DESCRIPTION

TITLE: PROCESS FOR FABRICATING A COMPOSITE STRUCTURE COMPRISING A THIN LAYER MADE OF SINGLE-CRYSTAL SiC ON A CARRIER SUBSTRATE MADE OF POLYCRYSTALLINE SiC

FIELD OF THE INVENTION

The present invention relates to the field of semiconductor materials for microelectronic components. The invention relates in particular to a process for fabricating a composite structure comprising a thin layer of single-crystal silicon carbide on a carrier substrate made of polycrystalline silicon carbide.

TECHNOLOGICAL BACKGROUND OF THE INVENTION

SiC is increasingly widely used to fabricate innovative power devices, to meet the needs of growing fields of application of electronics, such as electric vehicles in particular.

Power devices and integrated power-supply systems based on single-crystal silicon carbide are able to manage a much higher power density than their conventional silicon equivalents, and to do so with active regions of smaller size. In order to further limit the dimensions of power devices on SiC, it would be advantageous to fabricate vertical components rather than lateral components. To do this, vertical electrical conduction, between an electrode placed on the front face of the SiC structure and an electrode placed on the back face, must be permitted by said structure.

Nevertheless, high-quality single-crystal SiC (c-SiC) substrates intended for the microelectronics industry remain expensive and difficult to supply in large sizes. It is thus advantageous for layer transfer solutions to be used to produce composite structures typically comprising a thin layer

of single-crystal SiC (obtained from the high-quality c-SiC substrate) on a lower cost carrier substrate, for example made of polycrystalline SiC (p-SiC).

One well-known thin-layer transfer solution is the Smart Cut® process, which uses implantation of light ions in a single-crystal donor substrate, and joining by direct bonding, at a bonding interface, to a carrier substrate. The transfer of the thin layer, derived from the donor substrate, to the carrier substrate is carried out by means of a fracture along a buried weak plane generated by the implantation of light ions.

Another known transfer solution, in particular for silicon substrates, is the Eltran® process, which involves a porous layer on which the thin single-crystal layer is grown epitaxially, and joining by direct bonding to the carrier substrate. The transfer of the thin layer to the carrier substrate is carried out by means of a separation in the porous layer.

OBJECTIVE OF THE INVENTION

The present invention relates to an alternative solution to those of the prior art. It relates to a process for fabricating a composite structure comprising a thin layer made of single-crystal SiC positioned on a carrier substrate made of polycrystalline SiC. It also relates to an intermediate structure obtained during said fabrication process.

BRIEF DESCRIPTION OF THE INVENTION

The invention relates to a process for fabricating a composite structure comprising a thin layer made of single-crystal silicon carbide positioned on a carrier substrate made of polycrystalline silicon carbide, the process comprising:

a) a step of providing an initial substrate made of single-crystal silicon carbide, having a front face and a back face, and a carrier substrate made of polycrystalline silicon carbide having a front face and a back face,
b) a step of porosification applied to the initial substrate, in order to form a porous layer at least on the front face side of the initial substrate,
c) a step of forming a superficial layer made of amorphous silicon carbide, on the front face of the carrier substrate and/or on the porous layer,
d) a step of joining the initial substrate and the carrier substrate at their respective front faces, leading to the production of a first intermediate structure,
e) a heat treatment step applied to the first intermediate structure, at a temperature above 900°C, in order to crystallize the surface layer, at least partly in the form of single-crystal silicon carbide, starting from a contact interface with the porous layer, in order to form the thin layer, step e) leading to the production of a second intermediate structure,
f) a step of separation in the porous layer of the second intermediate structure, in order to obtain the composite structure on the one hand and the remainder of the initial substrate on the other hand.

