Title: Substrate with determinate thermal expansion coefficient

Technical field

The present invention relates to a substrate for the epitaxy of a useful layer made of a material chosen from semiconductor materials.

A substrate is closely tied to the useful layer that it supports, and it may thus have a considerable influence on the structure of the useful layer, especially from a number of aspects:

According to a first aspect, the crystal structure of the epitaxy substrate in the vicinity of its interface with the useful layer to be grown, and more particularly the crystalline nature and the lattice parameter that the substrate has at this point, can strongly influence the crystal structure of the useful layer.

This aspect is particularly made use of during epitaxy of a useful layer on the substrate, during which the lattice parameter of the useful layer is in registration with the lattice parameter of the substrate.

In order not to generate an excessive number of defects in the thin layers to be grown, the epitaxy substrate must therefore have, at least on the surface, a lattice parameter close to that of the constituent material of the useful layer.

According to a second aspect, the constituent material of the epitaxy substrate must not have a thermal expansion coefficient too different from that of the useful layer, at the working temperatures.

The term "working temperatures" is understood to mean the temperatures to which the substrate/useful layer assembly is subjected during the industrial process involved, which includes in particular the ambient temperature, the useful layer formation temperatures and other, heat treatment temperatures.

Too great a difference in expansion coefficient between the substrate and the useful layer induces in the useful layer high internal strains (in tension or in compression) that are liable to degrade the structural quality of the said layer.

The constituent material of the epitaxy substrate must therefore be chosen so that the substrate has an overall thermal expansion coefficient, at the working temperatures, close to that of the material of the useful layer to be grown.

(crystal and thermal expansion) properties cannot be separated and may not both correspond to the intended application.

The choice of the material of the useful layer to be grown is therefore very much limited to the possible choices of the constituent material of the bulk substrate.

Furthermore, the applications of the components to be produced, the performance of which depends strongly on the material and on the structure of the useful layer in which they have been produced, are thereby more restricted.

Thus, a given material and a given structure may be chosen for the useful layer, for the purpose of obtaining a given band gap and a given lattice parameter, this being, for example, highly desirable in the field of III-V alloys.

Solutions to the problem of choosing a suitable substrate have included the production of composite epitaxy substrates, the combination of several layers forming a crystallographic structure which make it possible to match a desired lattice parameter with the interface with the useful layer to be formed and/or to confine plastic defects.

Multilayer structures have thus been devised and used as metamorphic or buffer structures comprising a succession of several layers.

However, during heat treatments, if the various layers of such a composite substrate have different thermal expansion coefficients at the said working temperatures, they will expand differently and induce expansion strains in the layer that will be formed thereon (and may perhaps also induce strain relaxation by overall deformation of the substrate, which thus becomes deflected).

The main difficulty that therefore arises is to find an epitaxy substrate having a structure that permits a wide choice of materials with a useful epilayer to be grown, which offers:

- good lattice matching with the material of the useful epilayer to be grown; and
- a thermal expansion coefficient close to that of the material of the useful layer to be formed at the said working temperatures.

It is especially necessary to obtain this type of substrate when it is desired to produce components made of III-V material, for example for applications in optoelectronics, for which the level of the photovoltaic effects is controlled by the band structure of the III-V material.

In general, the substrates known in the prior art must often meet at

least two of the aforementioned criteria taken together.

The possible choices for epitaxy substrates suitable for achieving certain material and structural properties of the thin layers to be grown on their surface are therefore restricted, or even non-existent in certain cases.

Brief description of the invention

According to a first aspect, the object of the present invention is to improve the situation by proposing a composite support intended to receive a transferred layer made of a material chosen from crystalline materials, so that the assembly forms an epitaxy substrate, characterized in that it has a longitudinal plane of symmetry parallel to its principal surfaces and in that it consists of:

- a central first layer having a first thermal expansion coefficient at a specified temperature T and extending transversely on either side of the plane of symmetry; and
- at least one pair of lateral layers, the layers of each pair having, one with respect to the other:
  - arrangements in the composite support that are substantially symmetrical with respect to the plane of symmetry;
  - second thermal expansion coefficients at the temperature T that are substantially identical to one another; and
  - thicknesses that are substantially identical to one another;

and in that the materials constituting the layers of the composite support are chosen in such a way that the composite support has an overall thermal expansion coefficient at the temperature T that is close to the thermal expansion coefficient of the material of the transferred layer at the temperature T.

