

Method for dissolving a silicon dioxide layer

Field of the invention

The present invention relates to a method for dissolving a silicon dioxide layer in a structure of the semiconductor on insulator type.

5 Background of the invention

A dissolution method known from the prior art, and illustrated in Figures 1A and 1B, is a method for dissolving a silicon dioxide layer 1 in a structure 5 of the semiconductor on insulator type, comprising, 10 from its rear face 6 to its front face 7, a supporting substrate 8, the silicon dioxide layer 9 and a semiconductor layer 10.

The front face 7 corresponds to the free surface of the semiconductor layer 10.

15 A person skilled in the art will find a technical description of such a method in the articles by Kononchuk (Kononchuk et al., Novel trends in SOI technology for CMOS applications, Solid State Phenomena, Vols. 156-158 (1010) pp. 69-76, and 20 Kononchuck et al., Internal Dissolution of Buried Oxide in SOI Wafers, Solid State Phenomena, Vols. 131-133 (2008) pp. 113-118).

This dissolution method may be implemented in a furnace 1, illustrated in Figure 2, in which a

plurality of structures 5 are held on a support 4 so that the support 4 is suitable for holding the structures 5 with a predetermined distance - typically a few millimetres - between each structure 5, the front face 7 of a structure 5 being opposite the rear face 6 of the structure 5 adjacent to said front face 7.

The structures 5 are subjected to a non-oxidising atmosphere.

The non-oxidising atmosphere is provided by a continuous flow of inert or reducing gas.

The flow of inert gas enters the furnace 1 through an inlet 2, and emerges therefrom through an outlet 3.

The use of such a heat treatment causes the diffusion of oxygen atoms included in the silicon dioxide layer 9 through the semiconductor layer 10.

The reaction of said oxygen atoms with the semiconductor layer 10 generates volatile products comprising semiconductor monoxide (ScO).

However, the gases present on the surface of the structures 5, in particular the volatile products generated, have an influence on the dissolution.

Thus, the semiconductor monoxide slows the dissolution reaction when its concentration on the surface of the structures 5 increases.

Now, the composition of the atmosphere of the furnace 1 is not homogeneous.

This is because, because of the small spacing between the structures 5, the volatile products are discharged solely by diffusion at the edge of the structures 5.

The result of this is an accumulation of the volatile products that is greater at the centre of the surfaces of the structure 5 than at their edge.

10 This means that the dissolution reaction is more rapid at the periphery than at the centre of the structures 5.

Moreover, the atmosphere of the furnace 1 is obtained by a constant flow of an inert or reducing gas.

The flow of gas entrains, from its entry 2 into the furnace 1 to its discharge 3, at least some of the volatile products.

Consequently, during its path through the furnace 1, the flow of gas becomes loaded with volatile products.

Depending on their location in the furnace, the structures are therefore subjected to a variable concentration of volatile products.

Finally, the flow of gas may contain small quantities of oxygen.

Since a complete absence of oxygen in the gas flow would require using very complex means, a small percentage of oxygen in the gas flow entering the furnace is tolerated.

The oxygen included in the atmosphere of the furnace 1 limits the dissolution of the layer of silicon dioxide 9 and degrades the roughness of the free surface of the semiconductor layer 10.

The oxygen contained in the gas flow reacts preferentially with the structures 5 close to the gas inlet 2.

The gas flow is therefore depleted of oxygen from the inlet 2 of the furnace 1 towards the outlet 3.

This non-homogeneity of the atmosphere of the furnace 1 results in significant variabilities on the characteristics of the structures 5.

The main drawback of this dissolution method is that the non-homogeneity of the atmosphere of the furnace 1 leads to a degradation in the uniformity of thickness of the silicon dioxide layer 9 and of the semiconductor layer 10, as illustrated in Figure 1A.

This is because, at the end of the heat treatment, the thickness of the silicon dioxide layer 9

and the thickness of the semiconductor layer 10 are greater at the centre than at the edge of the structure.

