

Process for transferring a layer

FIELD OF THE INVENTION

- 5 The present invention relates to a process for transferring a layer.

PRIOR ART

Processes are known for transferring layers which comprise a step of providing
10 an initial substrate, a step of providing an intermediate substrate, a first step of
joining the intermediate substrate and the initial substrate, a step of thinning the
initial substrate after having been joined to the intermediate substrate, a step of
providing a final substrate, a second step of joining the thinned initial substrate
and the final substrate, and a step of detaching the intermediate substrate after
15 the second joining step. Such a process is described for example in document
WO0237556.

However, there remains a need for 3D integration applications for wafers
comprising for example components given that this type of process must not
20 exceed a certain thermal budget so as not to damage said components, in
particular the presence of metal lines in the initial substrate and/or in the final
substrate does not allow temperatures of maximum 300°C to be exceeded.

SUMMARY OF THE INVENTION

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The present invention aims to overcome these limitations of the prior art by
providing a layer transfer process which is implemented at low temperatures
below 300°C or even less. In this way it is possible to solve the problems that are
currently encountered.

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The invention relates to a layer transfer process comprising a step of providing
an initial substrate; a step of providing an intermediate substrate; a first step of

joining the intermediate substrate and the initial substrate; a step of thinning the initial substrate after having been joined to the intermediate substrate; a step of providing a final substrate; a second step of joining the thinned initial substrate and the final substrate; a step of detaching the intermediate substrate after the

5 second joining step, wherein the intermediate substrate comprises silicon on the surface that is intended to be joined to the initial substrate; the initial substrate comprises substantially no silicon on the surface that is intended to be joined to the intermediate substrate; depositing a first bonding layer, referred to as temporary, of SOG type comprising methylsiloxane in the liquid state by spin

10 coating carried out on the surface of the initial substrate which comprises substantially no silicon followed by a first heat treatment for densifying this first, temporary, bonding layer before the first joining step; the second joining step is carried out via a second bonding layer of SOG type comprising silicate or methylsilsexioquane in the liquid state and deposited by spin coating followed by

15 a second densifying heat treatment; and wherein the final substrate is designed such that it would deteriorate on application of a heat treatment exceeding 300°C.

In advantageous embodiments, the initial substrate comprises components designed such that they would deteriorate on application of a heat treatment

20 exceeding 300°C.

In advantageous embodiments, the first and/or the second densifying heat treatment is carried out at a temperature of less than 300°C, preferably less than 200°C, or more preferably less than 100°C.

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In advantageous embodiments, the first and/or the second joining step is carried out by direct bonding by molecular adhesion.

In advantageous embodiments, the initial substrate is chosen from the group of

30 lithium niobate and lithium tantalate.

In advantageous embodiments, the initial substrate is chosen from the group of GaAs, InP and Ge.

In advantageous embodiments, the intermediate substrate is silicon.

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In advantageous embodiments, the final substrate is silicon comprising components designed such that they would deteriorate on application of a heat treatment exceeding 300°C.

10 In advantageous embodiments, the final substrate is a flexible plastic.

In advantageous embodiments, the detaching step is carried out by a heat treatment at a temperature of less than 300°C, more preferably less than 200°C, or more preferably less than 100°C.

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DESCRIPTION OF THE FIGURES

Other features and advantages of the invention will be better understood from reading the following detailed description with reference to the appended drawing
25 in which:

- Figure 1 illustrates a layer transfer process according to one embodiment of the invention;

30 To improve the readability of the figures, the various layers are not necessarily shown to scale.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Figure 1 schematically illustrates the process for transferring a layer 100' obtained from an initial substrate 100 by means of a step of thinning 2' after having been joined, in a first joining step 1', to an intermediate substrate 200 via a first, temporary, bonding layer 300. This transfer process further comprises a second step of joining 3' said layer 100', after the thinning step 2', to a final substrate 500 via a second bonding layer 400 followed by a step of detaching at the interface present between the initial substrate 100 and the first, temporary, bonding layer 300.

The first, temporary, bonding layer 300 and the second bonding layer 400 are generally chosen from the family of SOGs (spin-on glasses), which exhibit the property of being in the liquid state at ambient temperature but may be densified, and solidified, by means of a suitable heat treatment.

This technique consists in rotating the substrate on which the layer (300, 400) is to be deposited on itself at a substantially constant and relatively high speed in order to spread said layer in the liquid state uniformly over the entire surface of the substrate by centrifugal force. To this end, the substrate is typically placed and held by vacuum chuck on a turntable.

A person skilled in the art is capable of determining the operating conditions, such as the volume deposited on the surface of the substrate, the speed of rotation of the substrate, and the minimum deposition time according to the desired thickness for the adhesive layer.

