

Masking a zone at the edge of a donor substrate during an ion implantation step

The present invention relates to the field of fabricating semiconductor-on-insulator (SeOI) substrates and, more particularly, to the ion implantation step carried out on a donor substrate to produce a predetermined separation zone inside said donor substrate.

A semiconductor-on-insulator (SeOI) substrate may be obtained by means of a SmartCut process. In this type of process, a layer is transferred from a donor substrate onto a carrier substrate by propagating a fracture wave along an interface in the donor substrate, which interface is embrittled beforehand by ion implantation, during a thermal annealing operation. During fracturing, micrometre-sized particles are created, in particular at the edge of the SeOI substrate.

It thus subsequently becomes necessary to clean the SeOI substrate and/or the remainder of the donor substrate using RCA cleaning processes. This therefore represents a loss of time and of resources.

Embodiments of the invention seek to overcome the drawbacks described above by providing a process making it possible to fabricate a donor substrate with a predetermined separation zone for transferring a layer from the donor substrate onto a carrier substrate, making it possible to decrease the level of particles produced in the step of detaching the carrier substrate with the transferred layer from the remainder of the donor substrate.

An aspect of the present invention provides a process for forming a predetermined separation zone inside a donor substrate, in particular to be used in a process of transferring a layer onto a carrier substrate, characterized in that the process comprises an atom and/or ion implantation step that is carried out such that the implantation dose in a zone at the edge of the donor substrate is lower than the implantation dose in a central zone of the donor substrate.

Thus, the zone at the edge of the donor substrate, where there may be an absence of bonding with the carrier substrate, is less damaged by the implantation step than the central zone of the donor substrate.

Thus, in this zone, there cannot be any stiffening effect due to the presence of the carrier substrate and the lower implantation dose decreases the formation of blisters and peeling during the thermal debonding treatment and ultimately decreases the creation of particles.

According to an embodiment, the implantation step may be carried out such that the implantation is limited to the central zone of the donor substrate. Thus, the ions are not implanted into the zone of the edge of the substrate and this zone may therefore be free of implanted ions, thereby further decreasing the creation of particles during annealing.

According to an embodiment, the zone of the edge of the donor substrate may comprise or may be limited to a chamfered zone on the edge of the donor substrate. The chamfered zone of a substrate corresponds to a zone on the edge of a substrate where the edge has been slanted such that the sharp angle of the edge has been broken. The width of the chamfered zone of a substrate is typically of the order of 0.5 to 3 mm. When bonding the donor substrate to the carrier substrate, the chamfered zone remains unbonded and the formation of blisters during thermal annealing may therefore be limited or absent in this zone.

According to an embodiment, the width of the zone of the edge of the substrate may be comprised between 1 mm and 5 mm, in particular comprised between 1 mm and 2 mm. Thus, the zone of the edge of the substrate may be chosen to be slightly larger than the chamfered zone.

According to an embodiment, the implantation of ions may be carried out using a mask on or above the zone of the edge of the substrate. According to one alternative, the implantation of ions may be carried out by scanning the substrate with an ion beam such that the implantation dose in the zone at the edge of the donor substrate is lower than the implantation dose in the central zone of the donor substrate, in particular such that the implantation is limited to the central zone of the donor substrate. These two process variants may be carried out in a straightforward manner.

According to an embodiment, the implantation of ions may comprise an implantation of hydrogen ions (H) or a co-implantation of helium and hydrogen ions (He-H).

According to an embodiment, the process may comprise a second ion implantation step, in particular carried out over the entire surface of the substrate with an implantation dose that is lower than in the first implantation step. Due to the lower concentration of the co-implant, the creation of particles during a thermal annealing operation may be avoided or at least decreased.

According to an embodiment, the first implantation step may be an implantation of helium ions and the second implantation step may be an implantation of hydrogen ions.

According to an embodiment, the implantation dose in the zone at the edge of the donor substrate may be lower than $1\text{e}16\text{ at/cm}^2$, in particular comprised between $0.5\text{e}16\text{ at/cm}^2$ and $7\text{e}16\text{ at/cm}^2$. For such implantation doses in the zone of the edge of the donor substrate, the creation of particles during a thermal annealing operation may be avoided or at least decreased.

Another aspect of the present invention provides a donor substrate for a process of transferring a layer onto a carrier substrate, comprising a predetermined separation zone wherein the implantation dose in a zone of the edge of the donor substrate is lower than the implantation dose in a central zone of the donor substrate, in particular produced by means of the process described above. The advantage is that, with such a substrate, a decrease in the level of particles produced in the detachment step of the layer transfer process may be obtained.

Another aspect of the present invention provides a process of transferring a thin layer from a donor substrate onto a carrier substrate, comprising the steps of a) attaching a donor substrate described above to a carrier substrate and b) carrying out a detachment operation at the site of the predetermined separation zone to detach a remaining portion of the donor substrate from the transferred layer to the carrier substrate. With this process using the donor substrate as described, a layer may be transferred while creating fewer particles.

According to one variant of the process, step b) may comprise a thermal annealing.

