DESCRIPTION

TITLE: SUPPORT PROVIDED WITH A GRAPHENE-OXIDE LAYER, INTENDED TO TRANSFER A LAYER BY LASER SEPARATION, AND PRODUCTION METHOD

TECHNICAL FIELD OF THE INVENTION

The invention relates to a support provided with one or more layers that are to be transferred and are intended to be separated from at least part of the support by laser irradiation at a separation layer included in the support, for the purpose of producing products in the field of semiconductors.

TECHNOLOGICAL BACKGROUND

The semiconductor industry is increasingly using thin-layer transfer techniques which consist, in a first step, in forming a thin layer on a first substrate, then, in a second step, in transferring the thin layer formed onto a second substrate.

The first substrate may be chosen for its compatibility with the conditions for forming the thin layer, or else the thin layer may be formed in the mass of the material forming this first substrate.

The second substrate is suitable for making use of this thin layer, for example by being compatible with subsequent production steps or else even by supporting a structure on which the thin layer will come to be integrated.

Among the thin-layer transfer techniques used in the semiconductor industry, separation by laser (laser lift-off – LLO) has been found to be an efficient method for separating a film or a stack of a plurality of films or one or a plurality of thin layers from a support substrate by means of a layer, known as the separation layer, the separation or degradation of which is triggered by laser.

In general, the separation layer is irradiated by laser through the support substrate. The separation layer must absorb a sufficient quantity of light at the wavelength of the laser to assist the separation or its degradation (for example by melting the separation layer locally or by giving rise to its dissociation into an elementary component), whereas the support substrate must be essentially transparent at this wavelength. A balance must be found between the power of the laser, the wavelength of the laser and the choice of the materials (for the separation layer and the support substrate) in order to permit the separation while protecting the one or more layers to be transferred against the impact of the dissipation of energy caused by the processes of interaction with the light: transfer of heat caused by the absorption into the separation layer or direct absorption of part of the laser irradiation by the one or more layers to be transferred.

Patent US 11,069,865 B2 describes a method for producing a flexible OLED display panel, wherein the display panel is produced on a glass plate covered with an organic separation layer which absorbs the UV radiation strongly. The display panel is detached from the glass plate by an operation of separation by laser, wherein the separation layer, which is capable of absorbing ultraviolet radiation, is irradiated through the glass plate by a laser operating in the ultraviolet domain, thus facilitating the separation.

The number of candidate materials acting as the separation layer is limited and even more scarce if the contamination specifications in the methods for producing semiconductor devices, in particular during front-end operations, are taken into consideration. One of the most commonly used materials is gallium nitride GaN which constitutes an advantageous solution for LLO by UV ultraviolet irradiation (referred to as UV-LLO), as described in the patent US 8,598,014 B2.

However, using GaN in production lines is often associated with contamination in front-end and back-end lines. Furthermore, UV-LLO associated with GaN requires thick layers of GaN, of which one part is burnt by the laser to carry out the LLO and a remaining part is adversely impacted by the increased temperature caused by the laser irradiation. Using UV for the LLO is also tedious because it requires a complex laser installation and poses energy-related risks as much for samples as for operators.

Document KR 20240027262 A1 describes a method for laser lift-off by irradiation of a layer of graphene, graphene oxide or reduced graphene oxide.

Document CN 117238747 A describes a method for laser lift-off using a lift-off layer formed of graphene oxide obtained by liquid deposition.

SUMMARY OF THE INVENTION

One subject of the invention is the use of a graphene-oxide layer as an optically absorbing layer in a method for separating a layer by laser irradiation (LLO), thus solving the problems mentioned above. More specifically, the invention relates to a structure capable of undergoing separation by laser irradiation and to a method for producing this structure.

Another subject of the invention is a method for producing an advanced structure based on the structure obtained by the method of the first subject of the invention.

For the purpose of implementing these subjects, a first aspect of the invention is a starting structure designed to undergo separation by laser irradiation, comprising a substrate, a transferred layer, and a graphene-oxide layer interposed between the substrate and the transferred layer. The transferred

layer may be made up of monocrystalline silicon carbide SiC or of sapphire.

