Title: CHEMICAL VAPOR DEPOSITION REACTOR AND METHOD FOR PREPARING POLYSILICON

Abstract: Disclosed are a chemical vapor deposition (CVD) reactor and a method for preparing polysilicon. Designed to perform a CVD process in a continuous manner, the CVD reactor and the preparation method of polysilicon allow for the mass production of polysilicon.
TITLE OF THE INVENTION
CHEMICAL VAPOR DEPOSITION REACTOR AND METHOD FOR
PREPARING POLYSILICON

BACKGROUND OF THE INVENTION

(a) Field of the Invention

The present invention relates to a chemical vapor deposition reactor, and a method for preparing polysilicon. More particularly, the present invention relates to a chemical vapor deposition reactor which produces polysilicon via a fully automated process, and a method for preparing polysilicon, using the same. This application claims priority to Korea Patent Application Nos. 10-2013-0073184 filed June 25, 2013 and 10-2014-0049390 filed. April 24. 2014, and the contents are herein incorporated by reference.

(b) Description of the Related Art

Polysilicon, a key component of solar cell, may be made by various polysilicon deposition methods. Inter alia, the deposition of polysilicon in a chemical vapor deposition (CVD) reactor, which is also known as "Siemens process" is typically used.

In Siemens process, a fine silicon filament is mounted in a bell-jar type reactor and heated via an electrode, with the concomitant feeding of a silicon precursor compound in a gaseous state, such as trichlorosilane, to the reactor, so that the silicon precursor compound is decomposed on the heated surface of the filament to form chunk polysilicon on the filament.

Typically in the Siemens process, the silicon filament is exposed at a temperature of 1,000°C or higher to trichlorosilane with a carrier gas. The trichlorosilane gas is decomposed to deposit silicon on the heated silicon filament, as illustrated in the following Equation 1, so that the heated silicon filament seems to grow.

[Equation 1]
2SiHCl$_3$ → Si + 2HCl + SiCl$_4$

The silicon obtained by this process is typically polycrystalline silicon.

FIG. 1 is a view illustrating the flow of a conventional Siemens process.

As shown in FIG. 1, the Siemens process is performed with cycles of the following steps (1) to (8):

Step (1): a bell-jar reactor covered by a suitable enclosure to allow high-temperature, air-tight operation is purged with nitrogen gas (N$_2$) and then with hydrogen gas (H$_2$), and a silicon filament, placed in the reactor, is heated to a high temperature by applying a high voltage to the filament (purge & ignition);

Step (2): a precursor compound of desired composition containing silicon (SiHCl$_3$, SiH$_2$Cl$_2$, SiCl$_4$, etc.) is fed in, together with hydrogen gas (H$_2$), to deposit silicon on the heated silicon filament in a chemical vapor deposition (CVD) manner (Deposition);

Step (3): the silicon-grown silicon filament is slowly cooled, and the reactor is purged with nitrogen gas (Cooling & Purge);

Step (4): the bell-jar reactor is opened by disengaging the base plate therefrom (Open);

Step (5): the silicon filament on which the silicon has been deposited is harvested (Harvest);

Step (6): the bell-jar reactor and the base plate are cleaned (Cleaning);

Step (7): a silicon filament is held in place on the base plate (Filament install);

and

Step (8): the bell-jar reactor is closed by engaging the base plate therewith (Close).

As mentioned above, the Siemens process is a combined decomposition/deposition process, and particularly, steps (4) to (8) need to be done manually, arising as a barrier to the mass production of polysilicon.

That is, the manufacture of polysilicon by the Siemens process is of a batch type in which many CVD reactors are sequentially operated (for example, about 25 or more CVD reactors for a factory with an annual capacity of ten thousand polysilicon),
raising the cost of labor. Thus, it acts as a critical impediment to the reduction in production cost by mass production.