The thicknesses of said first, temporary, bonding layer 300 and second bonding layer 400 are typically between 2 μm and 8 μm . Additionally, the spin coating technique used is advantageous in that the deposition of the layer (300, 400) is carried out at ambient temperature, and is followed by a densifying anneal at

quite a low temperature, which therefore does not cause the substrate on which the dielectric layer is formed to deform.

5 In one non-limiting example of the invention, the first and/or the second densifying heat treatment is carried out at a temperature of less than 300°C, preferably less than 200°C, or more preferably less than 100°C.

10 The detaching step is carried out by a heat treatment at a temperature of less than 300°C, more preferably less than 200°C, or more preferably less than 100°C

The first, temporary, bonding layer 300 is chosen from families of SOGs of "methylsiloxane" type, sold for example under the references "LSFxx" by FILMTRONICS.

15 The second bonding layer 400 is chosen from families of SOGs of "silicate" or "methylsilsexioquane" type, sold for example under the references "20B" or "400F" by FILMTRONIX or "FOX16" by DOW CORNING.

20 According to the invention, the initial substrate 100 comprises substantially no silicon on the surface that is intended to be joined to the intermediate substrate 200 and the intermediate substrate 200 comprises silicon on the surface that is intended to be joined to the initial substrate 100.

25 The presence or absence of silicon on the surface thus makes it possible to influence and adjust the bonding interface energy of the interfaces that are present between the initial substrate 100 and the first, temporary, bonding layer 300 and between the first, temporary, bonding layer 300 and the intermediate substrate 200. The presence or absence of silicon and thus of "silanol"-type molecular bonds on the surface determines these bonding interface energies
30 because said first, temporary, bonding layer 300 has a composition after densification such that bonds form via assimilation of said "silanol"-type molecular bonds.

According to one non-limiting example of the invention, the initial substrate 100 is chosen from the group of lithium niobate and lithium tantalate.

- 5 According to one non-limiting example of the invention, the initial substrate 100 is chosen from the group of GaAs, InP and Ge.

According to one non-limiting example of the invention, the intermediate substrate 200 is silicon.

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According to one non-limiting example of the invention, the intermediate substrate 200 is glass.

- 15 According to one non-limiting example of the invention, the intermediate substrate 200 is any substrate other than silicon but covered on the surface with a layer of polycrystalline silicon.

- 20 The initial substrate 100 on which the first, temporary, bonding layer 300 has been deposited and densified is joined to the intermediate substrate in the first joining step 1'.

- 25 After the step of thinning 2' the substrate 100, the second bonding layer 400 is deposited and densified either on the final substrate 500 or on the layer of the thinned initial substrate 100', or on both, in the second joining step 3'.

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- 30 The first and/or the second joining step (1', 3') are preferably carried out by direct bonding by molecular adhesion. The bonding is preferably carried out at ambient temperature, namely about 20°C. It is however possible to carry out the bonding hot at a temperature of between 20°C and 50°C, and more preferably between 20°C and 30°C.

Additionally, the bonding step is advantageously carried out at low pressure, i.e. at a pressure lower than or equal to 5 mTorr, which makes it possible to desorb the water from the surfaces forming the bonding interface, i.e. the surface of the electrically insulating layer 300 and the surface of the carrier substrate 100.

- 5 Carrying out the bonding step under vacuum makes it possible to improve the desorption of water at the bonding interface further still.

- 10 A heat treatment in order to strengthen the bonding interface may be carried out at low temperatures of up to 300°C without the entire assembly undergoing overly substantial deformations leading to the materials breaking or detachment at the bonding interface.

- 15 The first, temporary, bonding layer 300 according to the invention chosen from families of SOGs of "methylsiloxane" type together with the fact that the initial substrate 100 comprises substantially no silicon on the surface that is intended to be joined to the intermediate substrate 200 and the intermediate substrate 200 comprises silicon on the surface that is intended to be joined to the initial substrate 100 lead to the interface between the initial substrate 100 and the first, temporary, bonding layer 300 being weaker in terms of bonding interface energy
20 than the interface between the first, temporary, bonding layer 300 and the intermediate substrate 200.

- 25 These bonding interface energies obtained by the direct bonding between the surface of the initial substrate 100 to the intermediate substrate 200 via the first, temporary, bonding layer 300 of the present invention are high and allow the step of thinning the initial substrate 100 by chemical-mechanical polishing (CMP).

- 30 These bonding interface energies obtained are so high that the process according to the invention allows the step of thinning the initial substrate 100 by chemical-mechanical polishing (CMP) even in the case where a substantial difference in thermal expansion coefficient between the initial substrate 100 and the intermediate substrate 200 is present, which is the case for an initial substrate

100 of lithium niobate or lithium tantalate and an intermediate substrate 200 of silicon.

