

TREATMENT METHOD AND DEVICE OF THE working LAYER
OF A MULTILAYER STRUCTURE

This invention relates in general to the
5 characterisation of structures made from semiconductor
materials for applications in microelectronics, optics
and optoelectronics.

The structures relating to the invention are
multilayer structures including a so-called "working"
10 electrically conductive layer and an electrically
insulating layer.

The working layer is often a superficial layer of
the structure, and the electrically insulating layer is
buried in the thickness of the structure.

15 Such structures can for example be SOIs (Silicon
On Insulator). In this case, the working layer is the
superficial thin layer of silicon and the insulating
layer is the buried insulating layer (oxide, for
example). However this SOI example is not restrictive.

20 More precisely, the invention relates to a method
for treating a working electrically conductive layer of
a multilayer structure made from semiconductor
materials, the structure including under said working
layer an electrically insulating layer, said treatment
25 being designed to constitute in the said working layer
at least one island surrounded by the material of the
electrically insulating layer, the method including a
step of wet chemical etching of the working layer.

The invention also relates to the application of
30 such method to the characterisation of the electrical

properties of a multilayer structure made from semiconductor materials.

And the invention also relates to a device that can be implemented within the framework of such method.

5 Methods of the type mentioned above are already known.

Such methods make it possible to constitute in the working layer of a structure such as for example an SOI islands of electrically conductive material (silicon in
10 the case of an SOI).

It is indeed necessary to constitute such islands in order to realise certain operations on the structures relating to the invention.

These operations comprise in particular the
15 characterisation of the electrical properties of the structure.

Such characterisation can in particular be performed by implementing at least one pseudo-component of the structure, referred to as pseudo-MOSFET.

20 The pseudo-MOSFET is a macroscopic device similar to a transistor, much which requires for its manufacture a very limited number of technological steps.

Such a device can in particular be constituted in
25 a structure such as that mentioned above.

This device further presents the advantage of providing results that are characteristic of the material of the working layer in which it is manufactured, without requiring modifications that are
30 inherent to the CMOS manufacturing method (channel layout, etc.).

It is therefore simple to constitute in a structure (SOI or other) such a device, in order to characterise the electrical properties of this structure and in particular of its working layer.

5 A pseudo-MOSFET incorporated into an SOI uses the intrinsic MOS structure of the SOI, by using the buried oxide as a dielectric gate, the substrate as a gate, and two contacts on the working layer as source and drain. It has the form of a MOSFET, but inversed. It is
10 based on a simple MOSFET using contacts of the Schottky type.

Such a pseudo-MOSFET is shown schematically in figure 1 which illustrates the case of an SOI 10 comprising a thin working layer of silicon 11, an
15 insulating layer 12 and a substrate layer 13.

A pseudo-MOSFET was constituted in the SOI, in a determined region of the latter.

This pseudo-MOSFET comprises two contacts S and D in the working layer 11, for the source and drain of
20 the device respectively. Substrate layer 13 serves as a gate for it (contact V_G).

The pseudo-MOSFET thus constitutes an advantageous device for the characterisation of semiconductor structures. It is manufactured by spatially defining a
25 given pattern in the upper layer of this type of structure. This pattern is thus electrically isolated from the substrate layer 13 of the structure, thanks to the insulating layer 12.

It can be implemented according to the so-called
30 "Ψ-MOS Test" method of characterisation.

The " Ψ -MOS Test" method makes it possible to realise on the front side of the structure (i.e. the side that bears the working layer of the structure) two contacts via pressure of two tungsten carbide points.

5 These two contacts - which correspond to contacts S and D in figure 1 - are applied to the centre of the pattern defined in the upper layer of the structure.

10 The structure thus constitutes a characterisation sample (the terms "structure" and "sample" shall be used indifferently in the remainder of this text).

The rear side of the structure rests on a conductor plate on which is applied voltage. This contact on the rear side of the structure corresponds to the gate contact.

15 Within the framework of the " Ψ -MOS Test" method, several isolated islands are realised one after the other in the structure to be qualified, such as shown in figure 2.

20 Each one of these islands 15 is separated from the other islands by trenches along which the material of the working superficial layer has been removed, in such a way that the insulating layer is flush in these trenches.

25 And the characterisation of the structure according to this method is in general accomplished by characterising the various islands 15 of the structure, by applying the discreet contacts mentioned above.

30 It is thus possible to realise a mapping of the electrical properties of the structure, in its different islands.

Note that the characterised electrical parameters are typically the following: μ_e (electron mobility), μ_h (hole mobility), D_{it} (interface state density), V_{th} (threshold voltage), V_{FB} (flat band voltage), Q_{box} (charge of the insulating layer).

