

Method for depositing an epitaxial layer on a front side of a wafer and device for carrying out the method

The subject matter of the invention is a method for depositing an epitaxial layer on the front side of a wafer composed of monocrystalline material, this involving a provided
5 wafer being arranged on a susceptor and being heated to a deposition temperature by means of thermal radiation and a deposition gas being conducted across a front side of the wafer. The subject matter of the invention is furthermore a device for depositing an epitaxial layer on a front side of a wafer composed of monocrystalline material.

Prior art / problems

10 The deposition of an epitaxial layer on the front side of a wafer is usually done by means of CVD (chemical vapour deposition) in a CVD reactor, often in a single-wafer reactor. Such a CVD reactor is described in US 2014/0 251 208 A1 for example. Provided by a single-wafer reactor between an upper and a lower dome is a reaction
15 space in which a susceptor is held by susceptor support arms of a susceptor support shaft on susceptor support pins. The susceptor and a wafer rested on top is heated by means of thermal radiation by lamp arrays arranged above and below the domes, while a deposition gas is conducted across the front side of the wafer that is facing the upper dome.

US 2008/0118712 A1 describes a susceptor comprising a susceptor ring and a
20 susceptor base. The susceptor ring has a ledge for resting a wafer in the edge region of the back side of the wafer. The susceptor ring is rested on the susceptor base in order to deposit a layer on the front side of the wafer.

US 2007/0227441 A1 refers to periodic variations in thickness in the edge region of epitaxially coated silicon wafers. This is because of the different growth rates with
25 which the epitaxial layer grows. The different growth rates are linked to the crystal orientation of the front side of the wafer. The front side of the wafer is that face of the wafer on which the epitaxial layer is deposited. To homogenize the thickness of the epitaxial layer in the edge region, US 2007/0227441 A1 proposes that the structure of the susceptor be changed with the period of variations in thickness.

With the same goal, US 2015/0184314 A1 proposes limiting the width of the edge region of the wafer.

This teaching takes no account of the fact that wafers in which the mentioned variations in thickness are regarded as problematic are provided with an orientation notch in the edge region. In the case of silicon wafers with $\langle 100 \rangle$ orientation of the front side, the orientation notch is usually situated on one of the four sites at which an epitaxial layer grows comparatively rapidly and marks one of four $\langle 110 \rangle$ crystal directions. Occasionally, the orientation notch is also situated 45° away from such a site and marks one of four $\langle 100 \rangle$ crystal directions.

It is an object of the present invention to improve the flatness of wafers having a deposited epitaxial layer in the edge region, especially in the region of the notch, and, at the same time, to reduce periodic variations in thickness in the edge region without having to change, to this end, the susceptor or the shape of the edge region of the wafer.

The object of the invention is achieved by the methods and devices described in the claims.

The features specified with regard to the above-mentioned embodiments of the method according to the invention can be applied *mutatis mutandis* to the device according to the invention. Conversely, the features specified with regard to the above-mentioned embodiments of the device according to the invention can be applied *mutatis mutandis* to the method according to the invention. These and other features of the embodiments according to the invention are elucidated in the description of the figures and in the claims. The individual features can be realized either separately or in combination as embodiments of the invention. Furthermore, they can describe advantageous designs which are independently protectable.

Brief description of the figures

Figure 1 shows a wafer (101) having an orientation notch (102). The wafer (101) has a $\langle 100 \rangle$ orientation. The upper face of the wafer (101) is, for example, the (100)

plane. The orientation notch 102 marks one of four $\langle 110 \rangle$ crystal directions which, distributed around the circumference of the wafer at an interval of 90° , point to corresponding planes in the region of the edge of the wafer, on which planes an epitaxial layer grows at a comparatively higher rate than on planes in the region of the edge to which four $\langle 100 \rangle$ crystal directions point.

Figure 2 shows, in line with Figure 1, a top view of a wafer (201) with $\langle 110 \rangle$ orientation having an orientation notch (202).

