Description

Field of the Invention

This invention pertains to methods for manufacturing semiconductor devices. In particular, it pertains to silicon-on-insulator (SOI) technology, and to SOI devices.

Background of the Invention

SOI devices are known to have potential advantages (e.g., reduced junction capacitance, increased radiation hardness) over conventional silicon devices. Several techniques for producing SOI heterostructures and, in particular, for producing $Si/SiO_2/Si$ heterostructures of the type shown schematically in FIG.1, are known. Among the known techniques for producing such a heterostructure is the oxygen implantation technique, and this application pertains to this particular technique (sometimes referred to as "Separation by implanted oxygen" [SIMOX]) for forming such a heterostructure. For a review of the SIMOX technique see, for instance, P. L. F. Hemment, Materials Research Society Symposia, Proceedings, Vol. 53, pp. 207-221 (1986).

As generally practiced in the art, the SIMOX technique comprises implanting a sufficiently high dose of oxygen into a silicon body (typically a Si wafer) such that a stoichiometric oxygen-rich region is formed within the body. By this we mean that the oxygen distribution within the silicon body reaches a maximum concentration of at least two oxygen atoms per silicon atom. A typical implantation dose is 2×10^{18} oxygen atoms/cm^2. The (energy dependent) critical dose ϕ_c is the minimum dose at which, for a given implantation energy, a stoichiometric implant results. For instance, ϕ_c is about $1.4 \times 10^{18} cm^{-2}$ at 200 keV.

Prior art stoichiometric implants result in the formation of relatively thick (typically about 0.3 μm or more) layers of SiO_2, with a relatively thin (exemplarily about 0.1 μm) silicon overlayer. For several reasons, it would be desirable to be able to use lower implant doses, and/or to produce SOI wafers having a thinner buried oxide layer. Lower doses are desirable because they generally produce less damage in the Si body, and because they make possible increased throughput. Thinner oxide layers make possible devices requiring lower back bias isolation voltage, as compared to devices using a prior art (thicker) buried oxide layer.

Attempts have been made to obtain these desired results by merely reducing the implant dosage below ϕ_c such that a substoichiometric implant region, i.e., an implanted region wherein the maximum concentration of oxygen is everywhere less than two oxygen atoms per silicon atom, is formed. See, for instance, J. Stoemenos et al, Applied Physics Letters, Vol. 48(21), pp. 1470-1472 (1986). These authors report that implantation of a (only slightly) subcritical dose ($1.3x\ 10^{18} cm^{-2}$,200keV) of oxygen results in formation of an oxygen-rich layer with dispersed Si islands therein, and that annealing of such a sample at 1150 °C for two hours results in a coarsening of the dispersed Si and formation of SiO_2 precipitates in the Si overlayer near the Si/SiO_2 interface. Such a wafer in general would not be acceptable for device manufacture. Stoemenos et al also report that annealing such a wafer at 1300 °C for 6 hours produces a Si overlayer free of SiO_2 precipitates but produces a buried SiO_2 layer that contains a significant volume of dispersed Si islands. It is known that such islands may act as overlapping floating gates if MOS devices were formed in such SOI wafers. Thus, such prior art SIMOX wafers typically are also not acceptable for device manufacture.

S.S. Leu et al., Applied Physics Letters, Vol. 34(1), page 76, disclose that the quality of Si on sapphire can be improved by implantation, at 77K, of Si ions into the Si overlayer, such that an amorphous region is formed below the Si surface and near the Si/sapphire interface, followed by an anneal at 500-600 °C.

In view of the potential advantages associated with low dose implantation and with SIMOX heterostructures which have a relatively thin buried SiO_2 layer, a substoichiometric (subcritical) implant technique that can be used to reliably produce a $Si/SiO_2/Si$ heterostructure in which the buried SiO_2 layer is free of Si islands and in which the Si overlayer has a relatively low defect density and is of device quality would be of considerable significance. This application discloses such a technique.

We have discovered an implant method that can eliminate shortcomings of the prior art subcritical implant method. The inventive method comprises a subcritical implant, and further comprises at least one randomizing implant and subsequent appropriate heat treatment, and can produce $Si/SiO_2/Si$ heterostructures having a substantially homogeneous relatively thin buried SiO_2 layer and an overlayer of device-grade (*typically* $x_{min} < 5\%$) Si.

