

PREVENTIVE TREATMENT PROCESS FOR THE RING OF A
MULTILAYER WAFER

This invention relates to a treatment process for the ring of a multilayer wafer made by layer transfer and composed of materials chosen from among semiconductors.

5 The invention also concerns an associated multilayer wafer.

Processes are known for the transfer of layers to make multilayer structures from materials chosen from among semiconducting materials.

10 This type of process includes the following main steps:

- creation of a weakening zone within the thickness of a donor substrate, possibly in association with the creation of different layers at the surface of
- 15 the said donor substrate,
- bonding of the donor substrate with a receiving substrate,
- detachment at the weakening zone.

Following this detachment, at least one layer of the donor substrate was transferred onto the receiving substrate.

This type of process builds up wafers that may for
5 example be of the SOI (Silicon On Insulator) type.

They can also be used to make any type of multilayer wafers.

And the wafer obtained may have one or several intermediate layers between the surface layer of the
10 final wafer and the base layer corresponding to the receiving substrate.

Thus, an SOI has an intermediate insulating layer (for example made of SiO₂) between the receiving substrate and the surface layer made of silicon.

15 An example of such a transfer process is the SMARTCUT^(R) process, and a description of this type of process is given in the "Silicon-On-Insulator Technology: Materials to VLSI, 2nd Edition" book by Jean-Pierre Colinge, published by "Kluwer Academic
20 Publishers", p. 50 and 51.

A process of this type can be used to create multilayer wafers like those mentioned above.

It can also be used to create wafers with an extremely thin surface layer, with a thickness of the
25 order of a few microns or less.

It will be noted that it is possible that the transfer of a layer during the detachment step is accompanied by the creation of an approximately annular peripheral shoulder around the wafer that was formed.

30 This type of shoulder is currently called a ring.

And it is observed that detachments made within the framework of a SMARTCUT^(R) type process can thus generate rings.

This type of ring is diagrammatically shown in
5 Figure 1.

This figure shows the edge of an SOI type wafer 10.

The wafer 10 comprises a surface layer 101 (which usually corresponds to the so-called useful layer of
10 the wafer) made of monocrystalline silicon that overlaps an SiO₂ layer 102.

These two layers 101 and 102 are bonded to a layer 103 corresponding to the receiving substrate. For example, the layer 103 may be made of
15 polycrystalline silicon.

The layer 102 corresponds to an intermediate layer, i.e. to a layer inserted between the surface layer 101 of the wafer and its base layer 103.

The ring 110 can be seen in this figure.

This ring extends around the entire periphery of
20 the wafer 10. It is the result of a step for detachment of layers 101 and 102 from a weakened donor substrate.

This figure also shows that the intermediate
25 layer 102 is exposed at its peripheral edge 1020.

As will be seen, this exposure of the peripheral belt of the intermediate layer 102 can have negative consequences.

More precisely, complementary treatments are
30 usually applied to this type of wafer, after the

detachment step that produces the results shown diagrammatically in Figure 1.

One purpose of this type of complementary treatment is to improve the surface condition of the wafer (particularly to reduce the surface roughness) or to modify the crystalline structure of one or several layers, or to reinforce the bond between the layers of the wafer.

This type of treatment may involve a chemical attack and / or heat treatment of the wafer.

For example, it may include a "stabox" step.

Note that, by convention in this text, a "stabox" step formed on a wafer corresponds to the following sequence of operations:

. oxidation of the surface of the wafer - this operation is intended to deposit an oxide layer on the surface of the wafer that will protect this surface during the next heat treatment operation,

. stabilisation heat treatment of a bonding interface - for example by annealing at a temperature of the order of 1100°C,

. deoxidation of the oxide deposited on the surface of the wafer - for example by chemical attack in an HF etching type solution with an HF solution with a concentration of 10 to 20%.

It is found that when a "stabox" type step is carried out on an SOI wafer like that shown in Figure 1, the intermediate layer 102 of the wafer is attacked around its periphery.