**SUMMARY OF THE INVENTION**

Accordingly, the present invention has been made keeping in mind the above problems occurring in the prior art, and an object of the present invention is to provide a chemical vapor deposition (CVD) reactor which requires no manual operations and is operated in an ongoing manner.

Another object of the present invention is to provide a method for preparing polysilicon, using the chemical vapor deposition reactor.

In order to achieve above objects, the present invention provides a chemical vapor deposition reactor comprising:

- a base plate movable by a moving means; and
- a tunnel-shaped enclosure provided with a plurality of chambers divided by switchable partitions between adjacent chambers.

Also, the present invention provides a method for preparing polysilicon, comprising:

- loading a silicon filament on a movable base plate;
- installing a base plate in an enclosure provided with a plurality of chambers, the chambers being divided by switchable partitions between adjacent chambers; and
- performing a chemical vapor deposition (CVD) reaction, as the silicon filament-loaded base plate sequentially passing through the plurality of chambers within the enclosure.

Designed to perform a CVD process in a continuous manner, the CVD reactor and the preparation method of polysilicon according to the present invention can remarkably reduce the production cost and allows for the mass production of polysilicon.

**BRIEF DESCRIPTION OF THE DRAWINGS**
FIG. 1 is a view illustrating the flow of a conventional Siemens process. FIG. 2 is a view showing the structure of a CVD reactor according to one embodiment of the present invention. FIG. 3 is a view of base plates according to various embodiments of the present invention. FIG. 4 is a view illustrating the preparation method of polysilicon of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

All of the terms used in the specification are taken only to illustrate embodiments, and are not intended to limit the present invention. As used herein and in the appended claims, the singular forms "a", "an", and "the" include plural references unless the context clearly dictates otherwise. Unless the context clearly requires otherwise, throughout the description and the claims, the words "have", "comprise", "include" and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense, that is to say, in the sense of "including, but not limited to."

Additionally, the word "on" or "above," as used in the context of formation or construction of one element, means pertaining to the direct formation or construction of one element on another element directly or the additional formation or construction of one element between layers or on a subject or substrate.

The following detailed descriptions of embodiments of the invention are not intended to be exhaustive or to limit the invention to the precise form disclosed below. While specific embodiments of, and examples for the invention are described below for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize.

Hereinafter, a detailed description will be given of the present invention.

In accordance with one aspect thereof, the present invention provides a chemical vapor deposition (CVD) reactor comprising a base plate movable by a
moving means; and a tunnel-shaped enclosure provided with a plurality of chambers divided by switchable partitions between adjacent chambers.

There has been an increase in demand for high purity polysilicon used as a substrate in the fabrication of semiconductor devices or solar cells. Hence, the mass production of high purity polysilicon makes an important contribution to the advancement of the solar cell industry.

On the whole, a production process of polysilicon progresses as follows. First, metal silicon, obtained by a reduction process, is reacted with a reaction gas, such as hydrogen chloride, to form trichlorosilane in a gaseous phase which is then purified by distillation. Then, silicon is deposited from the contaminant-free trichlorosilane using a CVD reactor.

In this regard, the deposition of silicon from silane reactive gas such as trichlorosilane using a CVD reactor is generally achieved by the Siemens process. In the Siemens process, a silicon filament is mounted in, for example, a bell-jar type reactor and heated by applying a high voltage via electrodes, after which trichlorosilane is injected to the reactor and thermally decomposed to deposit silicon on the slim rod.

In practice, no limitations are given to the shape of the reactor. The silicon filament may be heated by high-temperature radiation or high-frequency or electromagnetic waves rather than electrodes. Also, the reactive gas introduced to the reactor is not limited to trichlorosilane, but may be extended to other silicon precursor material or compound gas such as silane, dichlorosilane, etc.

However, the Siemens process is a process which decomposition and deposition are combined, in a batch type process. That is, after completion of silicon deposition by CVD, worker's operations are necessarily needed including harvesting the silicon-grown silicon filament, cleaning the reactor and the base plate, holding a silicon filament in place on the base plate, and closing the reactor by engagement with the base plate.