The structure according to the invention makes it possible to provide a structure that is ready to be integrated into a method for producing a semiconductor device requiring a layer to be transferred from a first support to a second support. A starting structure or substrate for an integrated method for producing a semiconductor substrate device may thus be referred to as “epi-ready” since this structure or this substrate is ready to be used as a support for the growth of a layer by epitaxy. More generally, this layer is capable of undergoing any production step conventionally used in the domain of the semiconductor industry, such as a photolithography step, a heat or plasma treatment step, or else a step of depositing layers of electrically conductive, insulating or semiconductor materials.

One advantage of the structure according to the invention is that of providing an alternative to existing solutions which may lead to inconvenient contamination of the devices to be produced from this structure.

Another advantage is the level of optical absorption of infrared radiation by the graphene-oxide layer. During the operation of separation by laser irradiation, the energy of the incident radiation will be essentially absorbed by the graphene layer if the radiation has a suitable wavelength, thus limiting the thermal degradation of the rest of the structure, and in particular of the layer that is transferred onto the second support. Thus, it is not necessary to maximize the thickness of the graphene layer to absorb the highest possible amount of the laser irradiation and avoid it being absorbed by the other layers which could then undergo degradation, these other layers possibly being transparent to infrared radiation.

An additional advantage lies in the resistance of the graphene-oxide layer to high temperatures that are typical, for example, of methods for depositing a layer by epitaxy which are usually performed at between 800°C and 1500°C. For this additional reason, the structure according to the invention is compatible with a large number of methods that are likely to be applied to it in the field of semiconductors.

According to additional non-limiting features of the first aspect of the invention, considered individually or in any technically feasible combination:

- the substrate may be transparent to infrared radiation;
- the substrate may be transparent to radiation having a wavelength comprised between 9 and 11 μm;
- the substrate may be made up of silicon Si or of silicon carbide SiC; and
- the transferred layer may be made up of monocrystalline silicon carbide SiC or of sapphire.

A second aspect of the invention is a method for producing a starting structure designed to undergo separation by laser irradiation, comprising a substrate, a transferred layer, and a graphene-oxide layer interposed between the substrate and the transferred layer, the method comprising: a step of providing two substrates; a step of forming at least one multi-layer graphene layer on at least one of the two substrates; a step of oxygenating the at least one multi-layer graphene layer so as to form at least one graphene-oxide layer; a step of joining the two substrates via the at least one graphene-oxide layer; and a step of detaching part of one of the two substrates so as to leave the transferred layer on the other of the two substrates.

According to additional non-limiting features of the second aspect of the invention, considered individually or according to any technically feasible combination:

- the joining step may be carried out by direct contacting;

- a multi-layer graphene layer may be formed on each of the two substrates; and

- the method may further comprise a step of ionic implantation into the first substrate, so as to form a weakening plane in this first substrate and thus define the transferred layer; and

- the transferred layer may be made up of monocrystalline silicon carbide SiC or of sapphire.

A third aspect of the invention is a method for producing an advanced structure comprising a layer formed by epitaxy on the transferred layer of a starting structure designed to undergo separation by laser irradiation, comprising a substrate, a transferred layer, and a graphene-oxide layer interposed between the substrate and the transferred layer, the method comprising the steps of: providing the starting structure according to the first aspect of the invention; forming by epitaxy the layer formed by epitaxy on the transferred layer of the structure provided; joining a third substrate to the structure by directly contacting this third substrate with the epitaxied layer; and irradiating the graphene-oxide layer by infrared irradiation, so as to separate the transferred layer, the epitaxied layer and the third substrate from the substrate of the starting structure.

According to additional non-limiting features of the third aspect of the invention, considered individually or according to any technically feasible combination:

- the irradiation uses an electromagnetic wave having a wavelength comprised between 9 and 11 μm;

- the method may further comprise a step of removing the layer following the separation step; and

- the epitaxied layer is a layer of gallium nitride GaN; and

- the transferred layer may be made up of monocrystalline silicon carbide SiC or of sapphire.