This effect is diagrammatically illustrated in Figure 2.

This figure shows that the layer 102 has been affected by a removal of material towards the centre of the wafer (towards the right in the case shown in Figure 2).

5 This removal of material is the result of the attack on the peripheral belt around the layer 102 that was exposed by the etching solution used for the deoxidation operation, as described.

Figure 2 also shows that the surface layer 101 is
10 overhanging over this intermediate layer due to this setback of the intermediate layer, because its side edge go beyond the edge of the intermediate layer.

This overhanging configuration may be harmful.

In particular, the portion 1010 of the layer 101
15 that is thus overhanging may collapse and / or break.

This in itself is a disadvantage.

If a piece of this portion 1010 is detached, this piece would also form potential pollution for the wafer.

20 Such a detached piece could then be deposited on one of the faces of the wafer and deteriorate its surface condition (for example by scratching it or remaining stuck to it).

Wafers according to the invention are intended for
25 use in electronics, microelectronics and optronics, and must satisfy extremely strict surface condition specifications.

Therefore it will be understood that the overhanging configuration illustrated in Figure 2 is a
30 disadvantage.

It will also be seen that Figure 2 illustrates an additional effect of the "stabox" step.

This figure actually represents a curvature of the layers 101 and 102, the edge of these wafers being
5 raised and separated from the base layer 103.

This curvature thus corresponds to an additional effect of the "stabox" step to which the wafer was subjected, a distinct effect of the setback of the intermediate layer and the creation of an overhang.

10 This additional effect is the result of thermal stresses applied to the different layers of the wafer, particularly during the oxidation heat treatment of the wafer surface.

The different layers in the wafer do not have the
15 same coefficients of thermal expansion, and do not behave in the same way when they are exposed to a higher thermal budget.

This additional effect thus results in partial separation of layers 102 and 103 at the edge of the
20 layer 102.

And it will also be noticed that during the same oxidation heat treatment, the space left free between the layers 102 and 103 due to this separation was partially filled in by a new oxide 1021.

25 However, it will be noted that this additional effect is not a major disadvantage for the problem to be solved by the invention.

The disadvantage that the invention is aimed to solve relates to shrinkage of the intermediate
30 layer 102.

As we have seen above, this disadvantage may be the result of a chemical attack on the wafer.

It may also be the result of a different type of attack to the peripheral belt around an intermediate
5 layer sensitive to this attack.

An attack around the exposed periphery of an intermediate layer of oxide of an SOI can thus be observed, if this wafer has been subjected to a prolonged high temperature heat treatment, for example
10 in a furnace in which the wafers are treated in batches.

It may also be desirable to perform such a heat treatment on wafers, for example to modify the crystalline structure of some of their layers, or to
15 reduce the surface roughness of the wafer.

This type of prolonged high temperature heat treatment is conventionally carried out under hydrogen and / or argon atmosphere.

Note that in this text, "high temperature" means a
20 temperature exceeding the order of 950°C.

Note also that "prolonged" means a heat treatment applied for a duration of more than a few minutes.

Another example of a treatment that introduces disadvantages like those mentioned above is the case in
25 which a "stabox" step is performed (for example on an SOI type wafer) after carrying out a first "stabox" step and polishing on the wafer.

A non-limitative example of such a treatment is divulged in document WO 01/15218.

This document describes a surface treatment of an SOI type wafer involving a sequence of stabox / polishing / stabox type steps.

Figure 3a diagrammatically shows an SOI on which a first stabox step was carried out.

It will be seen in this figure that the edges of the layers 101 and 102 form a steep bevel following polishing.

And this bevel shape in this case further exposes the intermediate layer 102; this exposure is even greater than in the case shown in Figure 1.

Figure 3b shows the same SOI, on which a polishing step and then a second stabox step were carried out after the first stabox step.

This figure shows that the bevel shape has been modified by these new steps.

But the intermediate layer 102 is still exposed, and is therefore still subject to attack by subsequent treatments applied to the wafer.

