

METHOD FOR MANUFACTURING A SUBSTRATE

FIELD OF THE INVENTION

The invention relates to a method of manufacturing a substrate comprising a support substrate 1 having a first coefficient of thermal expansion (CTE) and a useful layer having a second coefficient of thermal expansion different from the first coefficient of thermal expansion.

BACKGROUND OF THE INVENTION

The manufacture of acoustic surface wave filters (F-SAW) may comprise inter-digitated metal comb electrodes 5 formed on one side of a piezoelectric material, for example lithium tantalate LiTaO_3 as shown in FIG.1.

The geometrical characteristics of the inter-digitated comb electrodes, such as the comb size, or their spacing, determine the resonance frequency and the quality factor of the SAW filters.

In this respect, the person skilled in the art can refer to the article "recent development of temperature compensated SAW devices, Ken-ya Hashimoto et al., Ultrasonics Symposium (IUS), 2011 IEEE International, p. 79 - 86 ".

In normal use, the filters may be subjected to temperatures comprised in the range of -40°C to 85°C .

However, piezoelectric materials such as lithium tantalate have a coefficient of thermal expansion of the order of 14 in at least one of these crystallographic directions.

Consequently, the temperature variations induce a variability of the geometric characteristics of the F-SAW filters.

To overcome this problem, it is possible to position a stiffener substrate on one side of the piezoelectric material.

FIG. 2 shows a structure comprising a silicon substrate 1, a layer of LiTaO_3 3 formed on the silicon substrate, and interdigitated comb metal electrodes 5 on the free surface 4 of the LiTaO_3 layer.

The low coefficient of thermal expansion of silicon, the latter being equal to $2.6 \cdot 10^{-6}/^{\circ}\text{C}$, makes it possible to limit the expansion of the LiTaO_3 layer and consequently to limit the variations of the resonance frequency and the quality factor of the F-SAW filter. This effect will thereafter be called "thermal compensation".

The method of manufacturing a substrate comprising a layer of LiTaO_3 on a silicon substrate involves the following manufacturing steps:

- a. providing a support substrate 1, for example of silicon;
- b. the transfer of a layer of LiTaO_3 3 on one of the faces of the support substrate 1, said front face 1a;

The transfer of the LiTaO_3 layer is generally carried out by assembling a LiTaO_3 substrate with a silicon substrate, followed by a step of thinning, for example mechanical, of the LiTaO_3 substrate.

This method is however not satisfactory because it requires a strengthening of the assembly interface of the LiTaO_3 stack on silicon by heat treatment.

Indeed, the differences in thermal expansion coefficient of LiTaO_3 and silicon cause a degradation of the assembly interface, namely a detachment and/or the appearance of cracks in the LiTaO_3 layer.

The document US 2009/0267083 A1 then proposes to overcome the aforementioned drawbacks by providing a trench network on the rear face of the support substrate 1. The realization of said trenches makes it possible to limit the constraints at the assembly interface and thus to ensure the integrity of the useful layer.

This solution is not satisfactory because it does not accommodate large differences in thermal expansion coefficient.

An object of the present invention is therefore to provide a method of manufacturing a substrate adapted to withstand heat treatment while retaining the thermal compensation effect.

BRIEF DESCRIPTION OF THE INVENTION

The invention aims to solve the technical problem and relates to a method of manufacturing a substrate comprising a useful layer placed on a receiving substrate, the method comprising the following steps:

- a. Providing a support substrate with a first coefficient of thermal expansion, having on one of its faces, called the front face, a first plurality of trenches parallel to each other in a first direction, and a second plurality of trenches parallel to each other in a second direction not parallel to the first direction;
- b. Transferring a useful layer, from the donor substrate to the support substrate, the useful layer having a second coefficient of thermal expansion different from the first coefficient of thermal expansion;

the method for manufacturing **being remarkable** in that an intermediary layer is inserted between the front face of the support substrate and the useful layer, the intermediate layer having a coefficient of expansion comprised between the first and second coefficient of thermal expansion.

Therefore, the presence of the first and the second plurality of trenches allows one to break the constraint field exerting itself on the interface formed between the intermediate layer and the support substrate.

Furthermore, the presence of the intermediate layer enables limiting the effect of the difference between the first and the second coefficient of thermal expansion, while maintaining a thermal compensation effect.

In addition, the presence of the intermediate layer enables having a space between the trenches of each of the pluralities of trenches greater than the dimension of an F SAW intended to be formed on the substrate thus obtained.

According to one embodiment, step b. of transferring the useful layer comprises the assembly of the donor substrate with the support substrate, and the thinning of the donor substrate in order to form the useful layer.