According to other advantageous and non-limiting features of the invention, taken individually or in any technically feasible combination:

- at the end of step b), the porous layer has a thickness of between 0.5 μm and 5 μm;
- at the end of step b), the porous layer comprises pores, the size of which is between 1 nm and 50 nm, and has a degree of porosification of between 10% and 70%;

- at the end of c), the surface layer has a thickness of less than or equal to 10 μm;
- at the end of c), the surface layer has a thickness of less than or equal to 1 μm, typically of the order of a hundred to several hundreds of nanometres;
- step c) comprises the deposition of an amorphous silicon carbide layer, at least on the front face side of the carrier substrate and/or at least on the porous layer, in order to form the surface layer(s);
- the amorphous silicon carbide layer deposited is highly doped and has a concentration of dopant species of greater than $10^{19}/cm^3$, or greater than $10^{20}/cm^3$;
- step c) comprises an amorphization of a surface layer of the carrier substrate, at least on the front face side thereof, in order to form the superficial layer;
- step d) comprises, prior to the joining of the initial substrate and the carrier substrate, the formation of a bonding layer on one and/or the other of the substrates, on teh side of the respective faces thereof, the bonding layer having, after joining, a total thickness of less than or equal to 10 nm;
- the bonding layer is composed of at least one material chosen from silicon, nickel, titanium and tungsten;
- during step e), a segmentation into nodules or a dissolution of the bonding layer allows direct contact, at least locally, between the superficial layer and the porous layer or between the superficial layer and the carrier substrate;
- the heat treatment of step e) is carried out at a temperature above or equal to 1000°C, preferentially above or equal to 1400°C, or above or equal to 1850°C;
- in step e), the crystallization of the superficial layer occurs at least partly in the form of polycrystalline

silicon carbide, starting from a contact interface with the carrier substrate, in order to form an intermediate layer;

- the fabrication process comprises after step f), a finishing step g) comprising mechanical and/or chemical treatment(s) on the composite structure, in order to eliminate residues of the porous layer from the front face of the thin layer and/or to correct the thickness uniformity of the composite structure;
- step g) comprises a heat treatment, applied to the composite structure, at a temperature of between 1000°C and 1900°C, before or after the mechanical and/or chemical treatment(s);
- the fabrication process comprises a step of reconditioning the remainder of the initial substrate for reuse as initial substrate for fabrication of a new composite structure.

The invention also relates to an intermediate structure comprising:
– a carrier substrate made of polycrystalline silicon carbide,
– at least one superficial layer made of amorphous silicon carbide, positioned on the carrier substrate, on the front face side thereof,
– a porous layer positioned on the superficial layer,
– an initial substrate made of single-crystal silicon carbide on the porous layer,

- the porous layer being positioned, directly in contact or via a bonding layer, on the superficial layer, a bonding interface being present between the porous layer and the superficial layer, or
- the superficial layer being positioned, directly in contact or via a bonding layer, on the carrier substrate,

a bonding interface being present between the carrier substrate and the superficial layer, or

- a superficial layer on the porous layer side being positioned, directly in contact or via a bonding layer, on another superficial layer on the carrier substrate side, a bonding interface being present between the two superficial layers.

BRIEF DESCRIPTION OF THE FIGURES

Other features and advantages of the invention will become apparent on reading the following detailed description of the invention, with reference to the appended figures, in which:

[Fig. 1] Figure 1 shows a composite structure produced using a fabrication process in accordance with the invention;

[Fig. 2a]
[Fig. 2b]
[Fig. 2c]
[Fig. 2c']
[Fig. 2d]
[Fig. 2d']
[Fig. 2d'']
[Fig. 2e]
[Fig. 2f]
[Fig. 2g] Figures 2a to 2g show steps of a fabrication process in accordance with the invention.

The figures are schematic representations that, for the sake of readability, have not been drawn to scale. In particular, the thicknesses of the layers along the z-axis are not to scale with respect to the lateral dimensions along the x- and y-axes; and the relative thicknesses of the layers with

respect to one another have not necessarily been respected in the figures.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a process for fabrication of a composite structure 100 comprising a thin layer 1 made of single-crystal silicon carbide (c-SiC will be used below to refer to single-crystal silicon carbide) positioned on a silicon carbiede carrier substrate 20 (Figure 1). The carrier substrate 20 is polycrystalline (p-SiC).

The process first comprises a step a) of providing an initial substrate 10 made of single-crystal silicon carbide (Figure 2a). The initial substrate 10 is preferentially in the form of a wafer having a diameter of 100 mm, 150 mm, 200 mm or 300 mm, and a thickness typically of between 300 and 800 microns. It has a front face 10a and a rear face 10b. The surface roughness of the front face 10a is advantageously chosen to be less than 1 nm Ra (average roughness), measured by atomic force microscopy (AFM), for example on a on a 20 micron x 20 micron scan. The initial substrate 10 may be of 4H or 6H polytype, and may have n- or p-type doping.

