DISCLOSURE OF THE INVENTION

Embodiments of the invention seek to design a front-side imager that can perform better than existing imagers, and in particular a substrate from which said imager may be obtained.

Preferably, this substrate must be able to be fabricated at low cost.

A first aspect of the invention relates to a front-side imager comprising in succession, from the back side to the front side of said front-side imager:

- a semiconductor carrier substrate,
- a first electrically insulating separating layer, and
- a single-crystal semiconductor layer, called the active layer, comprising a matrix array of photodiodes,

said imager being characterized in that it ~~furthermore~~ comprises, between the carrier substrate and the first electrically insulating layer:

- a second electrically insulating separating layer, and
- a second semiconductor or electrically conductive layer, called the intermediate layer, arranged between the second separating layer and the first separating layer, the second separating layer being thicker than the first separating layer,

and in that the imager furthermore comprises, on the active layer, a layer called the optical confinement layer having a coefficient of optical reflection from the front side toward the active layer higher than the coefficient of reflection from the active layer toward the front side.

By “front side” what is meant in the present text is that side of the imager which is intended to be exposed to light radiation, which side is located on the same side of the structure as the associated electronic components.

The first separating layer advantageously has a thickness comprised between 10 and 100 nm.

The second separating layer advantageously has a thickness comprised between 100 and 300 nm.

According to one embodiment, the intermediate layer is made of a doped polycrystalline or amorphous material.

According to one embodiment, the intermediate layer is made of doped silicon.

Alternatively, the intermediate layer is made of a metal.

The intermediate layer advantageously has a thickness comprised between 20 and 150 nm.

According to one embodiment, the active layer comprises a silicon seed layer.

According to another embodiment, the seed layer is a silicon-germanium layer.

According to one embodiment, the active layer furthermore comprises a single-crystal layer of silicon-germanium on the seed layer.

Particularly advantageously, the germanium content in the silicon-germanium layer is lower than or equal to 10%.

Preferably, the thickness of the silicon-germanium layer is smaller than a critical thickness defined as being a thickness beyond which the silicon-germanium relaxes.

According to another embodiment, the substrate furthermore comprises a silicon single-crystal layer on the seed layer, said silicon layer forming, with the seed layer, the active layer of the imager.

According to a second aspect of the present invention~~one embodiment~~, said substrate may be fabricated using a process comprising the following steps:

- providing a first donor substrate,

- forming a weakened zone in said first donor substrate, so as to delineate a first semiconductor layer,

- transferring said first layer to a semiconductor carrier substrate, an electrically insulating layer being at the interface between the donor substrate and the carrier substrate so as to form a structure comprising the carrier substrate, the electrically insulating layer, and the transferred layer,

- providing a second donor substrate,

- forming a weakened zone in said second donor substrate, so as to delineate a single-crystal semiconductor layer,

- transferring said single-crystal semiconductor layer to the structure, an electrically insulating layer being at the interface between the second donor substrate and the structure

- forming a layer called the optical confinement layer on the active layer, said optical confinement layer having a coefficient of optical reflection from the front side toward the active layer higher than the coefficient of reflection from the active layer toward the front side.

According to a third aspect of the present invention~~one alternative embodiment~~, the substrate may be fabricated using a process comprising the following steps:

- forming a structure by depositing an electrically conductive or semiconductor layer on a carrier substrate covered with an electrically insulating layer,

- providing a donor substrate,

- forming a weakened zone in said donor substrate, so as to delineate a single-crystal semiconductor layer,

- transferring said single-crystal semiconductor layer to the structure, an electrically insulating layer being at the interface between the second donor substrate and the structure

- forming a layer called the optical confinement layer on the active layer, said optical confinement layer having a coefficient of optical reflection from the front side toward the active layer higher than the coefficient of reflection from the active layer toward the front side.

Another subject of the invention relates to a process for fabricating a front-side imager such as described above.

According to one embodiment, said fabricating process comprises the following steps:

- providing a first donor substrate,

- forming a weakened zone in said first donor substrate, so as to delineate a first semiconductor layer,

- transferring said first layer to a semiconductor carrier substrate, an electrically insulating layer being at the interface between the donor substrate and the carrier

CLAIMS

1. A front-side imager comprising in succession, from the back side to the front side of said front-side imager:

- a semiconductor carrier substrate,
- a first electrically insulating separating layer, and
- a single-crystal semiconductor layer, called the active layer, comprising a matrix array of photodiodes,

said imager being characterized in that it ~~furthermore~~ comprises, between the carrier substrate and the first electrically insulating layer:

- a second electrically insulating separating layer, and
- a second semiconductor or electrically conductive layer, called the intermediate layer, arranged between the second separating layer and the first separating layer, the second separating layer being thicker than the first separating layer,

and in that the imager furthermore comprises, on the active layer, a layer called the optical confinement layer having a coefficient of optical reflection from the front side toward the active layer higher than the coefficient of reflection from the active layer toward the front side.

