

(MV/cm), for various receiver substrates in which the buried oxide layer was formed by direct bonding (substrate such as that in Figure 1) or by reverse bonding (substrate such as that in Figure 2) according to the prior art.

The two curves on the right in the graph, referenced D_1 and D_2 , correspond to two substrates obtained by direct bonding. In these two substrates, the oxide layer was formed by oxidation of the single-crystal semiconductor of the donor substrate and was then transferred to the charge-trapping layer.

The five curves on the left in the graph, referenced I_1 , I_2 , I_3 , I_4 , and I_5 , correspond to five substrates obtained by reverse bonding. In the substrates, the oxide layer was formed by oxidation of the charge-trapping layer made of polycrystalline silicon of the receiver substrate.

The electrical current was measured between ground and the free surface of the substrate by way of a piece of aluminium arranged on the oxide layer and a measurement probe.

Regarding the direct bonding, the two curves D_1 and D_2 exhibit a break in slope corresponding to a maximum electric field that the substrate may withstand before short-circuit of about 7 MV/cm. The value of the maximum electric field corresponding to the curve D_2 is slightly higher than that corresponding to the curve D_1 .

Regarding the reverse bonding, the five curves I_1 , I_2 , I_3 , I_4 , and I_5 exhibit a break in slope corresponding to a maximum electric field that the substrate may withstand before short-circuit of about 3 MV/cm. The value of the maximum electric field increases between I_1 and I_5 .

By comparison it may be seen that the value of the maximum electric field is clearly lower for substrates obtained by reverse bonding with respect to those obtained by direct bonding. The average distance between the two sets of curves is about 4 MV/cm.

Fabrication of a substrate by reverse bonding therefore induces a drop in the maximum electric field, this resulting in a corresponding drop in breakdown voltage.

BRIEF DESCRIPTION OF THE INVENTION

Embodiments of the invention seek to provide a process allowing the aforementioned drawbacks to be overcome. Embodiments of the invention aim to provide such a process allowing a receiver substrate to be fabricated for a semiconductor-on-insulator structure the buried oxide layer of which may possess a sufficient breakdown voltage for radiofrequency applications, while limiting production cost.

An aspect of the invention provides a process for fabricating a receiver substrate for a semiconductor-on-insulator structure for radiofrequency applications, comprising the following steps:

- providing a semiconductor substrate comprising a base substrate made of single-crystal material and a charge-trapping layer made of polysilicon arranged on the base substrate,
- oxidizing the charge-trapping layer in order to form an oxide layer arranged on said charge-trapping layer,

the process mainly being characterized in that the charge-trapping layer is oxidized at least partially at a temperature lower than or equal to 875°C, in the following way:

- starting the oxidation at a first temperature comprised between 750°C and 1000°C,
- decreasing the temperature to a second temperature below the first temperature and comprised between 750°C and 875°C,
- continuing the oxidation at the second temperature.

The temperatures lower than or equal to 875°C are lower than the temperatures at which the oxidation of a trapping layer is usually carried out in the prior art. Specifically, the applicant has discovered, surprisingly, that decreasing the temperature of oxidation of the charge-trapping layer allows the breakdown voltage of the formed oxide layer to be increased, contrary to what those skilled in the art in the field of radio frequencies would expect based on their current knowledge, such as in particular illustrated by publication [1].

The oxidation of the charge-trapping layer made of polysilicon consumes the polysilicon, and the rate of formation of the oxide depends on the crystal orientation of the polysilicon grains. Thus, the fact that the crystal grains of the polysilicon layer are oriented differently causes the silicon oxide formed from these grains to grow at different rates. For example, the oxide grows at a different rate in the <100> direction and in the <111> direction, from grains oriented in the same <100> and <111> directions. The indices <100> and <111> are Miller indices, which allow the orientation of the planes in a crystal to be determined, and therefore the orientation of the crystal grains in the crystal structure to be expressed.

These differences in the growth rate of the oxide depending on the orientation of the crystal grains of the polysilicon generate mechanical stresses within the crystal structure, and most particularly at the interface between the oxide layer in growth and the subjacent polysilicon layer. As the volume of the oxide layer in growth increases and as the oxidation progresses, these stresses are amplified at the polysilicon surface.

According to embodiments, the process has the following various features, which may be implemented alone or in technically feasible combinations thereof:

- the charge-trapping layer is oxidized at least partially at a temperature higher than or equal to 750°C. The oxidation rate is thus more compatible with industrial requirements and remains economically viable;
- the decrease in the temperature from the first temperature T_1 to the second temperature T_2 is gradual;

- at least 50%, and preferably at least 70%, of the thickness of the oxide layer is produced at the first temperature T_1 , and at least 20%, and preferably at least 30%, of the thickness of the oxide layer is produced at the second temperature T_2 ;
- the formed oxide layer has a thickness comprised between 200 nm and 400 nm;
- the charge-trapping layer has a thickness comprised between 20 nm and 500 nm;
- the charge-trapping layer is deposited beforehand on the base substrate made of single-crystal material by low-pressure chemical vapour deposition in a reactor.

