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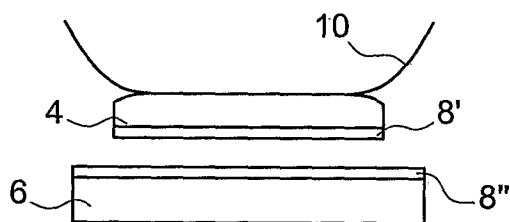
**Declaration under Rule 4.17:**

— of inventorship (Rule 4.17(iv))

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— with international search report  
— the filing date of the international application is within two months from the date of expiration of the priority period

(54) Title: METHOD FOR PRODUCING SELF-SUPPORTING MEMBRANES



**FIG. 2**

(57) Abstract: The invention relates to a method for separating a membrane (4) from a substrate (6), comprising : a) the fixing of at least one adhesive (10) solely on a part of the surface of said membrane which is not facing the substrate, b) the separation of the membrane by traction on one of the adhesives.

## METHOD FOR PRODUCING SELF-SUPPORTING MEMBRANES

### TECHNICAL FIELD AND PRIOR ART

The invention relates to a method for producing self-supporting membranes from detachable SeOI substrates (Semiconductor On Insulator), more specifically SOI (Silicon On Insulator) substrates.

The method of the present invention leads to a superficial layer to be separated or detached from its substrate, the structure exhibiting a weakened interface between the superficial layer and the substrate.

In various microelectronic, optoelectronic and electronic applications, it is advantageous to be able to detach a layer of semiconductors from a substrate, the layer being processed or not, in order to obtain a self-supporting layer. Moreover, in certain applications it may be advantageous, to form such a layer and to transfer it on a final substrate.

Various techniques have been developed for separating or detaching a semiconductor layer from its initial support. The most commonly known means consist in mechanically thinning the initial support substrate, or chemically etching the initial support substrate. A combination of the mechanical thinning with the chemical etching can also be carried out.

Although these methods lead to the withdrawal of the initial support, they lead to the destruction of it.

Other means have been made available for weakening a particular zone of the substrate in order to detach the structure.

For example, the patent WO 02/084721 describes a method for producing a detachable substrate comprising an interface with two different zones in term of mechanical strength. This interface can be obtained by different means, for example by bonding two surfaces

prepared in different ways, or by an weakened embedded layer or by a intermediate porous layer.

The detachment is thus either mechanical, with the use of blades or a liquid jet, or chemical.

5                   However, all these techniques are not suitable for producing self-supporting layers, more especially when the layers are thin, for example between several nanometres and several microns.

10                   Indeed, the introduction of a blade, or of any other opening system at the interface is not possible for relatively thin detachable semiconductor layers.

                  It is for this reason that techniques such as those described in document FR 2 848 723 have been made available. The technique described in this document employs a tool comprising two gripping elements temporarily fixed on each of the wafers to be separated, 15 which are bent by an actuator in a controlled manner in order to separate the two wafers.

                  Another technique consists in bonding an adhesive film (scotch tape) over the whole surface of the front face of a SOI substrate, then applying a tractive force on this adhesive film.

20                   Since the bonding energy of the adhesive film is higher than the bonding energy of the interface, the SOI is separated from the substrate and remains bonded to the adhesive film. A self-supporting membrane having the thickness of the initial SOI is thus obtained. The adhesive film is then separated from the membrane by chemical or 25 mechanical or thermal action or by the application of a UV beam if the film is UV sensitive.

                  However, the latter two techniques can only be applied to membranes of small thickness, from several hundred nanometres to several microns (typically  $\sim 3 \mu\text{m}$ ). This is because the adhesive film or the 30 gripping element generate or impose a deformation on the membrane

during the separation of the latter. Moreover, membranes of thin thickness are more flexible and can undergo this deformation without rupturing.

In the case of an SOI substrate with thin layers (<3 microns), the stress generated in the membrane by the deformation of the adhesive film or the gripping element is sufficiently low to avoid rupture of the film : the film is deformed more easily because of the thin thickness. In contrast, in the case of a thick SOI (thickness >3 microns, obtained by the BSOI technique for example), the stress generated in the membrane is greater, precisely because of its greater thickness, and the membrane can not undergo the deformations imposed by the film or by the gripping plate. Thereforeus, the membrane breaks during the separation.

Finally, none of the known techniques leads to a transfer of a film or a membrane.

## EXPLANATION OF THE INVENTION

The present invention proposes to overcome these drawbacks.