In order to overcome the problems encountered in the conventional process, the present invention provides a CVD reactor which can be operated in a continuous
manner without a need for manual work once a silicon filament is loaded, thus allowing for the mass production of polysilicon.

The CVD reactor of the present invention comprises a base plate movable by a moving means; and a tunnel-shaped enclosure provided with a plurality of chambers divided by switchable partitions between adjacent chambers.

As used herein, the term "chamber" means an internal space defined by the switchable partition, of the enclosure. For convenience, a chamber between one chamber and another is referred to as "interchamber", and also falls within the definition of the chamber.

The base plate is movable by a moving means, and is provided with a silicon filament support. The silicon filament support may be singular or plural, but the present invention is not limited by the number of the silicon filament supports. For mass production of silicon, a plurality of the silicon filament supports may be provided.

According to one embodiment of the present invention, the CVD reactor may be applied to the continuous-type production process of polysilicon.

The CVD reactor of the present invention is not a bell-jar type reactor in which only one silicon filament can be loaded each time, but comprises a tunnel-shaped enclosure. The enclosure is provided with a plurality of chambers which are separated by the switchable partitions between adjacent chambers. No particular limitations are imposed on the length or shape of the tunnel. For example, the tunnel may have a linear shape, a polygonal line-shape, a U-shape or an S-shape, etc.

The enclosure provides the base plate, and a closed space surrounding the periphery and upper space of the base plate, and is a place in which a series of silicon deposition processes including purging, heating, chemical vapor deposition, and cooling are conducted. These deposition processes of silicon are carried out while the base plate is driven by a moving means to continuously pass through the plurality of chambers within the enclosure.

In one embodiment of the present invention, conditions of the plurality of chambers such as chamber shapes, gas atmospheres, pressures, temperatures, etc. can
be independently controlled depending upon the process to be performed therein.

In one embodiment of the present invention, with the motion of the base plate, the partitions may be open or closed so as to allow the base plate to enter the plurality of chambers sequentially.

According to one embodiment of the present invention, when the base plate moves from one chamber to another, the partition between the adjacent chambers is opened, and while the base plate stays within one chamber, the either partitions of the chamber which the base plate is placed on are kept to be closed.

In one embodiment of the present invention, the plurality of chambers may include a 1<sup>st</sup> chamber, a 1<sup>st</sup> interchamber, a 2<sup>nd</sup> chamber, a 2<sup>nd</sup> interchamber, ..., an n<sup>th</sup> chamber, an n<sup>th</sup> interchamber, and an n+1<sup>th</sup> chamber (wherein n is an integer of 3 or more).

The each chamber may be filled with respective gases different in atmosphere from one to another, and the interchamber may have a mixed atmosphere of the gases from the both chambers adjacent thereto.

Hereinafter, a detailed description will be given of the constitution and operational steps of the CVD reactor according to one embodiment of the present invention.

In one embodiment of the present invention, a 1<sup>st</sup> chamber refers to a chamber that the silicon filament-loaded base plate first undergoes after introduction to the enclosure.

A 2<sup>nd</sup> chamber is a zone where a 1<sup>st</sup> purge process for purging the inside of the enclosure with an inert gas, such as nitrogen (N<sub>2</sub>) gas, is performed to block the inside of the enclosure from the external air atmosphere and to establish a pressure condition for a CVD process.

A 1<sup>st</sup> interchamber is located between the 1<sup>st</sup> and the 2<sup>nd</sup> chambers. The 1<sup>st</sup> interchamber serves as a buffer zone adapted to prevent gases from the 1<sup>st</sup> and the 2<sup>nd</sup> chambers from intermixing before the entry of the base plate to the 2<sup>nd</sup> chamber from the 1<sup>st</sup> chamber. Thus, while the base plate is located in the 1<sup>st</sup> interchamber, a gas atmosphere of the 1<sup>st</sup> interchamber is converted from the gas atmosphere of the 1<sup>st</sup>
chamber to a gas atmosphere of the 2nd chamber, and then the base plate is moved to the 2nd chamber.

