

HYBRID STRUCTURE FOR SURFACE ACOUSTIC WAVE DEVICE

FIELD OF THE INVENTION

The present invention relates to the field of surface acoustic wave devices. It relates in particular to a hybrid structure suitable for the production of surface acoustic wave devices.

BACKGROUND OF THE INVENTION

Acoustic resonator structures such as surface acoustic wave (SAW) devices use one or more interdigital transducers set in a piezoelectric substrate to convert electric signals into acoustic waves and vice versa. Such SAW devices or resonators are often used in filtering applications. Radio frequency (RF) SAW technology has high performances such as high insulation and low insertion losses. For this reason, it is widely used for RF duplexers in wireless communication applications. Nevertheless, to be more competitive with respect to bulk acoustic wave (BAW) duplexers, the performance of RF SAW devices needs to improve and, in particular, it is required that their frequency response be stable with respect to the temperature.

SAW device operating frequencies are temperature-dependent, in other words, the temperature coefficient frequency (TCF) depends partially on variations in the transducer interdigital electrode spacing, which are in turn generally due to relatively high coefficients of

thermal expansion (CTE) in the piezoelectric substrates used; in addition, the TCF depends on the coefficient of thermal velocity, since the expansion or contraction of the piezoelectric substrate is accompanied by an
5 acceleration or deceleration of the surface acoustic wave. A possible target in minimising the thermal coefficient frequency (TCF) is to minimise the expansion/contraction of the piezoelectric substrate, especially in the surface area in which the acoustic
10 waves are going to be propagated.

The article by K. Hashimoto, M. Kadota et al, "Recent Development of Temperature Compensated SAW Devices", IEEE Ultrason. Symp. 2011, pages 79 to 86, 2011, gives an overview of current approaches to overcoming
15 temperature dependence in SAW device frequency responses.

One approach consists in using a hybrid substrate, for example by spreading a piezoelectric layer over a silicon substrate. The low CTE of silicon helps limit
20 the temperature-based expansion/contraction of the piezoelectric layer. In the case of a piezoelectric layer of lithium tantalate (LiTaO₃), the previously cited article indicates that a ratio of 10 between the thickness of LiTaO₃ and the thickness of the silicon
25 substrate allows for an adequate improvement of the thermal coefficient frequency (TCF). One of the drawbacks of this approach is due to the presence of spurious acoustic waves (called "spurious acoustic modes" in the article "Characterization of bonded wafer

for RF filters with reduced TCF", B.P.Abbott et al, Proc 2005 IEEE International Ultrasonics Symposium, Sept 19-21, 2005, pages 926-929) which have a negative impact on the frequency characteristics of the resonator produced on the hybrid substrate. These spurious resonances are, in particular, linked with spurious reflections of the main acoustic wave (propagating mainly in a surface area of the layer of LiTaO3) on the underlying interfaces, and thus in particular the interface between the LiTaO3 and the silicon. One solution for reducing these spurious resonances is to increase the thickness of the layer of LiTaO3; this involves also increasing the thickness of the Si substrate to conserve the improvements of the TCF. In this case, the overall thickness of the hybrid substrate is no longer compatible with the need to reduce the thickness of the final components, in particular to target the cellular telephone market. Another solution, proposed by K. Hashimoto et al. consists of roughening the lower surface of the LiTaO3 layer (at the bonding interface with the substrate) so as to reduce the reflections of the acoustic wave on same. This roughening is one difficulty that needs to be managed when a direct bonding method, requiring very smooth assembly surfaces, is used for producing the hybrid substrate.

AIM OF THE INVENTION

One aim of the present invention is to provide an alternative solution to the solutions of the prior art.

One aim of the invention is, in particular, to propose a hybrid structure allowing the reduction and/or elimination of said spurious acoustic waves.

BRIEF DESCRIPTION OF THE INVENTION

5 The present invention relates to a hybrid structure for a surface acoustic wave device comprising a useful piezoelectric layer having a first free face and a second face disposed on a support substrate that has a lower coefficient of thermal expansion than that of the
10 useful layer. The hybrid structure is characterised in that the useful layer comprises an area of nanocavities.

The area of nanocavities is suitable for diffusing an acoustic wave propagating in the thickness of the
15 useful layer until said area; it reduces or even eliminates the spurious reflections of the acoustic wave, which generally occur at the one or more interfaces of the hybrid structure and have a negative impact on the frequency characteristics of the SAW
20 device.

