Process for transferring a circuit layer

FIELD OF THE INVENTION

The invention lies in the field of electronics, optics and/or optoelectronics.

The present invention relates more specifically to a process for transferring a buried circuit layer.

Various electronic components are manufactured from a substrate that includes such a buried circuit layer. Among these, mention may be made, by way of example, of the sensors using backside illumination technology (known to a person skilled in the art under the acronym of "BSI sensor", for "backside illumination sensor"). They are based on a novel arrangement of the various layers forming them. These sensors make it possible to increase the amount of light captured and are therefore more efficient. They are intended to be used in particular in the screens of the latest generation tablets and telephones.

BACKGROUND OF THE INVENTION

The thinning of a substrate used in the aforementioned technical fields may be carried out for example by chemical etching.

When a substrate of semiconductor-on-insulator (SeOI) type is thinned, the chemical etching is relatively easy to use since the buried oxide layer serves as an etch stop layer. When it is a question of a solid substrate, the thinning is slightly more complex since it is then necessary to create an etch stop layer, for example by p- or n-type doping of said solid substrate.

However, in the particular case where the donor substrate comprises a buried circuit layer, the

chemical etching of the layer of material that covers said buried circuit layer becomes truly problematic. Specifically, the chemical solutions used (for example sulfuric acid (H_2SO_4), phosphoric acid (H_3PO_4) or hydrofluoric acid (HF) in the case of the etching of silicon) are particularly aggressive with respect to metals and therefore with respect to the layer comprising said circuits.

This results in a lateral etching of this buried circuit layer which may reach a centimeter or more from the edge. The BSI sensors manufactured in the vicinity of this damaged zone are then unusable.

A process is already known from document EP 1 962 325 for manufacturing a bonded substrate, by transfer of layers, which comprises steps of producing a peripheral groove on the front side of a donor substrate, of thermal oxidation of this substrate, of bonding a receiver substrate to said front side and of thinning said donor substrate from its back side, until the bottom of said groove is reached.

Such a process makes it possible to transfer to the receiver substrate only the central portion of the donor substrate and to remove the poorly bonded peripheral portion thereof.

However, this document absolutely does not describe the treatment of donor substrates comprising a buried circuit layer and furthermore such a layer would not withstand the thermal oxidation carried out, or the thermal treatment after bonding at more than 1000°C, which are described in this document.

The objective of the invention is therefore to propose a process for transferring a buried circuit layer which resolves the aforementioned drawbacks of the prior art and in particular which avoids damaging these circuits.

For this purpose, the invention relates to a process for transferring a buried circuit layer (2).

In accordance with the invention, this process comprises the following steps:

- taking a donor substrate comprising internally an etch stop zone and covered on one of its sides, referred to as the "front" side, with a circuit layer,
- producing over the entire circumference of said donor substrate, on its side covered with the circuit layer, either a peripheral trench that extends at a distance from the lateral edge of this substrate, or a peripheral routing, this routing or this trench being produced over a depth such that they pass entirely through the circuit layer and extend into the donor substrate,
- depositing on the exposed side of said circuit layer and on the routed side or on the walls of said trench, a layer of a stop material that is selective with respect to the etching of said circuit layer, referred to as a "second stop layer", without filling said trench,
- bonding a receiver substrate to said donor substrate on the side covered by said second stop layer,
- thinning the donor substrate (1) by chemical etching of its back side, until said etch stop zone is reached, so as to obtain the transfer of said buried circuit layer to said receiver substrate.