Other features of the composite support are:

- the materials constituting the layers of the composite support are chosen in such a way that the composite support has an overall thermal expansion coefficient at several temperatures that is close to the thermal expansion coefficient of the material of the transferred layer at these temperatures;
- the material of the upper layer of the composite support, which is intended to support the transferred layer, is chosen in such a way as to have a lattice parameter close to that of the material of the transferred layer; and
- it includes a central layer made of SiC and a pair of layers each chosen to be made of one of the following crystalline or polycrystalline

materials: AlN, SiC, sapphire, Si.

According to a second aspect, the object of the invention is to propose a process for forming a layer on this composite support, characterized in that it comprises:

- crystalline growth of the layer on a growth substrate other than the composite support;
- bonding of the layer to the composite support; and
- removal of the growth substrate.

Other features of the process for forming a layer on a composite support are:

- it furthermore includes a step of producing components in the layer;
- it furthermore includes crystalline growth of a useful layer on the already transferred layer; and
- it furthermore includes a step of producing components in the useful layer.

According to a third aspect, the object of the invention is to propose a process for forming a plurality of epitaxy substrates, comprising the formation of a plurality of layers on a plurality of the said composite supports, characterized in that it is carried out using a wafer comprising a growth substrate and a multilayer structure on the growth substrate, the multilayer structure comprising a plurality of pairs of layers, each consisting of:

- a layer to be transferred;
- an intermediate layer subjacent to the layer to be transferred;

and in that it includes several steps of removing layers from the multilayer structure, each removal comprising the following steps:

- implantation of atomic species into an intermediate layer in order to create therein a region of weakness in the vicinity of the implant depth;
- bonding to a composite support of the layer to be transferred;
- injection of energy into the region of weakness, in order to detach the layer to be transferred from the multilayer structure;
- selective etching of that portion of the intermediate layer remaining on the detached layer to be transferred, thus producing the epitaxy substrate; and
- removal of material from the multilayer structure until another layer to be transferred is reached.

Other features of the process for forming a plurality of epitaxy

substrates are the following:

- it furthermore includes an epitaxial nucleation layer for a new layer to be transferred, on the multi-removal structure; and
- it furthermore includes a plurality of crystalline growth steps on the plurality of transferred layers, so as to form a plurality of respective useful layers.

According to a fourth aspect, the object of the invention is to propose a structure intended for electronics, optics or optoelectronics, characterized in that it includes an epitaxy substrate comprising a composite support and a transferred layer made of a material chosen from crystalline materials.

Other features of the structure are:

- the transferred layer is made of GaN;
- the composite support is a three-layer support and comprises:
  - a central layer made of SiC; and
  - a pair of layers, each made of sapphire;
- the transferred layer includes electronic components;
- the structure furthermore includes a useful layer formed by crystalline growth on the transferred layer; and
- the useful layer includes electronic components.

Brief description of the drawings

Other aspects, objects and advantages of the present invention will become more clearly apparent on reading the following detailed description of preferred methods of implementing it, these being given by way of non-limiting example and with reference to the appended drawings in which:

- Figure 1 shows a first composite support according to the invention, the substrate here being shown schematically in a cross-sectional view;
- Figure 2 shows a second composite support according to the invention, the composite support here being shown schematically in a cross-sectional view;
- Figure 3 shows the stress distribution through the thickness of the first composite support according to the invention;
- Figure 4 shows an epitaxy substrate according to the invention;
- Figure 5 shows a growth substrate from which thin layers are removed and transferred on to a composite support according to the invention; and
- Figure 6 shows a graph giving thermal expansion coefficients as a function of the lattice parameters for various materials.

Detailed description of the invention

A first object of the invention is to produce a composite support (i.e. one comprising a plurality of layers) having a suitable thermal expansion coefficient close to that of the crystalline layer to be transferred thereto (i.e. in or on which layer electronic, optical or optoelectronic components will be produced), which it supports, at the working temperatures.

A second main object of the invention is to produce an epitaxy substrate comprising a composite support that supports a layer that has been transferred thereto, this transferred layer forming a crystalline growth support with a useful layer.

A third main object of the invention is to be able to obtain many more degrees of freedom than one had in the prior art, as regards choice of the various materials constituting an epitaxy substrate, while greatly reducing or even removing, the restrictions associated with the risks of a substantial deflection appearing, which had to be taken into account in the prior art.