This method of characterisation thus makes it possible to perform in a synoptic manner a mapping characterising different islands of a same structure, which is advantageous.

10 In order to manufacture islands such as those shown in figure 2, a lithography method is implemented.

This type of method makes it possible to constitute several islands, even on structures of small size (with a diameter of 3 inches, for example).

15 But such a procedure is cumbersome to implement, and costly.

Furthermore, this type of method does not in general make it possible to constitute islands over the entire surface of a structure of significant size (e.g. case with diameters of 8 inches, or even more).

20 In a variant of the manufacture of islands by lithography, it is possible to manufacture on a sample structure an island of characterisation by etching the structure selectively through a "hard" masking.

25 In this variant, a selective attack of the structure by wet etching is generally implemented, in order to constitute the island.

Figure 3 thus shows a sample structure 100 related to the invention.

Two O-rings 21a, 21b are each pressed against a respective glass plate 20a, 20b and one of the sides of the sample structure.

This pressure is provided by means 22.

5 The two O-rings thus define across from the two sides of the sample structure 100 two regions 101a, 101b of the sample which are isolated in a sealed manner.

10 Sample 100 with its isolated regions is then exposed to an etching solution capable of selectively etching the working layer of the sample—for example KOH in the case of a silicon working layer sample.

15 By "selectively" etching the working layer is meant that only the working layer is etched, and that the adjacent layers are not etched.

This results in wet etching of the working layer, except across from regions 101a and 101b in which the layers of the original structure are preserved.

20 These regions correspond to an island at the level of which the sample shall be able to be characterised in the same manner as disclosed above concerning the "Ψ-MOS Test" method.

In this way, a sample is manufactured having a single island.

25 And the manufacturing method for this island, which implements wet etching, is not exposed to the inconveniences mentioned above concerning the method of constituting islands by lithography.

30 This type of method by wet etching is therefore advantageous.

But this type of method however only makes it possible to constitute a single island on a sample structure. It therefore does not make it possible to constitute several islands on the surface of the structure, in order to realise a mapping such as that mentioned above.

Embodiments of the invention seek to make it possible to constitute several islands on a same structure, without exposure to the inconveniences mentioned above concerning methods via lithography.

In accordance with a first aspect of the present invention, there is provided a device for simultaneously masking several regions of an electrically conductive working layer made from semiconductor materials, said working layer belonging to a multilayer structure which further includes an electrically insulating layer under said working layer, in order to constitute in said working layer one several islands surrounded by material of the electrically insulating layer, characterised in that it includes several elementary masks able to mask in a sealed manner the respective regions of said working layer in view of realising a wet etching of said structure once the said regions are masked, in that each elementary mask comprises a cavity and in that the device comprises means for establishing a depression or a controlled vacuum inside each cavity, once contact between each elementary mask and the structure is established, in order to sealingly apply each mask against the working layer.

Embodiments of the invention provide a method for treating a working electrically conductive layer of a multilayer structure made from semiconductor materials, the

structure including under said working layer an electrically insulating layer, said treatment being designed to constitute in the said working layer at least one island surrounded by the material of the electrically insulating layer, the method including a step of wet chemical etching of the working layer, method characterised in that prior to the wet etching step a selective masking of several regions of said working layer is realised in order to constitute several islands in this working layer, each region masked from the working layer corresponding to a respective island.

Preferred, but not restrictive, embodiments of this treatment method are the following:

- the wet etching step is realised simultaneously for the entire structure, said masked regions being protected from etching.

- the method implements the following steps:
 - sealed masking of each region of the structure corresponding to an island, by respective elementary masks.
 - wet etching with an etching solution selectively attacking said working layer, but not the electrically insulating layer or the elementary masks.
 - rinsing and drying of the structure.
- said sealed masking is obtained by tightening of a device having the general form of a clamp and equipped with elementary masks on the structure,
- the masking of each region is realised by applying an elastic masking of the suction cup type on said region.
- the masking of each region is realised by applying on said region a rigid mask associated with means of depression of said rigid mask,
 - said working layer is made of silicon,
 - the said structure is an SOI.

Embodiments of the invention also provide an application of such method to the characterisation of the electrical properties of a multilayer structure made from semiconductor materials.

Such an application can include the mapping of the electrical properties of the regions determined covering practically the entire surface of the working layer of the structure.