It concerns a method for separating a membrane from a substrate, comprising :

a) the fixing of at least one adhesive only on a part of the surface of said membrane,

b) the separation of the membrane or of at least a part of the membrane by application of a force on the adhesive, by a tractive force for example.

According to an embodiment of the invention, one or more adhesive film(s) are bonded not over the whole of the layer or the surface to be removed, detached or separated, but locally, on one or more zone(s) of this layer or this surface. This local bonding allows the separation or detachment to be initiated.

The membrane can have been initially bonded by molecular adhesion with the substrate or joined with it via a bonding layer

or via a substrate previously treated in order to increase its level of weakening.

The membrane can be of a semiconductor material or a piezoelectric material or a ferroelectric material. It can be in a weakly  
5 doped or strongly doped silicon, or in AsGa, or in Ge, or in SiC, or in GaN, or in InP or in LiNbO<sub>3</sub> or in LiTaO<sub>3</sub>. It can be a mono-layer or a multi-layer. It can also comprise a processed layer.

The invention can produce large-area membranes, for example circular membranes having a diameter between 100 mm and 300  
10 mm.

The separation (stage b) can be started previously by lateral chemical attack.

The membrane can have a thickness greater than several microns, preferably greater than 3 microns. The invention can lead to the  
15 fabrication of self-supporting membranes, in particular thick membranes, with a thickness greater than several microns, and that is detachable from SOI substrates.

The obtained self-supporting membrane can be used as such or, according to a variant, can be transferred onto a final support.

20 An weakened zone can be previously formed in the membrane ; the separation, from the substrate, of at least a part of the membrane can take place along this weakened zone.

This weakened zone can be produced by ionic or atomic implantation, before or after bonding of the membrane and the substrate.

25 Preferably, the interface between the membrane and the substrate has a controlled energy in order to facilitate the detachment of the membrane. As a variant or as a supplement, the interface between the substrate and the membrane can comprise a material selected in order to facilitate the detachment of the membrane.

## BRIEF DESCRIPTION OF THE DRAWINGS

- figures 1A, 1B and 2 represent a first embodiment of the invention.

5       - figures 3A, 3B and 4 represent a second embodiment of the invention.

- figure 5 represents another embodiment of the invention, with a plurality of adhesives.

- figures 6A and 6B represent another embodiment of the invention, with the formation of a fracture plane.

10       - figure 7 represents a membrane separated by a method according to the invention, then transferred onto a substrate.

## DETAILED EXPLANATION OF THE PARTICULAR EMBODIMENTS

The invention is described for a BSOI substrate, but can be generalised to any type of detachable SeOI (semiconductor on insulator) substrate.

15       As illustrated in figure 1A, a SeOI substrate is first selected, comprising a film or a membrane 4 of semiconductor material, and in particular in silicon or in Ge, or in SiC, or in GaN. Membrane 4 can also be in InP or in LiNbO<sub>3</sub> or in LiTaO<sub>3</sub>. It can also be in a piezoelectric material, or in a ferroelectric material. This membrane can be a mono-layer or a multi-layer.

20       Whatever its nature, and whether it is a mono- or multi-layer, according to another variant, it can comprise a processed layer. For example, it thus comprises holes and/or chips, and/or circuits and/or micro-systems.

25       A substrate 6 is, for example, also in silicon or in polysilicon or in any other semiconductor material.

A bonding interface 8 can be present between the two surfaces of the film or the membrane 4 and the substrate 6, the surfaces being preferably oxidised.

5 In a variant, the membrane 4 is bonded to the substrate 6 by molecular adhesion.

In a favourable configuration, the bonding interface of the structure SeOI will have been prepared in such a way that it promotes the subsequent detachment of the upper membrane 4. For example, the surfaces brought into contact undergo specific treatments in order to  
10 control the bonding energy, as described :

- in US 2004/222500 : in this document, an interface is produced by molecular bonding between the face of a layer (herein the membrane 4) and the face of a substrate (herein the substrate 6), a treatment of at least one of these two faces being previously applied in  
15 such a way that the mechanical strength of the interface is controlled, and compatible with subsequent detachment,

- in FR 2 860 249 : in this document, an intermediate layer (herein the layer 8), for example in PSG or in BPSG, is disposed at the interface membrane 6 – substrate 4, this intermediate layer comprising  
20 at least one base material in which extrinsic atoms or molecules, different from the atoms of the base material, are distributed, and in which a heat treatment is applied, for example at a temperature between 900°C and 1100°C; the formation of microbubbles or microcavities, in particular of a gaseous phase, is thus produced in an irreversible manner, in such a way  
25 that the intermediate layer is transformed in a porous layer capable of increasing in thickness,