Moreover, the area of nanocavities is formed in the thickness of the useful layer and does not affect the roughness of the second face, and this facilitates and improves the reliability of the assembly of the useful
25 layer on the support substrate.

According to advantageous characteristics of the invention, taken either separately or in combination:

- the area of nanocavities has a functional thickness of 50 nm to 3 microns;
- the area of nanocavities is closer to the second face than to the first face of the useful layer;
- 5 • the area of nanocavities is located at a distance of more than 50 nm from the second face of the useful layer;
- the nanocavities have, at least in part, a maximum dimension of 1 nm to 500 nm;
- 10 • the nanocavities take up 10% to 20% of the volume in the area of nanocavities;
- the nanocavities are substantially spherical or polyhedral;
- all or part of the nanocavities contain a gas;
- 15 • the area of nanocavities extends in a plane parallel to the second face of the useful layer;
- the area of nanocavities is continuous in a plane parallel to the second face of the useful layer;
- the area of nanocavities is discontinuous in a plane parallel to the second face of the useful layer;
- 20 • the support substrate comprises a material chosen among silicon, glass, silica, sapphire, alumina, aluminium nitride and silicon carbide;
- the useful layer comprises a piezoelectric material chosen among lithium tantalate (LiTaO_3), lithium niobate (LiNbO_3), quartz and zinc oxide (ZnO);
- 25 • the hybrid structure comprises an intermediate layer located between the second face of the useful layer and the support substrate.

The present invention also relates to a surface acoustic wave device comprising a hybrid structure as above. The frequency of the acoustic waves is advantageously comprised between 700 MHz and 3 GHz.

5 The present invention finally relates to a method for manufacturing a hybrid structure for a surface acoustic wave device comprising:

- a) A step of providing a useful piezoelectric layer having a first face and a second face;
- 10 b) A step of providing a support substrate that has a lower coefficient of thermal expansion than that of the useful layer;
- c) A step of assembling the second face of the useful layer on the support substrate.

15 The method is characterised in that it comprises a step of introduction of gaseous species into the useful layer to form an area of nanocavities.

According to advantageous characteristics of the invention, taken either separately or in combination:

- 20 • the useful layer provided in step a) is comprised in a piezoelectric donor substrate;
- the manufacturing method comprises, after the assembly step, a step d) of thinning the donor substrate to a thickness that is useful for forming the
- 25 useful layer;
- the gaseous species introduction step comprises at least one implantation of ions chosen among

hydrogen, helium, argon and other noble gases;

- The manufacturing method comprises a thermal-treatment step after the gaseous species introduction step;
- 5 • the introduction of gaseous species into the useful layer is carried out on the second face thereof, before the assembly step;
- the introduction of gaseous species into the useful layer is carried out on the first face thereof,
- 10 after the assembly step;
- the introduction of gaseous species into the useful layer is carried out locally by applying a mask.

BRIEF DESCRIPTION OF THE DRAWINGS

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

- figure 1 shows a hybrid structure according to the invention;
- figures 2a to 2e show a cross-section view (2a)
 20 and top views (2b to 2e) of hybrid structures according to the invention;
- figure 3 shows a hybrid structure according to the invention;
- figure 4 shows a surface acoustic wave device
 25 according to the invention;
- figures 5a to 5e show a method for manufacturing a hybrid structure according to a first embodiment;
- figures 6a and 6b show a method for manufacturing

a hybrid structure according to a second embodiment;

- figures 7a to 7c show a method for manufacturing a hybrid structure according to a third embodiment.

5 DETAILED DESCRIPTION OF THE INVENTION

In the descriptive part, the same references in the figures can be used for elements of the same type.

The figures are schematic representations which, for the sake of clarity, are not to scale. In particular,
10 the thicknesses of the layers according to the Z axis are not to scale relative to the lateral dimensions according to the X and Y axes. Likewise, the size of the nanocavities is not to scale relative to the layer thicknesses or other lateral dimensions of elements of
15 the invention.