The 1st chamber is separated from the 1st interchamber by a 1st partition while a 2nd partition is intercalated between the 1st interchamber and the 2nd chamber. The 1st and the 2nd partitions may be opened or closed depending on the motion of the base plate. That is, the 1st partition is opened when the base plate is moving from the 1st chamber to the 1st interchamber, and is closed after completion of the motion. In addition, the 2nd partition is opened when the base plate is moving from the 1st interchamber to the 2nd chamber, and then closed after the base plate completely enters the 2nd chamber.

Open-close states of the 1st and the 2nd partitions according to the motion of the base plate are summarized in Table 1, below.

<table>
<thead>
<tr>
<th>Step</th>
<th>Operation</th>
<th>Location of base plate</th>
<th>1st partition</th>
<th>2nd partition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introducing a base plate to 1st chamber (installment)</td>
<td>1st chamber</td>
<td>Closed</td>
<td>Closed</td>
</tr>
<tr>
<td>2</td>
<td>Opening 1st partition</td>
<td>1st chamber</td>
<td>Opened</td>
<td>Closed</td>
</tr>
<tr>
<td>3</td>
<td>Moving base plate to 1st interchamber</td>
<td>Between 1st and 2nd chambers</td>
<td>Opened</td>
<td>Closed</td>
</tr>
<tr>
<td>4</td>
<td>Closing 1st partition</td>
<td>1st interchamber</td>
<td>Closed</td>
<td>Closed</td>
</tr>
<tr>
<td>5</td>
<td>Changing gas atmosphere in 1st interchamber (air→N₂)</td>
<td>1st interchamber</td>
<td>Closed</td>
<td>Closed</td>
</tr>
<tr>
<td>6</td>
<td>Opening 2nd partition</td>
<td>1st interchamber</td>
<td>Closed</td>
<td>Opened</td>
</tr>
<tr>
<td>7</td>
<td>Moving base plate to 2nd chamber</td>
<td>Between 1st interchamber and 2nd chamber</td>
<td>Closed</td>
<td>Opened</td>
</tr>
</tbody>
</table>
Referring to Table 1, when the base plate is located in the 1st chamber, both the 1st and the 2nd partitions are closed, and the base plate is moved to the 1st interchamber as the 1st partition is opened. During the motion of the base plate, the 1st chamber and the 1st interchamber are spatially communicated with each other because the 1st partition is opened. Accordingly, the atmosphere of the 1st interchamber is a mixture of the air of the 1st chamber and the nitrogen of the 2nd chamber.

After the motion of the base plate is completed, that is, when the base plate completely enters the 1st interchamber, the 1st partition is closed so that the 1st chamber and the 1st interchamber are spatially independent from each other and become respective, closed spaces. Thereafter, the gas atmosphere of the 1st interchamber is converted from air to nitrogen gas.

Once the atmosphere is converted to nitrogen gas, the 2nd partition is opened to allow for the entry of the base plate to the 2nd chamber. After the entry of the base plate to the 2nd chamber is completed, the 2nd partition is closed so that the 1st interchamber and the 2nd chamber are spatially independent from each other and become respective, closed spaces.

In this manner, the base plate moves through the 1st chamber, the 1st interchamber, the 2nd chamber, the 2nd interchamber, ..., the nth chamber, the nth interchamber, and the n+1th chamber according to the opening and closing of the corresponding partitions, with the concomitant performance of proper processes in a continuous manner.

The moving speed and retention time in each chamber of the base plate can be adjusted according to the type and performance rate of the process to be performed in each chamber.

