

Method for producing a semiconductor substrate having an epitaxially deposited layer

TECHNICAL FIELD

The field of the invention is that of processes for the production of a semiconductor substrate comprising an epitaxially deposited layer.

DESCRIPTION OF THE ASSOCIATED ART

A process for epitaxial deposition on a semiconductor substrate is described, for example, in the document US 7 479 187 B2, which discloses that it is advantageous and often necessary to remove, from the surfaces of the epitaxy reactor, residues which have been deposited on these surfaces in an uncontrolled manner during the deposition, for example, of silicon on the semiconductor substrate. This stage, referred to as "*chamber etch*", is carried out more or less frequently depending on the degree of contamination and on the quality requirements. In some cases, it is appropriate to carry out a chamber etch after the deposition of an epitaxial layer on a semiconductor substrate before a subsequent epitaxial deposition is carried out on another semiconductor substrate. In other cases, the chamber etch can also take place less frequently, for example every 2 to 8 epitaxial depositions on semiconductor substrates.

The document US 7 479 187 B2 also provides for coating the etched surfaces in the epitaxy reactor with a thin silicon film by passing a deposition gas through the epitaxy reactor. The thin silicon film seals the surfaces and prevents contaminants which diffuse from the surfaces from penetrating the growing epitaxial layer during a subsequent epitaxial deposition. The deposition of a thin silicon film on the surfaces of the epitaxy reactor after the chamber etch is referred to as "*chamber coating*".

Epitaxial deposition processes require a susceptor, for example a graphite susceptor, which comprises one or more circular concavities, referred to as pockets, for example made of silicon carbide, each formed at a position of installation of a substrate. The passage of reactive gases between a pocket and the rear face of a substrate positioned on this pocket can result in a deposition of reactive gases on the rear face of the substrate. Such a deposition is liable to degrade the surface state of the rear face of the substrate. This

degraded surface state can render the substrate unsuitable for use in a process for the manufacture of electronic components, in particular manufacture of CMOS circuits.

In order to overcome this difficulty, it is known, for example from US 7 601 224 B2, to use susceptors possessed of gas passages in order to make it possible to direct a trickle of gas toward the rear face of the substrate able to prevent the flow of the reactive gases under the substrate, thus inhibiting the undesirable deposition of reactive gases on the rear face of the substrate.

The use of such susceptors is liable to disrupt the flow of the reactive gases in the chamber, which risks bringing about a non-uniformity of the epitaxial deposition. This use is also complex, expensive and requires a significant modification of the equipment.

BRIEF DESCRIPTION OF THE INVENTION

The invention is targeted at avoiding the deposition of reactive gases on the rear face of a substrate during an epitaxial deposition on the front face of the latter, while overcoming the abovementioned disadvantages of the susceptors having gas passages.

To this end, the invention provides a process for the production of a semiconductor substrate comprising an epitaxially deposited layer, successively comprising the stages of etching a susceptor of an epitaxy reactor, of coating the susceptor, of installation of a semiconductor substrate on the susceptor and of deposition of an epitaxial layer on the semiconductor substrate. The process additionally comprises, after the coating and before the deposition, the exposure of the susceptor to an oxygen-containing gas mixture. This exposure results in an oxidation of the susceptor, which will form an oxide layer. During the deposition of the epitaxial layer on a front face of the substrate, this oxide layer is found inserted between the susceptor and a rear face of the substrate and makes it possible to prevent the deposition of reactive gases on the rear face of the substrate. This process additionally comprises, after the installation of the semiconductor substrate on the susceptor and before the deposition of the epitaxial layer on the semiconductor substrate, a stage of baking the semiconductor substrate which removes, except on the underside of the semiconductor substrate, the oxide layer formed by the exposure of the susceptor to an oxygen-containing gas mixture.