In a broad aspect, the inventive method comprises randomization, by any appropriate technique, of at least the region of the silicon overlayer that is adjacent to the buried SiO_2 layer, in a $Si/SiO_2/Si$ heterostructure formed by any appropriate oxygen implantation technique, followed by an appropriate heat treatment. The details of the inventive method depend, inter aria, on the substrate temperature during the oxygen implant, as will be described below.

In an exemplary preferred embodiment the inventive method comprises providing a single crystal Si body having a predetermined crystal orientation and a major surface, implanting a subcritical dose of oxygen into the Si body through the major surface such that an oxygen-rich layer is formed within the Si body, with a silicon overlayer of relatively low oxygen content thereon.

The invention relies on our discovery that, with regard to formation of a buried SiO_2 layer in Si by means of a subcritical O implant, two different regimes can exist. One of these regimes is exemplified by J. Stoemenos et al. (op cit), and involves a subcritical implant at a relatively high substrate temperature (i.e., nominal temperature typically greater than about 350 °C). In this case subsequent heat treatment generally results in formation of a nonhomogeneous buried SiO_2 layer containing dispersed Si regions, and the silicon overlayer frequently also comprises dispersed second phase (SiO_2) regions. Such material typically is not useful for device fabrication. The other regime involves our discovery that, if the silicon substrate is at a relatively low temperature (nominal temperature typically less than about 350 °C), during the subcritical ion implant, appropriate heat treatment can result in formation of a substantially homogeneous thin SiO_2 layer and recrystallization of the silicon overlayer. However, under these conditions the regions of the Si substrate that are adjacent to the Si/SiO_2 interfaces are generally heavily twinned, frequently also making the heterostructure unsuitable for device fabrication.

Furthermore, the embodiment comprises heat treating the oxygen-implanted Si body such that a substantially stoichiometric buried SiO_2 layer is formed from the oxygen-rich layer, with at least some of the material of the Si overlayer having the predetermined crystal orientation. The embodiment further comprises implanting Si ions through the major surface, the dose being effective for causing substantial randomization of at least the overlayer material near the SiO_2 layer/overlayer interface, and heat treating the implanted Si body such that device grade overlayer material, of substantially the predetermined crystal orientation, with relatively low defect density near the buried SiO_2 layer/overlayer interface, results.

Brief Description of the Drawing

FIG. 1 schematically depicts a SOI heterostructure according to the invention;

FIG. 2 is a flow chart showing schematically major process steps of two exemplary embodiments of the inventive method;

FIG. 3 schematically shows an exemplary semiconductor device formed on a SOI wafer according to the invention; and

FIGS. 4 and 5 show Rutherford Backscattering Spectroscopy (RBS) spectra of an exemplary SOI heterostructure.

Detailed Description of Some Preferred Embodiments

FIG. 1 schematically depicts a SOI heterostructure 10 of the type that is of concern herein. The SiO_2 layer 11 is buried within a single crystal Si body. Desirably, Si overlayer 12 is of device quality and retains essentially the original lattice orientation of the Si body.

FIG. 2 is a combined flow chart for two alternative exemplary embodiments of the inventive process, in which the left and right hand branches apply for relatively low and high nominal temperature subcritical oxygen implants, respectively.

As will be appreciated by those skilled in the art, prior to the subcritical implant, the major surface of the substrate (typically a (100) surface) will be cleaned, and/or otherwise prepared. Such techniques are well known and will not be discussed herein. It is to be understood that implants are carried out in an appropriate vacuum.

Exemplarily, we have found that a subcritical implant dose advantageously is in the range from about 3×10^{17} to about 7×10^{17} oxygen ions/cm^2. However, this range is not to be considered limiting, since higher subcritical doses may be advantageously used at times, whereas even lower doses may result in useful buried SiO_2 layers.

In a currently preferred embodiment (corresponding to the left branch of FIG. 2), the nominal substrate temperature during the subcritical oxygen implant is relatively low, typically <350 °C. By the "nominal" substrate temperature we mean herein the temperature at which the substrate would be, absent any beam heating effects. For instance, we typically clamp our Si wafers to a stainless steel block that is maintained at a given temperature. The temperature of the block is considered to be the nominal substrate temperature.