This makes it possible to choose constituent materials of the substrate from a wider range of materials, the choice being based fundamentally on the following criteria:

- the surface lattice parameter; and
- the overall thermal expansion coefficient of the substrate,

in order to form, on the surface, a useful layer having the desired crystallographic and thermal expansion properties.

A fourth object of the invention is to propose a method of determining the materials and the structure of a substrate that makes it conceivable to consider the problem of the choice of lattice parameters separately from the problem of thermal expansion, which makes it possible to further increase the number of possible ways of producing a substrate having properties close to those desired for the useful layer to be formed on this substrate.

A fifth object is to form, on the surface of the epitaxy substrate according to the invention, a particularly thin useful layer having a crystal structure of high quality and with controlled elastic stresses.

As shown in Figure 4, an epitaxy substrate 30 according to the invention has the form of a wafer, the surfaces of which are substantially plane.

The epitaxy substrate 30 according to the invention comprises:

- a composite support 10 having a longitudinal plane of symmetry parallel to its principal surfaces; and

- a transferred layer 20 on the composite support 10.

The composite support 10 according to the invention consists of several layers.

The various constituent layers of the composite support 10 typically each have a thickness of the order of 1 μm to 1000 μm typically of the order of 100 μm.

Figure 1 shows a composite support 10 according to the invention for solving the problem of the difference in thermal expansion between the epitaxy substrate and the useful layer to be formed, and also the problems of deflection sometimes encountered with substrates of the prior art.

This composite support 10 has a longitudinal geometrical plane of symmetry 100.

The composite support 10 consists of:

- a central first layer 1 having a first thermal expansion coefficient at a specified temperature T and extending substantially symmetrically around the plane of symmetry 100; and
- a pair of lateral layers 2 and 2', one layer of each pair facing the other layer of the same pair:
  - an arrangement in the composite support that is substantially symmetrical with respect to the plane of symmetry,
  - a second, substantially identical, thermal expansion coefficient at the temperature T, and
  - a substantially identical thickness.

This composite support 10 exhibits a symmetry with regard to the configuration of the layers with respect to the same plane of symmetry 100 since there exists as many layers above the plane 100 as below it, and since the layers of any one pair have substantially the same thicknesses facing each other.

There is also a symmetry in the distribution within the composite support 10 of the thermal expansions, at the temperature T, of the materials making up the layers with respect to the plane 100, given that the layer 2 has substantially the same thermal expansion coefficient as the layer 2'.

The strains associated with the differences in thermal expansion between the layers therefore cannot be partly relaxed by the bending of the composite support 10 so as to form a deflection, given that the layer 2' "compensates for" the asymmetry of thermal expansion existing between the layer 1 and the layer 2.

In one particular configuration of the composite support 10, the layer

2' does not perfectly compensate for the asymmetry of the thermal expansion existing between the layer 1 and the layer 2 so as to form a slight deflection in the composite support 10 corresponding substantially to the opposite deflection of the layer to be transferred thereto, in such a way that, when the layer is transferred, the composite support 10/layer to be transferred assembly has a deflection tending towards zero.

In all cases, shear stresses are created at the layer 2'/layer 1 interface and at the layer 1/layer 2 interface (they are shown in Figure 2 by arrows).

To maintain structural quality of the upper layer 2, the difference in expansion between adjacent layers must not be too large, otherwise some of the interfacial strains in the layers 1, 2 and 2' will relax by the creation of plastic defects.

However, these layers 1, 2 and 2' (and especially the layer 2 that is intended to receive the transferred layer) each have a typical thickness of the order of several microns or even several tens of microns, and therefore a thickness capable of confining these defects at its interface with the central layer 1.

Figure 3 shows a graph of an example of the distribution of internal stresses (plotted on the x-axis, and denoted by σ) over the thickness (plotted on the y-axis) of the composite support 10 at a temperature T.

The stresses in the central layer 1, in the upper layer 2 and in the lower layer 2' are shown in the graph by the areas A_1, A_2 and $A_{2'}$, respectively.

The internal stresses appearing in a layer correspond to the free-expansion strains of the material making up this layer, these stresses deriving from the different expansion of the neighbouring layer.