A 3rd chamber is a zone configured to perform an ignition process for heating the silicon filament to a high temperature. Hence, the 3rd chamber may be filled with a hydrogen (H₂) gas atmosphere. In addition, the 3rd chamber may be provided with a
high-voltage applying apparatus or heater to maintain the silicon filament at a high temperature. In the 3rd chamber, the temperature of the silicon filament may be kept at anywhere from room temperature to about 600°C, or at about 200 to about 600°C.

A 2nd interchamber is intercalated between the 2nd and the 3rd chambers. The 2nd interchamber serves as a buffer zone adapted to prevent gases from the 2nd and the 3rd chambers from intermixing before the entry of the base plate to the 3rd chamber from the 2nd chamber. Thus, while the base plate is located in the 2nd interchamber, a gas atmosphere of the 2nd interchamber is converted from the gas atmosphere of the 2nd chamber to a gas atmosphere of the 3rd chamber, and then the base plate is moved to the 3rd chamber.

Likewise, a 3rd partition is provided between the 2nd chamber and the 2nd interchamber while the 2nd interchamber is separated from the 3rd chamber by a 4th partition. The 3rd and the 4th partitions may be opened or closed depending on the motion of the base plate. That is, the 3rd partition is opened when the base plate is moving from the 2nd chamber to the 2nd interchamber, and is closed after completion of the motion. In addition, the 4th partition is opened when the base plate is moving from the 2nd interchamber to the 3rd chamber, and then closed after the base plate completely enters the 3rd chamber.

A 4th chamber is provided as a zone to perform the deposition of silicon on the heated silicon filament by feeding a silicon precursor compound containing silicon, together with hydrogen gas. In the 4th chamber, the silicon filament is maintained at a temperature of as high as about 1,000 to about 1,200°C. For effective deposition, in addition, the 4th chamber is set to have a pressure of about 1 to about 10 atm, and preferably about 3 to about 6 atm.

The 4th chamber may be filled with a silicon precursor compound and a hydrogen gas atmosphere. Optionally, HCl gas may be partially present to promote the silicon deposition. Examples of the silicon precursor compounds useful in the present invention may include SiHCl₃, SiH₂Cl₂, SiCl₄, and a combination thereof, but are not limited thereto.

Between the 3rd and the 4th chambers is located a 3rd interchamber which
serves as a buffer zone adapted to prevent gases from the 3\textsuperscript{rd} and the 4\textsuperscript{th} chambers, different in atmosphere and temperature conditions from each other, from intermixing, before the entry of the base plate to the 4\textsuperscript{th} chamber from the 3\textsuperscript{rd} chamber. Thus, while the base plate is located in the 3\textsuperscript{rd} interchamber, a gas atmosphere of the 3\textsuperscript{rd} interchamber is converted from the gas atmosphere of the 3\textsuperscript{rd} chamber to a gas atmosphere of the 4\textsuperscript{th} chamber, and then the base plate is moved to the 4\textsuperscript{th} chamber.

The 3\textsuperscript{rd} chamber is separated from the 3\textsuperscript{rd} interchamber by a 5\textsuperscript{th} partition while a 6\textsuperscript{th} partition is intercalated between the 3\textsuperscript{rd} interchamber and the 4\textsuperscript{th} chamber. The 5\textsuperscript{th} and the 6\textsuperscript{th} partitions may be opened or closed depending on the motion of the base plate. That is, the 5\textsuperscript{th} partition is opened when the base plate is moving from the 3\textsuperscript{rd} chamber to the 3\textsuperscript{rd} interchamber, and is closed after completion of the motion. In addition, the 6\textsuperscript{th} partition is opened when the base plate is moving from the 3\textsuperscript{rd} interchamber to the 4\textsuperscript{th} chamber, and then closed after the base plate completely enters the 4\textsuperscript{th} chamber.

A 5\textsuperscript{th} chamber is a zone adapted to perform a cooling process of the silicon-grown silicon filament. To cool the silicon filament, hydrogen gas of room temperature may be continuously fed into the 5\textsuperscript{th} chamber.

