

SUBSTRATE FOR AN INTEGRATED RADIOFREQUENCY DEVICE AND METHOD
FOR MANUFACTURING SAME

FIELD OF THE INVENTION

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The present invention relates to a substrate for an integrated radiofrequency device. It also relates to the method for manufacturing such a substrate.

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TECHNOLOGICAL BACKGROUND OF THE INVENTION

Integrated devices are usually formed on substrates which are mainly used as supports for the manufacturing thereof. The increase in the degree of integration and expected performance of these devices has led to ever greater coupling between their performances and the characteristics of the substrate on which they are formed. This is more particularly true in the case of RF devices which process signals, the frequency of which ranges from about 3 kHz to 300 GHz, which are used in particular in the field of telecommunications (cellular telephones, Wi-Fi, Bluetooth, etc.).

As an example of device/substrate coupling, the electromagnetic fields from high-frequency signals which propagate in the devices penetrate into the depth of the substrate and interact with any charge carriers that may be contained therein. This results in a useless consumption of at least a part of the signal energy by coupling loss and possible influences between the components by crosstalk.

According to a second exemplary coupling, the charge carriers of the substrate may generate undesired harmonics, which may interfere with the signals which propagate in the integrated devices and degrade the quality thereof.

Such phenomena can specifically be observed when the substrate used, of the « silicon-on-isolator » type, comprises

a buried layer of insulator, between a support and a layer of devices whereon and wherein the integrated devices are formed. The charges trapped in the insulator lead to accumulate charges having complementary signs which form a conductive plane under such layer of insulator, in the support. In such conductive plane, the mobile charges may strongly interact with the electromagnetic fields generated by the components of the useful layer. A significant drop in the resistivity of the support can thus be observed, in a plane located directly under the buried layer of insulator, even when such support has a highly resistive electrical characteristic.

To prevent or limit such phenomenon, inserting a charges trapping layer, for example a layer of 1 to 5 microns of polycrystalline silicon between the buried insulator and the support, directly under the insulator, is known. The joints of the grains which form the poly-crystal are then traps for the charge carriers, since the latter can come from the trapping layer itself or from the underlying support. The appearance of the conductive plane under the insulator and the drop in the resistivity of the support are thus avoided. The manufacturing of such type of substrate is for example disclosed in the documents FR2860341, FR2933233, FR2953640, US2015115480, US7268060 or US6544656.

US20150115480 proposes forming the trapping layer in the form of a stack of polycrystalline or amorphous SiGe, Ge or SiC elementary layers, each elementary layer possibly having a thickness of at least about 5 nm and being covered with a layer passivation of some Angstrom.

US2016071959 describes a structure of silicon-on-insulator type comprising on a resistive support a possible thin insulating layer of a few nanometers thick and an amorphous layer of silicon doped with a thickness of between 25nm and 7 microns). The carbon concentration is between 1 and 10%.

US20130168835 discloses a method of forming a silicon on insulator substrate comprising providing a support substrate; forming a layer of high-resistivity material on the support substrate, the layer of high-resistivity material having a thickness of between 10 and 50 microns and comprising one of amorphous or polycrystalline silicon carbide, polycrystalline or amorphous diamond ; forming an insulating layer on the layer of high resistivity material; and assembling a donor wafer to an upper surface of the insulating layer to form the SOI substrate.

This solution of providing a trapping layer based on polycrystalline or amorphous semiconductor material, although quite effective, is relatively expensive, especially when the trapping layer is thick or composed of a stack of elementary layers. In addition, the formation of a thick layer, for example several microns, may lead to deform the wafer on which this layer is formed or to make this layer particularly rough, which makes the manufacturing process particularly difficult. This cost of the solution is difficult to justify for integrated devices requiring low RF performance.

The present invention aims at providing a substrate for applications in the fields of radiofrequency electronics and microelectronics which is simple and not expensive to produce while having a higher level of performances than a substrate of the silicon-on-insulator type which includes no trapping layer.

BRIEF DESCRIPTION OF THE INVENTION

To reach this goal, the object of the invention is to provide a substrate for applications in the fields of radiofrequency electronics and microelectronics comprising:

- a base substrate;

- a single carbon layer positioned on and directly in contact with the base substrate, with the carbon layer having a thickness strictly ranging from 1nm to 5nm;
- an insulator layer positioned on the carbon layer;
- a layer of devices positioned on the insulator layer.