One advantage of the methods is their simplicity and their excellent technical benefit with respect to their cost.

Another advantage of the methods according to the invention stems from the simplicity of the use of laser irradiation in the infrared domain coupled with the use of materials compatible with methods for producing semiconductor devices.

BRIEF DESCRIPTION OF THE FIGURES

Other features and advantages of the invention will become apparent from the detailed description of the invention which will follow, with reference to the appended figures, in which:
[Fig. 1] Figure 1 illustrates the steps of a method for producing a starting structure according to the invention;
[Fig. 2] Figure 2 is a flowchart summarizing the steps of the production method of Figure 1;
[Fig. 3] Figure 3 illustrates a variant of the method of Figures 1 and 2;
[Fig. 4] Figure 4 illustrates a method for producing an advanced structure on the basis of the starting structure of Figure 1;
[Fig. 5] Figure 5 is a flowchart summarizing the steps of the production method of Figure 4; and
[Fig. 6] Figure 6 illustrates one of the steps of the method of Figures 4 and 5.

DETAILED DESCRIPTION OF THE INVENTION

Embodiment of the invention – Structure Struct_0

One embodiment of the invention is described in detail below and illustrated by Figures 1 to 3.

Figure 1 illustrates the steps of a method 100 for producing a first structure Struct_0 according to the invention. One aim of this production method is to obtain a structure that is capable of being used as a basis for making a device in the domain of the semiconductor industry. Specifically, the

structure Struct_0 comprises a layer TrLay supported by a substrate Sub2 by way of a graphene-oxide layer GO, the latter possibly being degraded and/or reduced by infrared laser irradiation so as to detach the layer TrLay from the substrate Sub2. The benefit of this operation will be explained by way of example by means of Figures 4 to 6.

The process 100 begins with the provision of two substrates Sub1 and Sub2 with two provisioning stages 110 and 120, respectively. In this implementation example of the invention, the substrates Sub1 and Sub2 are made up of planar silicon carbide substrates, such as wafers of silicon carbide SiC.

In steps 130 and 140, layers of multi-layer graphene MG1 and MG2, made of carbon atoms C, are formed on the surface of the substrates Sub1 and Sub2 of SiC by conventional heat treatment, preferentially sublimating the atoms of silicon Si of the surfaces of the SiC. The number of graphene layers may be comprised between 5 and 20, this corresponding to thicknesses comprised between 1.5 and 14 nm. Reference may be made, for example, to the article by Piotr Ciochon et al., “Reversible graphitization of SiC: A route towards high-quality graphene on a minimally step bunched substrate”, in Applied Surface Science 528 (2020) 146917. In order to promote the obtention of the graphene layers MG1 and MG2 by this step, the substrates of SiC are preferably formed of monocrystalline SiC.

Alternatively, the graphene layers may be obtained by Chemical Vapour Deposition (CVD). In this case, the substrates of SiC may be polycrystalline as well as monocrystalline.

In a step 150 of implantation of at least one light entity, the substrate Sub1 is prepared for a step of separation of the layer TrLay originating from part of the thickness of the substrate Sub1, for example according to the Smart Cut™ technology.

To this end, the substrate Sub1 must be prepared by introduction of at least one light entity, such as hydrogen or helium, into this substrate. This introduction may correspond to hydrogen implantation, that is to say an ionic bombardment of hydrogen, here through the graphene layer MG1. In a manner known per se, and as illustrated by Figure 1, the hydrogen ions H^+ are implanted so as to form a weakening plane Frgl delimiting the layer TrLay to be transferred. The layer TrLay is situated on the side of the graphene layer MG1 in relation to this weakening plane Frgl.

The nature, the dose of the implanted entities and the implantation energy are chosen as a function of the thickness of the layer which it is desired to transfer and of the physicochemical properties of the substrate Sub1. In the case of a substrate Sub1 made of SiC, it will be possible to choose to implant a dose of hydrogen comprised between 10^{16} and 5.10^{17} at/cm^2 with an energy level comprised between 30 and 300 keV in order to delimit a layer TrLay of the order of 200 to 2000 nm in thickness.