Another drawback of this dissolution method is that it is not uniform for all the structures 5 of the semiconductor on insulator type contained in the furnace 1.

This is because the silicon dioxide layer 9 is not dissolved in the same proportions from one structure 5 to another.

The aforementioned drawbacks are not observed in a furnace 1 containing a single structure 5. However, given the relatively long heat treatment times and for economic reasons, executing such a method in a furnace 1 containing only one structure 5 cannot be envisaged from an industrial point of view.

However, some applications require having recourse to a silicon dioxide layer 9 with a thickness of less than 50 nm so as to be able to apply, for example, an electrical voltage exerted on devices produced in or on the semiconductor layer 10. A very precise control of the thickness of said silicon dioxide layer is then necessary.

Moreover, the structures 5 designated by the term FDSOI, standing for "fully depleted silicon on insulator", are particularly advantageous for producing electronic components such as FDMOS (fully depleted

metal oxide semiconductor) transistors, the channel of which is formed in or on the semiconductor layer 10.

Because of the extreme fineness of the thickness of the semiconductor layer 10 (i.e. around 10 nm), the threshold voltage of the transistor (usually denoted V_t), which depends on this thickness, is very sensitive to the variations in thickness of the semiconductor layer 10.

One aim of the invention is therefore to propose a method for dissolving a silicon dioxide layer affording precise control of the thicknesses of the semiconductor and silicon dioxide layers.

Brief description of the invention

The present invention aims to remedy the aforementioned drawbacks completely or partially, and relates to a method for dissolving a silicon dioxide layer in a structure of the semiconductor on insulator type, comprising, from its rear face to its front face, a supporting substrate, the silicon dioxide layer and a semiconductor layer, the dissolution method being implemented in a furnace in which a plurality of structures are held on a support, the support being suitable for maintaining a predetermined distance between each structure, the front face of a structure being opposite the rear face of the structure adjacent to said front face, the atmosphere of the furnace being a non-oxidising atmosphere, the dissolution method

causing the diffusion of oxygen atoms included in the silicon dioxide layer through the semiconductor layer and generating volatile products resulting from the reaction of said oxygen atoms with the semiconductor layer, said method being remarkable in that the furnace comprises traps suitable for reacting with the volatile products so as to reduce the concentration gradient of the volatile products parallel to the front face of at least one structure.

10 In the present text, the vertical direction is defined as being the perpendicular to the ground on which the furnace is installed. The terms "upper" and "lower" are defined with respect to this vertical direction.

15 Concentration gradient of the volatile products parallel to the front face of a structure means the variation in the concentration of the volatile products in the space lying between the front face of the structure and the rear face of the structure adjacent to said front face, and in directions lying in a plane parallel to the front face of the structure.

25 In contradistinction, a concentration gradient of the volatile products perpendicular to the front face of the structure is defined as being the non-uniformity of the concentration of volatile products in the space lying between the front face of the structure and the rear face of the structure adjacent to said front face,

and in a direction perpendicular to the front face of the structure.

Thus the arrangement in the furnace of traps suitable for reacting with the volatile products makes
5 it possible to absorb said products.

The result is a reduction in the concentration gradient of the volatile products parallel to the front face of each structure.

Consequently the dissolution kinetics of the
10 silicon dioxide layer is substantially equal at every point on the structure.

Moreover, the absorption of the volatile products makes it possible to have substantially the same concentration of volatile products in the vicinity of
15 the front face of each structure.

Thus the dissolution method is substantially uniform from one structure to another.

According to one embodiment, the traps are disposed on the rear face of the structures of the
20 semiconductor on insulator type.

Thus the traps are as close as possible to the front face of each structure.

Such proximity of the traps and the front surface of the structures affords better efficacy of the
25 trapping of the volatile products.

Moreover, the front face of each structure is exposed uniformly to the layer comprising the traps.

The concentration of volatile products on the surface of each structure is thus more uniform, and
5 therefore the parallel gradient is reduced.