Thus, Figure 4 shows that:

- A_2 is substantially identical to $A_{2'}$;
- A_1 is distributed in two substantially identical areas, each one on either side of the plane of symmetry 100.

This graph therefore demonstrates the symmetrical distribution of the stresses with respect to the plane of symmetry 100 in a composite support 10 that is symmetrical in its layer configuration.

With such a structure of the composite support 10 according to the invention, the possible choices of materials constituting a composite support 10 with a low deflection are increased compared with a composite support 10 of the prior art for which the various expansions existing between the various materials constituting it must be taken into strict

account, since the problem of the differences in expansion is solved by a "compensated expansion" solution.

Figure 2 shows a composite support 10 composed of five layers according to the invention, a central main layer 1 having a thermal expansion coefficient $\alpha_1(T)$ and two pairs of layers 2-2' and 3-3' each having respective thermal expansion coefficients $\alpha_2(T)$ and $\alpha_3(T)$, the whole assembly having a structure and a layer configuration substantially symmetrical with respect to the plane of symmetry 100.

In the same way as the three-layer composite support 10 discussed with reference to Figure 1, this five-layer composite support 10 exhibits a symmetry of thermal expansion with respect to the plane of symmetry 100.

This composite support 10 therefore has an expansion coefficient matched to the layer to be transferred, and only a slight deflection according to the invention.

Likewise, composite supports 10 consisting of more than five layers and exhibiting this symmetry of thermal expansion with respect to the plane of symmetry 100 are composite supports according to the invention.

Since the deflection problem is solved by the particular configuration of a composite support 10 according to the invention, the choice of materials will essentially be based on a surface lattice parameter criterion of the composite support 10 and an overall thermal expansion coefficient criterion.

The expression "overall thermal expansion coefficient" is understood here to mean the thermal expansion coefficient that the composite support 10 would have if it were formed from a single material.

The method presented below is a preferred, but not limiting, method according to the invention for choosing the materials and the configuration of the layers making up the composite support 10.

This method is divided into two phases:

(a) choice of a list of materials that can make up the upper layer of the composite support 10, this layer being intended to be adjacent to the layer to be transferred, based mainly on a lattice parameter sufficiently close to the material of the layer to be transferred;

(b) for each constituent material of the upper layer of the composite support 10 in the step (a), choice of a list of materials that can make up the other layers of the composite support 10, in such a way that the composite support 10 has, in the end, an overall expansion at the working temperatures which is close to the expansion of the constituent material of the layer to be transferred.

This method of determining the materials and the structure of the composite support 10 thus makes it possible to consider the problem of the choice of lattice parameter separately from the problem of the thermal expansion, thereby making it possible to further increase the possible ways of producing a composite support having properties close to those sought for the layer to be transferred on this composite support and therefore the eventual useful layer to be formed by epitaxy on the transferred layer.

Advantageously, the constituent materials of the layers of the composite support 10 are crystalline materials.

Now, the expansion of a crystalline material usually varies to a first approximation linearly with temperature.

The thermal expansion coefficient of each constituent crystalline layer of the composite support 10 therefore remains approximately constant with changes in temperature.

The overall thermal expansion coefficient α of the composite support 10 corresponding to the area expansion of the composite support 10 (or linear expansion if the surface of the composite support 10 has circular symmetry) at a given temperature is calculated for a number N of constituent layers of the composite support 10 by a linear formula of the type:

$$\alpha = f(\alpha_1, \alpha_2, ..., \alpha_N).$$

This formula also takes into account the thicknesses of the constituent layers of the composite support 10.

The overall thermal expansion coefficient α of the composite support 10 therefore also changes with temperature in an approximately constant manner.

Figure 6 shows a graph in which lattice parameters expressed in nanometres are plotted on the x-axis and thermal expansion coefficients expressed in $10^{-6}K^{-1}$ are plotted on the y-axis.

Crystalline materials lying within the graph are shown therein by circular spots:

- materials of cubic structure by open circles;
- materials of hexagonal structure by filled circles.

Thus, for example, if it is desired to form a layer to be transferred made of cubic GaN material (indicated by GaN(c)), an upper layer of the composite support 10 will be chosen, according to phase (a) of the said method, made of sapphire or MgO.

In phase (b) of the said method, by approximating the overall expansion coefficient of the composite support by the average of the sum of the thermal expansion coefficients of the constituent materials of the composite support 10, it may be seen that the average of the respective thermal expansion coefficients of 6H-SiC and sapphire gives roughly the thermal expansion coefficient of GaN.