The carbon layer which has a very low thickness forms a trapping layer which can be very easily, and quite surprisingly, very efficiently produced.

According to other advantageous and non-restrictive characteristics of the invention, taken either separately or in any technically feasible combination:

- the base substrate is a single-crystal silicon substrate having a resistivity of less than 100 ohm.cm;
- with the base substrate being a single-crystal silicon substrate having a resistivity above 100 or 1,000 ohm.cm;
- the carbon layer has a thickness ranging from 1 to 3nm;
- the substrate further comprises a bonding layer positioned between, and in contact with, the carbon layer and the insulator layer;
- the bonding layer has a thickness of less than 10nm;
- the bonding layer is made of an amorphous, polycrystalline silicon or made of silicon dioxide;
- the insulator layer is made of silicon dioxide;
- the layer of devices comprises silicon;
- with the layer of devices comprising at least one radiofrequency device.

A method for manufacturing a substrate for applications in the fields of radiofrequency electronics and microelectronics, comprising:

- a a step of exposing a base substrate (3) to a precursor gas containing carbon to saturate the exposed substrate with carbon species freed from the precursor gas and to form a single carbon layer (2) having a thickness ranging strictly from 1nm to 5nm on the base substrate;
- a step of assembling the base substrate and the source substrate so as to form an insulator layer between the base substrate and the source substrate;
- a step of thinning the source substrate to form a layer of devices.

According to other advantageous and non-restrictive characteristics of the invention, taken either separately or in any technically feasible combination:

- the method comprises a step of forming a bonding layer having a thickness of less than 10nm on, and in contact with, the carbon layer after the exposition step;
- the step of forming the bonding layer comprises the deposition of a bonding material and the polishing of the deposited bonding material;
- the source substrate is made of silicon and the step of forming the insulator layer comprises the oxidation of the source substrate;
- the source substrate comprises radiofrequency devices and the step of forming the insulator layer comprises the deposition of a silicon dioxide layer on the source substrate;
- the step of thinning the source substrate comprises a step of progressively reducing a part of the thickness of the source substrate by physical and/or chemical thinning;

- the step of thinning the source substrate comprises a first step of forming a brittle plane in the source substrate prior to the step of assembling, and a second step of breaking the source substrate at such brittle plane thereof, after the step of assembling;
- the carbon layer has a thickness strictly ranging from 1 to 3nm.

BRIEF DESCRIPTION OF THE DRAWINGS

Further characteristics and advantages of the invention will be clear from the detailed description of the invention, made in reference to the appended figures, among which:

- Figure 1 represents a substrate according to a first embodiment of the invention;
- Figure 2 represents a substrate according to a second embodiment of the invention;
- Figure 3 represents a method for manufacturing a substrate according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 schematically represents a first embodiment of a substrate 1 for applications in the fields of radiofrequency electronics and microelectronics according to the invention.

The substrate 1 of the first embodiment comprises a base substrate 3, a carbon layer 2 positioned on and directly in contact with the base substrate 3, with the carbon layer having a thickness strictly ranging from 1nm to 5nm, and preferentially from 1 to 3nm; an insulator layer 4 positioned on the carbon

layer 2 and a layer of devices 5 positioned on the insulator layer 4. The base substrate 3 provided with the carbon layer 2 forms the support 9 of the substrate 1.

5 The substrate 1 can have the shape of a circular plate, with standard dimensions, for example 200mm or 300mm, even 450mm in diameter. This is specifically the case when the substrate, and more particularly the layer of devices 5, carries no device. However, the invention is in no way restricted to these
10 dimensions or this shape.

 When the substrate 1 forms the support of a finished or semi-finished radiofrequency device, it will thus have the shape of a block of material having a longitudinal rectangular or
15 square section, the dimensions of which, from a few millimetres to a few centimetres, match the dimensions of the integrated device.

 The base substrate 3 has a thickness of several hundreds
20 of microns. Preferentially, the base substrate 3 has a high resistivity, above 100 or 1,000 ohms.cm, and more preferentially above 3,000 ohms.cm. The density of charges, holes or electrons, which might move in the base substrate 3, and thus affect the RF performances of the substrate, is thus limited. But the
25 invention is not limited to a base substrate having such a resistivity, and it also gives advantageous RF performances when the base substrate has a more conform resistivity, of the order of a few hundreds of ohms.cm, or 100 ohms.cm or less.

