METHOD FOR RECYCLING AN EPITAXIED DONOR WAFER

This invention relates in general to the formation of a structure comprising a thin layer made of a semiconductor material on a receiver wafer, the thin layer being transferred from a donor wafer to the receiver wafer.

The invention is aimed at allowing the recycling of the donor wafer after the thin layer has been transferred. More precisely, the invention is aimed at enabling recycling of a donor wafer including before transfer a support substrate on which a layer formed by epitaxial growth is supported, the thin layer being formed from part of the said epitaxied layer, and the donor wafer comprising after transfer the support substrate and the remaining unremoved part of the said epitaxied layer.

The donor wafer to be recycled is typically a negative originating from a transfer method comprising a step to bring the donor wafer into contact with a receiver wafer and a detachment step at an embrittlement zone created within the thickness of the

epitaxied layer, particularly created by ionic implantation.

For example, detachment is achieved by application of a thermal stress possibly combined with a mechanical stress (particularly like the SMART CUT® process), or by application of a mechanical stress alone (for example an ELTRAN® process that uses a pressurised fluid jet at a porous weakened layer) or by other means (use of ultrasound, etc.).

The main steps of one form of a transfer method with detachment at a the level of an embrittlement zone are described in Figure 1.

This Figure shows a series of steps 11 to 18 to manufacture an SeOI (Semiconductor On Insulator) type structure and also produce a remainder A' originating from the donor wafer A, this remainder corresponding to the "negative" mentioned above, starting from a support substrate 1 and a receiver wafer B.

Starting from step 11 in which we have a support substrate 1 (made of silicon in the example presented herein), a step 12 is performed designed to form a structure 2 comprising a layer or superposition of layers on the support substrate, by epitaxial growth.

In the example shown in Figure 1, the epitaxied structure 2 comprises a buffer layer 3 and a layer 4 on the buffer layer 3. The term hetero-epitaxial structure is also used to qualify this type of structure.

The buffer layer 3 located on the support substrate 1 has a mesh parameter on its surface significantly different from the mesh parameter of the support substrate 1. For example, the buffer layer may

be an SiGe layer, with a Ge concentration progressively increasing from the interface with the Si support substrate and consequently having a mesh parameter that is progressively modified to set up the transition between the two mesh parameters.

For example, this progressive modification of the mesh parameter may be achieved progressively within the thickness of the buffer layer.

It may also be achieved by "stages", each stage being a thin layer with a substantially constant mesh parameter different from the mesh parameter for the lower stage, so that the mesh parameter is discretely modified stage by stage.

The layer 4 is located on the buffer layer 3 and has the mesh parameter of the buffer layer surface, different from the mesh parameter of the support substrate. The layer 4 is typically made of a material relaxed by the buffer layer 3, in this case relaxed SiGe.

The buffer layer 3 and the layer 4 are formed by epitaxial growth on the support substrate 1, using known techniques such as CVD (Chemical Vapour Deposition) and MBE (Molecular Beam Epitaxy) techniques.

The layer 4 may be made in situ, directly after the formation of the subjacent buffer layer 3. The growth of layer 4 may also be achieved after a short finishing step of the subjacent buffer layer.

The steps 11 and 12 are thus used to form a donor wafer described as "fresh" in the remainder of this

description, since it does not originate from recycling.

The next step is step 13, consisting of a surface preparation step for the epitaxied structure 2 (in this case the surface of the layer 4). This surface preparation step for the layer is typically applied by removal of material from the surface of the "fresh" wafer, for example in the form of chemical mechanical polishing (CMP).

Step 14 is an optional step for the formation of an overlayer 5 on the surface of the donor wafer A, in other words on the surface of the layer 4 made of relaxed SiGe in the example presented in this description, by epitaxial growth (practically in the same way as that described above for formation of the layer 4). In this case, a hetero-epitaxied structure 2' including the buffer layer 3, the layer 4 and the overlayer 5 was formed on the support substrate 1.