As shown in the left branch of FIG.2, the (low temperature) subcritical oxygen implant is followed by an appropriate heat treatment such that substantially stoichiometric SiO_2 is formed from the oxygen-rich implant layer. Such a heat treatment advantageously comprises a low temperature anneal (exemplarily between 30 minutes and 3 hours at a temperature between 500 and 800 °C, preferably not exceeding 700 °C) which typically recrystalizes amorphous Si. The heat treatment also comprises a high temperature anneal, typically at a temperature greater than 1200 °C, for some appropriate extended period, exemplarily more than three hours. As will be appreciated by those skilled

in the art, the annealing time typically is inversely related to the annealing temperature. A minor amount of experimentation typically will suffice to determine an appropriate time/temperature combination. Although we currently prefer two-step heat treatment as discussed above, other annealing programs (e.g. a slow ramping up of the temperature, with a high temperature soak, or a simple high temperature anneal) may also be useful.

As will be evident to those skilled in the art, the heat treatment is advantageously carried out under non-oxidizing conditions, e.g., in vacuum, or in an inert atmosphere. The prior art knows formation of a relatively thick (e.g., 500 nm) oxide cap layer as a means for protecting the Si overlayer during the high temperature anneal. We have devised an advantageous technique for protecting the Si overlayer during a high temperature anneal. The technique, which is currently preferred by us, comprises carrying out the anneal in an atmosphere that comprises at least one inert gas as a major constituent (e.g., 99% Ar) and oxygen as a minor constituent (e.g., 1%), with the oxygen concentration being effective to result in the slow growth of a thin (e.g., 20 nm) protective SiO_2 layer during the heat treatment. The presence of this thin protective layer prevents both the pitting of the Si overlayer that frequently occurs when the annealing is carried out in nominally non-oxidizing conditions (vacuum or inert gas atmosphere), and the growth of a thick oxide layer that occurs if the annealing is carried out in more highly oxidizing conditions.

As shown in the left branch of FIG. 2, after the high temperature anneal the silicon body is subjected to a randomizing ion implant. We have found it to be advantageous to carry out the randomizing implant at a nominal substrate temperature of less than about 100 °C. Typically the substrate is nominally at room temperature, and we have also achieved good results when the substrate was cooled to about liquid nitrogen temperature (77 °K). Although we believe that a relatively low substrate during the randomizing implant can prevent healing of implant-produced lattice defects, it may be possible that under some conditions nominal substrate temperatures above 100 °C may also be acceptable.

Exemplarily, we have implanted silicon ions during the randomizing implant, with an exemplary dose being 3×10^{14} Si/cm^2. We currently believe that particularly useful Si doses typically are in the range from 2×10^{4} to 1×10^{15}/cm^2. We used implantation energies for both the subcritical oxygen implant and for the randomizing implant of 200 keV and 400 keV, respectively. However, a wide range of energies, e.g., 100 keV to about 2 MeV, is expected to be useful. Furthermore, the randomizing implant need not necessarily be a Si implant. For instance, an Ar or other noble gas implant may under some circumstances be used.

The function of the randomizing implant is, we currently believe, to amorphize at least the region of the silicon overlayer that is adjacent to the interface with the buried SiO_2 layer. However, typically the region of the bottom silicon layer that is adjacent to the interface with the buried SiO_2 layer is also amorphized. It is desirable that a portion of the top Si layer, typically the portion that is adjacent to the major surface of the silicon body, remain crystalline so as to provide a seed region for the oriented single crystal regrowth of the silicon overlayer.

In the preferred embodiment (left branch of FIG.2) the required randomizing implant is followed by an appropriate heat treatment. Exemplarily, the treatment comprises a relatively low temperature (~ 600 °C, > 1 hr) anneal. More generally, we consider annealing temperatures in the range 500-800 °C (preferably not exceeding 700 °C) to be useful, but under certain conditions annealing at a temperature outside of this range may also result in the regrowth of device-quality Si overlayer material. After this annealing treatment the heterostructure is stable with regard to heat treatments as encountered in device processing.

Another, but currently less preferred, embodiment of the inventive method (right branch of FIG. 2) comprises carrying out the oxygen implant at a relatively high nominal temperature (typically at least about 350 °C), followed by a first randomizing implant of the type described above. Subsequent to completion of the first randomizing implant the implanted Si body is heat treated, substantially as discussed in the context of the currently preferred embodiment. This heat treatment advantageously is followed by an optional second randomizing implant. The conditions of the second randomizing implant typically are similar to those of the first randomizing implant. The optional second randomizing implant generally will be followed by a low temperature anneal of the type discussed in the context of the currently preferred embodiment.