There is a 4\textsuperscript{th} interchamber between the 3\textsuperscript{rd} and the 4\textsuperscript{th} chambers. The 4\textsuperscript{th} interchamber serves as a buffer zone adapted to prevent gases from the 4\textsuperscript{th} and the 5\textsuperscript{th} chambers from intermixing, before the entry of the base plate to the 5\textsuperscript{th} chamber from the 4\textsuperscript{th} chamber. Thus, while the base plate is located in the 4\textsuperscript{th} interchamber, a gas atmosphere of the 4\textsuperscript{th} interchamber is converted from the gas atmosphere of the 4\textsuperscript{th} chamber to a gas atmosphere of the 5\textsuperscript{th} chamber, and then the base plate is moved to the 5\textsuperscript{th} chamber.

Likewise, a 7\textsuperscript{th} partition is provided between the 4\textsuperscript{th} chamber and the 4\textsuperscript{th} interchamber while the 4\textsuperscript{th} interchamber is separated from the 5\textsuperscript{th} chamber by an 8\textsuperscript{th} partition. The 7\textsuperscript{th} and the 8\textsuperscript{th} partitions may be opened or closed depending on the motion of the base plate. That is, the 7\textsuperscript{th} partition is opened when the base plate is moving from the 4\textsuperscript{th} chamber to the 4\textsuperscript{th} interchamber, and is closed after completion of the motion. In addition, the 8\textsuperscript{th} partition is opened when the base plate is moving from
the 4th interchamber to the 5th chamber, and then closed after the base plate completely enters the 5th chamber.

A 6th chamber is provided as a zone in which a second purge process is performed with an inert gas, such as nitrogen gas, so as to harvest the silicon-deposited, cooled silicon filament. After being stabilized under the inert gas, such as nitrogen gas, in the 6th chamber, the silicon filament may be discharged from a 7th chamber.

Between the 5th chamber and the 5th interchamber, between the 5th interchamber and the 6th chamber, between the 6th chamber and the 6th interchamber, and between the 6th interchamber and the 7th chamber are provided 9th to 12th partitions, respectively. These partitions are operated in the same manner as are described above.

In one embodiment of the present invention, the moving means by which the base plate is moved in the CVD reactor may be a conveyer belt. The base plate is movable in the moving direction of the conveyer belt.

In one embodiment of the present invention, the enclosure may be provided with an inlet for introducing the base plate thereto, and an outlet for discharging the base plate therefrom.

In one embodiment of the present invention, the CVD reactor may further comprise a silicon filament installing unit and a silicon filament harvesting unit which are located, respectively, at a front and a rear end of the enclosure.

FIG. 2 is a view showing the structure of a CVD reactor according to one embodiment of the present invention.

With regard to FIG. 2, the CVD reactor 200 comprises a base plate 80 movable by a moving means; and a tunnel-shaped enclosure 130 provided with a plurality of chambers 10, 10a, 20, 20a, 30, 30a, 40, 40a, 50, 50a, 60, 60a, and 70 which are separated by switchable partitions G1, G2, G3, G4, G5, G6, G7, G8, G9, G10, G11, and G12 between adjacent chambers.

The plurality of chambers are arranged sequentially, and designated 1st chamber 10, 1st interchamber 10a, 2nd chamber 20, 2nd interchamber 20a, 3rd chamber
30, 3rd interchamber 30a, 4th chamber 40, 4th interchamber 40a, 5th chamber 50, 5th interchamber 50a, 6th chamber 60, 6th interchamber 60a, and 7th chamber 70, respectively.

However, the CVD reactor of the present invention is not limited to the shapes and number of the chambers illustrated in FIG. 2, if necessary, the number of the chambers and the interchambers may be increased or decreased.