Detailed description of exemplary embodiments according to the invention

A device (Fig. 3) according to the invention comprises not only a susceptor (301), but also a mechanism for holding and rotating the susceptor (301) having a susceptor support shaft (302) and susceptor support arms (303). Furthermore, the mechanism for holding and rotating the susceptor (301) can comprise a wafer lift shaft (304) and wafer lift pins (305). An essential feature of the device is a ring (306) which is held by the susceptor support arms (303) and is arranged under the susceptor (301) without having direct contact with the susceptor (301). The ring (306) is held by the susceptor support arms (303) such that it cannot be shifted along its circumferential direction. Preferably, susceptor support pins (307), which are inserted through holes (402, 502, 602) in the ring (306), are situated on the susceptor support arms (303). The distance between an upper face of the ring (306) and a lower face of the susceptor (301) is preferably not less than 5 mm and not more than 10 mm.

Fig. 4 shows a top view of a ring (401) which, in the embodiment shown, has holes (402) and four inwardly pointing projections (403) which are arranged so as to be distributed across the circumference at an interval of 90° . This embodiment is suitable for use in a device as per Fig. 3 for depositing therein, according to the invention, an epitaxial layer on the front side of a wafer having a $\langle 100 \rangle$ orientation. Preferably, the ring (401) consists of quartz glass and the projections (403) consist of a material having low transmittance in the IR region of the spectrum. In this region, the transmittance of the projections (403) is preferably not more than 20% and particularly preferably not more than 5%, based on a material thickness of 10 mm. The projections (403) preferably consist of opaque quartz glass.

Fig. 5 shows a top view of a ring (501) which, in the embodiment shown, has holes (502) and two inwardly pointing projections (503) which are arranged so as to be distributed across the circumference at an interval of 180°. This embodiment is suitable for use in a device as per Fig. 3 for depositing therein, according to the invention, an epitaxial layer on the front side of a wafer having a $\langle 110 \rangle$ orientation.

Preferably, an inner edge (404, 504) of the projection (403, 503) of the ring (401, 501) is situated at a radial position, the distance of which in relation to a centre Z of the ring (401, 501) is not less than 140 mm, preferably not less than 145 mm and particularly preferably 148 mm to 150 mm.

Fig. 6 shows a top view of a ring (601) which, in the embodiment shown, has holes 602 and four inwardly pointing projections (603) which are arranged so as to be distributed across the circumference at an interval of 90°. This embodiment is suitable for use in a device as per Fig. 3 for depositing therein, according to the invention, an epitaxial layer on the front side of a wafer having a $\langle 100 \rangle$ orientation. In the embodiment depicted, the projections (603) are T-shaped and each comprise a web (604) and a ring segment (605). The ring segment (605) has a radial length and a width in the circumferential direction. The radial length is preferably not less than 3 mm and not more than 8 mm. Expressed as opening angle α , the width is preferably not less than 15° and not more than 25° and particularly preferably 20°. Preferably, the ring (601) and/or the webs (604) consist of quartz glass and the ring segments consist of a material having low transmittance in the IR region of the spectrum. In this region, the transmittance of the ring segment (605) is preferably not more than 20% and particularly preferably not more than 5%, based on a material thickness of 10 mm. The ring segments (605) preferably consist of opaque quartz glass.

Figures 7 and 8 show a susceptor ring (701, 801) having a resting face (703, 805) and the adjacent stepped boundary (702, 806). One embodiment of a susceptor ring (701, 801) according to the invention envisages that the resting face has an inwardly pointing projection. This means that the radial width W_1 of the resting face (703, 805) of the susceptor ring (701, 801) at an azimuthal position is greater than the radial width W_2 at the opposite position.

In addition, a wafer (704, 804) can preferably be positioned in the susceptor ring (701, 801) such that the position with the greatest width of the resting face W_1 (802) coincides with the position of the orientation notch (803).

In addition, the stepped boundary (Fig. 9, 901) adjacent to the rest can preferably be realized such that it has an inwardly pointing bulge (Fig. 9, 902).

Preferably, the azimuthal position of an inwardly pointing bulge of the stepped boundary (902) adjacent to the rest is identical to the azimuthal position of the inwardly pointing projection of the resting face (403, 503).