According to one embodiment, the thinning of the donor substrate is carried out using mechanical thinning.

According to one embodiment, the intermediate layer is formed, before step b. of transferring the useful layer, onto the support substrate or onto the donor substrate.

According to one embodiment, the intermediate layer comprises a glass material.

According to one embodiment, the intermediate layer comprises at least one of the materials included in the list: TEOS, BPSG, PSG, USG.

According to one embodiment, the trenches of the first plurality of trenches are regularly arranged every 3 to 10 millimetres.

According to one embodiment, the trenches of the second plurality of trenches are regularly arranged every 3 to 10 millimetres.

According to one embodiment, the trenches of the first and the second plurality of trenches have a depth between 1 and 100 μm .

According to one embodiment, the trenches of the first and the second plurality of trenches have a width between 1 and 100 μm .

According to one embodiment, the useful layer comprises at least one of the materials included in the list: LiTaO_3 , LiNbO_3 .

According to one embodiment, the difference between the first coefficient of thermal expansion and the second coefficient of thermal expansion is greater than $5 \cdot 10^{-6}/^{\circ}\text{C}$, and preferably greater than $10 \cdot 10^{-6}/^{\circ}\text{C}$.

According to one embodiment, the useful layer comprises at least one of the materials included in the list: Silicon, Germanium, Silicon carbide, Alumina, Sapphire, Aluminium Nitride.

The invention also involves a substrate comprised of:

- a. a support substrate with a first coefficient of thermal expansion, having on one of its faces, called the front face, a first plurality of trenches parallel to each other in a first direction, and a second plurality of trenches parallel to each other in a second direction not parallel to the first direction;
- b. a useful layer with a second coefficient of thermal expansion different from the first coefficient of thermal expansion and arranged on the support substrate;

the substrate **being remarkable in that** an intermediate layer is inserted between the front face of the support substrate and the useful layer, the intermediate layer having a coefficient of expansion between the first and second coefficient of thermal expansion.

DESCRIPTION OF THE DRAWINGS

The invention will be better understood in light of the description which follows the embodiments, specific and non-limiting, of the invention in reference to the Figures (drawings) attached herewith among which:

- Figure 1: representation of interdigitated combs forming a filter with surface acoustic waves;
- Figure 2: representation of a substrate used for producing a filter with surface acoustic waves according to the techniques of the Prior Art;
- Figure 3: schematic representation of an embodiment of the method for manufacturing according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

For the various embodiments, the same references will be used for identical elements or ensuring the same function, in the interests of simplification of the description.

The method according to the invention comprises a step a. of providing a support substrate 10 with a first coefficient of thermal expansion.

The support substrate 10 can comprise at least one of the materials chosen from the list: Silicon, Germanium, Silicon carbide, Alumina, Sapphire, Aluminium Nitride.

The support substrate 10 presents a coefficient of thermal expansion comprised of between $2 \cdot 10^{-6}$ et $9 \cdot 10^{-6}/^{\circ}\text{C}$.

For example, a support substrate 10 in silicon presents a coefficient of thermal expansion of $2.6 \cdot 10^{-6}/^{\circ}\text{C}$.

The support substrate 10 also comprises on one of its faces, that is the front face 11, a first plurality of trenches 12. The trenches of the first plurality of trenches 12 are parallel to each other in a first direction.

The support substrate 10 can also comprised, on its front face 11, a second plurality of trenches 13 (non-represented). The trenches of the second plurality of trenches 13 are parallel to each other in a second direction. The second direction is not parallel to the first direction.

The trenches of the first plurality of trenches 12 can be regularly arranged every 3 to 10 millimetres.

The trenches of the second plurality of trenches 13 can be regularly arranged every 3 to 10 millimetres.

The trenches of the first plurality of trenches 12 can have a depth between 1 and 100 μm .

The trenches of the second plurality of trenches 13 can have a depth between 1 and 100 μm .

The trenches of the first plurality of trenches 12 and the second plurality of trenches 13 can have a width between 1 and 100 μm .

The trenches of the first plurality of trenches 12 and of the second plurality of trenches 13 can be formed by a sawing wheel generally used in the microelectronic industry. The sawing techniques using such a sawing wheel are well known by people skilled in the art.

The width of the trenches of the first and the second plurality of trenches 13 is defined by the thickness of the sawing wheel.

In addition, the depth of the trenches is also defined by the sawing depth.

