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(54) **METHOD FOR LOCATING DEVICES**

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(57) **ABSTRACT**

The disclosure relates to a process for locating devices, the process comprising the following steps:

a) providing a carrier substrate comprising:

a device layer; and

alignment marks;

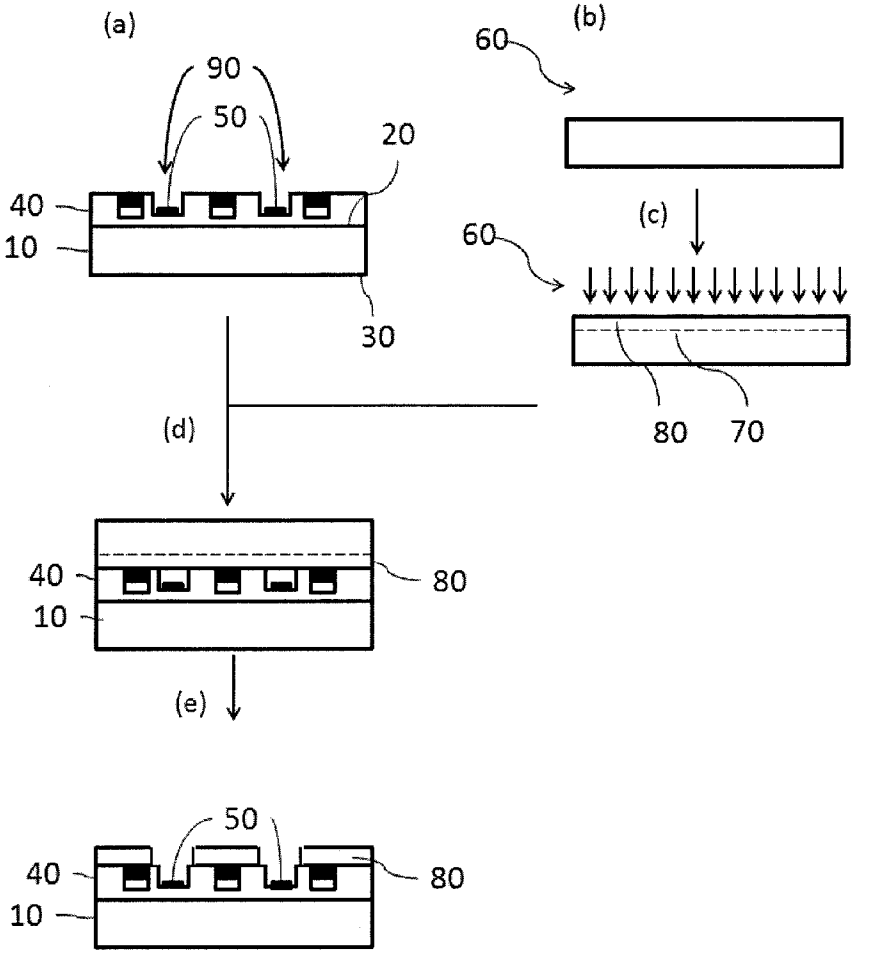
b) providing a donor substrate;

c) forming a weak zone in the donor substrate, the weak zone delimiting a useful layer;

d) assembling the donor substrate and the carrier substrate; and

e) fracturing the donor substrate in the weak zone so as to transfer the useful layer to the device layer;

wherein the alignment marks are placed in cavities formed in the device layer, the cavities having an aperture flush with the free surface of the device layer.