The invention relates to a hybrid structure 100 for a surface acoustic wave device comprising a useful piezoelectric layer 10 having a first free face 1 and a second face 2 disposed on a support substrate 20. The
20 useful layer 10 typically has a useful thickness of 1 micron to 50 microns, according to the type of SAW device to be produced on the hybrid structure 100. The useful layer 10 advantageously comprises a piezoelectric material chosen from lithium tantalate
25 (LiTaO₃), lithium niobate (LiNbO₃), quartz and zinc oxide (ZnO).

The support substrate 20 of the hybrid structure 100 has a lower coefficient of thermal expansion than that of the useful layer 10, at least along a crystallographic axis in the case of anisotropic materials. It may comprise a material chosen among silicon, glass, silica, sapphire, alumina, aluminium nitride and silicon carbide.

Evidently, this list of materials is not exhaustive, and other substrates or useful piezoelectric layers may be chosen according to the type of applications and the properties required.

The hybrid structure 100 also comprises an area 30 of nanocavities 31, in the useful layer 10, as shown in figure 1.

The nanocavities 31 preferably have a substantially spherical, polyhedral or ellipsoidal shape. This shape is advantageous in that it promotes multidirectional reflection and thus the diffusion of acoustic waves likely to propagate in the thickness of the useful layer 10, preventing them from reflecting on a planar surface such as the interface between the useful layer 10 and the support substrate 20. The nanocavities 31 can be empty or contain a gas or even a mixture of gases.

The nanocavities 31 typically have a maximum size of 1 nm to 500 nm; maximum size being understood to be, for example, the diameter of the nanocavity if it is

spherical or the largest diameter if it is slightly ellipsoidal. The density of nanocavities 31 in the area 30 is such that they preferably take up 10% to 20% of the volume of said area 30. The size and the density of the nanocavities 31 can affect the acoustic wave diffusion efficiency. Thus, the size and density parameters of the nanocavities 31 can be adjusted according to the frequency of the acoustic wave(s) propagating in the device to be produced on the hybrid structure 100.

The area 30 of nanocavities 31 advantageously has a so-called functional thickness e of 50 nm to 3 microns, along the Z axis in figure 1. The functional thickness e is advantageously chosen to be equal to or substantially smaller than the wavelength λ of the acoustic signal used for the SAW device, for example comprised between λ and $\lambda/8$. On the other hand, the maximum mean diameter of the nanocavities will preferably be chosen to be smaller than or equal to the wavelength λ of the acoustic wave, typically comprised between $\lambda/10$ and λ . This configuration promotes the interaction between the acoustic wave and the area 30 of nanocavities 31. In particular, the acoustic wave portion that usually reflects off the interfaces of the hybrid structure will be advantageously diffused by the area 30, resulting in strongly limiting or even eliminating the reflected component of the acoustic wave that is the source of the spurious effects.

The area 30 of nanocavities 31 is preferably near the second face 2 of the useful layer 10. In particular, it may be placed at a distance of the order of 50 nm from the second face 2. It may, as an alternative, be placed at a distance comprised between a few nm and around 30% of the useful thickness. For example, for a useful layer 10 with a useful thickness of 10 microns, the area 30 may be located at a distance of 50 nm to 3 microns from the second face 2.

The area 30 of nanocavities advantageously extends in a plane parallel to the second face 2 of the useful layer 10. It may be continuous in the useful layer 10, i.e. present throughout the hybrid structure 100. This configuration grants plenty of scope for positioning the SAW device on the hybrid structure 100.

As an alternative, the area 30 of nanocavities 31 can be discontinuous and only have a local presence, in certain regions of the useful layer 10, as shown in figure 2a. By way of non-limiting example, when viewed from above, the area 30 of nanocavities 31 can adopt the shape of strip patterns (figure 2b), circular patterns (figure 2c), regions complementing circular patterns (figure 2d) or even square patterns (figure 2e). A dimension, in the plane (x,y), of the regions comprising the area 30 of nanocavities, is preferably comprised between 1 and 10 microns.

The discontinuity of the area 30 of nanocavities 31 can offer advantages in the case of acoustic waves with

long wavelengths (of the order of 5 microns and more); indeed, the presence of larger patterns with larger periods than the nanocavities 31 can promote the interaction of the acoustic wave with the discontinuous area 30 and thus improve the diffusion of the wave.

According to another embodiment, the local area 30 of nanocavities can be present only in the regions on which the electrodes of the SAW device will be produced, the acoustic waves propagating between said electrodes.