Advantageously, the mesh parameter of the overlayer 5 is practically the same as the mesh parameter of the relaxed material on the free face of the structure 2; in the example presented, it is typically a strained Si layer on the surface of the relaxed SiGe layer 4.

The overlayer 5 may also include a first layer made of relaxed SiGe and a second layer made of strained Si arranged on the said first layer. In other words, an SiGe epitaxy is done before a strained Si layer is deposited, also by epitaxy.

One possible application of the donor wafer A is to take off a thin layer formed from a part of the

layer 4 of the epitaxied structure 2 on the support substrate 1, and if applicable, from the overlayer 5 formed on the surface of the structure 2 during the optional step 14.

An optional step is performed in 15, to form an oxide layer on the surface of the donor wafer and / or the receiver wafer to form an oxide layer 6, this step being related to the final product to be obtained, in this case an SeOI structure that includes an insulation layer corresponding to the oxide layer.

A step 16 is performed to implant ions in the donor wafer (for example hydrogen and / or helium ions) in order to form an embrittlement zone 7 within the thickness of the epitaxied structure 2, 2', and more precisely within the thickness of the layer 4 in the example given.

The next step 17 is to bond the oxidised donor wafer A with the receiver wafer B.

"Bonding" means creating an intimate and permanent contact that may correspond to molecular bonding and that may also be reinforced by adding a product between the facing surfaces of the oxidised donor wafer and the receiver wafer, to facilitate bonding of these two elements. In any case, bonding is usually preceded by cleaning of the surfaces to be bonded.

In step 18, the assembly thus formed by bonding is detached at the embrittlement zone 7. As mentioned above, this detachment may for example be done by applying a thermal and / or mechanical stress to this assembly.

As described in step 18, the result is thus:

- firstly, a positive P corresponding to an SeOI structure in which the superficial layer corresponds to the layer of the donor wafer A that was delimited by the embrittlement zone (including a part 50 of the layer 4 and possibly the overlayer 5 formed in the optional step 14). In other words, the transferred thin layer corresponds to the part of the structure 2 (and possibly 2') delimited by the embrittlement zone, on the side brought into contact with the receiver wafer B.

Thus, when steps 14 and 15 have been completed, a positive P is obtained comprising the receiver wafer B on which the oxide layer 6, the strained silicon overlayer 5 and the transferred part 50 of the relaxed SiGe layer 4, are stacked in sequence. The transferred part 50 is then typically removed so that the end result is an sSOI (Strained Silicon On Insulator) type structure.

When step 14 is not completed, the result is a positive comprising the receiver wafer B on which the oxide layer 6 and the transferred part 50 of the relaxed SiGe layer 4 are stacked in sequence. The next step is typically a deposit by epitaxial growth of a silicon layer on layer 50 (then acting as the growth substrate) and the silicon in the deposited layer is then strained by the relaxed SiGe in the subjacent layer 50. The end result is an SGOI (Strained silicon on SiGe On Insulator) type structure.

- Secondly, a negative A' corresponding to the part of the donor wafer that did not remain bonded to the receiver wafer B, and consequently comprising the

support substrate 1 and the remaining non-transferred part 40 of the epitaxied structure 2, 2'. In the event, the said remaining part 40 corresponds to the part of the layer 4 that did not remain bonded to the receiver wafer B (because it was subjacent to the embrittlement zone 7 at which the detachment was made).

When taking off a thin layer from a donor wafer, the thin layer being formed from a part of the donor wafer deposited by epitaxy, and particularly in the context of the application examples given above (formation of an sSOI or SGOI) structure, the negative is usually not recycled.

As a result of this lack of recycling of the negative A', when forming a (new) donor wafer (so as to take off another thin layer), it is essential to use a new support substrate and to form a new fresh wafer by repeating steps 11 and 12, to deposit by epitaxial growth a structure 2 comprising a layer or superposition of layers on the support substrate 1.

It is understandable that this lack of recycling is particularly prejudicial since the negative A' is not reused, and complex, long and expensive operations to form the epitaxied structure 2 on a support substrate have to be repeated.