Furthermore, the arrangement of the traps in the immediate vicinity of the front face of each structure limits the quantity of volatile products entrained by the gas flow.

10 Consequently the kinetics of the dissolution method is substantially equivalent for each of the structures.

Thus, since the dissolution reaction is no longer limited by the distance separating the successive
15 structures, it is possible to increase the loading capacity of the furnace in order to execute the dissolution method.

Moreover, this embodiment does not require any modification to the furnace.

20 According to one embodiment, the traps disposed on the rear face are included in a layer with a thickness greater than 30 nm, preferably greater than 50 nm.

According to one embodiment, the traps are included in a coating covering the support completely or partially.

Thus it is not necessary to add manufacturing
5 steps to the structures for executing the dissolution method.

Moreover, since the support is brought out of the furnace at each dissolution process, it can easily be coated with a suitable trapping material.

10 According to one embodiment, the traps are included in trapping layers at least partially covering the front face of substrates referred to as "trap substrates".

The trap substrates are disposed on the support,
15 each trap substrate being positioned in place of a structure of a semiconductor type, and inserted between two structures of the semiconductor on insulator type, the front face of the trap substrate being opposite the rear face of the structure of the semiconductor on
20 insulator type.

Thus it is not necessary to add manufacturing steps to the structures in order to execute the dissolution method.

Moreover, the trap substrates being brought out
25 of the furnace after each dissolution process, it is

possible to form new traps on the support when the latter are saturated with volatile products.

According to one embodiment, the traps are included in a coating wholly or partly covering the
5 internal wall of the furnace.

Inside of the furnace means the space in which the support holding the structures is introduced during the execution of the dissolution method.

According to one embodiment, the reaction between
10 the volatile products and the traps is a reaction of absorption of the volatile surfaces by the traps.

Thus the absorption of the volatile products by the traps prevents contamination of the furnace, support or structures.

15 According to one embodiment, the traps comprise silicon dioxide.

A thin layer comprising silicon dioxide disposed on the rear face of the structure, and with a thickness greater than 30 nm, or even greater than 50 nm, will
20 withstand a dissolution process at a temperature of between 900°C and 1300°C.

On the other hand, the native oxide naturally present on the rear face of a silicon on insulator structure, through its small thickness and its chemical

composition, will evaporate during such treatment and cannot fulfil the role of a trap.

5 In this regard, a person skilled in the art will find a technical description of the evaporation of the oxide in a non-oxidising atmosphere in E. Bussmann et al., Thermal instability of silicon-on-insulator thin films measured by low-energy electron microscopy, Innovation in Thin Film Processing and Characterisation, vol. 12, 012016, 2010.

10 Furthermore, silicon dioxide is compatible with the methods for manufacturing semiconductor structures.

According to one embodiment, the traps comprise at least one of the following materials: tungsten, aluminium nitride, alumina.

15 Thus these materials have the advantage of being very stable under temperature.

According to one embodiment, the semiconductor layer comprises silicon.

20 According to one embodiment, the semiconductor layer has a thickness greater than 100 nm, preferentially greater than 200 nm, even more preferentially greater than 300 nm.

Thus such thicknesses of the semiconductor layer slow down the dissolution reaction.

Consequently the traps have time to react effectively with the volatile products.

According to one embodiment, the layer of silicon dioxide has a thickness of less than 50 nm, preferably
5 less than 25 nm, even more preferentially less than 15 nm.

According to one embodiment, the atmosphere of the furnace comprises at least one species chosen from: argon, dihydrogen.

10 According to one embodiment, the temperature of the furnace is maintained at between 900°C and 1300°C.

According to one embodiment, traps suitable for reacting with the dioxygen included in the atmosphere of the furnace are disposed in the furnace.