The hybrid structure 100 according to the invention can likewise include an intermediate layer 40, disposed between the second face 2 of the useful layer 10 and the support substrate 20 (figure 3). This intermediate layer 40 is, for example, made of a material chosen among silicon oxide, silicon nitride, amorphous or polycrystalline silicon, etc. The intermediate layer 40 can have a function (electrical insulation, trapping of charge carriers, etc.) in the future SAW device, which will be produced on the hybrid structure 100. It can also be used to facilitate the assembly between the useful layer 10 and the support substrate 20, in particular for reinforcing the bonding energy of the assembly interface.

The hybrid structure 100 according to the invention is suitable for the production of a surface acoustic wave device 200, a simplified representation of which is provided in figure 4. Such a device 200 comprises, in

particular, metal electrodes 50 disposed on the first face 1 of the useful layer 10. One or more acoustic waves will be propagated between the electrodes 50 during the operation of the device 200.

5 The area 30 of nanocavities 31 of the hybrid structure 100 is suitable for diffusing an acoustic wave propagating in the thickness of the useful layer 10 until said area 30; it reduces or even eliminates the spurious reflections of the acoustic wave, which
10 generally occur at the one or more interfaces of the hybrid structure 100 and have a negative impact on the frequency characteristics of the SAW device 200.

The hybrid structure 100 according to the invention is particularly suited to the production of SAW devices
15 200 using acoustic wave frequencies of 700 MHz to 3 GHz.

The present invention further relates to a method for manufacturing a hybrid structure 100 for a surface acoustic wave device 200 comprising a first step of
20 providing a useful piezoelectric layer 10 having a first face 1 and a second face 2. The manufacturing method likewise includes a step of providing a support substrate 20 that has a lower coefficient of thermal expansion than that of the useful layer 10. It also
25 comprises a step of assembling the second face 2 of the useful layer 10 on the support substrate 20. As is known per se, different assembly techniques may be implemented, including bonding by molecular adhesion,

bonding by adhesive, or any other type of bonding suited to the production of a hybrid structure. An intermediate layer 40 can be added prior to the assembly, either on the second face 2 of the useful layer 10, or on the face to be assembled of the support substrate 20, or on both. This intermediate layer 40 is, for example, made of silicon oxide, silicon nitride or even polycrystalline silicon and has a thickness comprised between a few nanometres and a few microns. The intermediate layer 40 can be produced according to various techniques that are known in the prior art, such as thermal oxidation or nitridation treatments, chemical depositions (PECVD, LPCVD, etc.), and so on.

The manufacturing method according to the invention also comprises a step of introducing gaseous species into the useful layer 10 to form an area 30 of nanocavities 31. This step can be carried out before or after the step of assembling the useful layer 10 onto the support substrate 20. The gaseous species introduction step advantageously comprises at least one implantation of ions chosen among hydrogen, helium, argon and other noble gases. It is obviously possible to use other gases, capable of forming nanocavities 31 in the useful layer 10.

As is generally known for a person skilled in the art, the implantation energy is chosen as a function of the sought depth for the area 30 of nanocavities 31. The dose of implanted ions is chosen among the range that makes it possible to form nanocavities 31 in the

material of the useful layer 10, with a size and density advantageously allowing the nanocavities 31 to take up 10% to 20% of the volume in the area 30. The dose of implanted ions is likewise chosen to be lower than the dose that is likely to generate deformations or other damage on either one of the faces 1, 2 of the useful layer 10.

According to the chosen functional thickness of the area 30 of nanocavities 31, one or more ion implantation steps may be carried out in the active layer (10), with different implantation energies, in order to widen the implantation profile and thus said functional thickness or with the aim of forming a specific profile different from the substantially Gaussian profile generated by a single implantation.

According to one alternative, the gaseous species introduction step can be carried out locally in the useful layer 10. For this purpose, it is common to use a masking layer, deposited on the face of the useful layer 10 to be implanted, which protects regions in which it is sought to form the area 30 and which exposes regions in which the area 30 must be formed. It is thus possible to obtain a hybrid structure 100 such as those shown in figures 2a to 2e.

The manufacturing method can advantageously comprise a thermal-treatment step subsequent to the gaseous species introduction, making it possible to remove, at least partially, the gases from the useful layer 10 and

in particular to form and/or stabilise the nanocavities 31 in the material. This thermal treatment may, for example, be carried out at a temperature of 200°C to 900°C, during a period ranging from a few minutes to a few hours. The thermal treatment temperature will preferably be chosen to be lower than the Curie temperature of the piezoelectric material of the useful layer 10.