However, the applicant has proposed a technique for recycling a donor wafer that was used for taking off a thin layer, the thin layer being formed from part of a structure epitaxied on the support substrate of the donor wafer.

Thus, refer to document US 2004/0152284 that deals with recycling of a donor wafer for which the epitaxied

structure comprises a stack of SiGe layers epitaxied on an Si substrate. This document proposes to place a specific layer in the stack of layers, namely a layer called the stop layer acting as a barrier for a material attack. The presence of this stop layer then means that material can be removed selectively (particularly by selective chemical etching) when material is removed during recycling. With reference to Figures 7a - 7f in this document, the stop layer 3 is used for selective removal of the remaining part 7 after taking off the epitaxied structure 1. After this selective removal of material, a specific epitaxy operation has to be performed to reform a structure similar to the originally epitaxied structure (epitaxy of layer 4') and thus to create a wafer that can act as a donor wafer.

However, this approach has a number of disadvantages.

It requires that a specific epitaxy is performed to form the stop layer.

It also requires that a selective material removal step is carried out, and an additional epitaxy step to reform the epitaxied structure from which the thin layer is taken off.

However, the cost of an epitaxy step is relatively high, particularly due to the use of special equipments, the use of special gases or a relatively long execution time.

Therefore, this approach is not fully satisfactory and there is a need for a simple and less expensive

recycling technique for a negative that was used for taking off a thin epitaxied layer.

Embodiments of the invention seek to satisfy this need, and particularly the use of a recycling technique that is easy to integrate into the method for manufacturing of SeOI structures according to a SMARTCUT® type transfer process.

In accordance with a first aspect of the invention, there is provided a method of forming a structure comprising a thin layer made of a semiconductor material on a receiver wafer, including the following steps:

- surface preparation by removal of a thickness of material from a layer formed by epitaxial growth on a support substrate;
- transfer of part of the epitaxied layer to the receiver wafer so as to form the thin layer on the receiver wafer, a negative also being formed that includes the support substrate and a remaining non-transferred part of the said epitaxied layer.

characterised in that the thickness removed by the said surface preparation step is adapted such that application of the said surface preparation step to the negative enables the formation of a new thin layer from the remaining part which the thickness has been reduced by the surface preparation step.

The following describes some preferred but non-limitative embodiments of this method:

- material may be removed non-selectively;
- material may be removed by polishing, for example CMP type polishing;

- the thickness removed by removal of material may be between 0.1 and 4 μm;
- before the negative is used for the surface preparation step, a step may be performed on the negative to eliminate part of a taking off ring corresponding to a peripheral part of the transferred layer that remained fixed to the negative;
- the thickness removed by removal of material may be between 0.1 and 2 μm;
- the ring may be eliminated by polishing the edges of the negative;
- the ring may be eliminated by applying a local removal of material from the negative, for example by local plasma etching;
- a so-called donor wafer may comprise the support substrate on which the layer was formed by epitaxial growth, and the transfer may include steps consisting of forming an embrittlement zone within the thickness of the epitaxied layer, bringing the donor wafer and the receiver wafer into intimate contact and detaching at the level of the embrittlement zone, and after the negative has been formed, a degassing heat treatment step may be applied to it so as to burst the micro-cavities remaining in the negative;
- the degassing heat treatment may be an annealing carried out with a greater thermal budget than that used in the heat treatment for the detachment step;
- annealing may be done at a temperature of more than 700°C;
- the surface of the negative may be cleaned in a step performed after the degassing heat treatment;

- an RCA type cleaning may be done;
- a step may be performed to eliminate the oxide layer after cleaning;
- the oxide layer may be eliminated by HF type chemical etching;
- when the epitaxied layer is a relaxed SiGe layer formed by epitaxial growth on an SiGe buffer layer, and the said buffer layer is formed by epitaxial growth on an Si support substrate and has a Ge content that increases progressively from the interface with the support substrate, the transferred thin layer including part of the said relaxed SiGe layer, a CMP polishing operation may be carried out during the surface preparation step applied to the negative, during which the surface of the remaining non-removed part of the relaxed SiGe layer may be polished using a polishing pad with a compressibility of between 2 and 15% and a slurry containing not less than 20% of silica particles with a size of between 70 and 210 nm;
- when the epitaxied layer is made of relaxed SiGe, the method may comprise a step after the surface preparation step to form an overlayer by epitaxial growth comprising a layer of strained Si on the upper layer made of relaxed SiGe.