30 For reasons of availability and cost, the base substrate 3 is preferentially made of silicon, and specifically made of single-crystal silicon. This may be, for example, a CZ substrate having a low interstitial oxygen content which has, as is well known, per se,, a resistivity which may be above 1,000 ohms.cm.
35 The base substrate may also be made of another material: this may be, for example, sapphire, silicon carbide, silicon-germanium, III-V materials,... This may also be a more standard single-crystal substrate CZ, the resistivity of which is less

than 100 ohms.cm.

5 The substrate 1 also comprises, on and directly in
contact with the base substrate 3, a single carbon layer 2 having
a thickness strictly ranging from 1nm to 5nm, and preferentially
from 1 to 3nm. The carbon layer 2 aims at limiting the
resistivity loss which is generally observed in the support of
10 a substrate of the « silicon-on-insulator » type, under the
insulator layer, as has been recalled in the preamble.

 Within the scope of the present invention, « carbon layer
» means a layer made of carbon atoms only. The migration or the
15 diffusion of such atoms in the thickness of the base substrate
3, or the diffusion of the atoms composing the base substrate 3
in the carbon layer 2, on in a few atomic planes, may lead to
the forming of a layer, rich in carbon, but possibly containing
other species, specifically those the base substrate is made of.

20 Quite surprisingly, it has been observed that such carbon
layer 2, even with a very low thickness, was very efficient to
improve the RF performances of the substrate 1, specifically to
limit, or even totally avoid the drop in resistivity of the
25 support 9 at the interface thereof with the insulator layer 4.
For example, a 3nm carbon layer 2 deposited on a base substrate
3 having a resistivity above 1,000 ohms.cm makes it possible to
gain 20dbm in performance when measuring the second harmonic
distortion parameter, a distortion from coplanar lines, as
30 compared to a base substrate having no carbon layer 2. Such
characterization measurement is specifically disclosed in the
document entitled « White paper - RF SOI Characterisation » dated
March 2016, published by the SOITEC company.

35 This results from the fact that such a layer comprises a
significant density of defects forming traps for the charge
carriers. Such density of defects is by several orders of
magnitude above what could be obtained with a crystalline or

amorphous layer of a semi-conductive material having the same thickness, made of silicon, silicon-germanium, silicon carbide or any other material.

5 Because of the extreme thinness of a few nanometres, the carbon layer 2 is also little complex and cheap to produce, as compared to the trapping layers, several microns thick, of the prior art, which are made of polycrystalline and amorphous material.

10 As shown in Figure 1, the substrate 1 comprises an insulator layer 4 directly on the carbon layer 2. The substrate also comprises a layer of devices 5, on and in contact with the insulator layer 4. The characteristics of these two layers are
15 not essential to the invention. For example, the insulator layer 4 can be made of, or comprise, silicon dioxide or silicon nitride. It may also be a stacking of such materials. The thickness of the insulator layer 4 can be ranging from 10nm to 10 microns. The layer of devices 5 is usually made of single-
20 crystal silicon, but it could be made of any other material, whether semi-conductive or not, according to the nature of the RF device intended to be formed therein. Thus, to form an acoustic wave device, the layer of devices 5 can be made of an insulator such as lithium tantalate or lithium niobate. The
25 thickness of the layer of devices can range from 10nm to 10 microns. The devices can be formed in such layer of devices 5 when it is borne by the support 9, but, as will be disclosed hereunder, the devices can also be formed in this layer before it is added on the support 9. Obviously, the device layer is
30 continuous, ie it covers most of the main face of the substrate 1, so that this substrate can accommodate a high density of components.

35 Figure 2 schematically shows a second embodiment of the substrate 1 according to the invention.

The substrate 1 of the second embodiment comprises the same base substrate 3, the same carbon layer 2, the same insulator layer 4 and the same layer of devices 5 as in the substrate 1 of the first embodiment. To be concise, the descriptions thereof will not be repeated, and the same comments made in relation with the description of the substrate 1 of the first embodiment will also apply to the substrate 1 of the second embodiment.

As can easily be seen in Figure 2, the substrate 1 also comprises a bonding layer 7 positioned between, and in contact with, the carbon layer 2 and the insulator layer 4.