The trenches of the first and second pluralities of trenches can also be achieved by the formation of an etching mask on the front face 11 of the support substrate 10. The

aforementioned etching mask designs the shape of the trenches of the first and the second plurality of trenches 13, on the front face 11 of the support substrate 10.

The etching forming the trenches is therefore executed by using a suitable etching.

For example, the support substrate 10 in silicon, the etching mask is in silicon dioxide, and the etching is carried out with the help of a KOH solution.

After the forming of the trenches of the first and of the second plurality of trenches 13, an intermediate layer 20 is formed on the front face 11 of the support substrate 10.

The intermediate layer 20 can conformally cover the front face 11 of the support substrate 10 by conforming to the shape of the trenches.

The intermediate layer 20 can have a thickness comprised between 0.5 and 50 μm .

Advantageously, the intermediate layer 20 can deform itself plastically when it is subjected to a thermal treatment with a rise in temperature.

Advantageously the intermediate layer 20 can comprise a glass material.

For example, the intermediate layer 20 can comprise at least one of the materials included in the list: borophosphosilicate glass (BPSG), tetraethyl orthosilicate oxide (TEOS oxide), phosphosilicate glass (PSG), non-doped silicate (USG).

The method according to the invention also comprises a step b., which comprises the forming of a useful layer 31 on the intermediate layer 20.

The useful layer 31 can be formed by a method of layer transfer from a donor substrate 30.

The transfer step can comprise the assembly of a donor substrate 30 with the intermediate layer 20.

The assembly step can be a step of bonding by molecular adhesion.

A step of thermal treatment can be carried out in a way to reinforce the bonding interface.

For example, a thermal treatment can be carried out at a temperature between 80°C and 150°C, preferably between 100°C and 120°C, for a period of time comprised between 30 minutes and 4 hours, under non-oxidising atmosphere, for example under nitrogen and/or argon and/or helium .

In order to reinforce the bonding interface, the donor substrate 30 surface intended to be put into contact with the intermediate layer 20 can be activated with plasma.

For example, the activation can be executed with a dioxygen plasma (O_2) or with dinitrogen (N_2), for 30 seconds, at an output of 500 Watts, and a pressure of 50 mTorr.

The assembly step is therefore followed by a thinning of the donor substrate 30. Therefore, the thinned donor substrate 30 forms the useful layer 31.

The thinning of the donor substrate 30 can be executed by using techniques well known by a person skilled in the art, such as mechanical thinning, and/or by mechanical-chemical polishing.

The useful layer 31 can therefore, following the thinning step of the donor substrate 30, have a thickness comprised between 5 and 50 μm .

According to a variant of the method of manufacturing according to the invention, the intermediate layer 20 can be formed on the donor substrate 30. In these conditions, the assembly step comprises putting in contact the intermediate layer 20 with the front face 11 of the support substrate 10.

The useful layer 31 has a second coefficient of thermal expansion different from the first coefficient of thermal expansion.

The useful layer 31 can comprise a perovskite type material.

The useful layer 31 can comprise a dielectric material, the material preferably being a ferroelectric material.

The useful layer 31 can comprise at least one of the materials included in the list: LiTaO_3 , LiNbO_3 .

According to the invention, the intermediate layer 20 has a coefficient of thermal expansion between the first coefficient of thermal expansion and the second coefficient of thermal expansion.

The difference between the first coefficient of thermal expansion and the second coefficient of thermal expansion is greater than $5 \cdot 10^{-6}/^\circ\text{C}$, and preferably greater than $10 \cdot 10^{-6}/^\circ\text{C}$.

For such differences in thermal expansion coefficients, the method according to the invention enables to ensure the integrity of the package comprising the

support substrate 10, the intermediate layer 20 and the useful layer 31 at the time of thermal annealing.

In this way, the presence of the intermediate layer 20 enables limiting the effect of the difference between the first and the second coefficient of thermal expansion, while maintaining a thermal compensation effect.

In addition, the presence of at least the first plurality of trenches 12 on the front face 11 of the support substrate 10 enables disrupting the continuity of the constraints present at the interface formed by the intermediate layer 20 and said front face 11.

Therefore, taken in combination, the effect of the intermediate layer 20 and the presence of the at least first plurality of trenches 12 enables limiting the constraints exerting on the interfaces formed on the one hand, by the useful layer 31 and the intermediate layer 20, and on the other hand, by the intermediate layer 20 and the support substrate 10.

First embodiment

According to a first embodiment, the invention comprises the provision of a support substrate 10 in Silicon.

The first plurality of trenches 12 is achieved with a sawing wheel. The trenches of the first plurality of trenches 12 are spaced from each other by 3mm, have a depth of 100 μm , and a width of 100 μm .