In steps 160 and 170 of oxygenation, the graphene layers MG1 and MG2 are oxygenated to form graphene-oxide layers GO1 and GO2, respectively. These operations may be carried out, for example, according to Hummers' method or one of its derivatives, which involve the treatment of the graphene layers by means of $KMnO_4$ and NaO_3 in concentrated sulfuric acid H_2SO_4. Reference may be made to the article by Daniela C. Marcano et al., "Improved synthesis of graphene oxide", in *ACS Nano* 2010, 4, 8, 4806–4814.

There are two reasons to proceed with these oxygenation steps.

The first reason is that the oxygenation of the graphene layer adds functional (carbonyl, hydroxyl, epoxy) groups to it which give it a greater hydrophilicity, this making it easier

for these two layers to be bonded to one another in the following step 200.

The second reason is that the chemical bonds C-O between the carbon atoms and the oxygen atoms strongly absorb infrared radiation having a wavelength of around 1087 cm^{-1}, for example comprised between 9 and 11 µm. This feature will be utilized in step 340 of the method 300 illustrated by Figures 4 to 6.

In a joining step 200, the two substrates Sub1 and Sub2 are joined together by bringing the graphene-oxide layer GO1 into direct contact with the graphene-oxide layer GO2. These two layers adhere to each other by molecular bonding. This forms a stack Stck comprising, in this order, the substrate Sub2, the layer GO2, the layer GO1, and the substrate Sub1. The substrate Sub1 comprises the weakening plane Frgl. The layers GO1 and GO2 may be considered to collectively form a graphene-oxide layer GO.

In a detachment step 210 following step 200, the substrate Sub1 is split into two parts at the weakening plane Frgl, in this example according to the Smart Cut™ process.

Thus, in the present embodiment, part of the substrate Sub1 is detached from the rest of its volume to form a layer of interest, here the layer TrLay. As explained above, this layer was defined by the volume of the substrate Sub1 situated between the weakening plane Frgl and the graphene layer MG1, now the graphene-oxide layer GO1. After the step of joining the substrates Sub1 and Sub2, this layer TrLay is detached from the rest of the substrate Sub1 by fracturing at the weakening plane Frgl and is thus attached to the support Sub2. The assembly obtained is designated by Struct_0, a structure comprising, in this order, the substrate Sub2, the layer GO2, the layer GO1, and the layer TrLay which was transferred from the substrate Sub1 to the substrate Sub2.

This detachment step may thus comprise the application, to the stack Stck, of a heat treatment in a temperature range of the order of 80°C to 500°C in order to make possible the detachment of the layer TrLay and thus to complete the transfer of the latter onto the substrate Sub2. Instead of or in addition to the heat treatment, this step may comprise the application of a blade or a jet of gaseous or liquid fluid, or of any other force of mechanical nature, at the weakening plane Frgl.

In an optional step 220 following the detachment step 210 which led to the stack Stck being obtained, a stabilizing heat treatment may be applied to the stack Stck. The stabilizing heat treatment makes it possible to correct crystal defects present in the layer TrLay. This heat treatment may be provided in order to bring the stack to a temperature comprised between 300°C and 600°C for a period of time comprised between 30 minutes and 10 hours. This heat treatment is preferentially carried out by exposing the free face of the dielectric layer to a neutral gaseous atmosphere.

Following the detachment of the layer TrLay from the rest of the substrate Sub1, its free surface is uneven. In order to put it in a state in which it can be used as a support in, for example, a step of growing a layer by epitaxy, attachment to a third substrate, or any other operation such as those conventionally used in the semiconductor industry, it is necessary to prepare this surface and in particular to reduce its roughness, ideally so as to make it atomically planar.

Thus, in a surface preparation step 230, which may precede or follow step 220, a planarizing and polishing treatment is applied to the layer TrLay. This may be a Chemical Mechanical Polishing (CMP) treatment.