15 According to one embodiment, the traps intended to react with dioxygen are silicon substrates.

Brief description of the drawings

Other features and advantages will emerge from the following description of embodiments of a
20 dissolution method according to the invention, given by way of non-limitative examples with reference to the accompanying drawings, in which:

- Figures 1A-1B are schematic representations of a structure treated by a method for dissolution of a

structure of the semiconductor on insulator type according to the techniques known from the prior art;

- Figure 2 is a schematic representation of a furnace intended for executing a heat treatment for dissolution of a silicon dioxide layer according to the techniques known from the prior art;

- Figures 3A-3B are schematic representations of a structure treated according to the invention;

- Figure 4 is a schematic representation of a furnace intended for executing a heat treatment for dissolution of a silicon dioxide layer according to the invention;

- Figure 5 is a schematic representation of a structure treated according to one embodiment of the invention;

- Figure 6 is a schematic representation of a trap and substrate according to the invention.

Detailed description of embodiments of the invention

For the various embodiments, the same references will be used for identical elements or ones fulfilling the same function, for reasons of simplification of the description.

The dissolution method illustrated in Figures 3A and 3B is a method for dissolving a silicon dioxide

layer 90 in a structure 50 of the semiconductor on insulator type.

5 The structure 50 of the semiconductor on insulator type comprises, from its rear face 60 to its front face 70, a supporting substrate 80, the silicon dioxide layer 90 and a semiconductor layer 100.

10 The dissolution method is implemented in a furnace 10, illustrated in Figure 4, in which a plurality of structures 50 are held on a support 40, said structures being parallel to one another.

The front face 70 of a structure 50 is opposite the rear face 60 of the structure 50 adjacent to said front face 70.

15 The support 40 is suitable for holding the structures 50 with a predetermined distance between each structure 50.

The predetermined distance between each structure 50 may be less than 15 nm, preferably less than 10 nm.

20 The atmosphere of the furnace 10 is a non-oxidising atmosphere.

The dissolution method causes the diffusion of oxygen atoms included in the silicon dioxide layer 90 through the semiconductor layer 100.

Volatile products resulting from the reaction of said oxygen atoms with the semiconductor layer 100 are generated.

5 The volatile products comprise semiconductor monoxide (ScO).

10 Traps 110 suitable for reacting with the volatile products are disposed in the furnace 10 so as to reduce the concentration gradient of the volatile products parallel to the front face 70 of at least one structure 50.

The oxygen content of the non-oxidising atmosphere is preferably less than 10 ppm (ppm: parts per million).

15 The non-oxidising atmosphere of the furnace 10 is provided by an inert or reducing gas flow.

The inert or reducing gas flow can enter the furnace 10 through an inlet 20, and emerges therefrom through an outlet 30.

20 The atmosphere of the furnace 10 may comprise at least one species chosen from one of the following species: argon, dihydrogen.

During the dissolution process, the temperature of the furnace 10 can be maintained at a temperature between 900° and 1300°C, for example 1150°C.

The conditions of implementation of this dissolution method, in particular its duration, can be adapted in order to partially dissolve the silicon dioxide layer 90.

5 The supporting substrate 80 may comprise at least one of the following materials: silicon, germanium, alumina, quartz.

10 The semiconductor layer 100 may comprise at least one of the following materials: silicon, germanium, silicon germanium alloy.

According to a particularly advantageous embodiment, and as illustrated in Figure 5, the traps 110 are disposed on the rear face 60 of the structures 50.

15 Advantageously, a coating comprising the traps 110 may be formed on the rear face 60 of the structures 50.

Thus the traps 110 are as close as possible to the front face 70 of each structure 50.

20 Such proximity of the traps 110 and the front face 70 of the structures 50 affords better efficacy of the trapping of the volatile products.

Moreover, the front face 70 of each structure is exposed uniformly to the layer comprising the traps
25 110.

The concentration of the volatile products on the front face 70 of each structure 50 is thus more uniform, and therefore the parallel gradient is reduced.

5 Furthermore, the arrangement of the traps 110 in the immediate vicinity of the front face 70 of each structure 50 limits the quantity of volatile products entrained by the gas flow.

10 Consequently the variations in concentration of volatile products in the furnace 10 are reduced.

 Thus the variabilities in dissolution from one structure 50 to another are reduced.