Other aspects, purposes and advantages of this invention will become clearer after reading the following detailed description of preferred embodiments of the invention, given as a non-limitative example and with reference to the attached drawings in which Figure 1 has already been mentioned, and Figure 2 shows the transfer of the thin layer.

With reference to Figure 2, the Figure shows the manner in which detachment takes place during step 18 after bonding in step 17, and particularly the reason for the formation of a ring 80 (non-transferred zone) at the surface of the negative A'.

This Figure 2 (step 18) shows that the donor wafer A and the receiver wafer B are not detached over the entire facing surface area of these two elements.

In reality, the edges of these elements that are shown as sharp angles in the very diagrammatic views in Figure 1 are chamfered.

This is a standard procedure for thin wafers of semiconducting materials which in particular limits exposure of wafers to damage that could result from shocks on unchamfered edges.

Each manipulated wafer thus has a chamfer typically starting at 1.5 mm from the edge of the wafer. This chamfer thus forms a peripheral annular zone around the wafers.

It should be noted that the wafers are generally disk-shaped in a top view. It should also be noted that the chamfers shown in Figure 2 are not necessarily shown at a realistic scale.

This Figure (see step 17 in particular) shows that the implantation step (or more generally the step in which the embrittlement zone is formed) generated an embrittlement zone 7 extending within the thickness of the donor wafer A at an approximately constant depth under its surface in contact with the receiver wafer B, from one edge of the wafer A to the other.

Thus, the weakened zone 7 extends as far as the periphery of the wafer A, and opens up on this periphery at the level of chamfer of wafer A.

As shown with reference to step 17 in Figure 2, there is also a peripheral region around the assembly formed by the wafer A and the receiver wafer B in the form of an annular notch E, with a depth of the order of 1.5 mm (remember that the drawings are not to scale) surrounding this assembly.

And the weakened zone 7 opens up in this notched region E.

At the time of the detachment (step 15), not all of the layer 50 of the wafer A that was delimited by the embrittlement zone 7 is detached from the remainder of the wafer A (to form the positive P).

In reality, a ring 80 corresponding to the peripheral part of the layer 50 remains fixed to the wafer A and extends as far as its periphery.

The part of the layer 50 that was actually detached from the remainder of the wafer actually corresponds only to the region of this layer that was bonded to the receiver wafer B.

And due to the presence of the annular notch E, this region is a central region - that therefore leaves the ring 80 with a width comparable to the depth of the notch E, on the wafer A.

In particular, this projecting ring 80 has to be eliminated so that the negative derived from the transfer method can be recycled (this negative corresponding to element A' in Figure 2, step 18).

And the surface condition of the negative also has to be improved in its central region, because the detachment generated surface disturbances.

Note that the peripheral part 70 (see Figure 2) of the embrittlement zone 7 remains within the thickness of the ring 80.

And during the detachment, this peripheral part generated micro-cavities or cavities that remain buried within the thickness of the ring.

And these cavities have to be eliminated, since if such micro-cavities remain buried in the negative, they could expand or burst when other thermal treatments are performed on the wafer recycled from the negative.

Such a burst would project particles under the surface of the negative, so that it could not be reused under good conditions.

However, it would be desirable to be able to reuse the negative by exposing it to such thermal treatments (for example to cover it with oxide - step 14, or to make a detachment at a weakened zone - step 18).