Following the surface treatment step 230 and, where applicable, the stabilizing step 220, the structure Struct_0 may

be considered to be capable of being used, for example, as a support in the formation of a layer by epitaxy.

Figure 3 illustrates a variant of the method 100. In this variant, a single graphene layer is formed then oxidized. It is preferable to keep the graphene layer which will not be passed through by ions during the formation of the weakening plane Frgl. More specifically, the method 100 remains the same except that the graphene multilayer MG1 is not formed, and is therefore not oxidized. Thus, during the joining step 200, the graphene-oxide layer GO2 is brought into direct contact with the substrate Sub1. This layer is therefore formed directly on the volume of material of the substrate Sub1 intended to form the layer TrLay. In the stack Stck, the layer TrLay is defined by the volume of the substrate Sub1 situated between the weakening plane Frgl and the graphene layer GO2. Here, the graphene layer GO is formed uniquely of the graphene layer GO2.

One variant, which is not illustrated, of obtaining an oxidized or oxygenated graphene layer is to proceed via a wet route: according to known methods, a graphite powder may be suspended in a liquid solution containing oxygen (typically, the solutions used in Hummers' method) so as to obtain oxidized graphene in suspension, for example via sonication. This suspension may then be directly spread on a substrate to obtain an oxidized or oxygenated graphene layer.

The thicknesses of the graphene layers GO2 and, where applicable, GO1, may be adapted to define the thickness of the layer GO for the purpose of absorbing a more or less significant part of incident infrared radiation during a subsequent step of laser separation. These thicknesses will be determined, according to the criteria of the operator, depending on the nature of the layers that are going to be separated.

Embodiment of the invention – Structure Struct_1

Figures 4 to 6 illustrate an example of a method using the structure Struct_0, with the formation of an epitaxied layer Epi directly on the layer TrLay, and the transfer of this epitaxied layer onto a support Sub3.

This example illustrates the obtention of an advanced structure Struct_1 comprising a support Sub3 which supports an epitaxied layer of gallium nitride GaN.

A method 300 according to the invention starts with a step 310 of providing the structure Struct_0 obtained, for example, by means of the method 100 illustrated by Figures 1 to 3.

In an epitaxy step 320, a layer Epi of gallium nitride GaN is formed by epitaxy on the layer TrLay of silicon carbide, known to be a good substrate for growth of GaN of excellent crystalline quality, the layer of GaN thus formed possibly being considered to be monocrystalline.

In a joining step 330, a substrate Sub3 is joined to the structure Struct_0 via the layer Epi. The substrate Sub3 and the layer Epi are brought into close contact and fixed to one another by molecular bonding, for example by direct hydrophilic bonding.

The substrate Sub3 is chosen to be sufficiently planar and smooth to be capable of being bonded directly to the layer Epi. It may be, for example, a monocrystalline silicon wafer or any other material used in the field of semiconductors, such as sapphire, poly-SiC, mono or poly AlN or glass, or a combination of these materials. The substrate Sub3 is also chosen for its compatibility with the production steps intended to be subsequently applied to the layer Epi, such as steps of photolithography, plasma treatments, depositing electrically insulating or conductive layers, ionic implantations, heat treatments or other production steps used in the semiconductor industry.

In an irradiation step 340, a laser beam having a wavelength comprised in the infrared, preferably between 9 and 11 µm, irradiates the layer GO through the substrate Sub2. The density of power, the scanning speed of the beam and other parameters, such as the length and the frequency of irradiation light pulses, will be adapted by the operator to the transparency and the thickness of the material through which the layer GO is irradiated, as well as the thickness of the layer GO. Under the effect of this irradiation Irr, the layer GO may be degraded by decomposition as illustrated by Figure 4 and indicated by "X" in Figure 5. Alternatively and possibly conjointly, according to the irradiation parameters and therefore according to the temperature reached by the layer GO, the irradiation Irr may induce chemical reduction of the graphene-oxide layer GO so as to form reduced graphene oxide rGO having a volume much greater than the graphene oxide. Reference may be made to the article by Tung Xuan Tran et al., "Laser-Induced Reduction of Graphene Oxide by Intensity-Modulated Line Beam for Supercapacitor Applications", ACS Appl. Mater. Interfaces, 2018, Nov 21; 10(46):39777-39784. This increase in volume may help to move away one of the other two layers surrounding the layer GO.