According to other advantageous and nonlimiting features of the invention, taken alone or in combination:

- said etch stop zone is a layer, referred to as a "first stop layer", of a material that is selective with respect to the etching of the material of the back portion of the donor substrate;

- said etch stop zone is an interface between a doped front layer and a non-doped back layer of the donor substrate;

- the peripheral routing or the peripheral trench has a depth such that it passes through said etch stop zone, without penetrating into the back portion or the back layer of the donor substrate;

- the peripheral routing or the peripheral trench is produced over a depth such that it does not pass through said etch stop zone and in that, after the chemical etching thinning step, an additional step of mechanical removal of the residual peripheral ring of the donor substrate is carried out, in particular by grinding or chemical mechanical polishing (CMP);

- the peripheral routing or the peripheral trench has a depth such that it passes through said etch stop zone and extends into the back portion or the back layer of the donor substrate and, after the chemical etching thinning step, an additional step of mechanical removal of the residue of said second stop layer is carried out, in particular by grinding or chemical mechanical polishing (CMP);

- the second stop layer is deposited by a technique selected from chemical vapor deposition (CVD) or spin coating;

- the peripheral trench is produced with the aid of a technique selected from laser etching, dry etching and wet etching;

- said peripheral trench is located at a distance from the lateral edge of the donor substrate of less than or equal to 5 mm;

- the width of the trench is between 10 μm and 500 μm;

- the materials forming the first and the second stop layer are selected from oxides or nitrides;

- the materials forming the first and the second stop layer are selected from silicon oxide, silicon oxynitride or silicon oxycarbide;

- the materials forming the first and the second stop layer are identical;
- the donor substrate is produced from a semiconductor material;
- the bonding of the donor and receiver substrates takes place by molecular adhesion.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the invention will appear from the description that will now be given, with reference to the appended drawings, which represent, by way of indication but nonlimitingly, possible embodiments thereof.

In these drawings:

- figures 1 to 6 are diagrams representing the various steps of one embodiment of the process in accordance with the invention;
- figures 7 to 9 are diagrams representing some of the steps of another embodiment of the process in accordance with the invention; and
- figures 10A to 10D and 11A to 11D are detailed views on an enlarged scale of embodiment variants of certain steps of the process illustrated in figures 4 and 5.

DETAILED DESCRIPTION OF ONE EMBODIMENT

A first embodiment of the invention will now be described with reference to figures 1 to 6.

In figure 1, a donor substrate 1 can be seen that has a side 11, referred to as the "back side" and an opposite side 12, referred to as the "front side".

The front side 12 is covered with a circuit layer 2.

Moreover, this donor substrate 1 has internally an etch stop zone.

According to a first embodiment of the invention, this etch stop zone is a layer 7 of material referred to as a "first stop layer".

The stop layer 7 thus divides the donor substrate 1 between a portion 102, referred to as a "front" portion, which extends between this stop layer 7 and the circuit layer 2 and a portion 101, referred to as a "back" portion, which extends between this stop layer 7 and the back side 11.

In the example represented, these front 102 and back 101 portions are monolayers. However, they could also be multilayers.

The first stop layer 7 is produced from a material that is selective with respect to the material(s) forming said donor substrate 1 and in particular to its back portion 101.

This first stop layer 7 may be obtained by deposition, for example by chemical vapor deposition (CVD), or by epitaxy on the back portion 101. It may also be obtained by layer transfer.

The front portion 102 may be obtained after the formation of the layer 7, by the same techniques as those mentioned above for the layer 7.

According to another embodiment variant, the stop layer 7 may also be implanted in the donor substrate 7, by doping. This technique makes it possible to avoid the step of adding the front portion 102 mentioned above.

By way of purely illustrative example, the donor substrate 1 may be of "semiconductor-on-insulator"

(SeOI) or "silicon-on-insulator" (SOI) type. In this case, the stop layer 7 consists of silicon oxide (SiO_2).

According to a second embodiment of the invention, the etch stop zone may be simply an interface between two layers of the donor substrate. This embodiment variant is represented in figure 7. The interface bears the reference 7′ and extends between a back layer 101′ and a front layer 102′ of the donor substrate 1′.

Preferably, the front layer 102′ is a layer of the same chemical nature as the layer 101′, but highly doped.

It will be noted that irrespective of the embodiment of the etch stop zone 7, 7′, this is always produced before the formation of the circuit layer 2.

