Method for depositing a layer on a semiconductor wafer by means of CVD and chamber for carrying out the method

The invention relates to a method for depositing a layer on a semiconductor wafer by means of CVD (“chemical vapor deposition”) in a chamber, comprising conducting a deposition gas from a gas inlet opening of the chamber over the semiconductor wafer to a gas outlet opening of the chamber, wherein the deposition gas is conducted through a channel bounded at the top by a window that is transmissive to thermal radiation.

The typical construction of a chamber for depositing a layer on a semiconductor wafer by means of CVD is described in US 6,325,858 B1 for example. The chamber is divided into an upper half and into a lower half. The upper half is closed off by a cover, also called an upper dome. The cover comprises a base which forms the side wall of the cover and a window composed of quartz that is transparent to thermal radiation. The base is on a side wall of the chamber which is provided with a gas inlet opening and a gas outlet opening arranged opposite the latter. Situated between the upper half and the lower half of the chamber is a susceptor that receives the semiconductor wafer to be coated. The susceptor is held by a rack with spider-type arms and can be raised, lowered and rotated with the aid of the rack. The lower half of the chamber is closed off by a baseplate similar to the cover, said baseplate likewise being transparent to thermal radiation. Lamps arranged above the cover and below the base plate are activated in order to deposit a layer on a semiconductor wafer placed into the chamber. The deposition gas is conducted through the gas inlet opening to the gas outlet opening and over the semiconductor wafer on this path. In this case, it flows through a channel bounded by the window at the top.

One of the challenges when depositing a layer on a

semiconductor wafer by means of CVD is the requirement that the deposited layer is intended to have a layer thickness that is as uniform as possible. One measure of assessing the variation of the layer thickness is the range, defined as the difference between the maximum thickness t_{max} and the minimum thickness t_{min} of the layer. The parameter R derived therefrom describes the ratio of half of this difference and the mean thickness t_m in percent and is calculated according to the formula $R = 100\% *(t_{max} - t_{min})/2*t_m$. Accordingly, the layer thickness is all the more uniform, the smaller the value of R.

US 2002/0020358 A1 is devoted to improving the uniformity of the thickness of a layer deposited by means of CVD. The method described therein comprises producing a particular reaction zone (“prewafer reaction layer”) that combats an excessive layer growth in the edge region of the semiconductor wafer, which is known as the “edge effect”.

Since this method is comparatively complicated, the object of the present invention was to specify a possibility that can be realized more simply for improving the uniformity of the thickness of a layer deposited on a semiconductor wafer by means of CVD.

The invention relates to a method for depositing a layer on a semiconductor wafer by means of CVD in a chamber, comprising conducting a deposition gas from a gas inlet opening of the chamber over the semiconductor wafer to a gas outlet opening of the chamber, wherein the deposition gas is conducted through a channel bounded at the top by a window that is transmissive to thermal radiation, and at the bottom by a plane E in which the surface of the semiconductor wafer to be coated lies, wherein the speed at which the deposition gas is conducted over the semiconductor wafer is varied, by virtue of the fact that the distance D between the plane and the window is chosen in such a way that it is larger in a center region of the window and in

an edge region of the window on the outside than on the inside, and a tangent applied to the radial profile of the distance at the boundary between the center region and the edge region forms with the plane an angle of not less than 15° and not more than 25°, wherein the center region of the window is an inner region of the window that covers the semiconductor wafer, and the edge region of the window is an outer region of the window that does not cover the semiconductor wafer.

The inventors have discovered that the radial profile of the distance between the plane in which the surface of the semiconductor wafer to be coated lies and the window arranged above the semiconductor wafer can be used to locally influence the deposition rate, that is to say the speed at which the layer is deposited on the semiconductor wafer. The distance between the window and the plane also influences the speed at which the deposition gas flows over the semiconductor wafer. The speed is all the higher, the smaller the distance. The inventors have furthermore discovered that the deposition rate is lower in the case of a larger distance from the plane. Conversely, the deposition rate is higher if the distance from the plane is smaller. On the basis of this insight, the inventors have discovered, finally, how the radial profile of the distance from the plane has to be configured in order to be able to coat semiconductor wafers by means of CVD in such a way that the variation of the thickness of the deposited layer is particularly small. In this case, they have also taken account of the fact that with the distance remaining constant, it is observed that the deposition rate is lower in the center of the semiconductor wafer than at the edge of the semiconductor wafer.