Step a) also comprises the provision of a carrier substrate 20 made of polycrystaline silicon carbide having a front face 20a and a back face 20b (Figure 2a).
The carrier substrate 20 may be produced by a conventional technique such as sintering or chemical vapour deposition. It is preferentially in a form identical to that of the initial substrate 10, typically in the form of a wafer having a typical diameter and thickness mentioned above with reference to the initial substrate 10. The surface roughness of the front face 20a of the carrier substrate 20 is advantageously

chosen to be less than 1 nm Ra, at least when this face is intended to be directly joined in a subsequent step d) of the process.

The process then comprises a step b) of porosification applied to the initial substrate 10, to form a porous layer 11 (Figure 2b). The known methods of porosification of SiC, some of which are described or referenced in the publications by Y. Shishkin et al. ("Photoelectrochemical etching of n-type 4H silicon carbide", Journal of Applied Physics 96, 2311, 2004) and by Gautier et al. ("Electrochemical formation of porous silicon carbide for micro-device applications", Materials Science Forum, ISSN: 1662-9752, Vol.924, pages 943-946, 2018) could be applied to the initial substrate 10 to form the porous layer 11.

Advantageously, the porous layer 11 has a thickness of between 0.5 μm and 5 μm; the degree of porosification is preferentially between 10% and 70%, and the size of the pores is typically between 1 nm and 50 nm.
These characteristics are favourable, firstly to the crystallization in contact with the porous layer 11 (step e) of the process) of a layer 21 made of amorphous silicon carbide in single-crystal form, which layer is intended to form the thin layer 1 of the composite structure 100; secondly, the characteristics of the porous layer 11 are suitable for allowing and facilitating the separation within this layer, in a step f) of the process, while providing a sufficient mechanical strength during the previous steps.

The next step c) of the fabrication process according to the invention corresponds to the formation of a superficial layer 21, 12 made of amorphous silicon carbide, at least on the

front face 20a, 10a of the carrier substrate 20 or of the initial substrate 10.

According to a first embodiment, it is the substrate 20 which is provided at least on the front face 20a thereof with said superficial layer 21 made of amorphous silicon carbide (a-SiC) (Figure 2c).
According to a second embodiment, the superficial layer 12 made of amorphous silicon carbide is formed on at least the front face 10a of the initial substrate 10, namely on the porous layer 11 (Figure 2c').
According to a third embodiment, a superficial layer 21 is formed on the front face 20a of the carrier substrate 20 and another superficial layer 12 is formed on the porous layer 11, itself positioned on the initial substrate 10.
In one or other of the aforementioned embodiments, the superficial layer 21, 12 could also be formed on the back face 20b, 10b of the substrates 20, 10 in question.

Irrespective of the embodiment, the superficial layer 21, 12 advantageously has a total thickness of less than or equal to 10 μm.

In order to form this superficial layer 21, 12, step c) comprises, according to a first variant, the deposition of an a-SiC layer on the substrate 20, 10 in question. The deposition of amorphous SiC may be carried out by a chemical vapour deposition (CVD) technique, for example plasma-enhanced CVD (PECVD), or direct liquid injection CVD (DLI-CVD), by a physical vapour deposition technique, or by any other known technique. In the case of CVD deposition, a deposition temperature below 1100°C, or below 1000°C, is preferred; regarding the deposition precursors (methane or silane

chemistry), the C/Si ratio will preferentially be chosen to be greater than or equal to 1.

The deposition techniques mentioned make it possible to form a superficial layer 21, 12, the thickness of which may typically vary between 100 nm and 10 μm, for example around 1 μm. Similarly, the doping of the superficial layer 21, 12 made of a-SiC may be adjusted easily when it is formed by one of these techniques. It may notably be highly doped (usually of n-type, but optionally of p-type): for this, it comprises dopant species in a concentration of greater than $10^{19}/cm^3$, or of greater than $10^{20}/cm^3$. It should be remembered that the superficial layer 21, 12 is intended to be crystallized, at least partially, in single-crystal form, in order to form the thin layer 1 of the composite structure 100; thus, it may be highly doped in order to give rise to a thin layer 1 having a low resistivity, depending on the requirements of the intended application.