Another aspect of the present invention provides a device for limiting an implantation region to a zone at the edge of a donor substrate, in particular

a donor substrate such as described above, characterized in that the device includes a means suitable for carrying out the implantation such that the implantation dose towards a zone at the edge of the donor substrate is lower than the implantation dose in a central zone of the donor substrate.

Thus, it is possible to control the siting of the implantation zones on a substrate, in particular to delimit an implantation zone to a central zone of the substrate, to be able to decrease the creation of particles in a layer transfer process such as described above.

According to an embodiment, the means for limiting the implantation region to the central zone of the donor substrate may comprise a mask. According to another alternative, the mask may be a ring positioned on or above the donor substrate. According to one alternative, the mask may be configured to mask the zone of the edge of a donor substrate over a width comprised between 1 mm and 5 mm, in particular between 1 and 2 mm. Thus, the implantation profile in a substrate may be modified and predetermined in a straightforward manner to obtain implantation zones having various doses in one and the same substrate.

Another aspect of the present invention provides an ion implanter for implanting ions into a donor substrate comprising a device such as described above. Thus, an ion implanter may provide greater possibilities with respect to controlling the siting of the implantation zones on a substrate, in particular of delimiting an implantation zone to a central zone of the substrate.

The invention may be understood by referring to the following description together with the appended figures, in which numerical references identify the elements of the invention.

Figures 1a to 1f schematically show the various steps of the process of transferring a thin layer from a donor substrate onto a carrier substrate according to the invention.

Figure 2a shows a diagram of masking the edge of a substrate in an implantation step according to one variant of the invention.

Figure 2b shows a schematic view from above of a mask used for masking a zone of the edge of a substrate during the implantation operation according to one variant of the invention.

Claims

1. Process for forming a predetermined separation zone inside a donor substrate, in particular to be used in a process of transferring a layer onto a carrier substrate, **characterized in that**

the process comprises an atom and/or ion implantation step that is carried out such that the implantation dose in a zone of the edge of the donor substrate is lower than the implantation dose in a central zone of the donor substrate.

2. Process according to Claim 1, wherein the implantation step is carried out such that the implantation is limited to the central zone of the donor substrate.

3. Process according to Claim 1 or 2, for which the zone of the edge of the donor substrate comprises or is limited to a chamfered zone on the edge of the donor substrate.

4. Process according to at least one of Claims 1 to 3, wherein the width of the zone of the edge of the substrate is comprised between 1 mm and 5 mm, in particular comprised between 1 mm and 2 mm.

5. Process according to at least one of Claims 1 to 4, wherein the implantation is carried out using a mask on or above the zone of the edge of the donor substrate.

6. Process according to at least one of Claims 1 to 5, wherein the implantation is carried out by scanning the donor substrate with an ion beam such that the implantation dose towards the zone of the edge of the donor substrate is lower than the implantation dose in the central zone of the donor substrate, in particular such that the implantation is limited to the central zone of the donor substrate.

7. Process according to at least one of Claims 1 to 6, characterized in that the implantation comprises an implantation of helium ions (He) or a co-implantation of helium and hydrogen ions (He-H).

8. Process according to at least one of Claims 1 to 7, characterized in that the process comprises a second atom and/or ion implantation step, in particular carried out over the entire surface of the donor substrate with an implantation dose that is lower than in the first implantation step.

9. Process according to Claim 8, for which the first implantation step is an implantation of helium ions and the second implantation step is an implantation of hydrogen ions.

10. Process according to at least one of Claims 1 to 9, for which the implantation dose in the zone of the edge of the donor substrate is lower than $1\text{e}16\text{ at/cm}^2$, in particular comprised between $0.5\text{e}16\text{ at/cm}^2$ and $1\text{e}16\text{ at/cm}^2$.

11. Donor substrate for a process of transferring a layer onto a carrier substrate, comprising a predetermined separation zone wherein the implantation dose in a zone of the edge of the donor substrate is lower than the implantation dose in a central zone of the donor substrate, in particular produced by means of the process according to at least one of Claims 1 to 10.

12. Process of transferring a layer of a donor substrate onto a carrier substrate comprising the steps of:

- a) attaching a donor substrate according to Claim 11 to a carrier substrate;
- b) carrying out a detachment operation at the site of the predetermined separation zone to detach a remaining portion of the donor substrate from the layer transferred to the carrier substrate.

13. Process according to Claim 12, wherein step b) comprises a thermal annealing operation.

14. Device for limiting an implantation region to a zone of the edge of a donor substrate, in particular a donor substrate according to Claim 11, **characterized in that** the device includes a means suitable for carrying out the implantation such that the implantation dose towards a zone of the edge of the donor substrate is lower than the implantation dose in a central zone of the donor substrate.

15. Device according to Claim 14, wherein the means for limiting the implantation region to the central zone of the donor substrate may comprise a mask.

16. Device according to Claim 15, wherein the mask is a ring positioned on or above the donor substrate.

17. Device according to at least one of Claims 14 to 16, characterized in that the mask is configured to mask the zone of the edge of a donor substrate over a width comprised between 1 mm and 5 mm, in particular between 1 and 2 mm.

18. Ion implanter for implanting ions into a donor substrate comprising a device according to at least one of Claims 14 to 17.