After completion of the appropriate heat treatment SOI wafers according to the invention typically are ready for device fabrication by known methods. For a review of such methods see, for instance, D. H. Elliott, Integrated Circuit Fabrication Technology, McGraw-Hill (1982).

An exemplary electronic device (an enhancement-type n-channel MOS transistor) according to the invention is shown in FIG. 3, wherein layer 11 is the buried SiO_2 layer, and 12 refers to a portion of the Si overlayer. The portion of the overlayer is doped to be p-type, with two subportions being n^+. Oxide regions 31 serve to isolate 12 from other devices, to define contact windows,

and to provide gate insulation, all in a conventional manner. Numerals 32 refer to source, gate, and drain metal contacts.

Example I:

A (100) oriented single crystal Si wafer was cleaned by a conventional procedure and clamped to a stainless steel block in the target chamber of an ion implanter. With the steel block nominally at 100 °C, $3x10^{17}$ oxygen/cm^2 were implanted at 170 keV, resulting in formation of an oxygen-rich layer having an approximately Gaussian profile (depth of maximum about 370 nm, full width at half maximum about 180 nm). The wafer was transferred to a tube furnace, and maintained at 600 °C for 2 hours and at 1390 °C for 30 minutes in argon +1% oxygen. The anneal resulted in formation of an about 60 nm thick oxide layer from the oxygen-rich implant layer, with twinned Si at both interfaces. A RBS spectrum of the thus produced wafer was obtained by standard means [2 MeV He^+, (100) and 5° off (100)] and is shown in FIG. 4. As is well known, such spectra, including the well known quantity χ_{min} derived from the spectra, are standard indicators of the quality of thin crystal layers. Curves 40 and 41 are the random and channeled yields, respectively, and show that the buried oxide layer is essentially stoichiometric, the near-surface part of the Si overlayer is single crystal material, and the Si/SiO_2 interface regions are highly defective. Transmission electron microscopy showed the defective regions to be heavily twinned. Subsequent to RBS, the wafer was again transferred to the implanter, and $3x10^{14}$ silicon/cm^2 (400 keV) were implanted, with the wafer nominally at liquid N_2 temperature. The RBS yields of the randomized wafer are shown in FIG. 5, wherein curves 50 and 51 are the random and channeled yields. The amorphization of the Si adjacent to the SiO_2 layer, with the amorphized region extending almost to the Si surface, is evident. Following RBS the wafer was annealed at 600 °C for 2 hours in vacuum. The results of subsequent RBS are also shown in FIG. 5, wherein curve 52 is the channeled yield of the wafer after the second low temperature anneal. The improvement in crystal quality, especially of the Si overlayer, is clearly evident. In particular, the SiO_2/Si overlayer interface was essentially free of defects, with the overlayer being of device quality, with χ_{min} of about 3%. Electron microscopy was also performed on the wafer, and showed that the buried SiO_2 layer was essentially continuous, without Si islands, and the sharp boundaries, and confirmed the absence of twins in the Si overlayer.

Example II:

A second SOI wafer was prepared substantially as described in Example I, except that the nominal wafer temperature during the subcritical oxygen implant was 500 °C, the oxygen implant ($4x10^{17}$ oxygen/cm^2, 200 keV) was followed by a randomizing Si implant (nominal temperature 30 °C, $1x10^{15}$/cm^2, 460 keV), the subsequent heat treatment was followed by a second randomizing Si implant (conditions as above), and this was followed by a 600 °C anneal. The quality of the thus formed heterostructure was substantially as described in Example I.

Claims

1. Method of making an article comprising SiO_2 buried within a Si body, the method comprising the successive steps of:

   providing a single crystal Si body having a major surface;

   implanting oxygen ions into the Si body through the major surface such that a buried oxygen-rich layer is formed in the Si body, the oxygen implant being a subcritical oxygen implant, and the Si body being maintained during the subcritical oxygen implant at a relatively low temperature;

   submitting the oxygen-implanted Si body to a first heat treatment comprising an anneal at a temperature above 1200 °C such that the buried SiO_2 is formed from the oxygen-rich layer;

   carrying out, subsequent to said first heat treatment, a randomizing implant of Si or noble gas ions, the implant conditions selected such that at least some of the Si overlying and underlying said buried SiO_2 is substantially amorphized; and

   further heat treating the body at a temperature in the approximate range 500-800 °C to form a substantially homogeneous SiO_2 layer, with Si overlying and underlying the SiO_2 layer.