- in US2005/029224 : an interface is produced in order to have at least a first zone with a first level of mechanical strength and a second zone with a level of mechanical strength much less than that of the  
30 first zone ; this interface can be obtained by different means, for example

by bonding of two surfaces prepared in a different way, or by a weakened embedded layer or by a porous intermediate layer,

- in US 2006/019476 : in this document, microbubbles or microcavities lead to the constitution of a weakened layer 8 at the interface between a thin layer of semiconductor material (for example the membrane 4) and a face of a substrate 6; then, a heat treatment allows the increase of the weakening level.

In particular, documents US2004/222500 or US2006/019476 describe structures of the type D-BSOI™, or detachable structure SOI.

An adhesive film 10 is then applied on the surface 5 of the film or of the membrane 4 (surface situated on the opposite side of the bonding interface 8). As it will be seen below (figure 5), a plurality of films 10, 10', 10'' can be joined with surface 5. The contact surface between the film or the films 10, 10', 10'' and the surface 5 of the membrane 4 to be detached is preferably selected in such a way that :

- this contact surface is sufficiently large for the film or films 10 to adhere to membrane 4 to be detached and for the forces applied to the film(s) to be able to cause the detachment of this membrane,
- said contact surface is sufficiently small such that the deformation of the membrane 4 is compatible with the elasticity criteria of said membrane.

A ratio, for example, between 2 and 50 or between 2 and 100, preferably between 10 and 50 or preferably between 10 and 20 exists between the surface 5 of the membrane 4 and the surface of the adhesive film(s) applied against this surface 5.

Figure 1B represents the membrane 4 and an adhesive 10 in plan view. Figure 5 represents the case of a plurality of adhesives 10, 10', 10'' with the membrane 4 in plan view. In the following, the explanations will be restricted to the case of a single adhesive, but all the

considerations presented in the case of a single adhesive can be equally apply to the case of a plurality of adhesives.

The separation of the membrane 4 is initiated by the application of a force such as a tractive force, for example, on the adhesive 10. In the case of a plurality of adhesives, the traction can be applied to one or several adhesives. The membrane 4 is free, since it is only in contact with the adhesive film over a small area, and can thus be freely deformed. Thus, the stress and the deformation generated in the layer 4 are much weaker than with the method proposed in the prior art, which employs an adhesive over the whole area. The invention thus allows the detachment of the membrane 4 without rupturing it. Figure 2 represents the membrane after separation, a layer 8', 8" of Si oxide remaining on each of parts 4, 6, for example in the case of a D-BSOI™ substrate prepared on the basis of an oxide/oxide bonding and executed in such a way that it is detachable, for example according to one of the previously mentioned techniques, or in such a way that the bonding interface has a controlled bonding energy in order that the substrate is detachable, according to one of the previously mentioned techniques.

The total contact area between the membrane 4 and the adhesive 10 depends on the elastic parameters of the adhesive, the nature of the membrane to be detached (weakly doped silicon, or strongly doped silicon, or AsGa,...), the diameter of the substrate 6, the thickness of the membrane 4, and the bonding energy at the interface.

Thus, for a wafer 6 of diameter 150 mm for example, with a detachable layer 4 of thickness 50 microns, the contact area between adhesive 10 and the membrane 4 is of the order of 1 to 10 cm<sup>2</sup>, preferably around 4 cm<sup>2</sup>.

The higher the bonding energy between detachable the membrane 4 and the support 6, the greater the contact area, between the membrane and the adhesive(s), allowing the membrane 4 to be detached.

On the other hand, the contact area will also vary as a function of the shape of the contact (more or less wide rectangular shape, rounded shape ... etc).

A variant will be described in connection with figures 3A, 3B and 4. This variant employs the formation of an initiator.

As illustrated in figure 3A, the detachment of the membrane 4 can be facilitated by attacking the interface between the layers 8', 8'' laterally, for example by a chemical attack with HF. This lateral attack is symbolised by the two arrows 12, 12' in the figure 3A. The detachment is thus started, and the detachment of the membrane 4 can be done by exerting a weaker traction on the adhesive film 10. The risk of rupture of the membrane is thus reduced.

In the case of such lateral attack, it is also possible to limit the contact area between the adhesive 10 and the membrane 4.