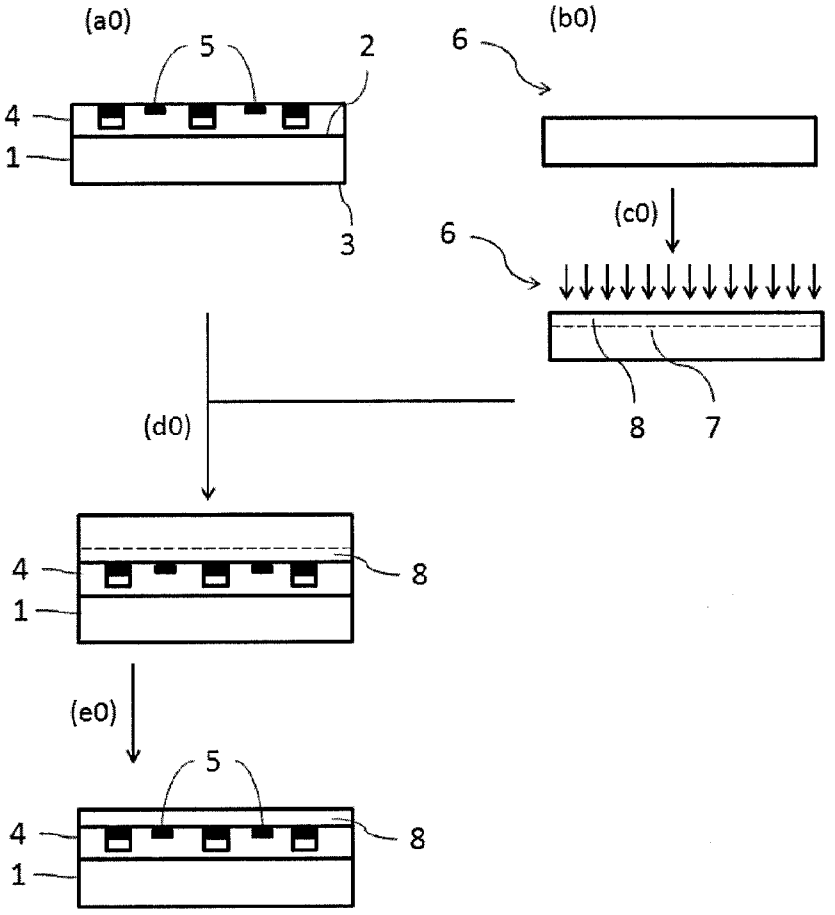


FIG. 1A
(PRIOR ART)

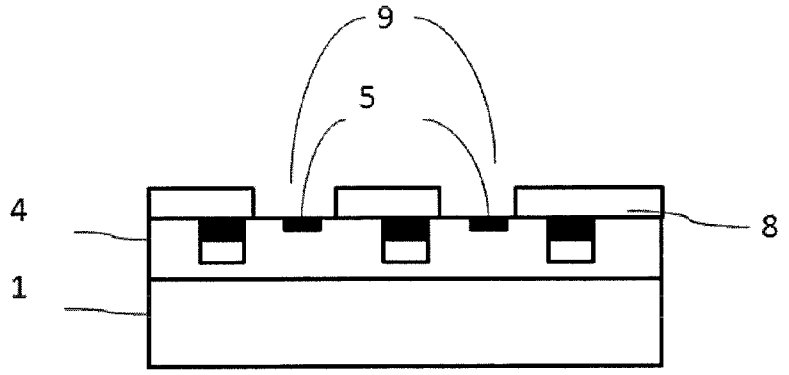


FIG. 1B
(PRIOR ART)