2. Method according to claim 1, wherein the Si body is maintained at a temperature less than about 350 °C during the subcritical oxygen implant.

3. Method of making an article comprising SiO_2 buried within a Si body, the method comprising the successive steps of:

   providing a single crystal Si body having a major surface;

   implanting oxygen ions into the Si body through the major surface such that a buried

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and to provide gate insulation, all in a conventional manner. Numerals 32 refer to source, gate, and drain metal contacts.

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Example II:

A second SOI wafer was prepared substantially as described in Example I, except that the nominal wafer temperature during the subcritical oxygen implant was 500 °C, the oxygen implant ($4x10^{17}$ oxygen/cm^2, 200 keV) was followed by a randomizing Si implant (nominal temperature 30 °C, $1x10^{15}$/cm^2, 460 keV), the subsequent heat treatment was followed by a second randomizing Si implant (conditions as above), and this was followed by a 600 °C anneal. The quality of the thus formed heterostructure was substantially as described in Example I.

Claims

1. Method of making an article comprising SiO_2 buried within a Si body, the method comprising the successive steps of:

providing a single crystal Si body having a major surface;

implanting oxygen ions into the Si body through the major surface such that a buried oxygen-rich layer is formed in the Si body, the oxygen implant being a subcritical oxygen implant, and the Si body being maintained during the subcritical oxygen implant at a relatively low temperature;

submitting the oxygen-implanted Si body to a first heat treatment comprising an anneal at a temperature above 1200 °C such that the buried SiO_2 is formed from the oxygen-rich layer;

carrying out, subsequent to said first heat treatment, a randomizing implant of Si or noble gas ions, the implant conditions selected such that at least some of the Si overlying and underlying said buried SiO_2 is substantially amorphized; and

further heat treating the body at a temperature in the approximate range 500-800 °C to form a substantially homogeneous SiO_2 layer, with Si overlying and underlying the SiO_2 layer.

2. Method according to claim 1, wherein the Si body is maintained at a temperature less than about 350 °C during the subcritical oxygen implant.

3. Method of making an article comprising SiO_2 buried within a Si body, the method comprising the successive steps of:

providing a single crystal Si body having a major surface;

implanting oxygen ions into the Si body through the major surface such that a buried

oxygen-rich layer is formed in the Si body, the oxygen implant being a subcritical oxygen implant and the Si body being maintained during the subcritical oxygen implant at a relatively high temperature;

carrying out a first randomizing implant of Si or rare gas ions; and

submitting the oxygen-implanted Si body to a first heat treatment comprising an anneal at a temperature above 1200 °C such that the buried SiO_2 is formed from the oxygen-rich layer, the buried SiO_2 forming a substantially homogeneous SiO_2 layer, with Si overlying and underlying the SiO_2 layer.

4. Method according to claim 3, wherein the Si body is maintained at a temperature greater than about 350 °C during the subcritical oxygen implant.

5. Method of claim 3 or 4, wherein subsequent to said anneal a second randomizing implant of Si or noble gas ions is carried out, the implant conditions selected such that at least some of the Si overlying and underlying the SiO_2 layer is substantially amorphized, and a further heat treatment of the body at a temperature in the approximate range 500-800 °C is carried out.

6. Method according to any of claims 1 to 5, wherein the randomizing implant or implants comprise(s) implantation of Si ions, and wherein the Si body is maintained at a temperature less than about 100 °C during the randomizing implant(s).

7. Method of claim 6, wherein from about 2×10^{14} to about 1×10^{15} Si/cm^2 are implanted during the randomizing implant or during at least one of the implants, and wherein the Si ions have an energy in the range from about 0.1 MeV to about 2 MeV.

8. Method of any of claims 1-7, wherein said heat treatment comprises contacting the Si body with an atmosphere adapted for causing the slow growth of a relatively thin SiO_2 layer.