Another aspect of the invention provides a process for fabricating a semiconductor-on-insulator structure for radiofrequency applications, characterized in that it comprises the following steps:

- fabricating a receiver substrate such as described above,
- providing a donor substrate comprising single-crystal substrate,
- bonding the donor substrate to the receiver substrate,
- transferring a layer of the donor substrate to the receiver substrate.

According to embodiments, the process has the following various features, which may be implemented alone or in technically feasible combinations thereof:

- the layer transferred from the donor substrate comprises a semiconductor;
- the layer transferred from the donor substrate comprises a ferroelectric material;
- the ferroelectric material is chosen from: LiTaO_3 , LiNbO_3 , LiAlO_3 , BaTiO_3 , PbZrTiO_3 , KNbO_3 , BaZrO_3 , CaTiO_3 , PbTiO_3 , KTaO_3 .
- said transfer comprises the following steps:
 - implanting atomic species in the donor substrate so as to form a weakened zone that delineates a layer of single-crystal semiconductor or ferroelectric material to be transferred,
 - bonding the donor substrate to the receiver substrate, the oxide layer and the layer of single-crystal semiconductor or ferroelectric material to be transferred being at the bonding interface,
 - detaching the donor substrate along the weakened zone in order to transfer the layer of single-crystal semiconductor or ferroelectric material to the receiver substrate, the oxide layer being arranged between the charge-trapping layer and the transferred layer of single-crystal semiconductor or ferroelectric material.

The single-crystal semiconductor or ferroelectric material preferably lies at the surface of the donor substrate, the implantation of atomic species being carried out directly through said surface.

DESCRIPTION OF THE FIGURES

CLAIMS

1. Process for fabricating a receiver substrate for a semiconductor-on-insulator structure for radiofrequency applications, comprising the following steps:
 - providing a semiconductor substrate comprising a base substrate made of single-crystal material and a charge-trapping layer made of polysilicon arranged on the base substrate,
 - oxidizing the charge-trapping layer in order to form an oxide layer arranged on said charge-trapping layer,the process being characterized in that the charge-trapping layer is oxidized at least partially at a temperature lower than or equal to 875°C, in the following way:
 - starting the oxidation at a first temperature comprised between 750°C and 1000°C,
 - decreasing the temperature to a second temperature below the first temperature and comprised between 750°C and 875°C,
 - continuing the oxidation at the second temperature.
2. Process according to Claim 1, wherein the charge-trapping layer is oxidized at least partially at a temperature higher than or equal to 750°C.
3. Process according to Claim 1 or Claim 2, wherein the decrease in the temperature from the first temperature to the second temperature is gradual.
4. Process according to one of Claims 1 to 3, wherein at least 50%, and preferably at least 70%, of the thickness of the oxide layer is produced at the first temperature, and at least 20%, and preferably at least 30%, of the thickness of the oxide layer is produced at the second temperature.
5. Process according to any one of the preceding claims, wherein the formed oxide layer has a thickness comprised between 200 nm and 400 nm.
6. Process according to any one of the preceding claims, wherein the charge-trapping layer has a thickness comprised between 20 nm and 500 nm.
7. Process according to any one of the preceding claims, wherein the charge-trapping layer is deposited beforehand on the base substrate made of single-crystal material by low-pressure chemical vapour deposition in a reactor.

8. Process for fabricating a semiconductor-on-insulator structure for radiofrequency applications, characterized in that it comprises the following steps:
 - fabricating a receiver substrate according to any one of the preceding claims,
 - providing a donor substrate comprising single-crystal substrate,
 - bonding the donor substrate to the receiver substrate,
 - transferring a layer of the donor substrate to the receiver substrate.
9. Process according to Claim 8, wherein the layer transferred from the donor substrate comprises a semiconductor.
10. Process according to Claim 8, wherein the layer transferred from the donor substrate comprises a ferroelectric material.
11. Process according to Claim 10, wherein the ferroelectric material is chosen from: LiTaO_3 , LiNbO_3 , LiAlO_3 , BaTiO_3 , PbZrTiO_3 , KNbO_3 , BaZrO_3 , CaTiO_3 , PbTiO_3 , KTaO_3 .
12. Process according to one of Claims 8 to 11, wherein said transfer comprises the following steps:
 - implanting atomic species in the donor substrate so as to form a weakened zone that delineates a layer of single-crystal semiconductor or ferroelectric material to be transferred,
 - bonding the donor substrate to the receiver substrate, the oxide layer and the layer of single-crystal semiconductor or ferroelectric material to be transferred being at the bonding interface,
 - detaching the donor substrate along the weakened zone in order to transfer the layer of single-crystal semiconductor or ferroelectric material to the receiver substrate, the oxide layer being arranged between the charge-trapping layer and the transferred layer of single-crystal semiconductor or ferroelectric material.
13. Process according to Claim 12, wherein the single-crystal semiconductor or ferroelectric material lies at the surface of the donor substrate, the implantation of atomic species being carried out directly through said surface.