15 Consequently the silicon dioxide layer 90 is dissolved substantially in the same proportions from one structure 50 to another.

 Alternatively or in a complementary manner, and as illustrated in Figure 6, the traps 110 may be included in trapping layers on the front face 70 of the substrates referred to as trap substrates 120.

20 The trap substrates 120 are disposed on the support 40 in place of certain structures 50.

 Consequently the variations in concentration of volatile products in the furnace 10 are reduced.

25 Thus the variabilities of dissolution from one structure 50 to another are reduced.

Particularly advantageously, the traps 110 disposed on the rear face 60 of the structures 50 or on the front face of the trapping layers of the trap substrates 120 may comprise silicon dioxide.

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On the other hand, the native oxide naturally present on the rear face of a structure of the silicon on insulator, through its small thickness and its chemical composition, evaporates during such treatment and cannot fulfil the role of a trap.

The traps 110 comprising silicon dioxide are advantageously formed by thin film deposition techniques.

Among film deposition techniques, low-pressure vapour deposition and plasma activated vapour deposition techniques known to persons skilled in the art will be cited.

Alternatively, the formation of a silicon dioxide film on the rear face 60 of a supporting substrate 80 made from silicon or on the front face of a trap substrate 120 can advantageously be executed by thermal oxidation.

The film formed on the rear face 60 of a structure 50 or on the front face of a trap substrate 120 may have a thickness greater than 30 nm, preferentially greater than 50 nm.

Alternatively, the traps 110 may comprise at least one of the following materials: titanium, tungsten, aluminium nitride, alumina.

5 These materials can absorb the semiconductor monoxide formed during the process of dissolution of the silicon dioxide layer 90.

10 These materials may be formed in the form of films by film deposition techniques known to persons skilled in the art. For example, evaporation techniques are particularly well suited to the formation of films of titanium and tungsten. Aluminium nitride and alumina are advantageously formed by chemical vapour deposition or atomic layer deposition techniques.

15 Alternatively or in a complementary fashion, traps 110 may be included in a coating covering all or part of the support 40.

Thus the traps 110 are close to the front face 70 of the structures 50.

20 Consequently, the volatile products are effectively trapped.

Particularly advantageously, the traps 110 comprise silicon dioxide.

25 The traps 110 comprising silicon dioxide are advantageously formed by vapour deposition techniques or by thermal oxidation. The coating formed on the

support 40 may have a thickness greater than 50 nm, or even greater than 500 nm.

Alternatively, the traps 110 may comprise at least one of the following materials: titanium, tungsten, aluminium nitride, alumina.

These materials may be formed in the form of a film by film deposition techniques known to persons skilled in the art. For example, chemical vapour deposition or atomic layer deposition techniques.

In a complementary fashion, the traps 110 are included in a coating wholly or partly covering the internal wall of the furnace 10.

Particularly advantageously, the traps 110 comprise silicon dioxide.

Alternatively, the traps 110 may comprise at least one of the following materials: titanium, tungsten, aluminium nitride, alumina.

Particularly advantageously, the semiconductor layer 100 has a thickness greater than 100 nm, preferentially greater than 200 nm, even more preferentially greater than 300 nm.

For such thicknesses of semiconductor layer 100, the dissolution speed is less than 0.5 Å/minute.

Thus the volatile products formed during the dissolution process have the time to diffuse towards the traps.

Consequently the variations in concentration of volatile products are reduced. Advantageously, the layer of silicon dioxide 90 has a thickness of less than 50 nm, preferentially less than 25 nm, even more preferentially less than 15 nm.

Advantageously, traps 120 suitable for reacting with the dioxygen included in the atmosphere of the furnace 10 may also be disposed in the furnace 10.

The traps 120 intended to react with dioxygen may be silicon substrates disposed on the substrate 40 in place of certain structures 50.

Preferably, the silicon substrates intended to react with the dioxygen included in the atmosphere of the furnace are disposed close to the inert or reducing gas inlet.