The sapphire/6H-SiC/sapphire structure therefore constitutes a composite support 10 that is particularly suitable for the formation on this composite support 10 of a cubic GaN layer, since it possesses:

- little deflection;
- a surface lattice parameter close to that of the GaN layer; and
- an overall thermal expansion close to that of GaN at the working temperatures.

Furthermore, the particularly high robustness of sapphire and SiC allows the thickness of the composite support 10 to be reduced compared with a composite substrate 10 made of less robust materials.

For certain desired final structures, comprising therefore the composite support 10 and the transferred layer 20, there is no need to take into account phase (a) in the said method.

This is especially the case in SeOI (Semiconductor On Insulator) structures in which a layer of insulation material separates the composite support 10 from the transferred layer.

The production of a composite support 10 according to the invention is advantageously carried out in two steps.

A first step in the production of the composite support 10 consists in providing a wafer that will serve as base element for this production, this wafer being advantageously chosen to be made of bulk material.

The wafer constitutes, for example, the said first layer of the composite support 10.

A second step in the production of the composite support 10 consists in forming the other layers, starting from the first layer provided in the first step, by deposition (of crystalline material, amorphous material, etc.) by ceramic production techniques, by sintering, etc.

This layer formation advantageously includes an operation of transferring the layer to be formed from a donor substrate (made of bulk or multilayer material) onto one of the surfaces of an already formed layer of the composite support 10, this operation taking place in two successive steps:

- bonding of the donor substrate to an already formed layer of the

composite support 10;

- removal of part of the donor substrate, the remaining part then constituting the layer to be transferred.

The said bonding, following the intimate contacting of the donor substrate with the already formed layer of the composite support 10, is advantageously effected by wafer bonding (molecular adhesion) between the two layers to be bonded.

This bonding technique, together with variants, is described, for example, in the document entitled "*Semiconductor Wafer Bonding*" (Science and Technology, Interscience Technology) by Q.Y. Tong, and U. Gösele, Wiley & Sons.

If necessary, the bonding is accompanied by a suitable pre-treatment of the respective surfaces to be bonded and/or an injection of thermal energy.

Thus, for example, a heat treatment carried out during the bonding strengthens the bonds formed.

The bonding may also be strengthened by a bonding layer inserted between the two substrates to be bonded together.

This bonding layer is applied to at least one of the two surfaces to be bonded together.

Silicon oxide (also called silica or SiO_2) is a material that may be chosen for producing such a bonding layer, it being possible to produce it by oxide deposition or by thermal oxidation or by any other technique.

A surface finish step may be carried out before and/or after bonding, for example by means of one of the techniques described above.

The said removal of material preferably uses one of the following techniques, individually or in combination: chemical etching and/or chemical-mechanical etching, polishing, lapping.

For example, it is possible to carry out optionally selective etching operations on the materials to be removed, using an "etch-back" process.

This technique consists in etching these materials "from the rear" that is to say from the free face of the growth substrate for the layer to be transferred, in order at the end to preserve the layer to be transferred.

Wet etching operations using etching solutions suitable for the materials to be removed may be carried out.

Dry etching operations may also be carried out in order to remove material, such as plasma etching or sputter etching.

The etching operation(s) may also be only chemical or electrochemical or photoelectrochemical.

The etching operation(s) may be preceded or followed by a mechanical treatment such as lapping, polishing, mechanical etching or sputtering of atomic species.

The etching operation(s) may be accompanied by a mechanical treatment, such as polishing, optionally combined with mechanical abrasive action in a CMP process.

That part of the wafer 10 that it is desired to remove may thus be entirely removed by a single chemical technique or by a chemical-mechanical technique.

This technique makes it possible in particular to maintain the surface quality and thickness uniformity of the layer to be transferred, close to those initially.

These techniques are proposed here by way of example, but they in no way constitute any limitation, the invention extending to all types of techniques that are capable of removing material in accordance with the process according to the invention.

Whatever the material removal technique chosen, a step of finishing the surface of the composite support is advantageously carried out, for example by means of one of the techniques already mentioned.

After the various layers of the composite support 10 have been formed using one of these techniques, the composite support 10 is then produced.