Specific embodiments of the manufacturing method will now be described in reference to figures 5, 6 and 7.

According to a first embodiment of the invention, the first step of the method consists of providing a donor substrate 11 made of piezoelectric material (figure 5a), including the useful layer 10. The donor substrate 11 comprises a first face 1' and a second face 2. For example, it may consist of a piezoelectric material chosen among lithium tantalate (LiTaO₃), lithium niobate (LiNbO₃), quartz and zinc oxide (ZnO).

The support substrate 20, which has a lower coefficient of thermal expansion than that of the donor substrate 11, is provided in a second step of the method (figure 5b). As indicated above, it may, for example, comprise a material chosen among silicon, glass, silica, sapphire, alumina, aluminium nitride and silicon carbide.

Prior to the assembly step, the gaseous species introduction step is carried out on the second face of

the donor substrate 11, as shown in figure 5c. It thus generates a buried area, the thickness and the depth of which is dependent on the energy and the dose of ion implantation, as well as on the nature of the donor substrate 11. This buried area will form the area 30 of nanocavities 31. According to whether the implantation is carried out entirely on the second face 2 or locally, the area 30 will be either continuous or discontinuous, in a plane parallel to the second face 2.

The nanocavities 31 are either directly present after implantation, or formed and stabilised by a subsequent thermal-treatment step. This thermal-treatment step also has the advantage, in the present embodiment, of diffusing outwards all or part of the gases of the donor substrate 11, prior to the assembly, which can in particular prevent degassing at the bonding interface, which is likely to degrade the mechanical strength and/or the quality thereof.

A step of assembling the second face 2 of the donor substrate 11 onto the support substrate 20 is then carried out (figure 5d). Bonding by molecular adhesion is an advantageous technique in that it does not require the addition of material in order to assemble the surfaces. It does, however, require a good surface condition (good flatness, low roughness, excellent cleanliness) to produce a high-quality assembly. The formation of the area 30 of nanocavities 31 according to the invention does not degrade the quality of the

second face 2; the gaseous species introduction step is defined so that the buried area does not generate any deformation or damage on the second face 2 to be assembled.

5 To consolidate the bonding interface, the bonded hybrid structure 101 advantageously undergoes a thermal treatment. It should be noted that the materials of the donor substrate 11 and the support substrate 20 have very different coefficients of thermal expansion. The
10 thermal treatment applied thus must remain at a temperature lower than the temperature at which the bonded structure 101 would be broken or damaged. The temperature range will typically be comprised between a few tens of degrees and 500°C.

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The manufacturing method according to this first embodiment of the invention also comprises a step of thinning the donor substrate 11, by the first face 1' thereof, so as to obtain a so-called useful thickness
20 of the useful layer 10 and to form the first free face 1 (figure 5e). This useful thickness depends on the type of acoustic wave device that will be produced on the hybrid structure 100.

The thinning step can be based on known grinding,
25 chemical mechanical polishing (CMP) and/or chemical etching (wet or dry) techniques. These methods are particularly suitable for forming thick useful layers,

for example from a few microns to several tens of microns, and up to a few hundred microns.

To form a thin useful layer 10, i.e. with a thickness of typically less than 2 microns, other layer-transfer methods may be implemented, including the Smart Cut™ method. This is based on an implantation of light ions of hydrogen and/or helium into the donor substrate 11 to form a fragilized buried layer, at a depth relative to the second face 2 that is no smaller than the useful thickness. This implantation step can be carried out prior to the assembly step, before or after the formation of the area 30 of nanocavities 31.

A step of detachment, after the assembly on the support substrate 20, then makes it possible to separate a thin surface layer from the donor substrate 11 (the useful layer 10), at the fragilized buried layer. Finishing steps, which may include thermal treatments and/or thinning by chemical etching or polishing, finally provide the required crystalline and surface quality to the useful layer 10. This method is particularly well suited to the production of thin useful layers.

According to a second embodiment of the invention, the step of introducing gaseous species into the useful layer 10 is performed after the assembly step. A hybrid structure 100' comprising the useful layer 10 disposed on the support substrate 20 is subjected to the gaseous species introduction step to form the area 30 of nanocavities 31 (figure 6a). The energy of the ions, in

the case of an implantation, is advantageously chosen so that the area 30 is formed in the lower third of the useful layer 10, close to the second face 2.