Some preferred but nonlimiting aspects of the present process are as follows:

- the oxygen-containing gas mixture is a mixture of hydrogen and of argon comprising between 0.1% and 10% of O₂;
- O₂ is introduced into the epitaxy reactor at a flow rate of between 0.1 and 10 slm;
- the exposure of the susceptor to an oxygen-containing gas mixture is carried out after said coating and before said installation;
- the oxide layer formed at the surface of the susceptor by the exposure of the susceptor to the oxygen-containing gas mixture exhibits a thickness of less than 10 Å;
- the stages of installation of a semiconductor substrate on the susceptor and of deposition of an epitaxial layer on the semiconductor substrate are repeated for at least one other semiconductor substrate without in the meantime etching, coating and oxidizing the susceptor;
- the exposure of the susceptor to an oxygen-containing gas mixture is carried out after said installation and before said deposition;
- the exposure of the susceptor to an oxygen-containing gas mixture is carried out while increasing the temperature of the epitaxy reactor to an epitaxial deposition temperature;
- the stages of installation of a semiconductor substrate on the susceptor, of exposure of the susceptor to an oxygen-containing gas mixture and of deposition of an epitaxial layer on the semiconductor substrate are repeated for at least one other semiconductor substrate without in the meantime etching and coating the susceptor.

BRIEF DESCRIPTION OF THE DRAWINGS

Other aspects, aims, advantages and characteristics of the invention will become more clearly apparent on reading the following detailed description of its preferred embodiments, which description is provided by way of nonlimiting example and made with reference to the appended drawings, in which:

- figure 1 is a diagrammatic representation of the change in the temperature inside an epitaxy reactor during an epitaxial deposition process according to the prior art;

- figure 2 is a diagrammatic representation of the change in the temperature inside an epitaxy reactor during an epitaxial deposition process according to a first embodiment of the invention;

- figure 3 is a diagrammatic representation of the change in the temperature inside an epitaxy reactor during an epitaxial deposition process according to a second embodiment of the invention;

- figure 4 is a diagrammatic representation of the stages of an epitaxial deposition process according to a first embodiment of the invention;

- figure 5 is a diagrammatic representation of the stages of an epitaxial deposition process according to a second embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention relates to a process for the production of a semiconductor substrate comprising an epitaxially deposited layer which comprises the exposure of a susceptor of an epitaxy reactor to an oxygen-containing gas mixture.

The invention thus makes use of an epitaxy reactor into which an oxygen-containing gas mixture can be introduced so as to expose the materials which are placed therein to the oxygen-containing gas mixture, thus carrying out an *in situ* oxidation of these materials. This *in situ* oxidation will form an oxide layer which, during the deposition of the epitaxial layer on a front face of the substrate, is found inserted between the susceptor and a rear face of the substrate and makes it possible to prevent the deposition of reactive gases on the rear face of the substrate.

As touched on below, the exposure of the susceptor to an oxygen-containing gas mixture is carried out after the "chamber coating" and before the formation of the epitaxial layer. By way of example, the exposure of a susceptor to an oxygen-containing gas mixture can be carried out after the "chamber coating", before the installation on the susceptor of a semiconductor substrate on which the epitaxial layer has to be deposited, or after the installation of the semiconductor substrate on the susceptor before carrying out the epitaxial deposition on the semiconductor substrate.

Figure 1 is a diagrammatic representation of the change over the time t in the temperature T inside an epitaxy reactor during an epitaxial deposition process according to the prior art. As is shown in Figure 1, after one or more epitaxial depositions EPI on semiconductor substrates, carried out in the epitaxy reactor (four epitaxial positions EPI in the example illustrated), the susceptor is etched during a chamber etch stage ETCH and coated during a chamber coating stage COAT with a silicon layer. After this, one or more additional epitaxial depositions EPI can be carried out before repeating the chamber etch ETCH and the chamber coating COAT.