Figure 4 represents the membrane after separation, a layer 8', 8'' of Si oxide remaining on each of parts 4, 6.

The performance of a method according to the invention is facilitated if the bonding interface (herein the interface 8) between the membrane 4 and the substrate 6 has a controlled energy.

Moreover, the nature of the material 8 eventually present at the interface between the substrate and the membrane 4 may be selected in such a way to lead to detachment of the membrane 4.

The control of the energy and/or the control of the nature of the material present at the interface to have a facilitated detachment are described for example in the documents already cited and commented on above: US2004/222500 or US2006/019476 or FR0311450 or US2005/029224.

In all these cases, a weakened zone 14 can be produced in the membrane 4, by ionic or atomic implantation 24 in said membrane (figure 6A), then it is bonded to a support substrate 6 (figure 6B, which adopts numerical references identical to those of figure 1A) and the

detachment of the membrane is realized via the adhesive film or films 10, 10', 10'' along weakened zone 14; such a method can produce a separation of the membrane 4 with respect to the support 6. A part of the membrane 4 thus remains on the substrate 6. It is also possible to carry out  
5 the bonding of the membrane 4 with the support substrate 6 before the ionic or atomic implantation step into the membrane 4 and then, to realize the separation with the adhesive means.

In order to create the weakened zone, « Smart Cut® » technique can be applied as described for example in the article by A.J.  
10 Auberton-Hervé et al. « Why can Smart-Cut change the future of microelectronics ? » published in International Journal of High Speed Electronics and Systems, Vol. 10, N°.1 (2000), p. 131-146.

The self-supporting membrane obtained by a method according to the invention can be used without any other support or  
15 substrate.

As a variant, it can be transferred to another substrate 20, as illustrated in figure 7.

## CLAIMS

1. A method for separating a membrane (4) from a substrate (6), comprising :

5 a) the fixing of at least one adhesive (10, 10', 10'') only on a part of the surface of said membrane which is not facing the substrate,

b) the separation, with respect to the substrate (6), of at least a part of the membrane (4) by the application of a force on at least one of the adhesives.

10 2. The method according to claim 1, the membrane (4) being initially bonded by molecular adhesion to the substrate (6).

15 3. The method according to claim 1, the membrane (4) initially being bonded via a bonding layer (8) to substrate (6) and via a substrate previously treated in order to increase its level of weakening.

20 4. The method according to any one of claims 1 to 3, the membrane (4) being of a semiconductor material or of a piezoelectric material or of a ferroelectric material.

25 5. The method according to any one of claims 1 to 4, the membrane (4) being in weakly doped or strongly doped silicon, or in AsGa, Ge, SiC, GaN, InP, LiNbO<sub>3</sub> or LiTaO<sub>3</sub>.

6. The method according to any one of claims 1 to 5, the membrane (4) being a mono-layer or multi-layer.

30 7. The method according to any one of claims 1 to 6, the membrane (4) comprising a processed layer.

8. The method according to claim 7, the processed layer comprising holes and/or chips and/or circuits and/or microsystems.

9. The method according to any one of claims 1 to 8, the separation being previously started by lateral attack (12, 12').

10. The method according to claim 9, the previous attack being of a chemical type.

11. The method according to any one of claims 1 to 10, the membrane (4) having a thickness greater than 3 microns.

12. The method according to any one of claims 1 to 11, the membrane (4) being circular.

13. The method according to any one of claims 1 to 13, the surface (5) of the membrane (4) and the surface of the adhesive film applied against this surface having a ratio between 2 and 100, preferably between 10 and 50.

14. The method according to any one of claims 1 to 14, the membrane (4) being intended to be self-supporting.

15. The method according to any one of claims 1 to 14, the membrane (4) being transferred, after separation, onto a support (20).

16. The method according to any one of claims 1 to 16, an weakened zone (14) being previously formed in the membrane (4).

17. The method according to claim 17, the separation, from the substrate (6), of at least a part of the membrane (4) taking place along the weakened zone (14).

5 18. The method according to any one of claims 17 or 18, the weakened zone being produced by ionic or atomic implantation, before or after the bonding of the membrane (4) and the substrate.

10 19. The method according to any one of claims 1 to 19, the interface between the membrane (4) and the substrate (6) having a controlled energy so as to facilitate the detachment of the membrane (4).

15 20. The method according to any one of claims 1 to 20, the interface between the substrate (6) and the membrane (4) comprising a material selected in order to facilitate the detachment of the membrane (4).