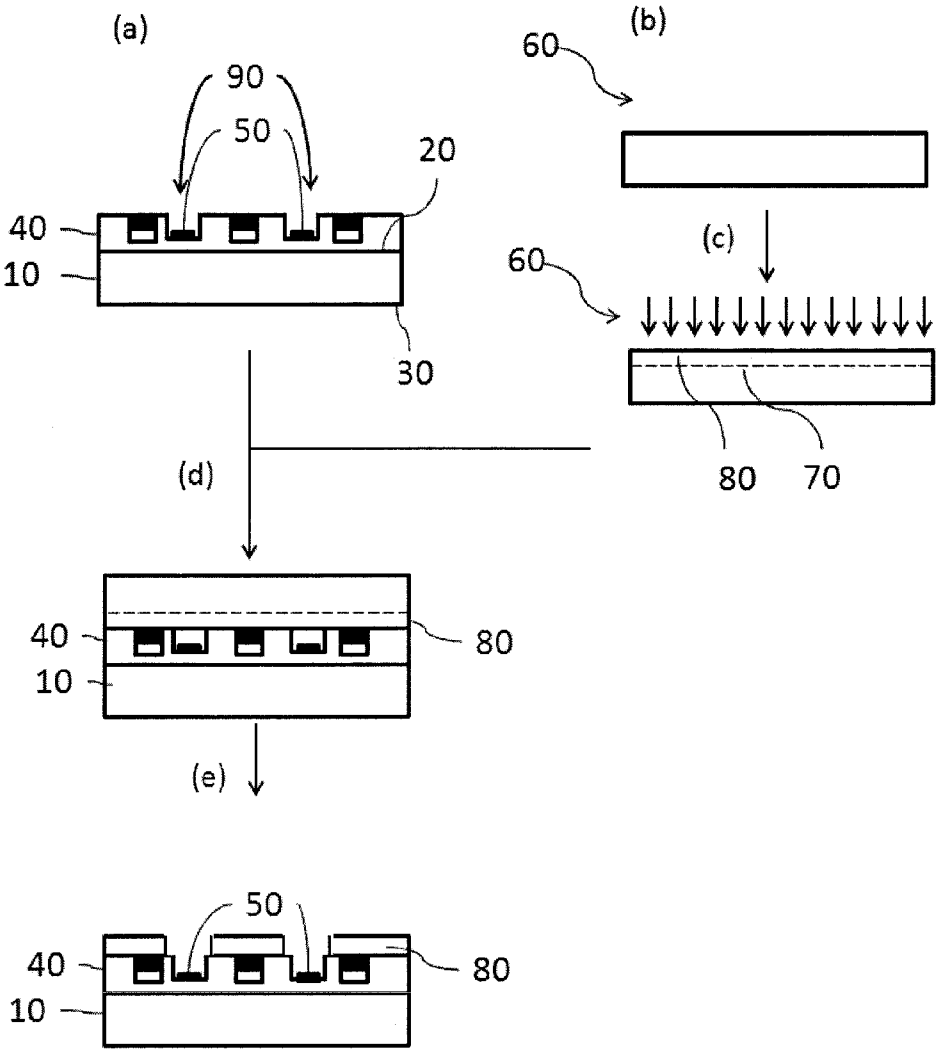


FIG. 2

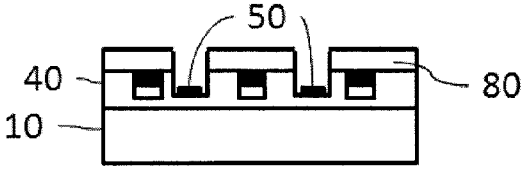


FIG. 3

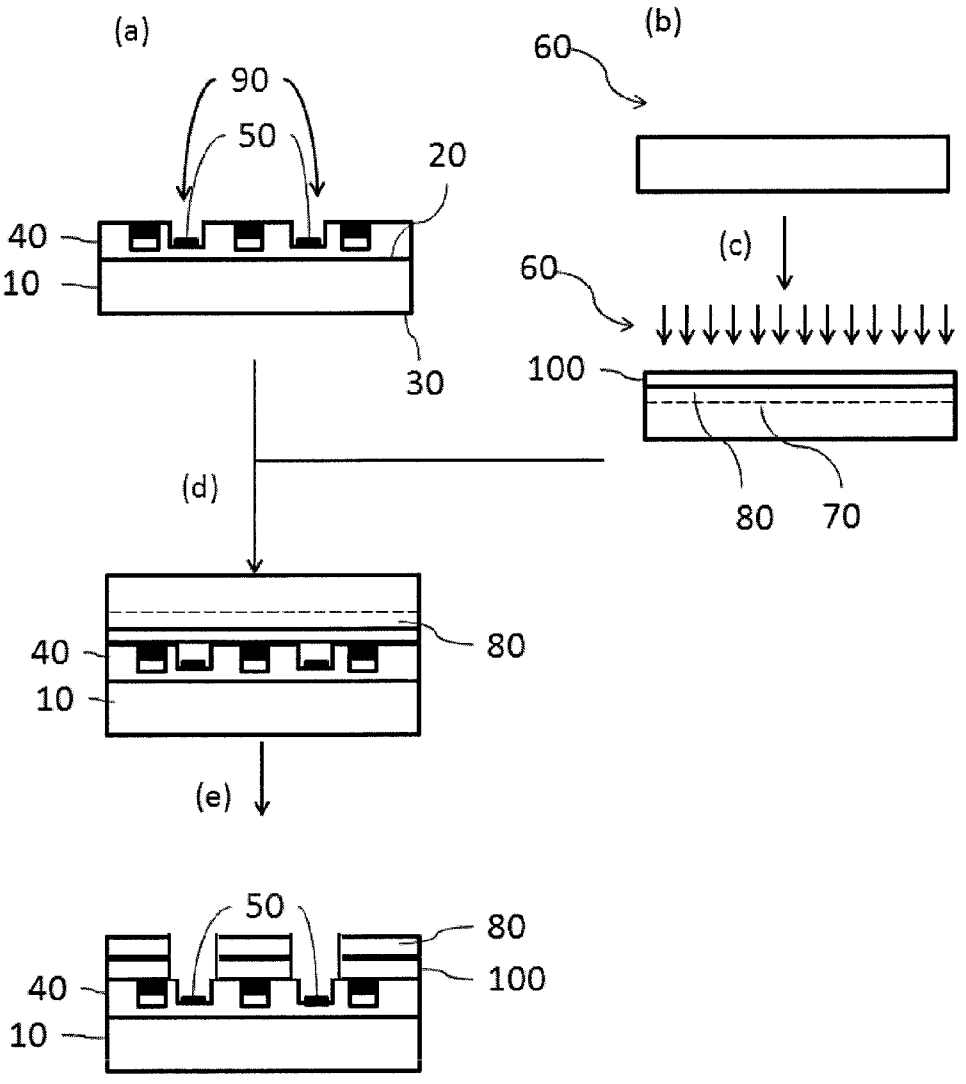


FIG. 4

METHOD FOR LOCATING DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a national phase entry under 35 U.S.C. §371 of International Patent Application PCT/FR2014/051568, filed Jun. 24, 2014, designating the United States of America and published in English as International Patent Publication WO 2015/007971 A1 on Jan. 22, 2015, which claims the benefit under Article 8 of the Patent Cooperation Treaty and under 35 U.S.C. §119(e) to French Patent Application Serial No. 1301697, filed Jul. 15, 2013, the disclosure of each of which is hereby incorporated herein in its entirety by this reference.

TECHNICAL FIELD

[0002] This disclosure relates to a process for locating devices after transfer of a useful layer to a carrier substrate.

BACKGROUND

[0003] A prior-art process for locating devices after transfer of a useful layer **8** to a carrier substrate **1**, as illustrated in FIG. **1**A, comprises the following steps:

[0004] a0) Providing a carrier substrate **1** comprising:

[0005] A front side **2**;

[0006] A back side **3** parallel to the front side **2**; and

[0007] A device layer **4** placed on the front side **2**, the device layer **4** comprising alignment marks **5**;

[0008] b0) Providing a donor substrate **6**;

[0009] c0) Forming a weak zone **7** in the donor substrate **6**, the weak zone **7** delimiting a useful layer **8**;

[0010] d0) Assembling the donor substrate **6** and the carrier substrate **1**; and

[0011] e0) Fracturing the donor substrate **6** in the weak zone **7** so as to transfer the useful layer **8** to the device layer **4**.

[0012] The device layer **4** comprises devices such as transistors, (npn or pnp) junctions, interconnections and any other structure. The useful layer **8** generally comprises an opaque semiconductor layer.

[0013] After the fracturing step e0), the useful layer **8** masks the devices of the device layer **4** and the alignment marks **5**.

[0014] The main drawback of this process is that the alignment marks **5** are no longer accessible or observable.

[0015] Therefore, such as shown in FIG. **1**B, which illustrates a common practice, apertures **9** (or holes) must be produced in the useful layer **8** in order to expose the alignment marks **5**.

[0016] The process for forming the apertures **9** generally comprises a photolithography step, followed by an etching step.

[0017] The photolithography step is intended to define the shape and position of the apertures **9** in the useful layer **8**. However, this step, carried out with no reference point other than the edge of the carrier substrate **1**, has a precision of +/−100 μm. Therefore, the alignment marks **5** can be localized only to within +/−100 μm. The apertures **9** must thus have a side length (i.e., a width) of about 250 μm. Such a side length consumes too much space, and is unacceptable.