Therefore, if the negative is to be used again, it is necessary to:

- eliminate the ring 80,
- eliminate the peripheral part 70 of the embrittlement zone that remained buried in the negative,
- improve the surface condition of the entire negative.

After the negative A' has been obtained, a thermal treatment of the said negative A' may be done so as to burst micro-cavities at the edge of the negative

(corresponding to the part 70 of the embrittlement zone). This thermal treatment is also called a degassing heat treatment of the ring.

This thermal treatment may be an annealing with a sufficiently large thermal budget to eliminate all these edge defects.

Therefore, in particular this thermal budget must be greater than budgets of heat treatments applied to the donor wafer from which the negative was generated (particularly annealing for detachment of the negative from the donor wafer A). These treatments were not sufficient to burst the micro-cavities.

This annealing aimed at eliminating micro-cavities can thus be an annealing carried out at temperatures exceeding the temperatures to which the negative was exposed during its constitution (in other words particularly at a temperature greater than the annealing temperature that resulted in detachment).

For example, this annealing may be carried out at a temperature of more than 700°C.

This annealing may be carried out in a neutral or oxidising atmosphere (argon, nitrogen, etc.).

This annealing can also be carried out under a "smoothing" atmosphere so as to reduce the surface roughness of the negative, for example under an atmosphere containing hydrogen.

After the degassing heat treatment, a surface cleaning of the negative can be carried out, for example by applying an RCA type cleaning.

Typically, RCA cleaning consists of treating the surfaces to be bonded with the following, in order:

- a first bath of a solution known as "SC1" (Standard Clean 1) and that includes a mix of ammonium hydroxide (NH_4OH), hydrogen peroxide (H_2O_2) and de-ionised water,

- a second bath of a solution called SC2 (Standard Clean 2) that includes a mix of hydrochloric acid (HCl), hydrogen peroxide (H_2O_2) and de-ionised water.

The first bath will be used mainly to remove isolated particles present on the surface of the wafer and to make the surfaces hydrophilic, while the second bath is intended more specifically to remove metallic contamination.

After this cleaning, it is possible to remove the oxide covering part of the surface of the negative (typically the ring and the back face as described above - and also the entire surface of the negative if the preceding degassing heat treatment was carried out under an oxidising atmosphere).

This may be done by chemical etching, for example by etching with HF.

Note that this step may be omitted if the negative was derived from a donor wafer that was not oxidised.

The invention proposes a transfer method of the type shown in Figure 1 in which a negative A' is used as a donor wafer for the surface preparation step.

In other words, the negative A' is "inserted" into the existing transfer method at step 13 as if it were a "fresh" wafer. The arrow R in Figure 1 shows this "insertion".

Such a negative A' is of the type formed after the detachment step 18 shown in Figure 1. As mentioned

above, a degassing heat treatment was advantageously performed on this negative, accompanied or not accompanied by cleaning and de-oxidation, after its formation and before it is used as a donor wafer for the surface preparation step.

In the context of the method according to the invention, the surface preparation step is thus applied on a negative A', in other words on the remaining non-removed part 40 of the structure 2 (layer or superposition of layers) epitaxied on the support substrate 1.

The thickness removed by the surface preparation step is designed particularly so that application of the said surface preparation step to the negative reduces the thickness of the said remaining part so as to enable removal of a new thin layer directly from the said remaining part with reduced thickness.

In particular, the objective is to consume a sufficient thickness to eliminate the ring and improve the surface condition of the remaining part of the epitaxied layer 4.

The surface preparation step applied to the negative is of the same type (particularly done with the same equipments) as that usually applied to a fresh wafer. Therefore, the invention provides a means of transparently recycling by adapting the classical surface preparation step for a fresh donor wafer. This step, already present in the existing method, is simply adapted to enable recycling (particularly for a greater thickness consumption).

In other words, it thus becomes possible to directly reintegrate the negative A' resulting from the detachment step 18 into the standard thin layer transfer method (for example to make an SeOI type structure using the SMARTCUT® process) and more precisely to reintegrate it so that the surface preparation step 13 is carried out directly on it without passing through the expensive epitaxy step 12.