The next step of the process is represented in figure 2 and consists in producing over the entire circumference of the donor substrate 1, on its side covered with the circuit layer 2, a peripheral trench 3 that extends at a distance from the lateral edge 13 of this donor substrate.

This trench 3 is produced over a depth such that it passes entirely through the circuit layer 2 and such that it extends into the donor substrate 1 to a depth which will be described in detail subsequently in connection with figures 10 and 11.

Preferably, the peripheral trench 3 is produced with the aid of a technique selected from laser etching, dry etching and wet etching. With the first two techniques, it is not necessary to protect the circuit layer 2; on the other hand with wet etching, it is necessary to add an etching mask on top of the layer 2, in order to etch only the desired portion.

By way of example, the trench 3 advantageously has a width L1 of between 10 μm and 500 μm. Furthermore, this peripheral trench 3 is preferably located at a distance D1 from the lateral edge 13 of the donor substrate of less than or equal to 5 mm. Such a distance makes it possible to maximize the retained central portion of the circuit layer 2, since it is this which will be used subsequently for the fabrication of electronic components.

The exposed side 21 of the circuit layer 2, that is to say its front side, and also the side and bottom internal walls of the trench 3, are then covered with a layer 4 of an etch stop material, which is selective with respect to the etching of said circuit layer 2 and is referred to as a "second stop layer".

This step takes place by deposition, preferably by a technique selected from chemical vapor deposition (CVD) or spin coating. Spin coating consists in depositing a viscous material over the central portion of the substrate and in spinning the latter about a central axis.

The step of forming the layer 4, illustrated in figure 3, is carried out while taking care of course not to fill the trench 3 previously formed. The viscosity of the material used to form the etch stop layer 4 and the speed of rotation are selected so as not to fill the trench 3.

The materials forming the first stop layer 7 and the second stop layer 4 are preferably selected from oxides or nitrides, more preferably selected from silicon oxide (SiO_2), silicon oxynitride (SiO_xN_y), silicon oxycarbide (SiO_xC_y) or silicon nitride (Si_3N_4).

Silicon oxide may for example be deposited using tetramethoxysilane (TEOS) in an oxygen or oxygen-argon plasma.

Advantageously but not necessarily, the materials forming the first stop layer 7 and the second stop layer 4 are identical.

The peripheral ring of materials that extends radially beyond the trench 3 bears the reference 14.

As represented in figure 4, a receiver substrate 5 is then bonded to the second stop layer 4 deposited on the donor substrate 1.

This bonding preferably takes place by molecular adhesion. It will be noted that the donor substrate 5 may optionally be covered with a bonding layer 50, for example a layer of silicon oxide (SiO_2) or a layer of silicon nitride (Si_3N_4).

As can be seen in figure 5, the thinning of the donor substrate 1 is then carried out by chemical etching starting from its back side 11, so as to remove the back portion 101, and reach the etch stop layer 7.

This step also has the effect of removing the peripheral ring 14 of said donor substrate, not bonded to the receiver substrate 5, either directly, or after an additional mechanical thinning step, as will be described subsequently in greater detail.

The circuit layer 2 buried beneath the front layer 102, transferred to the receiver substrate 5, is thus obtained. The final substrate thus obtained bears the reference 6 (see figure 6).

The presence of the stop layer 7 and of the second stop layer 4 on the exposed side 21 and the lateral edge of

the circuit layer 2 guarantees that the circuits are not damaged during the chemical etching thinning phase and prevents infiltrations.

In the case where the stop zone is a silicon oxide stop layer 7 and where the material of the back portion 101 is silicon, the chemical etching thinning will advantageously be carried out using a bath of tetramethylammonium hydroxide (TMAH) or KOH (potassium hydroxide).

In the case where the stop zone is a stop interface 7', and where the back layer 101' is silicon and the front layer 102' is highly doped silicon, the chemical etching thinning may be carried out using a solution of sulfuric acid (H_2SO_4), a solution of phosphoric acid (H_3PO_4), hydrofluoric acid (HF) or propanoic acid (C_2H_5COOH).