Thus, it is clear that the treatments (particularly chemical treatments, and / or prolonged high temperature heat treatments) applied to a multilayer wafer for which an intermediate layer is exposed around its peripheral edge, may introduce disadvantages.

Embodiments of the invention seek to overcome these disadvantages.

In accordance with a first aspect of the present invention, there is provided a process for treatment of the ring of a multilayer wafer made by layer transfer and composed of materials chosen from among semiconducting materials, said wafer comprising at

least an intermediate layer between a superficial region and a base layer, characterised in that the process includes the following steps: oxidation of a surface of the wafer, stabilisation heat treatment of bonding interfaces between the base layer and the intermediate layer and the superficial region, deoxidation of the oxidised surface of the wafer; and a rapid thermal annealing step carried out after the above steps to cause overlapping and encapsulation of the peripheral edge of said intermediate layer, by a layer of said superficial region of the surface of the wafer in order to prevent the attack on the peripheral part of said intermediate layer of the wafer during a subsequent treatment step of the wafer.

The following are preferred but non-limitative embodiments of such a process:

- the rapid thermal annealing is carried out immediately after the transfer of the wafer,
- the rapid thermal annealing is carried out after an additional treatment step between the transfer of the wafer and the said rapid thermal annealing,
- the rapid thermal annealing is carried out at a temperature of the order of 1200°C,
- the rapid thermal annealing is carried out for a duration of less than 3 minutes,
- the rapid thermal annealing is carried out under a hydrogen and / or argon atmosphere,
- the wafer is a SOI,
- the transfer was made using a SMARTCUT^(R) type process,
- the said subsequent treatment step of the wafer comprises a chemical attack, or a prolonged high temperature heat treatment.

Embodiments of the present invention also provide an associated wafer, obtained by a process as mentioned above.

Other aspects, purposes and advantages of the invention will become clearer after reading the following description with reference to the attached drawings, in which, apart from Figures 1, 2, 3a and 3b
5 that have already been commented upon with reference to the state of the art:

. Figure 4 is a view derived from a scanning electron microscope of an edge of an SOI wafer treated according to a first embodiment of the invention, and

10 . Figure 5 is a similar view of the edge of an SOI wafer treated according to a second embodiment of the invention (in this case the edge represents the "right" edge, while the "left" edge of the wafer is shown in the other figures).

15 Note that as a preliminary to this description, wafers to which the invention is applicable may be SOI wafers.

It may also be an arbitrary type of multilayer wafer satisfying the following two conditions:

20 . the wafer was obtained using a transfer method (for example a SMARTCUT^(R) type process), and

. at least one intermediate layer of the wafer is exposed laterally and may be attacked around its periphery by a subsequent treatment (for example a
25 chemical attack or a prolonged high temperature heat treatment), if the periphery of this intermediate layer is exposed.

Therefore, the starting point of the process according to the invention is a wafer that typically
30 comprises a ring like that shown diagrammatically in Figure 1.

According to the invention, a rapid thermal annealing of the wafer is carried out on this type of wafer in order to overlap and then encapsulate the peripheral edge of the exposed intermediate layer, by a layer on a surface region of the wafer.

A Rapid Thermal Annealing (RTA) type heat treatment is used. For reasons of simplicity, this treatment will be referred to as RTA in the rest of this text.

The Applicant has observed that the RTA caused a very beneficial effect in the exposed intermediate layer, in terms of the problems described in the introduction of this text.

More precisely, the RTA can make the surface layer of the wafer "drop off" (in fact layer 101 in Figure 1 that corresponds to a layer of monocrystalline silicon in the case of an SOI wafer).

And this surface layer also overlaps and encapsulates the periphery of the intermediate layer (layer 102 in Figure 1) that was previously exposed.

This overlapping and encapsulation effect is illustrated in Figure 4.

Figure 4 illustrates the case of an SOI wafer on which an RTA was carried out after being exposed to a stabox step.

The fact of having the RTA preceded by a stabox step stabilizes the bonding interface between the receiving substrate (layer 103) and the donor substrate (layers 101 and 102).