[0018] One aim of the disclosure is, therefore, to provide a simpler process for locating devices after transfer of a useful layer **8**, allowing smaller apertures to be formed than with prior-art techniques.

BRIEF SUMMARY

[0019] This disclosure aims to remedy the aforementioned drawbacks, and relates to a process for locating devices after transfer of a useful layer, the process comprising the following steps:

[0020] a) providing a carrier substrate comprising:

[0021] a device layer comprising a free surface; and

[0022] alignment marks;

[0023] b) providing a donor substrate;

[0024] c) forming a weak zone in the donor substrate, the weak zone delimiting a useful layer;

[0025] d) assembling the donor substrate and the carrier substrate; and

[0026] e) fracturing the donor substrate in the weak zone so as to transfer the useful layer to the device layer.

[0027] The alignment marks are placed in cavities formed in the device layer, the cavities having an aperture flush with the free surface of the device layer. The alignment marks are placed so as to make it possible to locate the devices.

[0028] The useful layer may be formed from a set of sublayers. The useful layer is generally opaque and, therefore, masks the device layer after step e).

[0029] The cavities have walls, and the volume delimited by the walls of a cavity and its aperture makes up the volume of the cavity.

[0030] By "alignment marks placed in cavities," is meant that the alignment marks are placed in the volume of the cavities.

[0031] The presence of through-holes in the useful layer has been observed after the fracturing step e), and in positional correspondence with the cavities. The holes thus extend through the cavities into the useful layer, so that the alignment marks are visible from the free surface of the useful layer.

[0032] Thus, the devices of the device layer may be located from the free surface of the useful layer.

[0033] Furthermore, it is not necessary to execute fabrication steps specific to the formation of holes in the useful layer. The holes are automatically formed in the positions of the cavities at the moment of the transfer of the useful layer.

[0034] According to one method of implementation, the assembly step d) comprises a direct bonding step executed in an environment at a pressure below 20 mbars.

[0035] Thus, it has been observed that the through-holes in the useful layer have a shape that corresponds to the aperture of the cavities. Therefore, the through-holes in the useful layer do not encroach beyond the aperture of the cavities.

[0036] According to one method of implementation, the cavities extend as far as into the carrier substrate.

[0037] According to one method of implementation, the alignment marks are placed at the bottom of the cavities.

[0038] According to one method of implementation, the device layer comprises devices regularly distributed over the entire extent of the device layer.

[0039] According to one method of implementation, an opaque layer is present on the useful layer before the assembly step d).

[0040] According to one method of implementation, the opaque layer comprises at least one material selected from the

following group: tungsten, titanium, tungsten silicide, titanium silicide, nickel silicide, nickel silicide and platinum.

[0041] According to one method of implementation, step c) of forming the weak zone is executed by implanting at least one of the species selected from the following group: hydrogen and helium.

[0042] According to one method of implementation, the fracturing step e) comprises a heat treatment executed at a temperature between 200° C. and 500° C.

[0043] According to one method of implementation, the thickness of the useful layer is smaller than 8000 Å and preferably smaller than 5000 Å.

[0044] According to one method of implementation, the useful layer comprises sublayers of different doping.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] Other features and advantages will become apparent from the following description of methods of implementation of a process for locating devices according to the disclosure, which are given by way of nonlimiting example and with reference to the appended drawings, in which:

[0046] FIGS. **1**A and **1**B are schematic representations of a structure obtained with a process for locating devices according to prior-art techniques;

[0047] FIG. **2** is a schematic representation of a process for locating devices according to one embodiment of the disclosure;

[0048] FIG. **3** is a schematic representation of the structure obtained with the process for locating devices according to a second embodiment of the disclosure; and

[0049] FIG. **4** is a schematic representation of the process for locating devices according to one embodiment of the disclosure.

DETAILED DESCRIPTION

[0050] For the various methods of implementation, the same references will be used for elements that are identical or that provide the same function, for the sake of simplicity of the description.

[0051] FIGS. **2** and **3** schematically illustrate a process for locating devices.