This surface preparation step also provides a means of making the surface condition of the remaining part directly compatible with removal of a new thin layer.

During a surface preparation step for a fresh donor wafer, a thickness of the order of 20 nm is typically removed so as to prepare the surface of the epitaxied structure 2. The thickness of the ring is typically of the order of 200 nm, and therefore the classical surface preparation step is adapted to consume a greater thickness, so that it is applicable to the negative.

Therefore one advantage of the method according to the invention lies in the fact that the negative can be inserted in the existing manufacturing line. Therefore there is no need to implement a special technique for recycling of the negative, in particular unlike the solution presented in document US 2004/0152284 mentioned above. In particular, no additional operation such as selective etching or epitaxy type operation is carried out.

Note that this eliminates disadvantages related to selective removal of material (typically by chemical

etching), particularly when the invention is used with standard equipment (while chemical etching requires a special device).

For example, material can be removed by polishing the remaining part 40 (see Figure 1) of layer 4.

In particular, the objective here is to polish the surface of the negative A' to eliminate the ring 80.

This polishing can also lower the roughness of the entire surface of the negative to the required level to enable transfer of a new thin layer. Typically, the objective is to reduce the roughness to less than 2 angstroms RMS in 10 x 10 μm^2 AFM.

Note that advantageously, since the part 70 of the embrittlement zone 7 was neutralised by the degassing heat treatment that burst the micro-cavities, this part 70 is not likely to be subjected to problems during polishing that might occur if there had been no prior heat treatment (bursting during polishing, or micro-cavities that remain buried and could burst during subsequent heat treatments).

Note that polishing of the ring is facilitated due to the fact that the micro-cavities in part 70 of the weakened zone have burst, this bursting having weakened the ring, facilitating its removal during polishing.

The surface preparation step removes a thickness Tr from the remaining part 40.

In order to enable transfer of a new thin layer from the remaining part with a lower thickness, the minimum thickness to be removed depends particularly on the thickness of the ring and the surface condition to be reached. The maximum thickness to be removed must be

such that the remaining part with reduced thickness is thicker than the minimum thickness Tm below which it is no longer possible to transfer a thin layer with thickness Ts.

Consider a layer 4 with thickness Ti (between 1 and 50 µm) after the surface preparation step 13 on a fresh donor wafer A. Subsequent to the implantation steps 16 and the detachment step 17, the remaining part 40 of the layer 4 has a thickness Ti - Ts, where Ts represents the thickness of the removed thin layer 50.

Subsequent to surface preparation of the negative, the thickness of the remaining part 40 is Ti - (Ts + Tr).

Thus, in each recycling step, a thickness (Ts + Tr) is removed resulting from taking off (Ts) and removal of material to eliminate the ring and prepare the surface (Tr).

It is thus possible to evaluate the number N of possible recycling operations according to Ti - N.(Ts+Tr) > Tm. An example of this number N is given in the presentation of a special case for application of the method according to the invention.

Note that in the example applications given herein, the minimum thickness Tm is typically of the order of 0.4 µm.

If the minimum thickness Tm is reached (either after several recycling cycles, or even after a single recycling cycle), note that another deposition can be performed by epitaxial growth of layer 4, but without having to recreate the subjacent buffer layer 3. The result is a saving in the time and cost of the

epitaxial growth step presented as reference 12 in Figure 1.

Obviously, such a new deposition by epitaxial growth of layer 4 could also be done before the minimum thickness Tm is reached. For example, this new deposition could be done systematically after each step to remove material applied to the negative, to recreate a layer 4 with thickness Ti.

Note that when an sSoi structure is being manufactured, a step 14 is performed to form the overlayer 5. As already mentioned, this step may consist of performing an epitaxy of a first layer made of relaxed SiGe, followed by epitaxy of a strained Si layer arranged on the said first layer. In such a case and in a manner similar to the new deposition of the layer 4 mentioned above, the said first layer of relaxed SiGe is epitaxied after the surface preparation step applied to the negative and before a new deposition of a strained Si layer is made.