The irradiation of step 340 thus allows separation of the layer TrLay from the substrate Sub2 in step 350. This forms a structure comprising, in this order, the substrate Sub3, the epitaxied layer Epi, the transferred layer TrLay and the rest of the layer GO formed of graphene oxide and/or reduced graphene oxide rGO. Steps 340 and 350 may also be considered to be a single step of irradiation and separation.

In a step 360, the rest of the layer GO and the layer TrLay are cleared away so as to remove the layer Epi. This cleaning may be carried out by Chemical Mechanical Polishing (CMP). This forms a structure which comprises, in this order, the substrate Sub3 and the layer Epi of GaN.

At any time following the step of joining the substrate Sub3 to the structure Struct_0, a step 370 of stabilizing heat treatment may be applied to the assembly formed. The stabilizing heat treatment makes it possible to correct crystal defects present in the layer Epi and contributes to consolidating the fixing between the layer Epi and the substrate Sub3. This heat treatment may be provided in order to bring the stack to a temperature comprised between 300°C and 600°C for a period of time comprised between 30 minutes and 10 hours. This heat treatment is preferentially carried out by exposing the free face of the dielectric layer to a neutral gaseous atmosphere. Carried out after the step 360 of clearing away the layer TrLay, this treatment may advantageously repair the damage caused to the layer Epi by this step 350. At the end of the steps above, the structure Struct_1 is obtained.

There are other methods to obtain thin layers of gallium nitride and transfer them onto a receiver substrate, in particular those using Smart Cut™ technology. This technology is based on the formation of a weakening plane in a thick donor substrate, for example a monocrystalline wafer obtained from a massive monocrystalline ball of the desired material. The depth of this weakening plane defines the thickness of a material layer which will be able to be detached from the wafer. This weakening plane is obtained by ionic implantation of light entities into the wafer, through one of its surfaces. However, the depth to which this implantation plane is found is limited by the maximum acceleration voltage of the ionic implantation equipment available on the market. Thus, a layer which is able to be detached from the donor substrate sees its thickness limited by the maximum implantation depth of the ions forming the weakening plane.

By contrast, the method 300 described above, applied here to gallium nitride, advantageously makes it possible to avoid

this limitation in thickness while allowing easy transfer of the layer obtained. Specifically, the layer Epi may be epitaxied according to arbitrary thicknesses (while remaining subject to the critical epitaxy thickness), independently of the ionic implantation equipment available. Next, a support substrate is joined to the epitaxied layer.

Alternative embodiments

The example presented above relates to the formation of a layer Struct_0 using substrates Sub1 and Sub2 of silicon carbide SiC. Other substrates may be used, provided that at least one of them is compatible with the formation of a graphene layer and its oxygenation treatment. Mention may be made, for example, of substrates of sapphire, poly-SiC, mono or poly AlN or glass, or a combination of these materials, but any other substrate that meets the condition of compatibility stated above could be used, such as those used in the semiconductor industry.

With regard to the formation of the structure Struct_1, an additional condition to that stated in the preceding paragraph is that the substrate Sub2, support of the layer TrLay via the layer GO, is substantially transparent to the wavelength used during the step of irradiating the layer GO. Mention may be made again of substrates of silicon carbide and of silicon for Sub2. “Substantially transparent” means when at least 10% of the wavelength in question is transmitted through this substrate.

Alternatively, and although this is not the preferred method a priori, it would be possible to irradiate the layer GO through the substrate Sub3 and the layer TrLay. In this case, it is the substrate Sub3 which must be substantially transparent to the wavelength used during the step of irradiating the layer GO. In this case, mention may be made again of substrates of silicon carbide and of silicon for Sub3.

In this document, the figures are not necessarily to scale. Some features and some components may be represented in an exaggerated manner relative to other components or in a somewhat schematic form, and some details of conventional elements may not be represented in the interest of clarity and of conciseness.