2. The imager as claimed in claim 1, wherein the first separating layer has a thickness comprised between 10 and 100 nm.

3. The imager as claimed in either of claim~~s~~ 1 ~~and~~ or 2, wherein the second separating layer has a thickness comprised between 100 and 300 nm.

4. The imager as claimed in one of claims 1 to 3, wherein the intermediate layer is made of a material among: doped polycrystalline or amorphous material, doped silicon, or metal.

5. The imager as claimed in one of claims 1 to 4, wherein the intermediate layer has a thickness comprised between 20 and 150 nm.

6. The imager as claimed in one of claims 1 to 5, wherein the active layer comprises a silicon seed layer.

7. The imager as claimed in one of claims 1 to 5, wherein the active layer comprises a silicon-germanium seed layer.

8. The imager as claimed in either of claim~~s~~ 6 or~~and~~ 7, wherein the active layer furthermore comprises a single-crystal layer of silicon-germanium on the seed layer.

9. The imager as claimed in claim 8, wherein the germanium content in the silicon-germanium layer is lower than or equal to 10%.

10. The imager as claimed in either of claim~~s~~ 8 or~~and~~ 9, wherein the thickness of the silicon-germanium layer is smaller than a critical thickness defined as being a thickness beyond which the silicon-germanium relaxes.

11. The imager as claimed in claim 6, wherein the active layer furthermore comprises a single-crystal layer of silicon on the seed layer.

~~12. The imager as claimed in one of claims 1 to 11, furthermore comprising, on the active layer, a layer called the optical confinement layer having a coefficient of optical reflection from the front side toward the active layer higher than the coefficient of reflection from the active layer toward the front side.~~

~~13.~~12. The imager as claimed in claim 1~~2~~, wherein said optical confinement layer comprises a layer of titanium nitride between two layers of silicon oxide.

~~14.~~13. The imager as claimed in one of claims 1 to 1~~2~~3, wherein each photodiode is separated from an adjacent photodiode by at least one electrically isolating trench extending up to the first electrically insulating layer.

~~15.~~14. The imager as claimed in claim 1~~3~~4, wherein said trench comprises an electrically conductive or semiconductor via extending up to the intermediate layer between walls made of an electrically insulating material.

~~16.~~15. The imager as claimed in either of claims 1~~4~~5 and 1~~3~~4 when dependent on claim 1~~3~~4, wherein said at least one trench extends through the optical confinement layer.

~~17.~~16. The imager as claimed in claim 1~~4~~5, wherein each trench comprises a first wall extending up to the intermediate layer and a second wall extending at least partially into the second separating layer so as to electrically isolate a segment of the intermediate layer, the electrically conductive or semiconductor via being electrically connected to said segment of the intermediate layer.

~~18.~~17. A process for manufacturing a front-side imager, comprising the following steps:

- providing a first donor substrate,

- forming a weakened zone in said first donor substrate, so as to delineate a first semiconductor layer,

- transferring said first layer to a semiconductor carrier substrate, an electrically insulating layer being at the interface between the donor substrate and the carrier substrate so as to form a structure comprising the carrier substrate, the electrically insulating layer, and the transferred layer,

- providing a second donor substrate,

- forming a weakened zone in said second donor substrate, so as to delineate a single-crystal semiconductor layer,

- transferring said single-crystal semiconductor layer to the structure, an electrically insulating layer being at the interface between the second donor substrate and the structure,

- growing epitaxially a single-crystal semiconductor layer on the transferred single-crystal semiconductor layer, said epitaxial single-crystal semiconductor layer forming, with the transferred single-crystal semiconductor layer, an active layer of the imager

- forming a layer called the optical confinement layer on the active layer, said optical confinement layer having a coefficient of optical reflection from the front side toward the active layer higher than the coefficient of reflection from the active layer toward the front side.

~~19.~~18. A process for manufacturing a front-side imager, comprising the following steps:

- forming a structure by depositing an electrically conductive or semiconductor layer on a carrier substrate covered with an electrically insulating layer,

- providing a donor substrate,

- forming a weakened zone in said donor substrate, so as to delineate a single-crystal semiconductor layer,

- transferring said single-crystal semiconductor layer to the structure, an electrically insulating layer being at the interface between the second donor substrate and the structure,

- growing epitaxially a single-crystal semiconductor layer on the transferred single-crystal semiconductor layer, said epitaxial single-crystal semiconductor layer forming, with the transferred single-crystal semiconductor layer, an active layer of the imager

- forming a layer called the optical confinement layer on the active layer, said optical confinement layer having a coefficient of optical reflection from the front side toward the active layer higher than the coefficient of reflection from the active layer toward the front side.

~~20. The process as claimed in either of claims 18 and 19, furthermore comprising forming a layer called the optical confinement layer on the active layer, said optical confinement layer having a coefficient of optical reflection from the front side toward the active layer higher than the coefficient of reflection from the active layer toward the front side.~~

19~~21~~. The process as claimed in ~~one~~ either of claim~~s~~ 17~~8~~ or~~to~~ 18~~20~~, furthermore comprising forming a matrix array of photodiodes in the active layer.