[0052] To facilitate the illustration, the respective thicknesses of the various layers are not shown to scale.

[0053] Step a) of the process for locating devices comprises providing a carrier substrate **10** comprising a front side **20** and a back side **30** parallel to the front side **20**.

[0054] The carrier substrate **10** may comprise a bulk substrate on which a device layer **40** is formed on the front side **20** of the carrier substrate **10**.

[0055] The bulk substrate may consist of any material conventionally used in the microelectronics, optics, optoelectronics and photovoltaic industries.

[0056] In particular, the bulk substrate may comprise at least one material selected from the following group: silicon, silicon carbide, silicon germanium, glass, a ceramic and a metal alloy.

[0057] The device layer **40** comprises devices, such as electronic devices (for example transistors, junctions, etc.), interconnections and/or metalized zones.

[0058] The devices are formed using techniques well known to those skilled in the art.

[0059] The devices may be regularly distributed over the entire extent of the device layer **40**.

[0060] Cavities **90** are formed in the device layer **40**. The cavities **90** are open and comprise an aperture flush with the free surface of the device layer **40**.

[0061] The cavities **90** comprise walls. The walls of the cavity **90** and the aperture of the cavity **90** delimit the volume of the cavity **90**.

[0062] Advantageously, the cavities **90** may extend as far as into the carrier substrate **10**.

[0063] Alignment marks **50** are placed in the volume of the cavities **90**, and the alignment marks **50** are away from the aperture of the cavities **90**.

[0064] The alignment marks **50** are placed so as to make it possible to precisely locate the devices of the device layer **40**.

[0065] Alignment marks **50** are conventionally used to align photolithography masks.

[0066] The alignment marks **50** may take the form of crosses, chevrons or interference patterns, or any other form liable to allow the precise location of the devices to be determined.

[0067] In this respect, those skilled in the art will find a technical description of the alignment or photolithography masks in *Fundamentals of Microfabrication: The Science of Miniaturization,* 2nd ed., Marc J. Madou, Nanogen, Inc., San Diego, Calif.

[0068] Advantageously, the alignment marks **50** are placed at the bottom of the cavities **90**.

[0069] Step b) of the process for locating devices comprises providing a donor substrate **60**.

[0070] The donor substrate **60** may be made of any material conventionally used in the microelectronics, optics, optoelectronics and photovoltaic industries.

[0071] In particular, the donor substrate **60** may comprise at least one material selected from the following group: silicon, silicon carbide and silicon germanium.

[0072] The donor substrate **60** may comprise a semiconductor material.

[0073] Step c) of the process for locating devices may comprise forming a weak zone **70** in the donor substrate **60**.

[0074] The donor substrate **60** comprises a first surface. The weak zone **70** and the first surface of the donor substrate **60** delimit a useful layer **80** intended to be transferred to the device layer **40**.

[0075] The weak zone **70** may be obtained by implanting atomic species. The weakening implantation may be carried out with a single species (for example, hydrogen or helium), but may also be carried out with a plurality of sequentially implanted species (for example, hydrogen and helium).

[0076] Advantageously, the hydrogen is implanted with an energy of between 20 and 70 keV, and a dose of between 4×10^{16} and 6×10^{16} atoms/cm^2.

[0077] The helium may be implanted with an energy of between 20 and 70 keV, and a dose of between 0.5×10^{16} and 3×10^{16} atoms/cm^2.

[0078] In some embodiments, the useful layer **80** may have a thickness smaller than 8000 Å and preferably smaller than 5000 Å.

[0079] Step d) of the process for locating devices may comprise assembling the donor substrate **60** and the carrier substrate **10**.

[0080] In some embodiments, the assembly step d) may be executed by direct bonding.

[0081] The assembly may be executed by bringing the useful layer **80** into direct contact with the device layer **40**. The

assembly is executed so as to preserve, at least in part, the volume of the cavities **90**. Therefore, the presence of cavities **90** generates unbonded zones.

[0082] The assembly step d) may comprise a direct bonding step executed in an environment at a pressure below 20 mbar (2000 Pa).

[0083] Such as illustrated in FIG. **4**, an intermediate layer **100** may be placed on the useful layer **80** before the assembly step d).