9. Method of claim 8, wherein the atmosphere comprises inert gas as a major component and oxygen as a minor component.

Patentansprüche

1. Verfahren zur Herstellung eines Gegenstands mit in einem Siliziumkörper eingegrabenem SiO_2, wobei das verfahren die nachfolgenden Schritte umfaßt:

Bereitstellung eines Siliziumeinkristallkörpers mit einer Hauptoberfläche;

Implantation von Sauerstoffionen in den Siliziumkörper durch die Hauptoberfläche, so daß sich im Siliziumkörper eine eingegrabene sauerstoffreiche Schicht ausbildet, wobei das Sauerstoffimplantat ein unterkritisches Sauerstoffimplantat ist, und der Siliziumkörper während der unterkritischen Sauerstoffimplantation auf einer relativ niedrigen Temperatur gehalten wird;

Durchführung einer ersten Wärmebehandlung des sauerstoffimplantierten Siliziumkörpers, die ein Glühen bei einer Temperatur oberhalb von 1200 °C umfaßt, so daß das eingegrabene SiO_2 aus der sauerstoffreichen Schicht gebildet wird;

Durchführung einer randomisierenden Implantation von Silizium oder Edelgasionen nachfolgend auf die erste Wärmebehandlung, wobei die Implantationsbedingungen so gewählt werden, daß zumindest ein Teil des Siliziums, das über- und unterhalb des eingegrabenen SiO_2 liegt, im wesentlichen amorphisiert wird; und

eine weitere Wärmebehandlung des Körpers bei einer Temperatur im Bereich von ungefähr 500-800 °C, um eine im wesentlichen homogene SiO_2-Schicht zu erreichen, wobei Silizium über und unter der SiO_2-Schicht liegt.

2. Verfahren nach Anspruch 1, wobei der Siliziumkörper während der unterkritischen Sauerstoffimplantation auf einer Temperatur unterhalb von etwa 350 °C gehalten wird.

3. Verfahren zur Herstellung eines Gegenstands mit in einem Siliziumkörper eingegrabenem SiO_2, wobei das Verfahren nachfolgende Schritte umfaßt:

Bereitstellung eines Siliziumeinkristallkörpers mit einer Hauptoberfläche;

Implantation von Sauerstoffionen in den Siliziumkörper durch die Hauptoberfläche, so daß sich im Siliziumkörper eine eingegrabene sauerstoffreiche Schicht ausbildet, wobei das Sauerstoffimplantat ein unterkritisches Sauerstoffimplantat ist, und der Siliziumkörper während der unterkritischen Sauerstoffimplantation auf einer relativ hohen Temperatur gehalten wird;

Durchführung einer ersten randomisierenden Implantation von Silizium- oder Edelgasionen; und

Durchführung einer ersten Wärmebehandlung des sauerstoffimplantierten Siliziumkörpers, die ein Glühen bei einer Temperatur oberhalb von 1200 °C umfaßt, so daß das eingegrabene SiO_2 aus der sauerstoffreichen Schicht gebil-

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det wird, wobei eine im wesentlichen homogene SiO_2-Schicht erreicht wird, mit über- und unterhalb der SiO_2-Schicht liegendem Silizium.

4. Verfahren nach Anspruch 3, wobei der Siliziumkörper während der unterkritischen Sauerstoffimplantation auf einer Temperatur oberhalb von etwa 350 °C gehalten wird.

5. Verfahren nach Anspruch 3 oder 4, wobei nachfolgend auf das Glühen eine zweite randomisierende Implantation von Silizium oder Edelgasionen durchgeführt wird, und zwar bei solchen ausgewählten Implantationsbedingungen, daß zumindest ein Teil des Siliziums, das über- und unterhalb der eingegrabenen SiO_2-Schicht liegt, im wesentlichen amorphisiert wird, und eine weitere Wärmebehandlung des Körpers bei einer Temperatur im Bereich von ungefähr 500 bis 800 °C erfolgt.

6. Verfahren nach einem der Ansprüche 1 bis 5, wobei die randomisierende(n) Implantation(en) die Implantation von Siliziumionen beinhaltet, und wobei der Siliziumkörper während der Implantation(en) auf einer Temperatur von weniger als etwa 100 °C gehalten wird.

7. Verfahren nach Anspruch 6, wobei während des randomisierenden Implantierens oder während zumindest einer der Implantationen von etwa $2*10^{14}$ bis etwa $1*10^{15}$ Si/cm^2 implantiert werden, und wobei die Siliziumionen eine Energie im Bereich von etwa 0,1 MeV bis etwa 2 MeV haben.

8. Verfahren nach einem der Ansprüche 1 bis 7, wobei die Wärmebehandlung beinhaltet, daß der Siliziumkörper mit einer speziell angepaßten Atmosphäre in Kontakt gebracht wird, die das langsame Wachstum einer relativ dünnen SiO_2-Schicht verursacht.