It can be seen in Figure 4 that the intermediate layer 102 is entirely encapsulated by the surface

layer 101. The layer 102 is thus protected from subsequent heat treatments that may be applied to the wafer.

5 The RTA is carried out at a high temperature for a short period.

In the case of a treatment of an SOI wafer, the treatment may be carried out at a temperature of the order of 1200°C for a period of less than 3 minutes.

10 This RTA is carried out in a hydrogen and / or argon atmosphere.

The RTA can also be done immediately after the wafer has been detached.

15 In this case, the bonding interface between the layer 103 and the rest of the wafer was not stabilized by a heat treatment.

20 But tests carried out by the Applicant have demonstrated that this embodiment can also be used to achieve the overlapping and encapsulation effect of the intermediate layer without degrading this bonding interface.

Figure 5 is an illustration of this embodiment of the invention.

25 It can be seen again that the surface layer 101 overlaps and encapsulates the intermediate layer 102 that is thus protected from subsequent treatments.

And it can also be seen that the RTA has not degraded the bonding interface between layers 102 and 103.

30 The RTA can thus be used immediately after the wafer has been detached, or during a subsequent step.

In particular, it has been seen that the RTA can be done after a stabox step (see Figure 4).

In general, use of this RTA during a prior step is a means of securing the intermediate layer for
5 subsequent heat treatment steps that may be applied to the wafer.

Note that wafers concerned by this invention are not limited to SOI wafers.

According to the invention, it is possible to
10 overlap and encapsulate several intermediate layers in the wafer rather than a single layer.

In general, use of the invention causes overlapping and encapsulation of a surface region of the wafer by a layer. In particular, this layer may be
15 the surface layer of the wafer, as shown in the examples illustrated and commented upon above.

Note that in all embodiments of the invention, the RTA protects the intermediate layer of the wafer so that it is then possible to apply treatments like those
20 mentioned at the beginning of the text, to this wafer.

In particular, a wafer treated according to the invention can be subjected to a prolonged high temperature heat treatment, while this type of treatment would have degraded the intermediate layer if
25 the invention is not used.

However note that in this case, a polishing step (possibly CMP) should not be done between the RTA according to the invention and the prolonged high temperature heat treatment.

30 This polishing step would at least partially destroy the protection applied to the intermediate

layer by the invention, such that the prolonged high temperature heat treatment could degrade the intermediate layer.

CLAIMS

1. Process for treatment of the ring of a multilayer wafer made by layer transfer and composed of materials chosen from among semiconducting materials, said wafer comprising at least an intermediate layer between a superficial region and a base layer, characterised in that the process includes the following steps:

oxidation of a surface of the wafer,

stabilisation heat treatment of bonding interfaces between the base layer and the intermediate layer and the superficial region,

deoxidation of the oxidised surface of the wafer;

and a rapid thermal annealing step carried out after the above steps to cause overlapping and encapsulation of the peripheral edge of said intermediate layer, by a layer of said superficial region of the surface of the wafer in order to prevent the attack on the peripheral part of said intermediate layer of the wafer during a subsequent treatment step of the wafer.

2. Process according to claim 1, characterised in that the rapid thermal annealing is carried out at a temperature of the order of 1200°C.

3. Process according to one of the above claims, characterised in that the rapid thermal annealing is carried out for a duration of less than 3 minutes.

4. Process according to one of the above claims, characterised in that the rapid thermal annealing is carried out under a hydrogen and/or argon atmosphere.

5. Process according to one of the above claims, characterised in that the wafer is a SOI.

6. Process according to one of the above claims, characterised in that the transfer was made using a SMARTCUT® type process.

7. Process according to one of the above claims, characterised in that the said subsequent treatment step of the wafer comprises a chemical attack, or a prolonged high temperature heat treatment.

8. Process according to claim 7, characterized in that the prolonged high temperature heat treatment consists of a heat treatment exceeding the order of 950 °C for a duration of more than a few minutes.