[0084] The intermediate layer **100** may be an opaque layer placed on the useful layer **80**.

[0085] The opaque layer may comprise at least one material selected from the following group: tungsten, titanium, tungsten silicide, titanium silicide, nickel silicide, nickel silicide and platinum.

[0086] Step e) of the method for locating devices comprises fracturing the donor substrate **60** in the weak zone **70** so as to transfer the useful layer **80** to the device layer **40**.

[0087] Thus, after step e), the useful layer **80** masks the devices.

[0088] If an opaque layer has been formed on the useful layer **80** prior to the assembly step d), the opaque layer is then located intermediate between the useful layer **80** and the device layer **40** after the fracturing step.

[0089] Advantageously, the fracturing step e) may comprise a heat treatment executed at a temperature between 200° C. and 500° C.

[0090] Particularly advantageously, after the fracturing step e), the presence of through-holes has been observed in the useful layer **80**, and the opaque layer in the case where the latter is present.

[0091] Moreover, the through-holes in the useful layer **80** are in positional correspondence with the cavities **90**, so that the through-holes extend the cavities **90** into the useful layer **80**.

[0092] Furthermore, the aperture of each cavity **90** is inscribed in the aperture of a hole of the useful layer **80**.

[0093] In embodiments in which step d) comprises direct bonding executed in an environment at a pressure below 20 mbar (2000 Pa), each through-hole in the useful layer **80** may have an aperture that corresponds to the aperture in the cavity **90** into which it extends, such as illustrated in FIG. **3**.

[0094] The presence of these holes in the useful layer **80** is advantageously capitalized upon to expose the alignment marks **50** placed in the cavities **90**.

[0095] Thus, it is possible to locate the devices masked by the useful layer **80**.

1. A process for locating devices after transfer of a useful layer, the process comprising the following steps:

a) providing a carrier substrate comprising:
a device layer comprising a free surface; and
alignment marks;

b) providing a donor substrate;

c) forming a weak zone in the donor substrate, the weak zone delimiting a useful layer;

d) assembling the donor substrate and the carrier substrate; and

e) fracturing the donor substrate in the weak zone so as to transfer the useful layer to the device layer;

wherein the alignment marks are placed in cavities formed in the device layer, the cavities having an aperture flush with the free surface of the device layer.

2. The process according to claim **1**, in which the assembly step d) comprises a direct bonding step executed in an environment at a pressure below 20 mbars.

3. The process according to claim **2**, wherein the cavities extend into the carrier substrate.

4. The process according to claim **3**, wherein the alignment marks are placed at the bottom of the cavities.

5. The process according to claim **4**, wherein the device layer comprises devices distributed over an entire extent of the device layer.

6. The process according to claim **4**, wherein an opaque layer is present on the useful layer before the assembly step d).

7. The process according to claim **6**, wherein the opaque layer comprises at least one material selected from the following group: tungsten, titanium, tungsten silicide, titanium silicide, nickel silicide, nickel silicide and platinum.

8. The process according to claim **4**, wherein the step c) of forming the weak zone is executed by implanting at least one of the species selected from the following group: hydrogen and helium.

9. The process according to claim **4**, wherein the fracturing step e) comprises a heat treatment executed at a temperature between 200° C. and 500° C.

10. The process according to claim **1**, wherein the thickness of the useful layer is smaller than 8000 Å.

11. The process according to claim **1**, wherein the useful layer comprises sublayers of different doping.

12. The process according to claim **10**, wherein the thickness of the userful layer is smaller than 5000 Å.

13. The process according to claim **1**, wherein the cavities extend into the carrier substrate.

14. The process according to claim **1**, wherein the alignment marks are placed at the bottom of the cavities.

15. The process according to claim **1**, wherein the device layer comprises devices distributed over an entire extent of the device layer.

16. The process according to claim **1**, wherein an opaque layer is present on the useful layer before the assembly step d).

17. The process according to claim **1**, wherein the step c) of forming the weak zone is executed by implanting at least one of the species selected from the following group: hydrogen and helium.

18. The process according to claim **1**, wherein the fracturing step e) comprises a heat treatment executed at a temperature between 200° C. and 500° C.

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