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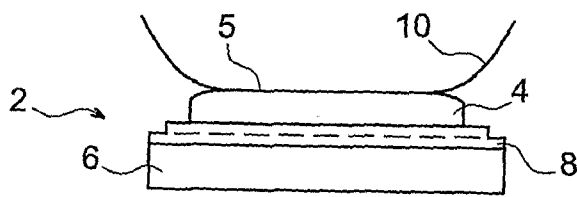


FIG. 1A

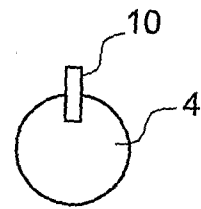


FIG. 1B

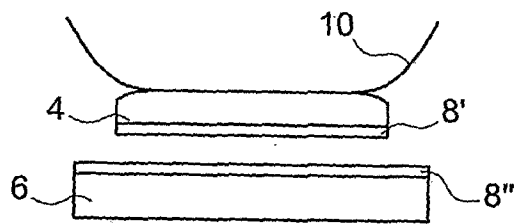


FIG. 2

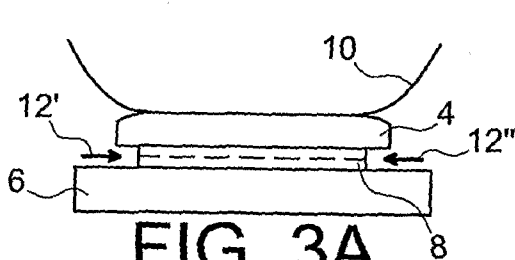


FIG. 3A

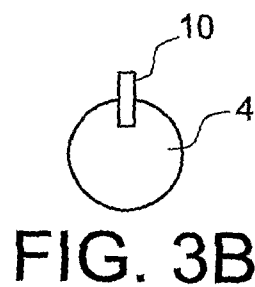


FIG. 3B

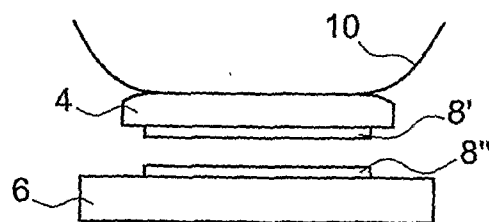


FIG. 4

2 / 2

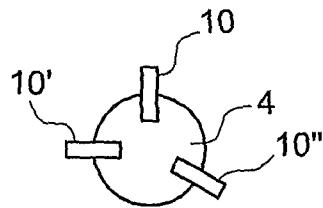


FIG. 5

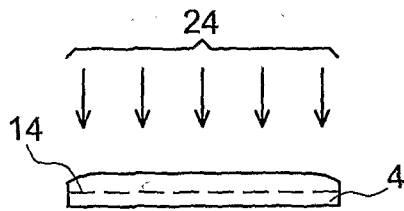


FIG. 6A

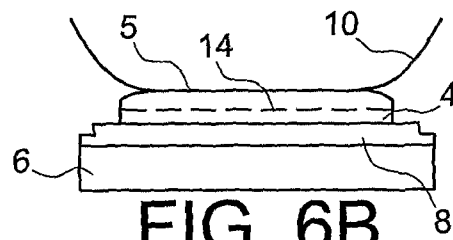


FIG. 6B



FIG. 7

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/IB2008/000781

A. CLASSIFICATION OF SUBJECT MATTER  
INV. B81C5/00 H01L21/762

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L B81C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                  | Relevant to claim No. |
|-----------|---------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | WO 01/93325 A (COMMISSARIAT ENERGIE ATOMIQUE) 6 December 2001 (2001-12-06)                                          | 1,6-20                |
| Y         | page 23, line 9 - page 23, line 24; figure 2E                                                                       | 2-5                   |
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|           | page 10, line 17 - page 10, line 33; figure 14                                                                      |                       |
| Y         | US 2004/222500 A1 (COMMISSARIAT ENERGIE ATOMIQUE) 11 November 2004 (2004-11-11)                                     | 4,5                   |
|           | cited in the application<br>paragraph [0042] - paragraph [0044]<br>paragraph [0077] - paragraph [0080];<br>figure 1 |                       |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

### \* Special categories of cited documents :

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Date of the actual completion of the international search

11 June 2008

Date of mailing of the international search report

20/06/2008

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Authorized officer

Seegerberg, Tomas

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2008/000781

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
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