According to a second variant, step c) comprises the amorphization of a surface layer of the substrate in question, in order to form the superficial layer 21, 12 made of a-SiC. This amorphization maybe carried out by a known technique, such as ion bombardment (for example with Si or C ions) or neutron bombardment, with appropriate energies for forming an amorphous layer 21, 12 having the desired thickness.

In the case of an amorphization of a surface layer of the substrate 20 (first embodiment and third embodiment), the polycrystalline structure of the carrier substrate 20 may be rendered amorphous for example by ion bombardment.

According to this second variant of formation of the superficial layer 21, 12, the thickness of the latter is preferentially less than 1 μm, typically of the order of a hundred to several hundreds of nanometres.

The fabrication process according to the invention next comprises a step d) involving the joining of the initial substrate 10 and the carrier substrate 20 at their respective front faces 10a, 20a (Figure 2d, Figure 2d', Figure 2d'').
In the first embodiment (Figure 2d), the porous layer 11 and the superficial layer 21 are thus joined along a bonding interface 3, leading to a first intermediate structure 30 being obtained.
In the second embodiment (Figure 2d'), the superficial layer 12 is joined to the carrier substrate 20, along a bonding interface 3', leading to a first intermediate structure 30' being obtained.
Lastly, in the third embodiment (Figure 2d''), the superficial layers 22, 12 respectively formed on the carrier substrate 20 and the porous layer 11 are joined along a bonding interface 3'', leading to a first intermediate structure 30'' being obtained.

As will be specified below, irrespective of the embodiment, the bonding interface 3, 3', 3'', in step d), may involve direct contact between the surfaces joined or indirect contact between the surfaces joined, via a bonding layer.

The joining of step d) is based on direct bonding by molecular adhesion. As is well known per se, such bonding does not require an adhesive material, as bonds are made at the atomic level between the joined surfaces. Several types of molecular adhesion bonding exist, which differ in particular differ in terms of their temperature, pressure, atmosphere conditions or treatments prior to bringing the surfaces into contact. Mention may be made of room-temperature bonding with or without prior plasma activation of the surfaces to be joined, atomic diffusion bonding (ADB), surface-activated bonding (SAB), etc.

The joining step d) can comprise, prior to bringing the faces to be joined into contact, conventional sequences of chemical cleaning (for example, RCA cleaning) and of surface activation (for example, by means of oxygen or nitrogen plasma) or other surface preparations (such as scrubbing), which are likely to promote the quality of the bonding interface 3, 3', 3'' (low defect density, high adhesion energy).

As mentioned previously and optionally, step d) comprise, prior to bringing the faces to be joined of the substrates 20, 10 into contact, the formation of a bonding layer on one and/or the other of said faces. The bonding layer may therefore be deposited (for example by chemical vapour deposition CVD) on the porous layer 11 and/or on the superficial layer 21 (in the first embodiment), directly on the carrier substrate 20 and/or on the superficial layer 12 (in the second embodiment) or else on one and/or the other of the superficial layers 22, 12 (in the third embodiment).
The bonding layer may be composed of at least one material chosen from silicon, nickel, titanium, tungsten, etc. It is preferentially of reduced thickness, typically its total thickness is less than or equal to 10 nm, or less than or equal to 5 nm. In the first embodiment, it is crucial that the bonding layer have a small thickness enabling the segmentation thereof in the form of nodules or the dissolution thereof during the heat treatment of the subsequent step e): this then provides a direct contact, at least locally, between the porous layer 11 and the superficial layer 21: this direct contact is essential for the correct implementation of the crystallization taking place in the next step e). If the bonding layer is made of semiconductor material (such as silicon in particular), it could be doped so as to promote vertical electrical conduction.

As illustrated in Figure 2d, the first intermediate structure 30 resulting from step d), in the first embodiment of the invention, comprises, starting from the carrier substrate 20, and therefore in a reverse order to that seen in the figure:
- a carrier substrate 20 made of polycrystalline silicon carbide with a back face 20b,
- a superficial layer 21 made of amorphous silicon carbide, on the carrier substrate 20, on the front face 20a side thereof,
- a porous layer 11 positioned, directly in contact or via a bonding layer, on the superficial layer 21, a bonding interface 3 being present between the porous layer 11 and the superficial layer 21,
- an initial substrate 10 made of single-crystal silicon carbide on and in contact with the porous layer 11.