Returning to the description of the surface preparation step, polishing may be conventionally done like a non-selective material removal polishing, using a rotating polishing head, turning facing a polishing plate that is also free to rotate (about a rotation axis that may be parallel to the rotation axis of the head), the polishing plate being covered with a polishing pad, the negative being inserted between the head and the plate and with its surface to be polished facing the pad the fabric covering the plate.

Advantageously, polishing may be appropriate to remove material from a hetero-epitaxial structure, for

example polishing of the type described by the Applicant in his international patent application PCT/EP2004/006186 deposited on June 8 2004 and not yet published.

Typically, the objective is to implement Chemical Mechanical Polishing (CMP) using a polishing pad with a compressibility of between 2 and 15% and an abrasive liquid (slurry) containing not less than 20% of silica particles with a size of between 70 and 210 nm.

According to one particularly advantageous embodiment of the invention, when the surface preparation step is applied to a negative, a step to eliminate at least part of the ring is applied before the said surface preparation step is implemented.

If at least part of the ring is eliminated in advance, less polishing will be necessary than for the case in which the ring is not at least partially eliminated in advance.

For example, the thickness Tr consumed during the surface preparation step on the remaining part 40 of the epitaxied structure is typically of the order of 0.1 to 4 µm when the ring is not eliminated in advance. This thickness Tr is of the order of 0.1 to 2 µm when the ring is eliminated in advance.

Note here that the thickness Tr in the embodiment in which the ring is not eliminated in advance is typically greater than the thickness of the ring. It is usually difficult to perform a CMP at the periphery of the wafer (at the location of the ring), therefore it is necessary to consume a greater thickness than the thickness of the ring.

The advantage of the step to eliminate the ring lies in the fact that the thickness to be removed during surface preparation of the negative is limited. This lower thickness consumption potentially increases the number of possible recycling operations.

Furthermore, the thickness to be consumed is then closer to the thickness consumed during the classical surface preparation step for a fresh wafer. Therefore this advantageous embodiment of the invention has the advantage that it only requires a slight adaptation to the method according to the state of the art.

The ring can be eliminated:

- using a so-called "edge polish" technique adapted to reduce the thickness of the ring by polishing the edges of the negative. With this technique, two different polishing plates are applied, each plate being covered with a polishing pad on which a liquid abrasive is sent. For example, an upper plate Ps inclined by 15° from the surface of the negative could be used with a lower plate Pi inclined by 22°. It can be understood that by adjusting the angle, it is possible to penetrate to a greater or lesser extent inside the wafer. Apart from the consumption of the thickness of the ring, this technique also provides a means of reconstituting a chamfer around the edge of the wafer.

- by a local material removal technique, for example using a DCP (Dry Chemical Polishing) type technique. For example, a local plasma etching can be performed by positioning a mask on the central part of the negative and by applying a plasma etching (H_2 or

O_2) so as to consume the thickness of the part of the negative not protected by the mask, in other words the ring.

A purely illustrating example of the advantageous embodiment of the method according to the invention presented above is given below, for which the initial thickness Ti of the layer 4 (in other words after a first surface preparation step applied to a fresh wafer) is 10 µm (Ti is usually between 1 and 50 µm).

We will consider removal of a thin layer with thickness Ts equal to 0.2 µm (Ts is usually between 0.05 and 0.5 µm).

The thin layer is removed using a SMARTCUT® type transfer method, and during recycling the ring is eliminated and material is then non-selectively removed from the remaining part 40 of the epitaxied structure using CMP type polishing adapted to remove a thickness Tr equal to 0.5 µm.

The number N of possible recycling operations is then equal to 13.