To deposit an epitaxial layer on a front side of a wafer composed of monocrystalline material, the wafer is preferably arranged in the described device such that the orientation notch of the wafer has the same azimuthal position as a projection of the ring. Thereafter, the wafer is brought to a deposition temperature by means of thermal radiation which is directed towards a front side and towards a back side of the wafer and deposition gases are conducted across the front side of the wafer.

Said deposition gases preferably contain silanes, chlorosilanes or mixtures thereof, diluted in a carrier gas (preferably hydrogen).

What is understood by said deposition temperature is the temperature at which a layer is deposited on the wafer under the given boundary conditions.

The means of the described device ensure the selective reduction of the intensity of a portion of the thermal radiation which is directed towards the back side of the wafer, the result being that first subregions on the edge of the wafer, in which a growth rate of the epitaxial layer at uniform temperature of the wafer is greater because of the orientation of the monocrystalline material, are heated more weakly than in adjacent second subregions.

The above description of exemplary embodiments is to be understood exemplarily. The disclosure made thereby firstly enables a person skilled in the art to understand the present invention and the associated advantages and secondly encompasses alterations and modifications to the described structures and methods that are also obvious in the understanding of a person skilled in the art. Therefore, all such

alterations and modifications and also equivalents are to be covered by the scope of protection of the claims.

Figure 10 illustrates the effect achieved by use of the method according to the invention in epitaxy. Here, the azimuthal coordinates in degrees [$^{\circ}$] are plotted on the x-axis D_x . The y-axis D_y shows layer thickness in dimensionless coordinates, which are measured along a perimeter of the wafer. Dashed line A represents the height curve which can be achieved using prior-art methods. Solid line B is achieved by use of the method according to the invention. The orientation notch was situated at position 0° , or 360° .

Claims

1. Device for depositing an epitaxial layer on a front side of a wafer having an orientation notch, comprising
a mechanism for holding and rotating a susceptor having a susceptor support shaft
5 and susceptor support arms; and
a ring which is held by the susceptor support arms and has inwardly pointing projections; and
the susceptor, comprising a susceptor ring having a resting face for resting the wafer in the edge region of a back side of the wafer and a stepped outer boundary
10 of the susceptor ring that is adjacent to the resting face,
the resting face having an inwardly pointing projection.
2. Device according to Claim 1, characterized in that
the stepped outer boundary of the susceptor ring that is adjacent to the resting face has an inwardly pointing bulge.
- 15 3. Device according to either of the preceding claims, characterized in that
a projection of the ring is situated at the same azimuthal position as a projection of the resting face.
4. Device according to Claim 1 or 2, characterized in that
a projection of the ring is situated at the same azimuthal position as an inwardly
20 pointing bulge on the stepped boundary.
5. Device according to any of the preceding claims, characterized in that the ring consists of quartz glass.
6. Device according to any of the preceding claims, characterized in that
a projection of the ring is made from a material which selectively reduces the
25 intensity of thermal radiation passing through it,
the result being that first subregions on the edge of a wafer rested on the susceptor, in which a growth rate of the epitaxial layer at uniform temperature of the wafer is greater because of the orientation of the monocrystalline material, are heated more weakly than in adjacent second subregions.

7. Device according to any of the preceding claims, characterized in that the ring has two or four projections.
8. Method for depositing an epitaxial layer on a front side of a wafer composed of monocrystalline material, comprising
- 5 providing the wafer having an orientation notch;
arranging the wafer on a device according to Claims 1 to 7, with the result that the orientation notch of the wafer has the same azimuthal position as a projection of the ring;
heating the wafer to a deposition temperature by means of thermal radiation which
- 10 is directed towards a front side and towards a back side of the wafer;
conducting a deposition gas across the front side of the wafer; and
selectively reducing the intensity of a portion of the thermal radiation which is directed towards the back side of the wafer, the result being that first subregions on the edge of the wafer, in which a growth rate of the epitaxial layer at uniform
- 15 temperature of the wafer is greater because of the orientation of the monocrystalline material, are heated more weakly than in adjacent second subregions.
9. Method according to Claim 8, characterized in that
- 20 the intensity of the portion of the thermal radiation is selectively reduced by
arranging material having low transmittance in the IR region of the spectrum in the beam path of the thermal radiation.