Figure 2d' illustrates the first intermediate structure 30' resulting from step d), in the second embodiment of the invention; it comprises:
- a carrier substrate 20 made of polycrystalline silicon carbide,
- a superficial layer 12 made of amorphous silicon carbide, positioned, directly in contact or via a bonding layer, on the carrier substrate 20, on the front face 20a side thereof, a bonding interface 3' being present between the carrier substrate 20 and the superficial layer 12,
- a porous layer 11 on the superficial layer 12,
- an initial substrate 10 made of single-crystal silicon carbide on and in contact with the porous layer 11.

Lastly, Figure 2d'' illustrates the first intermediate structure 30'' resulting from step d), in the third embodiment of the invention; it comprises:

- a carrier substrate 20 made of polycrystalline silicon carbide,
- a superficial layer 21 made of amorphous silicon carbide, on the carrier substrate 20, on the front face 20a side thereof,
- another superficial layer 12 made of amorphous silicon carbide, positioned, directly in contact or via a bonding layer, on the superficial layer 21, a bonding interface 3'' being present between the two superficial layers 21, 12,
- a porous layer 11 on the superficial layer 12,
- an initial substrate 10 made of single-crystal silicon carbide on and in contact with the porous layer 11.

The next step e) of the fabrication process involves a heat treatment applied to the first intermediate structure 30, 30', 30'', at a temperature above 900°C, in order to crystallize the surface layer 21, 12 (Figure 2e). The temperature of the heat treatment is advantageously greater than or equal to 1000°C, or greater than or equal to 1400°C, or even greater than or equal to 1850°C. By way of example, for a 1 μm superficial layer 21, 12 made of a-SiC, a heat treatment at 1700°C for 30 min may be applied.
The superficial layer 21, 12 crystallizes, via a solid-phase epitaxy phenomenon, in the form of single-crystal silicon carbide, starting from an interface of direct contact between the porous layer 11 (the SiC of which has a single-crystal structure) and the superficial layer 21, 12 made of a-SiC. The superficial layer crystallized in single-crystal form forms the thin layer 1.
It may be that only a portion of the superficial layer 21, 12 crystallizes in single-crystal form. This is because the crystallization may occur at least partly in the form of polycrystalline silicon carbide, starting from the contact interface with the carrier substrate 20: an intermediate layer 22 is then formed, extension of p-SiC of the carrier substrate

20 up to the thin layer 1 made of c-SiC. In other words, the intermediate layer 22 is interposed between the carrier substrate 20 and the thin layer 1. The interface between the intermediate layer 22 and the thin layer 1 has the advantage of being perfectly closed as it is defined from the same a-Si material (superficial layer(s) 21, 12) by the meeting of the c-SiC and p-SiC crystallization fronts. This is an interesting advantage compared to a bonding interface between two materials of different crystalline nature (p-SiC/c-SiC for example), the complete closure of which is notably dependent on the roughness and surface finish of said materials before joining.

In order to obtain such an intermediate layer 22, provision is notably made, if no superficial layer 21 is present on the carrier substrate 20 (i.e. in the second embodiment), for the superficial layer 12 made of a-Si (on the porous layer 11 side) to be in direct contact with the carrier substrate 20, in the absence of a bonding layer or by the use of a discontinuous bonding layer, for example a bonding layer that forms a set of nodules between which the carrier substrate 20 is in direct contact with the superficial layer 12.

Step e) leads to a second intermediate structure 40 being obtained, irrespective of the embodiment implemented, in which structure all or part of the superficial layer(s) 21, 12 is crystallized in single-crystal form in order to form the thin layer 1 (Figure 2e).

The fabrication process finally comprises a step f) of separation in the porous layer 11 of the second intermediate structure 40, in order to obtain the composite structure 100 on the one hand and the remainder 10' of the initial substrate on the other hand (Figure 2f).