The intermediate layer 20, formed directly on the front face 11 of the support substrate 10, is in borophosphosilicate glass, and its thickness is between 0.5 and 50 μm , for example 2 μm .

The intermediate layer 20 conforms to the topography of the front face 11 of the support substrate 10.

Still according to the first embodiment, a donor substrate 30 of LiTaO_3 is provided.

The surface of the donor substrate 30 intended to be placed in contact with the intermediate layer 20 is activated by plasma comprising dioxygen.

The surface of the activated donor substrate 30 is therefore assembled with the intermediate layer 20 by molecular adhesion.

The assembly interface formed by the donor substrate 30 and the intermediate layer 20 is reinforced by a thermal annealing carried out at 100°C for a period of 3 hours under an argon atmosphere.

The donor substrate 30 is then thinned mechanically to a thickness of 20 μm , in order to form the useful layer 31.

Second embodiment

The second embodiment differs from the first embodiment in that the intermediate layer 20 is formed on the donor substrate 30 rather than on the front face 11 of the support substrate 10 and in that the plasma activation is achieved on the front face 11 of the support substrate 10.

CLAIMS

1. Method for manufacturing a substrate comprising a useful layer (31) arranged on a receiving substrate, the method comprising the following phases:
 - a. Providing a support substrate (10) presenting a first coefficient of thermal expansion, having on one of its faces, called the front face (11), a first plurality of trenches (12) parallel to each other in a first direction, , and a second plurality of trenches (13) parallel to each other in a second direction not parallel to the first direction;
 - b. Transferring a useful layer (31), from the donor substrate (30), on the support substrate (10), the useful layer (31) having a second coefficient of thermal expansion different from the first coefficient of thermal expansion;the method for manufacturing being characterised in that an intermediate layer is inserted between the front face (11) of the support substrate (10) and the useful layer (31), the intermediate layer (20) having a coefficient of expansion comprised between the first and second coefficient of thermal expansion.
2. Method for manufacturing according to claim 1, in which phase b. of transfer of the useful layer (31) comprises the assembly of the donor substrate (30) with the support substrate (10), and the thinning of the donor substrate (30) in order to form the useful layer (31) .
3. Method for manufacturing according to claim 2, in which the thinning of the donor substrate (30) is carried out by mechanical thinning.
4. Method for manufacturing according to one of claims 1 to 3, in which the intermediary layer (20) is formed, before phase b. of transfer of the useful layer (31), on the support substrate (10) or on the donor substrate (30).
5. Method for manufacturing according to one of claims 1 to 4, in which the intermediate layer (20) comprises glass material.
6. Method for manufacturing according to claim 5, in which the intermediate layer (20) comprises at least one of the materials included in the list: TEOS, BPSG, PSG, USG.
7. Method for manufacturing according to one of claims 1 to 6, in which the trenches of the first plurality of trenches (12) are regularly arranged every 3 to 10 millimetres.
8. Method for manufacturing according to one of claims 1 to 7, in which the trenches of the second plurality of trenches (13) are regularly arranged every 3 to 10 millimetres.

9. Method for manufacturing according to one of claims 1 to 8, in which the trenches of the first and second plurality of trenches have a depth between 1 and 100 μm .
10. Method for manufacturing according to one of claims 1 to 9, in which the trenches of the first and second plurality of trenches (13) have a width of between 1 and 100 μm .
11. Method for manufacturing according to claims 1 to 10, in which the intermediate layer (31) comprises at least one of the materials included in the list: LiTaO_3 , LiNbO_3 .
12. Method for manufacturing according to one of claims 1 to 11, in which the difference between the first coefficient of thermal expansion and the second coefficient of thermal expansion is greater than 5, preferably greater than 10.
13. Method for manufacturing according to claims 1 to 12, in which the support substrate (10) comprises at least one of the materials included in the list: Silicon, Germanium, Silicon carbide, alumina, sapphire, aluminium nitride.
14. Substrate comprising:
 - c. a support substrate (10) having a first coefficient of thermal expansion, and comprising on one of its faces, called the front face (11), a first plurality of trenches (12) parallel to each other in a first direction, and a second plurality of trenches (13) parallel to each other in a second direction not parallel to the first direction;
 - d. a useful layer (31) having a second coefficient of thermal expansion different from the first coefficient of thermal expansion and arranged on the support substrate (10);the substrate being characterised in that an intermediate layer is inserted between the front face (11) of the support substrate (10) and the useful layer (31), the intermediate layer (20) having a coefficient of expansion comprised between the first and second coefficient of thermal expansion.