Of course, the invention is not limited to the embodiments described, and variant embodiments may be introduced thereto without departing from the scope of the invention as defined by the claims.

CLAIMS

1. Starting structure (Struct_0) designed to undergo separation by laser irradiation, comprising a substrate (Sub2), a transferred layer (TrLay), and a graphene-oxide layer (GO, GO2) interposed between the substrate (Sub2) and the transferred layer (TrLay), wherein the transferred layer is made up of monocrystalline silicon carbide SiC or of sapphire.

2. Structure according to Claim 1, wherein the substrate (Sub2) is transparent to infrared radiation.

3. Structure according to Claim 1, wherein the substrate (Sub2) is transparent to radiation having a wavelength comprised between 9 and 11 µm.

4. Structure according to any one of Claims 1 to 3, wherein the substrate is made up of silicon Si or of silicon carbide SiC.

5. Method (100) for producing a starting structure (Struct_0) designed to undergo separation by laser irradiation, comprising a substrate (Sub2), a transferred layer (TrLay), and a graphene-oxide layer (GO, GO2) interposed between the substrate (Sub2) and the transferred layer (TrLay), the method comprising:

- a step (110, 120) of providing two substrates (Sub1, Sub2);
- a step (130, 140) of forming at least one multi-layer graphene layer (MG1, MG2) on at least one of the two substrates (Sub1, Sub2);
- a step (160, 170) of oxygenating the at least one multi-layer graphene layer so as to form at least one graphene-oxide layer (GO1, GO2);

- a step (200) of joining the two substrates (Sub1, Sub2) via the at least one graphene-oxide layer (GO1, GO2, GO); and

- a step of detaching (210) part of one (Sub1) of the two substrates so as to leave the transferred layer (TrLay) on the other of the two substrates (Sub2).

6. Production method according to Claim 5, wherein the joining step (200) is carried out by direct contacting.

7. Production method according to Claim 5 or 6, wherein a multi-layer graphene layer (MG1, MG2) is formed on each of the two substrates (Sub1, Sub2).

8. Method according to any one of Claims 5 to 7, further comprising a step (150) of ionic implantation into the first substrate (Sub1), so as to form a weakening plane (Frgl) in this first substrate (Sub1) and thus define the transferred layer (TrLay).

9. Method according to any one of Claims 5 to 8, wherein the transferred layer (TrLay) is made up of monocrystalline silicon carbide SiC or of sapphire.

10. Method (300) for producing an advanced structure (Struct_1) comprising a layer (Epi) formed by epitaxy on a transferred layer (TrLay) of a starting structure (Struct_0) designed to undergo separation by laser irradiation, comprising a substrate (Sub2), the transferred layer (TrLay), and a graphene-oxide layer (GO, GO2) interposed between the substrate (Sub2) and the transferred layer (TrLay), the method comprising the steps of:

- providing (310) the starting structure (Struct_0);

- forming (320) by epitaxy the layer (Epi) on the transferred layer (TrLay) of the structure (Struct_0) provided;

- joining (330) a third substrate (Sub3) to the structure (Struct_0) by directly contacting this third substrate (Sub3) with the epitaxied layer (Epi); and

- irradiating (340) the graphene-oxide layer (GO) by infrared irradiation (Irr), so as to separate (350) the transferred layer (TrLay), the epitaxied layer (Epi) and the third substrate (Sub3) from the substrate (Sub2) of the starting structure (Struct_0).

11. Method according to Claim 10, wherein the irradiation (Irr) uses an electromagnetic wave having a wavelength comprised between 9 and 11 µm.

12. Method according to Claim 10 or 11, further comprising a step (360) of removing the layer (Epi) following the separation step (350).

13. Method according to any one of Claims 10 to 12, wherein the epitaxied layer is a layer of gallium nitride GaN.

14. Method according to any one of Claims 10 to 13, wherein the transferred layer (TrLay) is made up of monocrystalline silicon carbide SiC or of sapphire.