The separation step f) is carried out by applying a mechanical stress to the second intermediate structure 40. The stress may be exerted by the pressing and/or inserting of a tool (for example a blade or other bevelled shape) on the edge of said intermediate structure 40, opposite the porous layer 11. Alternatively, the mechanical stress may be applied by waterjet or air jet, directed towards the edge of the structure 40, still opposite the porous layer 11. Irrespective of the separation technique used, the mechanical stress applied must be suitable for propagating a fracture wave in the porous layer 11, which is of lower mechanical strength compared to the other layers or interfaces in the second intermediate structure 40.
By taking care to protect the free faces of the second intermediate structure 40, the separation could optionally be promoted by lateral chemical etching of the porous layer 11.

At the end of the separation step f), the free face 1a of the thin layer 1 of the composite structure 100 may have residues 11r of porous layer (Figure 2f), in the same way as the front face 10'a of the remainder 10' of initial substrate.

The process according to the invention may therefore comprise a step g) of mechanical and/or chemical treatment(s) of the composite structure 100, in order to remove residues 11r of porous layer 11 from the front face 1a of the thin layer 1 and/or to correct the thickness uniformity of the composite structure 100 (Figure 2g).

The step g) may comprise a chemical mechanical polishing (CMP) and/or a chemical or plasma treatment (etching or cleaning) and/or a mechanical treatment (grinding), in order to remove the residue 11r.

The step g) may also comprise cleaning operations of Caro (piranha etch) and/or SC1/SC2 (Standard Clean 1, Standard Clean 2) and/or HF (hydrofluoric acid) type, or an N2, Ar or CF4 plasma, to further improve the quality of the free face 1a of the thin layer 1.

The step g) may comprise a he treatment, applied to the composite structure 100, at a temperature of between 1000°C and 1900°C, for around one hour and up to several hours. This heat treatment may be carried out before or after the abovementioned mechanical and/or chemical treatments(s). Its objective is to stabilize the composite structure 100 by noticeably developing, where appropriate, the crystalline quality of the thin layer 1, such that the structure 100 is perfectly compatible with subsequent heat treatments at very high temperatures, which are required for the fabrication of components on and/or in said layer 1.

Lastly, the fabrication process may comprise a step of reconditioning the remainder 10' of the initial substrate for reuse as initial substrate 10 for a new composite structure 100 (Figure 2g). Mechanical and/or chemical treatments, similar to those applied to the composite structure 100 to remove the residue 11r, may be applied to the front face 10'a of the remaining substrate 10'. The reconditioning step may also comprise one or more treatments of the edges of the remaining substrate 10' and/or of its back face 10'b, by chemical-mechanical polishing, grinding, and/or dry or wet chemical etching.

Of course, the invention is not limited to the embodiments and to the examples which have been described, and variant embodiments can be added to it without departing from the scope of the invention as defined by the claims.

CLAIMS

1. Process for fabricating a composite structure (100) comprising a thin layer (1) made of single-crystal silicon carbide positioned on a carrier substrate (20) made of polycrystalline silicon carbide, the process comprising:

a) a step of providing an initial substrate (10) made of single-crystal silicon carbide, having a front face (10a) and a back face (10b), and a carrier substrate (20) made of polycrystalline silicon carbide having a front face (20a) and a back face (20b),

b) a step of porosification applied to the initial substrate (1), in order to form a porous layer (11) at least on the front face (10a) side of the initial substrate (10),

c) a step of forming a superficial layer (21, 12) made of amorphous silicon carbide, on the front face (20a) of the carrier substrate (20) and/or on the porous layer (11),

d) a step of joining the initial substrate (10) and the carrier substrate (20) at their respective front faces, leading to the production of a first intermediate structure (30, 30', 30''),

e) a heat treatment step applied to the first intermediate structure (30, 30', 30''), at a temperature above 900°C, in order to crystallize the superficial layer (21, 12), at least partly in the form of single-crystal silicon carbide, starting from a contact interface with the porous layer (11), in order to form the thin layer (1), step e) leading to the production of a second intermediate structure (40),

f) a step of separation in the porous layer (11) of the second intermediate structure (40), in order to obtain the composite structure (100) on the one hand and the remainder (10') of the initial substrate on the other hand.