Figure 2 and Figure 3 are diagrammatic representations of the change over the time t in the temperature T inside an epitaxy reactor during an epitaxial deposition process according to embodiments of the invention. As is shown in these figures, the process of the invention comprises a stage, designated ISO, of exposure of the susceptor to an oxygen-containing gas mixture, this stage ISO being carried out after the chamber coating COAT and before carrying out an epitaxial deposition EPI.

Figure 4 represents stages of a process for the production of a semiconductor substrate comprising an epitaxially deposited layer according to a first embodiment of the invention. This process requires a susceptor S of an epitaxy reactor, for example a graphite susceptor, which comprises one or more circular concavities P , referred to as pockets, for example made of silicon carbide, each formed at a position of installation of the substrate.

During stage (a), the susceptor is subjected to a chamber etch stage, for example in H_2 and HCl . The H_2 can be introduced into the epitaxy reactor at a flow rate of 3 to 100 slm (standard liter per minute), while the HCl can be introduced into the epitaxy reactor at a flow rate of 5 to 20 slm. The chamber etch stage can be carried out at a temperature of between $1050^{\circ}C$ and $1200^{\circ}C$ for a period of time of between 20 seconds and 400 seconds.

During stage (b), the susceptor is subjected to a chamber coating stage in order to form thereon a silicon film 10, for example a polycrystalline silicon film. The chamber coating stage can comprise the introduction of a mixture of H_2 and of TCS (trichlorosilane) into the epitaxy reactor. The H_2 can be introduced into the epitaxy reactor at a flow rate of 3 to 100 slm (standard liter per minute), while the TCS can be introduced into the epitaxy reactor at a flow rate of 10 to 19 slm. The chamber coating stage can be carried out at a

temperature of between 1000°C and 1150°C for a period of time of between 10 seconds and 100 seconds.

During stage (c), the coated susceptor is exposed to an oxygen-containing gas mixture. This exposure forms an oxide layer 20 at the surface of the susceptor. The thickness of this oxide layer is, for example, less than 10 Å. More particularly, as touched on above, this stage (c) carries out an *in situ* oxidation of the susceptor, the oxygen-containing gas mixture which is introduced into the epitaxy reactor reacting *in situ* with the coated susceptor to form the oxide layer 20. In figure 2, these three stages (a), (b) and (c) are respectively denoted ETCH, COAT and ISO.

The stage of exposure of the susceptor to the oxygen-containing gas mixture can be carried out at a temperature of between 900°C and 1100°C for a period of time of between 5 seconds and 100 seconds. The oxygen-containing gas mixture to which the susceptor is exposed during the *in situ* oxidation can comprise hydrogen as carrier gas and argon comprising between 0.1% and 10% of O₂. In one possible embodiment, the *in situ* oxidation comprises the introduction of oxygen into the epitaxy reactor at a flow rate of between 0.1 and 10 slm with carrier gas H₂ at a flow rate of between 5 and 100 slm.

The process is continued by a stage (d) of installation of one or more semiconductor substrates 30 on the oxide layer 20 of the susceptor S (more precisely at the position(s) of installation of the substrates corresponding to the pocket(s)). The oxide layer 20 is thus inserted between the susceptor and the rear face of each of the substrate(s), thus preventing the diffusion of reactive gases between the susceptor and the rear face of the substrate(s) during the subsequent stages.

The process subsequently comprises a stage (e) of baking the semiconductor substrate(s) 30 on the susceptor S, which removes the oxide layer 20 except on the underside of the semiconductor substrate(s) 30 (i.e. the oxide layer remains present between the rear face of the substrate(s) and the susceptor) and a stage (f) of deposition of an epitaxial layer 40 on the front face of each of the semiconductor substrate(s) 30. In figure 2, these two stages (e) and (f) are respectively denoted by BAKE and EPI. As illustrated in figure 2, the baking is generally carried out after a rise in temperature, and the epitaxial deposition is carried out after the baking and is followed by a fall in temperature. In order

to simplify the illustration, the baking stage BAKE is indicated only once in figure 2 but it is understood that a baking stage of this type precedes each epitaxial deposition EPI.