CLAIMS

1. Method of forming a structure comprising a thin layer made of a semiconductor material on a receiver wafer, including the following steps:

- surface preparation by removal of a thickness of material from a layer formed by epitaxial growth on a support substrate;

- transfer of part of the epitaxied layer to the receiver wafer so as to form the thin layer on the receiver wafer, a negative also being formed that includes the support substrate and a remaining non-transferred part of the said epitaxied layer,

characterised in that the thickness removed by the said surface preparation step is adapted such that application of the said surface preparation step to the negative enables the formation of a new thin layer from the remaining part which thickness has been reduced by the surface preparation step.

2. Method according to the previous claim, characterised in that the removal of material is a non-selective removal.

3. Method according to the previous claim, characterised in that material is removed by polishing, for example CMP type polishing.

4. Method according to the previous claim, characterised in that the thickness removed by removal of material is between 0.1 and 4 µm.

5. Method according to one of the previous claims, characterised in that before the negative is used for the surface preparation step, a step is performed on the negative to eliminate part of a taking off ring corresponding to a peripheral part of the transferred layer that remained fixed to the negative.

6. Method according to the previous claim, characterised in that the thickness removed by removal of material is between 0.1 and 2 µm.

7. Method according to the previous claim, characterised in that the ring is eliminated by polishing the edges of the negative.

8. Method according to one of claims 5 and 6, characterised in that the ring is eliminated by applying a local removal of material from the negative, for example by local plasma etching.

9. Method according to one of the previous claims, in which a so-called donor wafer comprises the support substrate on which the layer was formed by epitaxial growth, and the transfer includes steps consisting of forming an embrittlement zone within the thickness of the epitaxied layer, bringing the donor wafer and the receiver wafer into intimate contact and detaching at the level

of the embrittlement zone, characterised in that after the negative has been formed, a degassing heat treatment step is applied to it so as to burst the micro-cavities remaining in the negative.

10. Method according to the previous claim, characterised in that the degassing heat treatment is an annealing carried out with a greater thermal budget than that used in the heat treatment for the detachment step.

11. Method according to the previous claim, characterised in that annealing is done at a temperature of more than 700°C.

12. Method according to one of the three previous claims, characterised in that the surface of the negative is cleaned in a step performed after the degassing heat treatment.

13. Method according to the previous claim, characterised in that an RCA type cleaning is done.

14. Method according to one of the two previous claims, characterised in that a step is performed to eliminate the oxide layer after cleaning.

15. Method according to the previous claim, characterised in that the oxide layer is eliminated by HF type chemical etching.

16. Method according to one of the previous claims, in which the epitaxied layer is a relaxed SiGe layer formed by epitaxial growth on an SiGe buffer layer, the said buffer layer being formed by epitaxial growth on an Si support substrate and having a Ge content that increases progressively from the interface with the support substrate, the

transferred thin layer including part of the said relaxed SiGe layer, characterised in that a CMP polishing operation is carried out during the surface preparation step, using a polishing pad with a compressibility of between 2 and 15% and a slurry containing not less than 20% of silica particles with a size of between 70 and 210 nm.

17. Method according to one of the previous claims, in which the epitaxied layer is a relaxed SiGe layer, characterised in that after the preparation step, it includes an epitaxial growth step intended to form an overlayer comprising a strained Si layer on the relaxed SiGe upper layer.

ABSTRACT

METHOD FOR RECYCLING AN EPITAXIED DONOR WAFER

The invention relates to a method of forming a structure comprising a thin layer (5, 50) made of a semiconductor material on a receiver wafer (B), including the following steps:

- surface preparation (13) by removal of a thickness (Tr) of material from a layer (4) formed by epitaxial growth on a support substrate (1);
- transfer of part (5, 50) of the epitaxied layer to the receiver wafer (B) so as to form the thin layer on the receiver wafer, a negative (A') also being formed that includes the support substrate (1) and a remaining non-transferred part (40) of the epitaxied layer,

characterised in that the thickness (Tr) removed by the said surface preparation step is adapted such that application of the said surface preparation step to the negative (A') enables the formation of a new thin layer from the remaining part (40) which thickness has been reduced by the surface preparation step.

Figure 1