The invention also relates to a chamber for depositing a layer on a semiconductor wafer by means of CVD, comprising a gas inlet opening for leading a deposition gas into the chamber, a gas outlet opening for conducting away the deposition gas from

the chamber, a susceptor for receiving a semiconductor wafer to be coated, and a window that is transmissive to thermal radiation and is arranged opposite the susceptor, wherein the distance between a plane in which the surface of the semiconductor wafer to be coated lies and the window is larger in a center region of the window and in an edge region of the window on the outside than on the inside, and a tangent applied to the radial profile of the distance at the boundary between the center region and the edge region forms with the plane an angle of not less than 15° and not more than 25°, wherein the center region of the window is an inner region of the window that covers the semiconductor wafer, and the edge region of the window is an outer region of the window that does not cover the semiconductor wafer.

The invention is explained in more detail below with reference to figures.

Figure 1 shows the features of a chamber configured according to the invention in cross section.
Figure 2 shows the radial profile of the distance D between the window and the plane E using the example of a window embodied according to the invention.
Figures 3 to 5 show the radial profile of the layer thickness of semiconductor wafers that were coated with and without the use of the invention, taking account of an edge exclusion of 3 mm.

The chamber in accordance with Figure 1 comprises a side wall with a gas inlet opening 1 for feeding a deposition gas into the chamber, and a gas outlet opening 2 for conducting away the deposition gas from the chamber, a susceptor 3 for receiving a semiconductor wafer 4 to be coated, and a window 5 arranged opposite the susceptor. The window 5 is connected to a base 6, which lies on the side wall of the chamber. It is transmissive to thermal radiation and is preferably composed of quartz. The

surface of the semiconductor wafer to be coated defines a plane E that is at a specific distance D from the window 5. The distance D preferably lies in a range of 25 – 35 mm. The lower area of the base lies parallel to the plane E. The partial area of the window which covers the semiconductor wafer to be coated is referred to hereinafter as the center region 7 of the window. Its radius corresponds to the radius of the semiconductor wafer. The outer area of the window adjoining the center region is referred to hereinafter as the edge region 8 of the window. The ratio of the width of the center region and the width of the edge region of the window typically lies in the range of 1.5 to 2.5.

The speed at which a deposition gas is conducted over the semiconductor wafer is not constant, since the distance between the window and the plane in which the surface of the semiconductor wafer to be coated lies changes. The radial profile of the distance is configured in such a way that the distance decreases from the edge region of the window toward the center region of the window. The magnitude of the speed is symbolized by the length of arrows in figure 1.

Figure 2 shows the distance D between the window and the plane E using the example of a window embodied according to the invention as a function of the distance L from the center of the window, and hence the radial profile of the distance D. This profile is characterized by the fact that at the location at which the center region of the window adjoins the edge region of the window, a tangent applied to the radial profile of the distance D forms with the plane E an angle which is not less than 15° and not more than 25°.

Particularly preferred configurations of the window are those in which the distance decreases as follows as viewed from the outside to the inside: in the center region of the window in such a way that the difference D_{max}-D_{min} between the maximum and

the minimum distance of the window from the plane is not less than 0.5 mm and not more than 2 mm, and in the edge region of the window in such a way that the difference D_{max}-D_{min} between the maximum and the minimum distance of the window from the plane in the center region of the window is not less than 0.5 mm and not more than 2 mm.

Owing to the smaller width of the edge region of the window relative to the width of the center region of the window, the change in the distance is larger in the edge region of the window than in the center region of the window. The distance does not have to decrease continuously as viewed from the outside to the inside. It can also remain constant in particular in an inner section of the center region, as shown by the radial profile in accordance with figure 2.

Example/Comparative Example:

An epitaxial layer composed of silicon was in each case deposited on semiconductor wafers composed of silicon having a diameter of 300 mm. The way in which the embodiment of the window affects the radial profile of the thickness of a layer deposited on the semiconductor wafers was tested. Only the window wherein the radial profile of the distance D from the plane E corresponded to the illustration in figure 2 was embodied according to the invention. A semiconductor wafer that was coated in a chamber comprising this window received a layer whose thickness profile is shown in figure 3 (example).

The window that was used for coating the semiconductor wafer whose layer thickness profile is illustrated in figure 4 (comparative example 1) had the following properties: the radial profile of the distance D of the window from the plane E was configured in such a way that the tangent that was applied to the boundary between the center region and the edge region formed with the plane E at an angle of 9.2°. In the center region, the window was configured in such a way that the

difference D_{max}-D_{min} between the maximum and the minimum distance of the window from the plane E had the value 2.3 mm. In the edge region, the window was configured in such a way that the difference D_{max}-D_{min} between the maximum and the minimum distance of the window from the plane E had the value 2.9 mm.