5 A thermal treatment may be carried out in order to form and/or stabilise the nanocavities 31 of the area 30. This thermal treatment must take into account the difference in the coefficient of thermal expansion of the materials that make up the hybrid structure 100, shown in figure 6b.

10 According to a third embodiment of the invention, during the first supply step of the method, the first face 1 of the useful layer 10 is disposed on a temporary substrate 60 (figure 7a). It is advantageously transferred by the Smart Cut method and
15 thus includes a residue of the fragilized buried layer on its second face 2.

An intermediate layer 40 is preferably deposited on the second face 2 of the useful layer 10 prior to the assembly thereof on the support substrate 20 (figure
20 7b).

The temporary substrate 60 is then removed, either by mechanical or chemical thinning, or by removal at the interface between the first face 1 of the useful layer 10 and the temporary substrate 60.

25 Figure 7c shows the hybrid structure 100 obtained: the residue of the fragilized buried layer, formed during the Smart Cut method, makes it possible to generate the

area 30 of nanocavities 31, in this embodiment, near the second face 2 of the useful layer 10.

This third embodiment is advantageous when the coefficients of thermal expansion (CTE) of the materials of the hybrid structure 100 make it difficult to directly apply the Smart Cut method to transfer a thin useful layer 10 onto the support substrate 20. In this case, the useful layer 10 is first formed on a temporary substrate 60 (which can have the same CTE as the useful layer 10 or an intermediate CTE between that of the useful layer 10 and that of the support substrate 20), and then transferred onto the support substrate 20. The implantation of light ions required for the Smart Cut method is then used to form the area 30 of nanocavities 31, avoiding any additional steps. In this third embodiment, however, there is little flexibility in the functional thickness of the area 30 and in the characteristics (dimensions, density, etc.) of the nanocavities 31, since the implantation parameters are dictated initially by the Smart Cut method.

Example 1:

A donor substrate 11 made of LiNbO₃ is implanted, on its second face 2, with helium ions, having an energy of 180 keV and a dose of $3.5 \cdot 10^{16}$ He/cm². A protective layer, for example made of SiO₂, is advantageously deposited on the second face 2, prior to the

implantation, in order to limit the contamination of the donor substrate 11 during the implantation step.

Such an implantation typically forms an area 30 of nanocavities 31 with a functional thickness of the order of 700 nm, at a distance of the order of 350 nm from the second face 2.

The protective layer is removed by chemical etching.

A thermal treatment at 700°C during 2 hours is carried out to stabilise the nanocavities 31 and remove all or part of the helium from the donor substrate 11.

The donor substrate 11 and a support substrate 20 made of silicon, for example with thicknesses of 350 microns and 625 microns, respectively, then undergo cleaning sequences, before being assembled by molecular adhesion, thus forming a bonded hybrid structure 101. The face 2 of the donor substrate 11 is of very high quality, compatible with direct bonding, and the implantation of gases to form the area 30 does not generate any surface deformations or damage.

Consecutive steps of grinding and polishing are applied to the first face 1' of the donor substrate 11, until obtaining the useful layer 10, with a useful thickness of 20 microns. The hybrid structure 100 according to the invention is thus formed.

This structure is suited to the production of a surface acoustic wave device 200, including in particular the

formation of interdigital metal electrodes 50 on the first face 1 of the useful layer 10. The presence of the area 30 of nanocavities 31 according to the invention makes it possible to attenuate or even
5 eliminate the spurious reflections of acoustic waves on the interface between the useful layer 10 and the support substrate 20: the acoustic waves propagating towards said interface are reflected in multiple directions, and thus diffused by the plurality of
10 nanocavities 31 forming the area 30.

Example 2:

A masking layer is formed on the second face 2 of a donor substrate 11 made of LiTaO_3 , resulting in masked regions and exposed regions. The exposed regions form,
15 for example, circular blocks, as shown viewed from above in figure 2c, separated from one another by masked regions. The exposed regions have a diameter of 5 microns, the separation between two adjacent exposed regions also being 5 microns.