5 The second joining step takes place via a second bonding layer 400 of the SOG type comprising silicate or methylsilsexioquane in the liquid state and deposited by spin coating followed by a second densifying heat treatment, and in which the final substrate is designed such that it would deteriorate on application of a heat treatment exceeding 300°C. It should be noted that the bonding interface energies obtained by the direct bonding between the surface of the thinned initial
10 substrate 100' to the final substrate 500 via the second bonding layer 400 of the present invention are higher than the bonding interface energies obtained by the direct bonding between the surface of the initial substrate 100 to the intermediate substrate 200 via the first, temporary, bonding layer 300 of the present invention.

15 The detaching step 4' is carried out by a heat treatment at a temperature of less than 300°C, more preferably less than 200°C, or more preferably less than 100°C.

20 Thus, the detaching step 4' makes it possible to detach at the interface between the initial substrate 100 and the first, temporary, bonding layer 300. This interface corresponds to the initially prepared surface of the initial substrate 100 for the deposition of the first, temporary, bonding layer 300. The detaching frees this surface, and thus the components that are potentially present in the initial substrate 100, and thus allows a co-integration of components that is
25 straightforward and ready to be accessed easily after having transferred the thinned layer of the initial substrate 100'.

In addition to applying a thermal stress such as described above, a mechanical stress, for example by inserting a blade at the wafer edge, may be applied
30 instead.

According to one non-limiting example of the invention, the final substrate 500 is silicon comprising components designed such that they would deteriorate on application of a heat treatment exceeding 300°C.

- 5 According to another non-limiting embodiment, illustrated schematically in Figure 2, the final substrate 500 may be silicon material further comprising a trapping layer towards the interface to be joined with the thinned layer 100' of the initial substrate 100, making it possible to trap electric-charge carriers caused by the frequency operation of radiofrequency components. This layer thus makes it possible to decrease insertion losses and improve the performance of said devices.

- 10 According to one non-limiting example of the invention, the final substrate 500 is a flexible plastic. Together with a thinned layer of initial substrate 100' made of piezoelectric material, this allows any application comprising components for "wearable" application.

- 15 Furthermore, it should be noted that the size of the final substrate 500 is not limited and multiple transfers of different initial substrates 100 to one and the same final substrate are possible.

CLAIMS

1. Layer transfer process comprising the following steps:

a step of providing an initial substrate (100);

5 a step of providing an intermediate substrate (200);

a first step of joining (1') the intermediate substrate (200) and the initial substrate (100);

a step of thinning (2') the initial substrate (100) after having been joined to the intermediate substrate (200);

10 a step of providing a final substrate (500);

a second step of joining (3') the thinned initial substrate (100') and the final substrate (500);

a step of detaching (4') the intermediate substrate (200) after the second joining step (4');

15 characterized in that

the intermediate substrate (200) comprises silicon on the surface that is intended to be joined to the initial substrate (100);

the initial substrate (100) comprises substantially no silicon on the surface that is intended to be joined to the intermediate substrate (200);

20 depositing a first bonding layer, referred to as temporary (300), of SOG type comprising methylsiloxane in the liquid state by spin coating carried out on the surface of the initial substrate which comprises substantially no silicon followed by a first heat treatment for densifying this first, temporary, bonding layer before the first joining step;

25 the second joining step (3') is carried out via a second bonding layer (400) of SOG type comprising silicate or methylsilsexioquane in the liquid state and deposited by spin coating followed by a second densifying heat treatment;

and in that the final substrate (500) is designed such that it would deteriorate on application of a heat treatment exceeding 300°C.

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2. Process for transferring a layer according to the preceding claim, wherein the initial substrate (100) comprises components designed such that they would deteriorate on application of a heat treatment exceeding 300°C.
- 5 3. Transfer process according to one of the preceding claims, wherein the first and/or the second densifying heat treatment is carried out at a temperature of less than 300°C, preferably less than 200°C, or more preferably less than 100°C.
- 10 4. Transfer process according to one of the preceding claims, wherein the first and/or the second joining step (1', 3') is carried out by direct bonding by molecular adhesion.
- 15 5. Transfer process according to one of the preceding claims, wherein the initial substrate (100) is chosen from the group of lithium niobate and lithium tantalate.
6. Transfer process according to Claims 1 to 4, wherein the initial substrate (100) is chosen from the group of GaAs, InP and Ge.
- 20 7. Transfer process according to one of the preceding claims, wherein the intermediate substrate (200) is silicon.
8. Transfer process according to one of the preceding claims, wherein the final substrate (500) is silicon comprising components designed such that they would deteriorate on application of a heat treatment exceeding 300°C.
- 25 9. Transfer process according to one of Claims 1 to 7, wherein the final substrate (500) is a flexible plastic.
- 30 10. Transfer process according to one of the preceding claims, wherein the detaching step (4') is carried out by a heat treatment at a temperature of less than 300°C, more preferably less than 200°C, or more preferably less than 100°C.