The window that was used for coating the semiconductor wafer whose layer thickness profile is illustrated in figure 5 (comparative example 2) had the following properties: the radial profile of the distance D of the window from the plane E was configured in such a way that the tangent that was applied to the boundary between the center region and the edge region formed with the plane E at an angle of 32.5°. In the center region, the window was configured in such a way that the difference D_{max}-D_{min} between the maximum and the minimum distance of the window from the plane E had the value 0.3 mm. In the edge region, the window was configured in such a way that the difference D_{max}-D_{min} between the maximum and the minimum distance of the window from the plane E had the value 2.2 mm.

As shown by the comparison of the layer thickness profiles, the thickness t of the deposited layer in the profile of the diameter d fluctuated to a considerably lesser extent in the case of the semiconductor wafer coated according to the invention and in the case of the comparative examples. What is particularly noticeable about the comparative examples, moreover, is the layer thickness that decreases significantly on the outside (comparative example 1) and the layer thickness that increases significantly on the outside (comparative example 2). In order to quantify the variation of the thickness of the deposited layers, the parameter R described in the introduction was determined, wherein the arithmetic mean of the layer thicknesses that were measured at 96 distributed positions taking account of the edge exclusion of 3 mm was used as the mean layer thickness t_m. The result is summarized in the following table:

Table:

	Example	Comparative Example 1	Comparative Example 2
R	0.48%	0.82%	0.80%

Patent Claims

1. A method for depositing a layer on a semiconductor wafer by means of CVD in a chamber, comprising conducting a deposition gas from a gas inlet opening of the chamber over the semiconductor wafer to a gas outlet opening of the chamber, wherein the deposition gas is conducted through a channel bounded at the top by a window that is transmissive to thermal radiation, and at the bottom by a plane E in which the surface of the semiconductor wafer to be coated lies, wherein the speed at which the deposition gas is conducted over the semiconductor wafer is varied, by virtue of the fact that the distance D between the plane and the window is chosen in such a way that it is larger in a center region of the window and in an edge region of the window on the outside than on the inside, and a tangent applied to the radial profile of the distance at the boundary between the center region and the edge region forms with the plane an angle of not less than 15° and not more than 25°, wherein the center region of the window is an inner region of the window that covers the semiconductor wafer, and the edge region of the window is an outer region of the window that does not cover the semiconductor wafer.

2. The method as claimed in claim 1, wherein the difference D_{max}-D_{min} between the maximum and the minimum distance of the window from the plane in the center region of the window is not less than 0.5 mm and not more than 2 mm.

3. The method as claimed in claim 1 or claim 2, wherein the difference D_{max}-D_{min} between the maximum and the minimum distance of the window from the plane in the edge region of the window is not less than 0.5 mm and not more than 2 mm.

4. A chamber for depositing a layer on a semiconductor wafer by means of CVD, comprising a gas inlet opening for leading a deposition gas into the chamber, a gas outlet opening for

conducting away the deposition gas from the chamber, a susceptor for receiving a semiconductor wafer to be coated, and a window that is transmissive to thermal radiation and is arranged opposite the susceptor, wherein the distance between a plane in which the surface of the semiconductor wafer to be coated lies and the window is larger in a center region of the window and in an edge region of the window on the outside than on the inside, and a tangent applied to the radial profile of the distance at the boundary between the center region and the edge region forms with the plane an angle of not less than 15° and not more than 25°, wherein the center region of the window is an inner region of the window that covers the semiconductor wafer, and the edge region of the window is an outer region of the window that does not cover the semiconductor wafer.

5. The chamber as claimed in claim 4, wherein the difference D_{max}-D_{min} between the maximum and the minimum distance of the window from the plane in the center region of the window is not less than 0.5 mm and not more than 2 mm.

6. The chamber as claimed in claim 4 or claim 5, wherein the difference D_{max}-D_{min} between the maximum and the minimum distance of the window from the plane in the edge region of the window is not less than 0.5 mm and not more than 2 mm.

7. The chamber as claimed in any of claims 4 to 6, wherein the distance D is 25-35 mm.

8. A semiconductor wafer comprising an epitaxial layer, wherein the thickness of the layer is non-uniform, wherein the parameter R which describes the variation of the thickness of the layer and is calculated in accordance with the formula $R = 100\% * (t_{max} - t_{min})/2*t_m$ is less than 0.5%, wherein in the formula t_{max} denotes the maximum thickness of the layer, t_{min} denotes the minimum thickness of the layer, and t_m denotes the mean thickness of the layer.