Such bonding layer 7 aims at facilitating the manufacturing of the substrate as will be disclosed in details hereunder. It can be made of amorphous, polycrystalline silicon or of silicon dioxide, but other materials can be considered too. The possible influence thereof on the level of RF performances of the substrate is secondary. However, care shall be taken that it does not affect such performances. For this purpose, the thickness and the conductivity thereof will be limited as much as possible. Preferably, the bonding layer 7 has a thickness of less than 10nm. When made of a semi-conductive material, the bonding layer 7 has a concentration in dopant of less than 10¹⁴ atoms per cubic centimetre. It may be rich in carbon so as to be resistive.

Whatever the embodiment selected, the substrate 1 contains no other layer but the single carbon layer 2 and, if need be, the bonding layer 7, between the base substrate 3 and the insulator layer 2. The level of RF performances, and specifically the resistivity of the support 9 in a plane located under the insulator layer 2, is essentially provided by the carbon layer 2.

An advantage of the substrate 1 of the invention is that the carbon layer 2 is not sensitive to the heat treatment which the substrate might be exposed to. It will unlikely lose its

charge trapping effects by recrystallization as is the case for polycrystalline or amorphous trapping layers of the state of the art. The substrate 1 can thus be exposed, in the course of its manufacturing or in the course of the forming of the RF devices in and on the layer of devices 5, to a high temperature, for example up to 1,200°C when the base substrate 3 and the layer of devices 5 are made of silicon.

In reference to Figure 3, an exemplary manufacturing method according to the invention is now described.

Generally speaking, the manufacturing of the substrate 1 comprises the preparation of the base substrate 3 to provide it with the carbon layer 2 (and possibly with the bonding layer 7) to form the support 9, and the transfer of a layer of devices 5 on the support 9.

The preparation of the base substrate 3 is particularly simple and achievable with standard equipment industry. The base substrate 3 is provided in a conventional deposition chamber or even in a chamber of an annealing furnace in which a gas can be circulated to control its atmosphere. As is well known per se, the base substrate 3 may be prepared prior to deposition to be exposed to a carbon-containing precursor gas, for example to remove a native oxide layer from its surface.

As is schematically represented in FIG. 3a, the chamber is then flowed with a precursor gas containing carbon, for example C₃H₈, at a temperature of the order of 1000°C, and preferably greater than 1000°C for exposing the base substrate 3 to this precursor gas and forming the carbon layer 2. The precursor gas may comprise or be composed, for example, of methane (CH₄), ethane (C₂H₆), propane (C₃H₈), acetylene (C₂H₂), ethylene (C₂H₄), etc. The carbon species released by the precursor gas under the effect of temperature bind to the atomic species forming the exposed surface of the base substrate 3. This reaction can be interrupted naturally when this surface is

saturated with carbon, leading to the formation of a carbon layer 2 having a thickness of a few atomic planes, strictly between 1 and 5 nm and even strictly between 1 and 3 nm. The duration of this exposure is sufficient so that the carbon layer covers the exposed surface of the base substrate 3 and the thickness is strictly between 1 and 5nm, or between 1 and 3nm. The exposure time is of the order of a few minutes, ideally and in a nonlimiting manner between 2 and 10 minutes, and at the end of this period, the chamber can be purged of the precursor gas containing carbon or its interrupted flow. As previously discussed, it is possible for carbon atoms to diffuse in some atomic planes in the thickness of the base substrate 2. Similarly, atomic species of the base substrate may also migrate into the deposited carbon layer. In any case, and whatever the exact nature of the layer that is formed, only carbon atoms are deposited to form the carbon layer 2.

At the end of this step, the support 9, shown in Figure 3b, is obtained. This support is intended to be assembled, for example by molecular adhesion to a source substrate 8. Or this purpose, it should be noted that the exposed surface of the carbon layer 2 does not require any particular smoothing treatment, in particular by polishing, since, as a matter of fact, it has, directly after being formed, a roughness, smaller than 5A RMS, low enough to enable the assembling thereof to the source substrate 8. It is also to be note that the particularly thin carbon layer has a very uniform thickness over the entire surface of the support 9. Such a uniform thickness and such a low level of roughness cannot be obtained with thicker layers, especially those exceeding 1 or 10 microns. The support 9 is not likely to deform when it undergoes a heat treatment, by the effect of the stresses that can develop in the thick layers when they have different thermal expansion coefficients.