Embodiments of the invention further provide a system for treating a working electrically conductive layer of a multilayer structure made from semiconductor materials, the structure

including under said working layer an electrically insulating layer, said treatment being designed to constitute in the said working layer at least one island surrounded by the material of the electrically insulating layer, characterised in that the device includes several elementary masks in order to mask in a sealed manner the respective regions of the working layer so as to realise wet etching of said structure once said regions have been masked.

Preferred, but not restrictive, embodiments of such device are the following:

- the elementary masks include rigid masks associated with means of depression,
- the elementary masks include elastic masks of the suction cup type,
- the device includes a pad bearing said masks,
- the device has a general configuration in the form of a clamp with two jaws of which a first jaw bears said masks, in such a way that when the clamp tightens on the structure, the masks make a sealed contact with the structure,
- the second jaw of the device bears spurs in order to ensure that the rear side of the opposed structure is maintained against the side of the structure bearing the working layer, when the clamp is tightened on the structure.

Other aspects, purposes and advantages of the invention shall appear clearer as the following description of this invention is read, referring to the appended drawings in which, further to figures 1 and 3 for which comments have already been made above:

- Figures 4a and 4b are respectively a side view and a front view of a device according to a first embodiment of the invention,

- Figure 4c is a schematic representation of an elementary mask implemented in the device in figures 4a and 4b,

- Figures 5a and 5b are respectively a side view and a front view of a device according to a second embodiment of the invention,

- Figure 5c is a schematic representation of an elementary mask implemented in the device in figures 5a and 5b.

In reference to figures 4a and 4b, is shown a device for treating a multilayer structure comprised of a superficial electrically conductive working layer, and a buried electrically insulating layer.

This structure can be an SOI, for example.

Such a structure can be treated by a device according to a first embodiment of the invention (corresponding to figures 4a and 4c) or by a device according to a second embodiment of the invention (corresponding to figures 5a and 5c).

The structure is not shown in these figures, for reasons of clarity (the area destined to receive this structure is nevertheless shown via a dotted line in figure 4b).

Device 30 in figures 4a and 4b has a general configuration in the form of a clamp with two jaws.

Figure 4a thus shows a first jaw 310, and a second jaw 320. The two jaws are articulated around axis 330,

and can be closed and opened by pivoting around this axis.

In the part of the device opposed to this axis 330, device 30 has a handle 311, 321 in association with
5 each respective jaw 310, 320.

Device 30 can thus be opened or closed by hand, by an operator.

Note however that it is possible as a variant to provide that these operations be realised by a machine
10 acting on the two handles 311, 321.

A closing lock 340 of the device is also provided at the level of these two handles.

This lock serves to maintain the device in closed position, when the structure has been placed inside the
15 device.

The lock 340 can for example include a tightening screw 341 for the two handles.

Note on the sides across from jaws 310 and 320, at the level of the part of the device that is to receive
20 the structure, lining pads 312, 322 that are respectively associated with the two sides across from these jaws.

Each one of these pads is attached by any means known per se to its associated jaw side (for example by
25 forced insertion, gluing or any other means, etc.).

The pads have a generally circular shape, in order to receive a region corresponding to the shape of the structures that shall be treated by the device.

Note that this device can include fool-proof
30 devices or guide marks in order to ensure correct positioning of a structure placed in the device.

In particular, a snug (not shown) can be provided destined to work with a notch which is generally found at the periphery of the structures relating to the invention.

5 It is also possible to provide various guide marks in order to position structures of different sizes (for example disks of various diameters). These guide marks can in particular be provided on one and/or the other of the two pads.

10 The pad 312 carries several elastic suction cups 3120, of the same material as the rest of the pad.

As a variant, it is also possible to provide that these suction cups be attached in a removable manner on the pad in predetermined places. One can for example
15 provide to constitute in the pad means for receiving such removable suction cups (for example in the form of threading designed to receive the screw of a suction cup).

Each suction cup is designed to form a sealed
20 contact with the surface of the structure, when the latter has been positioned in the device and the device has been closed around it.

In this respect, note that the structure is placed in the device in such a way that the working layer of
25 this structure is across from the suction cups.

It is possible according to a variant to provide that the second pad 322 be equipped with protruding spurs in order to maintain the wafer and the structure when the latter is in position in the closed device.

30 Figure 4a thus shows a series of protruding spurs 3220.

Figure 4a shows that a spur is across from each suction cup.

It is however possible in this variant to adapt the number and layout of the spurs. In any case, this number and layout must make it possible to apply enough pressure on this structure when the device is closed on the structure to be treated in order to guarantee that the contact is sealed between the working side of the structure and suction cups 3120.