20 The donor substrate 11 is then implanted on the second face 2 thereof, with helium ions, consecutively, with several energy levels: 140 keV, 160 keV, 180 keV and with a dose of $2 \cdot 10^{16}$ He/cm² applied for each energy level.

25 The masking layer is removed by chemical etching.

A thermal treatment at 580°C during 2 hours is carried out to stabilise the nanocavities 31 and remove all or part of the gases from the donor substrate 11.

5 The donor substrate 11 and a support substrate 20 made of silicon then undergo cleaning sequences, before being assembled by molecular adhesion, thus forming a bonded hybrid structure 101. The face 2 of the donor substrate 11 is of very high quality, compatible with direct bonding, and the implantation of gases to form
10 the area 30 does not generate any surface deformations or damage.

Consecutive steps of grinding and polishing are applied to the first face 1' of the donor substrate 11, until obtaining the useful layer 10, with a useful thickness
15 of 20 microns. The hybrid structure 100 according to the invention is thus formed.

This structure is suited to the production of a surface acoustic wave device 200, including in particular the formation of interdigital metal electrodes 50 on the
20 first face 1 of the useful layer 10. The presence of the area 30 of nanocavities 31 according to the invention makes it possible to attenuate or even eliminate the spurious reflections of acoustic waves on the interface between the useful layer 10 and the
25 support substrate 20: the acoustic waves propagating towards said interface are reflected in multiple directions, and thus diffused by the plurality of nanocavities 31 forming the area 30.

CLAIMS

1. A hybrid structure (100) for a surface acoustic wave device comprising a useful piezoelectric layer (10) having a first free face (1) and a second face (2) disposed on a support substrate (20) that has a lower coefficient of thermal expansion than that of the useful layer (10), the hybrid structure (100) being characterised in that the useful layer (10) comprises an area (30) of nanocavities (31).
2. The hybrid structure (100) for a surface acoustic wave device according to the preceding claim, wherein the area (30) of nanocavities (31) has a functional thickness of 50 nm to 3 microns.
3. The hybrid structure (100) for a surface acoustic wave device according to one of the preceding claims, wherein the area (30) of nanocavities (31) is located at a distance of more than 50 nm from the second face (2) of the useful layer (10).
4. The hybrid structure (100) for a surface acoustic wave device according to one of the preceding claims, wherein the nanocavities (31) have, at least in part, a maximum size of 1 nm to 500 nm.
5. The hybrid structure (100) for a surface acoustic wave device according to one of the preceding claims, wherein the area (30) of nanocavities (31) extends in a plane parallel to the second face (2) of the useful layer (10).

6. The hybrid structure (100) for a surface acoustic wave device according to one of the preceding claims, wherein the support substrate (20) comprises a material chosen among silicon, glass, silica, sapphire, alumina, aluminium nitride and silicon carbide.
7. The hybrid structure (100) for a surface acoustic wave device according to one of the preceding claims, wherein the useful layer (10) comprises a piezoelectric material chosen among lithium tantalate (LiTaO_3), lithium niobate (LiNbO_3), quartz and zinc oxide (ZnO).
8. The hybrid structure (100) for a surface acoustic wave device according to one of the preceding claims, comprising an intermediate layer (40) located between the second face (2) of the useful layer (10) and the support substrate (20).
9. A surface acoustic wave device (200) comprising a hybrid structure (100) according to one of the preceding claims.
10. A method for manufacturing a hybrid structure (100) for a surface acoustic wave device comprising:
- a) A step of providing a useful piezoelectric layer (10) having a first face (1) and a second face (2);
 - b) A step of providing a support substrate (20)

that has a lower coefficient of thermal expansion than that of the useful layer (10);

c) A step of assembling the second face (2) of the useful layer (10) on the support substrate (20);

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The method being characterised in that it comprises a step of introducing gaseous species into the useful layer (10) to form an area (30) of nanocavities (31).

10 11. The method for manufacturing a hybrid structure (100) according to the preceding claim, wherein the step of introducing gaseous species comprises at least one implantation of ions chosen among hydrogen, helium, argon and other noble gases.

15 12. The method for manufacturing a hybrid structure (100) according to one of the two preceding claims, comprising a thermal-treatment step after the step of introducing gaseous species.

20 13. The method for manufacturing a hybrid structure (100) according to one of the three preceding claims, wherein the introduction of gaseous species into the useful layer is carried out locally by applying a mask.