As the carbon layer 2 has a different nature from that of the source substrate 8, it may have a surface requiring a preparation which will also be different from that of the source substrate 8. Thus to simplify the manufacturing method, and

according to an alternative solution to this method, the invention can provide to form, on the carbon layer 2, a bonding layer 7, the surface of which can be prepared as the source substrate is. It may be, for example, cleaning with chemical substances having identical or similar compositions, dispensed by the same equipment. Such approach contributes to the low cost of manufacturing of the substrate 1.

When, according to an alternative solution to the manufacturing method, forming a bonding layer 7 on the carbon layer 2 is desired, a second precursor gas can be introduced into the chamber as a substitute for or as a complement of the precursor rich in carbon for a determined time to deposit a thickness of bonding material. Care shall be taken to deposit a low thickness so as to limit the substrate 1 manufacturing time and cost as much as possible. It can, for example, range from a few dozens of nanometres to a few hundreds of nanometres. The second precursor gas can be made of SiH_4 to form a bonding layer made of polycrystalline or amorphous silicon.

Such « in-situ » embodiment is particularly advantageous, since it makes it possible to combine, in a single step and on a single piece of equipment, the step of forming the carbon layer 2 and the deposition of the bonding material the bonding layer 7 is made of. But, alternately, the deposition of the bonding material can be executed on another piece of equipment, for example a piece of equipment making it possible to deposit a silicon oxide material. Whatever the nature of the bonding material and the equipment with which such material is deposited on the carbon layer 2, care shall be taken to limit the thickness to a few hundreds of nanometres as mentioned above. The thickness of the bonding material is then prepared, for example by mechanical-chemical polishing, so as to make the surface thereof smooth enough, of less than 5Å RMS, to enable the assembling thereof to the source substrate 8. This is shown in Figure 3c. Such step of smoothing leads to thinning the thickness of the bonding material, to provide the bonding layer 7, the thickness of which preferably must not exceed 10nm, so as not to affect

the RF performances of the substrate too much. Upon completion of this step, and as shown in Figure 3d, a support 9 comprising the bonding layer 7 is obtained, the thickness of which does not exceed 10nm, positioned directly on the carbon layer 2, itself directly positioned on the base substrate 3.

Whether the selected support 9 comprises a bonding layer or not , the transfer of the layer of devices 5 is executed by assembling the face of a source substrate 8 to the support 9. The source substrate may include RF devices or it may be formed by a block of material with no device.

Advantageously, such assembling corresponds to a bonding by molecular adhesion of the surfaces of the substrate 8 and of the support 9 in contact with each other.

The transfer may include, prior to the step of assembling, a step of forming a thickness of insulator on the support 9 and/or on the source substrate 8. After assembling, the thickness or thicknesses form(s) the insulator layer 4. When the insulator is formed by deposition, such deposition may be followed by a step of polishing. Such insulator can comprise, for example, silicon oxide or silicon nitride. When the source substrate is made of silicon and has no device, the step of forming the insulator layer may include the oxidation thereof. Figure 3e shows the source substrate 8 provided with the insulator layer. Assembling the source substrate 8 with the support 9 leads to placing the insulator layer 4 between the support 9 and the source substrate 8, as shown in Figure 3f, when the support 9 comprises no bonding layer, and shown in Figure 3g, when the support 9 comprises a bonding layer 7.

To reinforce such assembly, exposing the structure of Figures 3f and 3g to a thermal annealing can be considered. The step of annealing can be executed, in the method, directly after the step of assembling and/or after the step of thinning which is disclosed hereunder. As mentioned above, such annealing may include the exposure of the structures to a high temperature,

without taking the risk of affecting the RF performances of the substrate obtained when the manufacturing method is completed.

After the step of assembling, the donor substrate is
5 thinned to form the layer of devices 5.

The step of thinning can be executed by the progressive
reduction of a part of the thickness of the source substrate
through a physical and/or chemical thinning.
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Alternately, this can be a fracture at the brittle plane
previously formed in the source substrate prior to the assembling
thereof with the support, according to the principles of the
Smart Cut™ technology.
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Steps of finishing the layer of devices 5, as well as a
step of polishing, a step of heat treatment under a reducing or
neutral atmosphere (in a vertical, horizontal, oven or in fast
heat treatment equipment), a sacrificial oxidation can follow
20 the step of thinning.

