterized in that the first sacrificial oxidation step (100) comprises a substep (110) of oxidizing the semiconductor material, over at least part of the thickness of this material containing the first defects (21), and a substep (120) of removing the material thus oxidized.

3. The process as claimed in either of the preceding

claims, characterized in that the second sacrificial oxidation step (300) comprises a substep (310) of oxidizing the oxidizable material, over at least part of the thickness of material containing the second defects (15), and a substep (320) of removing the material thus oxidized.

4. The process as claimed in either of claims 2 and 3, characterized in that at least one sacrificial oxidation step (100, 300) furthermore includes a step (130, 330) of annealing the substrate (1).

5. The process as claimed in claim 4, characterized in that each oxidation substep (110, 310) of each sacrificial oxidation step (100, 300) is capable of forming, before the end of the annealing step (130, 330), an oxide layer (14) protecting the rest of the substrate (1).

6. The process as claimed in one of the preceding claims, characterized in that a layer of material is removed over a thickness of greater than 100 Å by means of the second sacrificial oxidation step (300).

7. The process as claimed in claim 6, characterized in that a layer of material is removed over a thickness of between 400 Å and 1000 Å by means of the second sacrificial oxidation step (300).

8. A process for fabricating a substrate (1) for microelectronics or optoelectronics, comprising a working layer (6) intended especially for the production of circuits and at least partly composed of an oxidizable semiconductor material, said layer being

exposed on one of the faces of the substrate, the process comprising:

- a step of implanting atoms, beneath one face of a semiconductor wafer intended to form the working layer, in an implantation region;
- a step of bringing that face of the wafer which has undergone the implantation into intimate contact with a support substrate (2);
- a step of cleaving the wafer, in the implantation region, in order to transfer part of the wafer onto the support substrate (2) and form, on the latter, a thin film forming the working layer (6);
- a first sacrificial oxidation step (100) for removing from the surface of the working layer (1) a certain thickness of the constituent material of the latter;
- a step (200) of polishing that face of the working layer which has undergone the first sacrificial oxidation step (100); and
- a second sacrificial oxidation step (300) to again remove from the surface of the working layer (1) a certain thickness of the constituent material of the latter.

9. The process as claimed in one of the preceding claims, characterized in that the working layer (6) is made of silicon.

10. The process as claimed in claim 8, characterized in that a layer of silicon having a defect concentration corresponding to surface densities of defects of greater than 5×10^2 cm^{-2} is removed by means of the second sacrificial oxidation step (300).