A first method of producing an epitaxy substrate 30 (as shown, for example, in Figure 4) comprises crystalline growth of the layer 20 to be transferred on the composite support 10, for example by CVD epitaxy or MBE. This first method means that the composite substrate 10 has at least its upper surface made of crystalline material.

This epitaxy may optionally be preceded by the formation of a nucleation layer.

With reference to Figure 4, a cubic GaN layer 20 to be transferred is thus grown epitaxially on a composite support 10 consisting of a sapphire layer 2'/6H-SiC layer 1/sapphire layer 2 structure.

A second method of producing an epitaxy substrate 30 comprises the following steps:

- crystalline growth of the layer 20 to be transferred on a growth substrate other than the composite support 10;
- bonding the composite support 10 to the layer 20 to be transferred; and
- removal of material, the material to be removed being here the

growth substrate and possibly part of the layer 20 to be transferred.

As previously, the bonding may be carried out with or without a bonding layer.

The removal of material may be carried out using one of the three following techniques:

A first material removal technique comprises:

- formation, in the growth substrate for the layer to be transferred, of a weak interface by forming at least one porous layer by anodization, by implantation of atomic species or by any other porosification technique, as described for example in document EP 0 849 788 A2;
- supplying energy into the weak layer, such as a mechanical treatment, or another injection of energy, in order to detach the layer to be transferred at the weak layer.

To form a weak layer within the growth substrate for the layer to be transferred, the porous layer is advantageously formed on a wafer of a single-crystal material, and then secondly a layer of non-porous crystalline material is grown on the porous layer, the non-porous material having substantially the same lattice parameter as that of the wafer, the said growth substrate then consisting of the wafer, the porous layer and the non-porous Si layer.

A second material removal technique called Smart-Cut®, can also be used here, this comprising the following steps:

- implantation, before the bonding, into the layer to be transferred or into its growth substrate, of the atomic species (such as hydrogen or helium ions) for forming a region of weakness at a depth close to the depth of implantation;
- then an injection of energy, after bonding, into the region of weakness, such as a thermal and/or a mechanical treatment, or another injection of energy, in order to detach the layer to be transferred in the region of weakness.

Advantageously, the region of weakness is subjected to a heat treatment during or after implantation in order to further weaken it.

This non-limiting material removal technique makes it possible to remove, rapidly and en bloc, a substantial portion of the growth substrate for the layer to be transferred.

It also allows the possibility of reusing the portion removed from this growth substrate in another process, such as for example, a process according to the invention.

The known Smart-Cut® technique is described, for example, in a number of

works dealing with wafer reduction techniques, such as for example that by Jean-Pierre Colinge "*Silicon-On-Insulator Technology: Materials to VLSI*", 2nd edition, Kluwer Academic Publishers, pages 50 and 51.

A third material removal technique that can be employed is chemical or chemical-mechanical etching "from the rear".

A preferred material removal technique according to the invention comprises the use of one of these three types of material removal, followed by selective etching between the material of the remaining growth substrate and the layer 20 to be transferred, thus making it possible to remove the remaining material on the layer 20 to be transferred.

The selective chemical etching may be carried out by wet etching, employing an etching solution suitable for the materials to be etched.

The selective chemical etching may be carried out by dry etching, such as plasma etching or sputter etching.

The etching may also be only chemical, electrochemical or photoelectrochemical.

The layer 20 to be transferred constitutes, in this situation, a stop layer for the etching of the remaining part of the growth substrate after material removal using one of the three techniques.

In general, the etching selectivity of a layer B with respect to a layer A is quantified by a selectivity factor given by the ratio:

$$\frac{\text{etch rate of the layer A}}{\text{etch rate of the layer B}}.$$

The chemical etchants must therefore be chosen so as to maximize this ratio in the case in which the layer A is the layer to be transferred and the layer B is the remaining part of the growth substrate.

Thus, the layer 20 to be transferred will be hardly etched, or even not etched at all, by these chemical etchants.

By implementing such a preferred technique according to the invention, it is thus possible to form, on the composite support 10, a particularly thin layer with a structure similar to the initial structure obtained during its growth on the growth substrate.

By implementing such a technique, it is possible to form, on the composite support 10, a layer 20 so thin that it has a substantially elastic structure in such a way that it follows the slightest deformations of the composite support 10.

A layer about 10 nanometres in thickness may thus be formed.