9. Verfahren nach Anspruch 8, wobei die Atmosphäre Inertgas als Hauptbestandteil und Sauerstoff als Nebenbestandteil enhält.

Revendications

1. Procédé de fabrication d'un article comprenant du SiO_2 enterré à l'intérieur d'un bloc de Si, ce procédé comprenant les étapes successives suivantes :

on fournit un bloc de Si monocristallin ayant une surface principale ;

on implante des ions oxygène dans le bloc de Si à travers la surface principale, de façon à former une couche enterrée riche en oxygène dans le bloc de Si, l'implantation d'oxygène étant une implantation d'oxygène sous-critique, et le bloc de Si étant maintenu à une température relativement basse pendant l'implantation d'oxygène sous-critique ;

on soumet le bloc de Si ayant subi l'implantation d'oxygène à un premier traitement thermique comprenant un recuit à une température supérieure à 1 200° C, de façon à former le SiO_2 enterré à partir de la couche riche en oxygène ;

on effectue, à la suite du premier traitement thermique, une implantation d'ions de Si ou d'un gaz noble, créant une structure désordonnée, avec les conditions d'implantation sélectionnées de façon qu'au moins une partie du Si se trouvant au-dessus et au-dessous du SiO_2 enterré soit pratiquement convertie sous forme amorphe ; et

on soumet le bloc à un traitement thermique supplémentaire à une température dans la plage approximative de 500-800° C, pour former une couche de SiO_2 pratiquement homogène, avec du Si au-dessus et au-dessous de la couche de SiO_2.

2. Procédé selon la revendication 1, dans lequel le bloc de Si est maintenu à une température inférieure à environ 350° C pendant l'implantation d'oxygène sous-critique.

3. Procédé de fabrication d'un article contenant du SiO_2 enterré à l'intérieur d'un bloc de Si, ce procédé comprenant les étapes successives suivantes :

on fournit un bloc de Si monocristallin ayant une surface principale ;

on implante des ions oxygène dans le bloc de Si à travers la surface principale, de façon à former une couche enterrée riche en Oxygène dans le bloc de Si, l'implantation d'oxygène étant une implantation d'oxygène sous-critique et le bloc de Si étant maintenu à une température relativement élevée pendant l'implantation d'oxygène sous-critique ;

on effectue une première implantation d'ions de Si ou d'un gaz rare créant une structure désordonnée ; et

on soumet le bloc de Si ayant subi l'implantation d'oxygène à un premier traitement thermique comprenant un recuit à une température supérieure à 1 200° C, de façon que le SiO_2 enterré se forme à partir de la couche riche en oxygène, le SiO_2 enterré formant une couche de SiO_2 pratiquement homogène, avec du Si au-dessus et au-dessous de la couche de SiO_2.

4. Procédé selon la revendication 3, dans lequel le bloc de Si est maintenu à une température supérieure à environ 350° C pendant l'implantation d'oxygène sous-critique.

5. Procédé selon la revendication 3 ou 4, dans lequel à la suite du recuit, on effectue une seconde implantation d'ions de Si ou d'un gaz noble, créant une structure désordonnée, avec les conditions d'implantation sélectionnées de façon qu'au moins une partie du Si se trouvant au-dessus et au-dessous de la couche de SiO_2 soit pratiquement convertie sous forme amorphe, et on effectue un traitement thermique supplémentaire du bloc à une température dans la plage approximative de 500-800° C.

6. Procédé selon l'une quelconque des revendications 1 à 5, dans lequel l'implantation ou les implantations créant une structure désordonnée sont des implantations d'ions Si, et dans lequel le bloc de Si est maintenu à une température inférieure à environ 100° C pendant la ou les implantations créant une structure désordonnée.

7. Procédé selon la revendication 6, dans lequel on implante entre environ 2×10^{14} et 1×10^{15} Si/cm^2 pendant l'implantation créant une structure désordonnée, ou pendant l'une au moins de ces implantations, et dans lequel les ions Si ont une énergie dans la plage allant d'environ 0,1 MeV à environ 2 MeV.

8. Procédé de l'une quelconque des revendications 1-7, dans lequel le traitement thermique comprend la mise en contact du bloc de Si avec une atmopshère appropriée pour provoquer la croissance lente d'une couche relativement mince de SiO_2.

9. Procédé selon la revendication 8, dans lequel l'atmopshère comprend un gaz inerte à titre de composant principal et de l'oxygène à titre de composant secondaire.