The baking stage BAKE can be carried out in H₂ introduced at a flow rate of between 3 and 100 slm. It can be carried out at a temperature of between 950°C and 1200°C for a period of time of between 5 seconds and 100 seconds.

The epitaxial deposition EPI stage is carried out in H₂ using a reactive gas for the epitaxial deposition, such as TCS. The TCS can be introduced at a flow rate of between 5 and 50 slm while the carrier gas H₂ can be introduced at a flow rate of between 3 and 100 slm. The epitaxial deposition EPI stage can be carried out at a temperature of between 950°C and 1200°C for a period of time of between 10 seconds and 1000 seconds.

According to a possible alternative form of this first embodiment, the stages of installation of a semiconductor substrate on the susceptor, of baking of the semiconductor substrate and of deposition of an epitaxial layer on the semiconductor substrate are repeated for at least one other semiconductor substrate without in the meantime etching, coating and oxidizing *in situ* the susceptor. By way of example, from four to six epitaxial depositions can be carried out before exposing the susceptor to a new sequence of etching, of coating and of *in situ* oxidation. In Figure 2, four epitaxial depositions EPI are carried out between two sequences of etching ETCH - coating COAT - *in situ* oxidation ISO of the susceptor.

Figure 5 represents the stages of a process for the production of a semiconductor substrate comprising an epitaxially deposited layer according to a second embodiment of the invention. Stages (a) and (b) are respectively a chamber etch stage and a chamber coating stage similar to those touched on above with regard to figure 4. After the coating, the process comprises a stage (c) of installation of one or more semiconductor substrates 30 on the susceptor S (more precisely at the position(s) of installation of the substrates corresponding to the pocket(s)). As illustrated diagrammatically in figure 5, the semiconductor substrate 30 can exhibit degraded values of local flatness in its edge region.

The exposure of the coated susceptor to an oxygen-containing gas mixture subsequently takes place in stage (d), by an *in situ* oxidation during which the oxygen-containing gas mixture introduced into the epitaxy reactor reacts *in situ* with the coated

susceptor to form an oxide layer 25 located both on the front face of the semiconductor substrate and on the rear face of the semiconductor substrate, between the semiconductor substrate and the coated susceptor. The thickness of this oxide layer is, for example, less than 10 Å. In figure 3, this *in situ* oxidation is denoted ISO.

The oxygen-containing gas mixture to which the susceptor is exposed during the *in situ* oxidation can comprise hydrogen as carrier gas and argon comprising between 0.1% and 10% of O₂. In one possible embodiment, the *in situ* oxidation comprises the introduction of oxygen into the epitaxy reactor at a flow rate of greater than 0.1 slm while carrier gas H₂ is introduced at a flow rate of between 5 and 100 slm so as to ensure contact of the layer on the coated susceptor.

The *in situ* oxidation of the susceptor is followed by a stage (e) of baking one or more semiconductor substrate(s) 30 on the susceptor S, which removes the oxide layer 25 except on the underside of the semiconductor substrate(s) 30 (i.e. it remains present between the rear face of the substrate(s) and the susceptor), and by a stage (f) of deposition of an epitaxial layer 40 on each of the semiconductor substrate(s) 30. In figure 3, these two stages (e) and (f) are respectively denoted by BAKE and EPI. As illustrated in figure 3, the baking is generally carried out after a rise in temperature, and the epitaxial deposition is carried out after the baking and is followed by a fall in temperature. In order to simplify the illustration, the baking stage BAKE is indicated only once in figure 3 but it is understood that a baking stage of this type precedes each epitaxial deposition EPI.

According to this second embodiment, the *in situ* oxidation ISO of the susceptor can be carried out during the rise in temperature, that is to say during the increase in the temperature, of the epitaxy reactor until an epitaxial deposition temperature is reached. By way of example, the *in situ* oxidation ISO of the susceptor is carried out during the rise in temperature at a rate of rise of 3 to 10°C/s, up to a temperature of between 600°C and 1100°C. Its duration can be of between 5 seconds and 200 seconds.