10 This pressure must also remain distributed and limited enough in order to avoid damage to the structure.

Naturally, even distribution of the spurs and suction cups on the surface of the respective pads 312, 15 322 is preferred.

Figure 4c shows in a schematic manner a suction cup 3120, in contact with the structure 100 to be treated.

Device 30 can also include several suction cups 20 3120, in which each one masks in a sealed manner the respective regions of the working layer of the structure 100.

It is therefore possible to realise wet etching of the structure, once said regions have been masked, 25 without the etching solution attacking said regions.

In practise, device 30 containing a structure is plunged into an etching solution, or the structure placed in the device is soaked by any manner known per se with this solution.

30 In the case of a structure whose working layer is of silicon, the etching solution can be KOH. In any

case, the etching solution is selected so as to etch only the material of the working layer.

The material of the various constituents of device 30 must be adapted in order to not be attacked by the etching solution.

One can for example provide that pads 312, 322 and their suction cups and spurs are made of rubber that is not attacked by the etching solution.

The invention makes it possible to constitute in this way islands that correspond to the regions of the working layer of the structure that have been preserved from etching by the masking of the suction cups.

The islands have typically a round shape for avoiding edge effects (this being illustrated in particular in figure 4b).

And these islands have typically a diameter of at least 1 cm.

A round shape and such a diameter are indeed well adapted for the application to a Ψ -MOS Test.

And in the case of the invention, one benefits from the advantages of a lithographic method (in particular the possibility of constituting several island simultaneously) without being subject to its cumbersomeness, and furthermore a reduced cost price.

Implementation of the invention thus implies:

- The realisation of selective masking of several regions of the working layer of the structure to be treated, in order to constitute in this working layer several islands, each region masked from the working layer corresponding to a respective island,

- Then a wet etching step in order to constitute said islands.

And the wet etching step is realised simultaneously for the entire structure.

5 After wet etching, rinsing and drying steps of the structure (for example via nitrogen blowing) are carried out.

Sealed masking of the regions of the working layer of the structure is thus obtained by tightening a
10 device in the general form of a clamp equipped with elementary masks on said structure.

We have seen that this device can be of the type shown in figures 4a and 4b.

It can according to another embodiment of the
15 invention be as device 40 in figures 5a and 5b.

In this embodiment of the invention, the device for treating the structure is comprised of a single jaw 410.

And the elementary masks that were realised in the
20 form of elastic suction cups 3120 (figures 4a and 4c) are here realised by rigid means 4120 associated with means of depression.

Means 4120 define amongst themselves a network of cavities 4121, and these cavities communicated with a
25 source of depression (assimilated to a vacuum).

These means 4120 constitute elementary masks for the realisation of islands (each cavity 4121 allowing a respective island to be defined on the structure).

Means 4120 can in particular be realised in the
30 form of seals.

Contrary to device 30 in figures 4a and 4b, device 40 only has one jaw 410.

This single jaw is linked to the vacuum via a network. The plate is directly placed on means 4120.

5 It is maintained on these means thanks to the vacuum, in view of its immersion in the etching solution.

And except for specific elements relating to a second jaw, as well as elementary masks realised in the form of suction cups, all of the comments made above concerning device 30 also apply to device 40.

One can thus provide for fool-proof devices and/or guide marks of the structure (including for structures of different sizes).

15 And the general method for implementing device 40 is the same as for device 30 (except for the forming of the sealed contact of the regions of the structure on which islands are to be constituted with the corresponding positions of the treatment device).

20 Means 4120 can be constituted by a single part 412, itself borne by jaw 410.

This part 412 can be a rigid part, or have a certain degree of elasticity (in particular at the level of means 4120, in order to guarantee a sealed contact with the structure).

25 Part 412 can be attached to jaw 410 by any manner known per se.

The schematic structure of elementary mask 4120 is shown in figure 5c.

30 Each elementary mask defines a cavity 4121 when it is placed into contact with the structure 100, and

maintained in contact with the structure following the application of a depression at the level of the cavity.

It is thus provided means for establishing a depression or a controlled vacuum inside the cavity
5 4121, once contact between the elementary mask and the structure is established.

These means can include a general depression circuit 4125, that can be connected with a depression source via connector 41250.

10 Valve 41251 thus makes it possible to selectively establish a depression in this circuit 4125.

And it is also possible to provide in association with each elementary mask an individual valve, as shown in figure 5c (valve 4122).