In the latter situation, a composite support 10 according to the invention is highly advantageous, especially as it exhibits little deflection.

Figure 5 shows a process for producing a plurality of epitaxy substrates 30 (such as, for example that shown in Figure 4) by the multi-removal of thin layers 20A, 20B, 20C, 20D, 20E, 20F and 20G in a multilayer structure I grown epitaxially on a growth substrate 30, so as to transfer them each on to a composite support 10 according to the invention.

The multilayer structure I comprises the thin layers 20A, 20B, 20C, 20D, 20E, 20F and 20G that alternate respectively with intermediate layers 40A, 40B, 40C, 40D, 40E, 40F and 40G, the whole assembly having been advantageously grown epitaxially, layer by layer, starting with the growth substrate 50, using growth techniques such as CVD or MBE.

A preferred multi-removal process according to the invention includes a step that comprises the following operations:

(A) implantation of atomic species into the intermediate layer 40G so as to create therein a region of weakness 101 in the vicinity of the implant depth;

(B) bonding of the layer 20G to the composite support 10 according to the invention;

(C) injection of energy into the region of weakness 101 in order to detach the layer 20G to be transferred and that part of the intermediate layer 40G located between the region of weakness 101 and the layer 20G to be transferred, and thus to remove the layer 20G to be transferred;

(D) selective etching of the remaining part of the intermediate layer 40G on the detached layer 20G to be transferred, thus producing a first epitaxy substrate 30; and

(E) removal of the remaining part of the intermediate layer 40G, so as to recycle the multilayer structure, the removal possibly being carried out for example by selective etching.

A multilayer structure I' finally obtained then consists of the following layers: 20F/40F/20E/40E/20D/40D/20C/40C/20B/40B/20A/40A.

Steps substantially identical to the above step may then be carried out in order:

- to remove, respectively and in succession the thin layers 20F, 20E, 20D, 20C, 20B and 20A relative to the respective regions of weakness 102, 103, 104, 105, 106 and 107 in order to transfer them to the respective second, third, fourth, fifth and sixth composite supports 20, so as to form respective second, third, fourth, fifth and sixth epitaxy substrates

30; and

- to recycle the respective multilayer structures after removal so that a subsequent removal is possible.

This multilayer structure I is particularly advantageously used when the formation of a layer 20 to be transferred requires a growth substrate 50 that is complex to produce, such as a growth substrate 50 comprising metamorphic layers.

With this preferred multi-removal process, such a growth substrate 50 is used for several removal operations.

This therefore makes the process profitable, especially as regards the economic cost that such a growth substrate 50 represents.

In an even more advantageous configuration, this growth substrate 40 is protected by a stop layer for the selective chemical etching of the lower layer of the multilayer structure I, which makes it possible, once the multilayer structure I has been entirely consumed by the various removal and recycling operations, to smooth the surface of the growth substrate 40 by a suitable selective etching operation and to possibly repeat the formation of another multilayer structure I for other multi-removal operations.

Optionally, electronic or optoelectronic components may be produced in the layer 20 to be transferred, before or after the layer has been transferred.

Optionally, crystalline growth of a useful layer (not shown) is carried out on the transferred layer 20 of the epitaxy substrate 30.

Electronic or optoelectronic components may be produced in this useful layer, before or after transfer of the layer.

The present invention is particularly suitable for constituent alloys of the layer 20 to be transferred that are chosen from the family of III-V materials or II-VI materials, but it can also be applied to IV-IV alloys.

In the layers made of crystalline or semiconductor materials presented in this document, other constituents may be added thereto, such as carbon with a carbon or diamond concentration in the layer in question that is substantially less than or equal to 50% or more particularly, with a concentration of less than or equal to 5%.

The composite support 10 can be formed from all types of materials that are capable, in combination, of achieving the said physical properties of the composite substrate (especially a thermal expansion coefficient matched to the layer to be transferred thereto).

It should be pointed out that, in the case of alloy materials, the chosen

alloys may be binary, ternary, quaternary or of higher order.