The baking stage BAKE can be carried out in H₂ introduced at a flow rate of between 3 and 100 slm. It can be carried out at a temperature of between 950°C and 1200°C for a period of time of between 5 seconds and 100 seconds. The epitaxial deposition EPI stage is carried out in H₂ using a reactive gas for the epitaxial deposition, such as TCS. The TCS can

be introduced at a flow rate of between 5 and 50 slm while the carrier gas H₂ can be introduced at a flow rate of between 3 and 100 slm. The epitaxial deposition EPI stage can be carried out at a temperature of between 950°C and 1200°C for a period of time of between 10 seconds and 1000 seconds.

According to a possible alternative form of this second embodiment, the stages of installation of a semiconductor substrate on the susceptor, of exposure of the susceptor to an oxygen-containing gas mixture, of baking of the semiconductor substrate and of deposition of an epitaxial layer on the semiconductor substrate are repeated for at least one other semiconductor substrate without in the meantime etching and coating the susceptor. By way of example, from four to six epitaxial depositions can be carried out before exposing the susceptor to a new sequence of etching ETCH and of coating COAT. In figure 3, four epitaxial depositions EPI of this type are carried out between two sequences of etching ETCH and of coating COAT of the susceptor, each epitaxial deposition EPI being preceded by an *in situ* oxidation ISO of the susceptor.

CLAIMS

1. A process for the production of a semiconductor substrate comprising an epitaxially deposited layer, successively comprising the following stages:

- etching (ETCH) a susceptor (S) of an epitaxy reactor;
- coating (COAT) the susceptor;
- installation of a semiconductor substrate (30) on the susceptor;
- deposition (EPI) of an epitaxial layer (40) on the semiconductor substrate (30);

and additionally, after the coating and before the deposition, the exposure (ISO) of the susceptor to an oxygen-containing gas mixture, said exposure resulting in an oxidation of the susceptor which will form an oxide layer (20, 25) at the surface of the susceptor, said oxide layer (20, 25) being found, during the deposition of the epitaxial layer on a front face of the semiconductor substrate, inserted between the susceptor and a rear face of the semiconductor substrate;

and additionally, after the installation and before the deposition (EPI), a baking (BAKE) of the semiconductor substrate which removes said oxide layer (20, 25) except on the underside of the semiconductor substrate (30).

2. The process as claimed in claim 1, in which the oxygen-comprising gas mixture is a mixture of hydrogen and of argon comprising between 0.1% and 10% of O₂.

3. The process as claimed in claim 2, in which O₂ is introduced into the epitaxy reactor at a flow rate of between 0.1 and 10 slm.

4. The process as claimed in one of claims 1 to 3, in which the oxide layer (20, 25) formed by the exposure (ISO) of the susceptor to the oxygen-containing gas mixture exhibits a thickness of less than 10 Å.

5. The process as claimed in one of claims 1 to 4, in which said exposure (ISO) is carried out after the coating (COAT) and before said installation.

6. The process as claimed in claim 5, in which the stages of installation of a semiconductor substrate on the susceptor and of deposition of an epitaxial layer on the semiconductor substrate are repeated for at least one other semiconductor substrate without in the meantime etching, coating and exposing the susceptor to an oxygen-containing gas mixture.
7. The process as claimed in any one of claims 1 to 4, in which said exposure (ISO) is carried out after said installation and before said deposition.
8. The process as claimed in claim 7, in which said exposure is carried out while increasing the temperature of the epitaxy reactor to an epitaxial deposition temperature.
9. The process as claimed in either of claims 7 and 8, in which the stages of installation of a semiconductor substrate on the susceptor, of exposure of the susceptor and of deposition of an epitaxial layer on the semiconductor substrate are repeated for at least one other semiconductor substrate without in the meantime etching and coating the susceptor.