15 The invention thus makes it possible to realise several islands in the working layer of a same structure to be characterised, via a wet etching method that is simple and advantageous.

It is furthermore possible to treat in this way
20 different structure sizes.

Further note that the implementation of the invention is further simplified due to the fact that pads 312, 322 as well as part 422 can be attached in a removable manner to their respective clamp jaws, for
25 removal and cleaning after wet chemical etching.

The invention can be implemented advantageously in order to realise a mapping of the electrical properties of determined regions of the working layer of a structure relating to the invention.

And as we have seen, these determined regions cover practically the entire surface of the working layer of the structure to be characterised.

It shall be noted that the invention differs from
5 known techniques which include the creation of at least one island at the surface of a multilayer structure. In this respect two prior art techniques are briefly exposed and discussed below.

One known technique is disclosed in US 6 159 829.

10 In this document, the top Si layer of a structure is etched through a mask by a mixing of HNO₃, CH₃COOH and HF. Such etching (with its HF) shall etch not only the top layer of the structure, but also the layer underneath.

15 In the case of the invention, on the contrary, only the top layer (the working layer) is etched - in particular because the etching is carried out with an etching solution which etches only the working layer (KOH for a working layer in Si)

20 It shall furthermore be noted that in the case of US 6 159 829, the masking must be made from resin - which shall stick to the surface of the structure. In the case of the invention, the masking is obtained by replaceable and reusable means, which makes the
25 invention particularly simple and efficient.

Finally, the article "a review of the pseudo-MOS transistor in SOI wafers : operation, parameters extraction, and applications" (IEEE transactions on electron devices, vol. 47, n° 5, may 2000) also
30 provides indications on some type of etching.

But this article does not provide details on the type of technique used - in particular it does not mention in any manner a selective etching.

5 It shall furthermore be noted that this article teaches only (as illustrated in figure 1 of this article) creating a single Si island, whereas the application of the invention to a Ψ -MOS Test needs several islands.

CLAIMS

1. Device for simultaneously masking several regions of an electrically conductive working layer made from semiconductor materials, said working layer belonging to a multilayer structure which further includes an electrically insulating layer under said working layer, in order to constitute in said working layer one several islands surrounded by material of the electrically insulating layer,

characterised in that it includes several elementary masks able to mask in a sealed manner the respective regions of said working layer in view of realising a wet etching of said structure once the said regions are masked, in that each elementary mask comprises a cavity and in that the device comprises means for establishing a depression or a controlled vacuum inside each cavity, once contact between each elementary mask and the structure is established, in order to sealingly apply each mask against the working layer.

2. Device according to claim 1, characterised in that the elementary masks include rigid masks associated with means of depression.

3. Device according to claim 1, characterised in that the elementary masks include elastic masks of the suction cup type.

4. Device according to claim 1, characterised in that the device includes a pad bearing said elementary masks.

5. Device according to anyone of the preceding claims characterised in that the device has a general configuration in the form of a clamp with two jaws of which a first jaw bears said masks, in such a way that when the clamp is tightened on the structure, the masks form a sealed contact with the structure.

6. Device according to claim 5, characterised in that the second jaw of the device bears spurs in order to ensure that the rear side of the opposed structure is maintained against the side of the structure bearing the working layer, when the clamp is tightened on the structure.

7. Treatment method of a working electrically conductive layer of a multilayer structure made from semiconductor materials, the structure including under said working layer an electrically insulating layer, said treatment being destined to constitute in said working layer several islands surrounded by material of the electrically insulating layer, method including a wet chemical etching step of the working layer, method characterised in that prior to the wet etching step a selective and simultaneous masking of several regions of said working layer is realised in a sealed manner by using the device according to anyone of the preceding claims, in order to constitute several islands in this working layer, each region masked from the working layer corresponding to a respective island.

8. Method according to claim 7, characterised in that the wet etching step is realised simultaneously for the entire structure, said regions masked being protected from etching.

9. Method according to claims 7 or 8, characterised in that the method implements the following steps:

- wet etching with an etching solution selectively attacking said working layer, but not the electrically insulating layer or the elementary masks,
- rinsing and drying of the structure.

10. Method according to claims 7 or 8, characterised in that said working layer is made of silicon.

11. Method according to claim 10, characterised in that said structure is an SOI.

12. Application of the method according to anyone of the previous claims 7 to 11 to the characterisation of the electrical properties of a multilayer structure made from semiconductor materials.

13. Application according to claim 12 to the mapping of the electrical properties of determined regions covering practically the entire surface of the working layer of the structure.