2. Fabrication process according to the preceding claim, in which, at the end of step b), the porous layer (11) has a thickness of between 0.5 μm and 5 μm.

3. Fabrication process according to either of the preceding claims, in which, at the end of step b), the porous layer (11) comprises pores, the size of which is between 1 nm and 50 nm, and has a degree of porosification of between 10% and 70%.

4. Fabrication process according to one of the preceding claims, in which, at the end of step c), the superficial layer (21, 12) has a thickness of less than or equal to 10 μm.

5. Fabrication process according to one of the preceding claims, in which, at the end of step c), the superficial layer (21, 12) has a thickness of less than or equal to 1 μm, typically of the order of a hundred to several hundreds of nanometres.

6. Fabrication process according to one of the preceding claims, in which step c) comprises the deposition of an amorphous silicon carbide layer, at least on the front face (20a) side of the carrier substrate (20) and/or at least on the porous layer (11), in order to form the superficial layer(s) (21, 12).

7. Fabrication process according to the preceding claim, in which the amorphous silicon carbide layer deposited is highly doped and has a concentration of dopant species of greater than $10^{19}/cm^3$, or greater than $10^{20}/cm^3$.

8. Fabrication process according to one of Claims 1 to 5, in which step c) comprises an amorphization of a surface layer of the carrier substrate (20), at least on the front face (20a) side thereof, in order to form the superficial layer (21).

9. Fabrication process according to one of the preceding claims, in which step d) comprises, prior to the joining of the initial substrate (10) and the carrier substrate (20), the formation of a bonding layer on one and/or the other of the substrates, on the side of the respective front faces thereof,
the bonding layer having, after joining, a total thickness of less than or equal to 10 nm.

10. Fabrication process according to the preceding claim, in which the bonding layer is composed of at least one material chosen from silicon, nickel, titanium and tungsten.

11. Fabrication process according to either of the preceding two claims, in which, during step e), a segmentation into nodules or a dissolution of the bonding layer allows direct contact, at least locally, between the superficial layer (21) and the porous layer (11) or between the superficial layer (12) and the carrier substrate (20).

12. Fabrication process according to one of the preceding claims, in which the heat treatment of step e) is carried out at a temperature above or equal to 1000°C, preferentially above or equal to 1400°C, or above or equal to 1850°C.

13. Fabrication process according to one of the preceding claims, in which, in step e), the crystallization of the superficial layer (21, 12) occurs at least partly in the form of polycrystalline silicon carbide, starting from a contact interface with the carrier substrate (20), in order to form an intermediate layer (22).

14. Fabrication process according to one of the preceding claims, comprising, after step f), a finishing step g) comprising mechanical and/or chemical treatment(s) on the composite structure (100), in order to eliminate residues (11r) of the porous layer (11) from the front face (1a) of the thin layer (1) and/or to correct the thickness uniformity of the composite structure (100).

15. Fabrication process according to the preceding claim, in which step g) comprises a heat treatment, applied to the composite structure (100), at a temperature of between 1000°C and 1900°C, before or after the mechanical and/or chemical treatment(s).

16. Fabrication process according to one of the preceding claims, comprising a step of reconditioning the remainder (10') of the initial substrate for reuse as initial substrate (10) for the fabrication of a new composite structure (100).

17. Intermediate structure (30, 30') comprising:

- a carrier substrate (20) made of polycrystalline silicon carbide,
- at least one superficial layer (21, 12) made of amorphous silicon carbide, positioned on the carrier substrate (20), on the front face (20a) side thereof,

- a porous layer (11) positioned on the superficial layer (21, 12),
- an initial substrate (10) made of single-crystal silicon carbide on the porous layer (11),

the porous layer (11) being positioned, directly in contact or via a bonding layer, on the superficial layer (21), a bonding interface (3) being present between the porous layer (11) and the superficial layer (21), or

the superficial layer (12) being positioned, directly in contact or via a bonding layer, on the carrier substrate (20), a bonding interface (3') being present between the carrier substrate (20) and the superficial layer (12), or

a superficial layer (12) on the porous layer (11) side being positioned, directly in contact or via a bonding layer, on another superficial layer (21) on the carrier substrate (20) side, a bonding interface (3'') being present between the two superficial layers (21, 12).