The transfer process represented in figures 7 to 9 will now be described. It is a variant of the process described previously with reference to figures 1 to 6. The same components bear the same numerical references.

In this case, the donor substrate, referenced 1', is subjected to a peripheral routing. The routed portion bears the reference 3'.

This routing is carried out over the entire circumference of the donor substrate 1' and to a depth such that it passes entirely through the circuit layer 2 and extends into the donor substrate 1'.

This routing may be carried out by polishing or grinding, for example using a tool applied to a portion of the lateral edge 13 of the donor substrate 1'.

The second stop layer 4 is therefore deposited both on the exposed side 21 of the circuit layer 2 and on the routed lateral side 13′ of the donor substrate 1.

After bonding to the receiver substrate 5 (see figure 8) and chemical thinning of the donor substrate 1 (see figure 9), the circuit layer 2 transferred to the receiver substrate 5 is obtained, either directly, or after an additional step of mechanical polishing, as will be described subsequently.

The final substrate referenced 6′ is obtained, which differs from the substrate 6 from figure 6 in that the front portion 102 is replaced by the front layer 102′.

Although the option of peripheral annular routing has been described solely in connection with figures 7 to 9, in which the donor substrate 1′ is a substrate that comprises a stop interface 7′, it should be understood that this routing step could also be carried out on the donor substrate 1 represented in figures 1 to 6, which comprises the stop layer 7.

Conversely, the donor substrate 1′ from figures 7 to 9 could be subjected to the formation of the peripheral trench 3, as described in figures 1 to 6.

In the various embodiments described above, the thicknesses of the first stop layer 7 and of the second stop layer 4 preferably lie between 0.01 μm and 100 μm.

The parameter regarding the depth of the peripheral trench 3 in the donor substrate 1′ will now be described in connection with figures 10A to 10D and 11A to 11D. Although not represented in these figures, the reasoning is the same whether the trench 3 is replaced by a peripheral routing 3′ or whether the donor substrate is a substrate 1′ having a stop interface 7′.

In figure 10A, the trench 3 is produced over a depth such that it passes entirely through the circuit layer 2 and extends into the donor substrate 1' but without reaching the stop layer 7.

In the variant represented in figure 10B, this trench 3 this time reaches the stop layer 7 but does not pass through it.

In both these scenarios, after the step of chemical thinning of the back portion 101, and as can be seen respectively in figures 11A and 11B, the peripheral ring 14 remains attached to the front portion 102 by a greater or lesser thickness of material. In both these cases, it will be necessary to carry out an additional step of mechanical removal of this residual ring 14, in particular by a lateral chemical mechanical polishing or grinding.

In the embodiment variant represented in figure 10C, the peripheral trench 3 has a depth such that it passes through the etch stop layer 7, without however penetrating into the back portion 101 of material of the donor substrate 1.

In this case, the chemical etching is sufficient to remove the peripheral ring 14. Indeed, the residual thickness 40 of the second stop layer 4 is too small and therefore too fragile to retain the peripheral ring 14. This variant is therefore the preferential embodiment variant of the invention (see figure 11C).

Finally, according to a fourth embodiment variant of the invention, the peripheral trench 3 has a depth such that not only does it pass through the etch stop layer 7 but it extends into the back portion 101 (see figure 10D).

In this case, and as represented in figure 11D, after the chemical etching step, it is observed that a "step" 41 of the material of the second stop layer 4 remains. This step will then be removed either due to its inherent fragility at its small thickness, or by grinding or chemical mechanical polishing, if it is desired to obtain a defect-free planarity.

Owing to the features of the invention, the circuit layer 2 is protected during its transfer and the layer 102' or the front portion 102 which covers it may be adjusted to the desired thickness by choosing the position of the stop layer 7.