After such thinning, and if need be finishing processes,
a substrate 1 according to the invention is obtained, as shown
in Figure 3h, when the support 9 comprises no bonding layer, and
25 in Figure 3i when the support 9 comprises a bonding layer 7.

When the source substrate 8 is a simple semi-conductor
substrate, i.e. it does not comprise any integrated device, a
substrate of the semi-conductor-on-isolator type is thus
30 obtained, wherein the layer of devices 5 is a layer of blank
semi-conductors. The substrate can then be used to form
integrated devices, and specifically radiofrequency integrated
circuits.

35 When the source substrate 8 has previously been processed
to form integrated devices at the surface thereof, when such
method is completed, a layer of devices 5 which comprises such
devices is obtained.

Of course, the invention is not limited to the described embodiments and alternative solutions can be used without leaving the scope of the invention as defined in the claims.

CLAIMS

1. A substrate (1) for applications in the fields of radiofrequency electronics and microelectronics comprising:
- a base substrate (3);
 - a single carbon layer (2) positioned on and directly in contact with the base substrate (3), with the carbon layer (2) having a thickness strictly ranging from 1nm to 5nm;
 - an insulator layer (4) positioned on the carbon layer (2);
 - a layer of devices (5) positioned on the insulator layer (4).
2. A substrate (1) according to the preceding claim, wherein the base substrate (3) is a single-crystal silicon substrate having a resistivity of less than 100 ohm.cm.
3. A substrate (1) according to claim 1, wherein the base substrate (3) is a single-crystal silicon substrate having a resistivity above 100 or 1,000 ohm.cm.
4. A substrate (1) according to one of the preceding claims, wherein the carbon layer (2) has a thickness ranging from 1 to 3nm.
5. A substrate (1) according to one of the preceding claims, further comprising a bonding layer (7) positioned between, and in contact with, the carbon layer (2) and the insulator layer (4).
6. A substrate (1) according to the preceding claim, wherein the bonding layer (7) has a thickness of less than 10nm.
7. A substrate (1) according to one of the preceding two claims, wherein the bonding layer (7) is made of an amorphous, polycrystalline silicon or made of silicon dioxide.

8. A substrate (1) according to one of the preceding claims, wherein the insulator layer (4) is made of silicon dioxide.

9. A substrate (1) according to one of the preceding claims, wherein the layer of devices (5) comprises silicon.

10. A substrate (1) according to one of the preceding claims, wherein the layer of devices (5) comprises at least one radiofrequency device.

11. A method for manufacturing a substrate (1) for applications in the fields of radiofrequency electronics and microelectronics, comprising:

- a step of exposing a base substrate (3) to a precursor gas containing carbon to saturate the exposed substrate with carbon species freed from the precursor gas and to form a single carbon layer (2) having a thickness ranging strictly from 1nm to 5nm on the base substrate;
- a step of forming a thickness of insulator on the carbon layer (2) and/or on a source substrate (8);
- a step of assembling the base substrate (3) and the source substrate (8) so as to form an insulator layer (4) between the base substrate (3) and the source substrate (8);
- a step of thinning the source substrate (8) to form a layer of devices (5).

12. A method according to the preceding claim, comprising a step of forming a bonding layer (7) having a thickness of less than 10nm on, and in contact with, the carbon layer (2) after the exposition step.

13. A method according to the preceding claim, wherein the step of forming the bonding layer (7) comprises the deposition of a bonding material and the polishing of the deposited bonding material.

14. A method according to one of claims 11 to 13, wherein the source substrate (8) is made of silicon and the step of

forming the insulator layer (4) comprises the oxidation of the source substrate (8).

5 15. A method according to one of claims 11 to 13, wherein the source substrate (8) comprises radiofrequency devices and the step of forming the insulator layer (4) comprises the deposition of a silicon dioxide layer on the source substrate (8).

10 16. A method according to one of claims 11 to 15, wherein the step of thinning the source substrate (8) comprises a step of progressively reducing a part of the thickness of the source substrate by physical and/or chemical thinning.

15 17. A method according to one of claims 11 to 15, wherein the step of thinning the source substrate (8) comprises a first step of forming a brittle plane in the source substrate (8) prior to the step of assembling, and a second step of breaking the source substrate (8) at such brittle plane thereof, after
20 the step of assembling.

18. A method according to one of claims 11 to 17, wherein the carbon layer (2) has a thickness ranging strictly from 1 to 3nm.

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