Even more preferentially, the silicon substrates are disposed upstream of the inert or reducing gas flow with respect to the structures 50.

Thus the oxygen included in the inert or reducing gas flow reacts with the traps 120 before reaching a structure 50.

The method for dissolving a layer of silicon dioxide 90 according to the invention makes it possible to make the composition of the atmosphere of the furnace 10 homogeneous.

5 The accumulation of volatile products is reduced.

Consequently it is possible to limit the degradation in the uniformity and thickness of the silicon dioxide layer 90 and of the semiconductor layer 90 found in the prior art.

10 Moreover, the method according to the invention allows a more uniform dissolution from one structure 50 to another, compared with the method of the prior art.

CLAIMS

1. A method for dissolving a silicon dioxide layer (90) in a structure (50) of the semiconductor on insulator type, comprising, from its rear face (60) to its front face (70), a supporting substrate (80), the silicon dioxide layer (90) and a semiconductor layer (100), the dissolution method being implemented in a furnace (10) in which a plurality of structures (50) are held on a support (40), the support (40) being suitable for holding the structures (50) with a predetermined distance between each structure (50), the front face (70) of a structure (50) being opposite the rear face (60) of the structure (50) adjacent to said front face (70), the atmosphere of the furnace (10) being a non-oxidising atmosphere, the dissolution method causing the diffusion of oxygen atoms included in the silicon dioxide layer (90) through the semiconductor layer (100) and generating volatile products resulting from the reaction of said oxygen atoms with the semiconductor layer (100), said method being characterised in that the furnace (10) comprises traps (110) suitable for reacting with the volatile products so as to reduce the concentration gradient of the volatile products parallel to the front face (70) of at least one structure (50).

2. A dissolution method according to claim 1, in which the traps (110) are disposed on the rear face (60) of the structures (50) of the semiconductor on insulator type.

3. A dissolution method according to claim 1 or 2, in which the traps (110) are included in a coating completely or partly covering the support (40).

5 4. A dissolution method according to one of claims 1 to 3, in which the traps (110) are included in trapping layers on the front face (70) of the substrates, referred to as trap substrates (120), the trap substrates (120) being disposed on the support (40), each trap substrate being inserted between two
10 structures (50) of the semiconductor on insulator type, the front face (70) of the trap substrate being opposite the rear face (60) of the structure (50) of the semiconductor on insulator type.

15 5. A dissolution method according to one of claims 1 to 4, in which the traps (110) are included in a coating completely or partly covering the internal wall of the furnace (10).

20 6. A dissolution method according to one of claims 1 to 5, in which the reaction between the volatile products and the traps (110) is a reaction of absorption of the volatile products by the traps (110).

7. A dissolution method according to one of claims 1 to 6, in which the traps (110) comprise silicon dioxide.

25 8. A dissolution method according to one of claims 1 to 6, in which the traps (110) comprise at

least one of the following materials: titanium, tungsten, aluminium nitride, alumina.

9. A dissolution method according to one of claims 1 to 8, in which the semiconductor layer (110) comprises silicon.

10. A dissolution method according to one of claims 1 to 9, in which the semiconductor layer (100) has a thickness greater than 100 nm, preferably greater than 200 nm, even more preferentially greater than 300 nm.

11. A dissolution method according to one of claims 1 to 10, in which the silicon dioxide layer (90) has a thickness of less than 50 nm, preferentially less than 25 nm, even more preferentially less than 15 nm.

12. A dissolution method according to one of claims 1 to 11, in which the atmosphere of the furnace (10) comprises at least one species chosen from: argon, dihydrogen.

13. A dissolution method according to one of claims 1 to 12, in which the temperature of the furnace (10) is maintained at between 900°C and 1300°C.

14. A dissolution method according to one of claims 1 to 13, in which traps (120) suitable for reacting with the dioxygen included in the atmosphere of the furnace (10) are disposed in the furnace (10).

15. A dissolution method according to claim 14, in which the traps (12) intended to react with dioxygen are silicon substrates disposed on the support (40).