CLAIMS

1. A process for transferring a buried circuit layer (2), characterized in that it comprises the following steps:

- taking a donor substrate (1, 1′) comprising internally an etch stop zone (7, 7′) and covered on one of its sides (12), referred to as the "front" side, with a circuit layer (2),

- producing over the entire circumference of said donor substrate (1, 1′), on its side covered with the circuit layer (2), either a peripheral trench (3) that extends at a distance from the lateral edge (13) of this substrate, or a peripheral routing (3′), this routing (3′) or this trench (3) being produced over a depth such that they pass entirely through the circuit layer (2) and extend into the donor substrate (1, 1′),

- depositing on the exposed side (21) of said circuit layer (2) and on the routed side (13′) or on the walls of said trench (3), a layer of a stop material (4) that is selective with respect to the etching of said circuit layer (2), referred to as a "second stop layer", without filling said trench (3),

- bonding a receiver substrate (5) to said donor substrate (1, 1′) on the side covered by said second stop layer (4),

- thinning the donor substrate (1) by chemical etching of its back side (11), until said etch stop zone (7, 7′) is reached, so as to obtain the transfer of said buried circuit layer (2) to said receiver substrate (5).

2. The process as claimed in claim 1, characterized in that said etch stop zone is a layer (7), referred to as a "first stop layer", of a material that is selective with respect to the etching of the material of the back portion (101) of the donor substrate (1).

3. The process as claimed in claim 1, characterized in that said etch stop zone is an interface (7′) between a doped front layer (102′) and a non-doped back layer (101′) of the donor substrate (1′).

4. The process as claimed in one of the preceding claims, characterized in that the peripheral routing (3′) or the peripheral trench (3) has a depth such that it passes through said etch stop zone (7, 7′), without penetrating into the back portion (101) or the back layer (101′) of the donor substrate (1, 1′).

5. The process as claimed in one of claims 1 to 3, characterized in that the peripheral routing (3′) or the peripheral trench (3) is produced over a depth such that it does not pass through said etch stop zone (7, 7′) and in that, after the chemical etching thinning step, an additional step of mechanical removal of the residual peripheral ring (14) of the donor substrate (1, 1′) is carried out, in particular by grinding or chemical mechanical polishing (CMP).

6. The process as claimed in one of claims 1 to 3, characterized in that the peripheral routing (3′) or the peripheral trench (3) has a depth such that it passes through said etch stop zone (7, 7′) and extends into the back portion (101) or the back layer (101′) of the donor substrate (1, 1′) and in that, after the chemical etching thinning step, an additional step of mechanical removal of the residue (41) of said second stop layer (4) is carried out, in particular by grinding or chemical mechanical polishing (CMP).

7. The process as claimed in one of the preceding claims, characterized in that the second stop layer (4) is deposited by a technique selected from chemical vapor deposition (CVD) or spin coating.

8. The process as claimed in one of the preceding claims, characterized in that the peripheral trench (3) is produced with the aid of a technique selected from laser etching, dry etching and wet etching.

9. The process as claimed in one of the preceding claims, characterized in that said peripheral trench (3) is located at a distance (D1) from the lateral edge (13) of the donor substrate (1, 1') of less than or equal to 5 mm.

10. The process as claimed in one of the preceding claims, characterized in that the width (L1) of the trench (3) is between 10 μm and 500 μm.

11. The process as claimed in one of the preceding claims, characterized in that the materials forming the first (7) and the second (4) stop layer are selected from oxides or nitrides.

12. The process as claimed in claim 11, characterized in that the materials forming the first (7) and the second (4) stop layer are selected from silicon oxide (SiO_2), silicon oxynitride (SiO_xN_y) or silicon oxycarbide (SiO_xC_y).

13. The process as claimed in one of the preceding claims, characterized in that the materials forming the first (7) and the second (4) stop layer are identical.

14. The process as claimed in one of the preceding claims, characterized in that the donor substrate (1) is produced from a semiconductor material.

15. The process as claimed in one of the preceding claims, characterized in that the bonding of the donor (1) and receiver (5) substrates takes place by molecular adhesion.