CLAIMS

1. Composite support (10) intended to receive a transferred layer (20) made of a material chosen from crystalline materials, so that the assembly forms an epitaxy substrate (30), characterized in that it has a longitudinal plane of symmetry (100) parallel to its principal surfaces and in that it consists of:

- a central first layer (1) having a first thermal expansion coefficient at a specified temperature T and extending transversely on either side of the plane of symmetry; and
- at least one pair of lateral layers (2, 2'; 3, 3'), the layers of each pair having, one with respect to the other:
  - arrangements in the composite support (10) that are substantially symmetrical with respect to the plane of symmetry;
  - second thermal expansion coefficients at the temperature T that are substantially identical to one another; and
  - thicknesses that are substantially identical to one another;

and in that the materials constituting the layers of the composite support (10) are chosen in such a way that the composite support (10) has an overall thermal expansion coefficient at the temperature T that is close to the thermal expansion coefficient of the material of the transferred layer (20) at the temperature T.

2. Composite support according to the preceding claim, characterized in that the materials constituting the layers of the composite support (10) are chosen in such a way that the composite support (10) has an overall thermal expansion coefficient at several temperatures that is close to the thermal expansion coefficient of the material of the transferred layer (20) at these temperatures.

3. Composite support according to either of the preceding claims, characterized in that the material of the upper layer of the composite support (10), which is intended to support the transferred layer (20), is chosen in such a way as to have a lattice parameter close to that of the material of the transferred layer (20).

4. Composite support according to one of the preceding claims, characterized in that it includes a central layer made of SiC and a pair of layers each chosen to be made of one of the following crystalline or

polycrystalline materials: AlN, SiC, sapphire, Si.

5. Process for forming a layer on a composite support (10) according to one of the preceding claims, characterized in that it comprises:

- crystalline growth of the layer (20) on a growth substrate (50) other than the composite support;
- bonding of the layer to the composite support (10); and
- removal of the growth substrate (50).

6. Process for forming a layer on a composite support according to the preceding claim, characterized in that it furthermore includes a step of producing components in the layer (20).

7. Process for forming a layer on a composite support according to Claim 5, characterized in that it furthermore includes crystalline growth of a useful layer on the already transferred layer (20).

8. Process for forming a layer on a composite support according to the preceding claim, characterized in that it furthermore includes a step of producing components in the useful layer.

9. Process for forming a plurality of epitaxy substrates, comprising the formation of a plurality of layers on a plurality of composite supports, each according to one of Claims 1 to 4, characterized in that it is carried out using a wafer comprising a growth substrate (50) and a multilayer structure on the growth substrate, the multilayer structure comprising a plurality of pairs of layers, each consisting of:

- a layer (20A, 20B, 20C, 20D, 20E, 20F, 20G) to be transferred;
- an intermediate layer (40A, 40B, 40C, 40D, 40E, 40F, 40G) subjacent to the layer to be transferred;

and in that it includes several steps of removing layers from the multilayer structure, each removal comprising the following steps:

- implantation of atomic species into an intermediate layer in order to create therein a region of weakness in the vicinity of the implant depth;
- bonding to a composite support (10) of the layer to be transferred;
- supplying energy into the region of weakness, in order to detach the layer to be transferred from the multilayer structure;

- selective etching of that portion of the intermediate layer remaining on the detached layer to be transferred, thus producing the epitaxy substrate (30); and
- removal of material from the multilayer structure until another layer to be transferred is reached.

10. Process for forming a plurality of epitaxy substrates according to Claim 9, characterized in that it furthermore includes an epitaxial nucleation layer for a new layer to be transferred, on the multilayer structure.

11. Process for forming a plurality of epitaxy substrates according to either of Claims 9 and 10, characterized in that it furthermore includes a plurality of crystalline growth steps on the plurality of transferred layers, so as to form a plurality of respective useful layers.

12. Structure intended for electronics, optics or optoelectronics, characterized in that it includes an epitaxy substrate (30) comprising a composite support (10) according to one of Claims 1 to 4 and a transferred layer (20) made of a material chosen from crystalline materials.

13. Structure according to the preceding claim, characterized in that the transferred layer (20) is made of GaN.

14. Structure according to the preceding claim, characterized in that the composite support (10) is a three-layer support and comprises:

- a central layer (1) made of SiC; and
- a pair of layers (2, 2'), each made of sapphire.

15. Structure according to one of the three preceding claims, characterized in that the transferred layer (20) includes electronic components.

16. Structure according to one of Claims 12 to 14, characterized in that it furthermore includes a useful layer formed by crystalline growth on the transferred layer (20).

17. Structure according to the preceding claim, characterized in that the useful layer includes electronic components.