In one embodiment of the present invention, the CVD reactor 200 may further comprise a conveyer belt 100 which runs in one direction. In this respect, the base plate 80 may be moved in the running direction of the conveyer belt 100.

According to one embodiment of the present invention, while the conveyer belt 100 travels in one direction and/or on an endless track, steps of introducing the silicon filament 90-loaded base plate 80 to the enclosure 130, performing a CVD process within the enclosure 130, and harvesting a polysilicon-grown silicon filament 90 can be carried out in a continuous manner.

The silicon filament 90 is loaded on the base plate 80. Although only two silicon filaments 90 are shown in FIG. 2, the present invention is not limited thereto, if necessary, one to tens silicon filaments may be loaded. A greater number of the silicon filaments loaded in each round results in greater production capacity of polysilicon per time.

In one embodiment of the present invention, the enclosure 130 may be provided with an inlet 110 for introducing the silicon filament 90-loaded base plate 80 thereto, and an outlet 120 for discharging the base plate 80 carrying the polysilicon-grown silicon filament 90 therefrom.

In one embodiment of the present invention, the base plate may be configured to be loaded with a plurality of silicon filaments.

FIG. 3 is a view of base plates according to various embodiments of the present invention.

Referring to FIG. 3, the base plate may be loaded with one or more silicon filaments in various types, for example, with only one silicon filament as in Type A, or with a plurality of silicon filaments in a widthwise direction as in Type B, in a
lengthwise direction as in Type C, or in array patterns as in Types D and E. Of course, the silicon filament may be loaded in patterns and/or numbers other than those shown in FIG. 3, with no limitations regarding the pattern and number of silicon filaments given to the present invention.

As described above, the CVD reactor of the present invention is designed to perform the Siemens process including purging, deposition, and cooling within one enclosure, in a continuous manner, with the consequent minimization of manual operations, and thus allows for the automation of the Siemens process. In addition, the CVD reactor of the present invention can remarkably increase the production of polysilicon in unit time thanks to its capacity of loading a plurality of silicon filaments in each time.

Because a conventional bell-jar reactor has one chamber therein, the chamber must be purged with new gas whenever a subsequent process is performed therein. In contrast, the reactor of the present invention is provided with many chambers set forth to perform respectively designated processes therein while the base plate travels the chambers. Accordingly, the chambers need not to be purged with new gas for every process, significantly reducing time and amount for purging gas.

Therefore, the present invention can produce polysilicon on a mass scale, with a significant reduction in production cost.

In accordance with another aspect thereof, the present invention provides a method for preparing polysilicon, comprising:

- loading a silicon filament on a movable base plate;
- installing a base plate in an enclosure provided with a plurality of chambers, the chambers being divided by switchable partitions between adjacent chambers; and
- performing a chemical vapor deposition (CVD) reaction, as the silicon filament-loaded base plate sequentially passing through the plurality of chambers within the enclosure.

The preparation method of polysilicon of the present invention may be implemented using the above-illustrated CVD reactor.

FIG. 4 is a view illustrating the preparation method of polysilicon of the
Referring to FIG. 4, first, a silicon filament is loaded on a base plate. Driven by a moving means which moves in one direction like a conveyer belt, the silicon filament-loaded base plate is introduced to a 1st chamber located within a tunnel-shaped enclosure.

After the base plate is installed within the 1st chamber, a 1st partition between the 1st chamber and a 1st interchamber is opened during which time the base plate is transferred to the 1st interchamber by the moving means. When the base plate is completely located within the 1st interchamber, the 1st partition is closed.

In the 1st interchamber, air is present in mixture with nitrogen (N₂) gas. That is, the 1st interchamber is provided as a buffer zone to conduct conversion from a gas atmosphere of the 1st chamber to a gas atmosphere of the subsequent 2nd chamber.

Next, a 2nd partition between the 1st interchamber and a 2nd chamber is opened during which time the base plate is moved to the 2nd chamber by the moving means. Once the base plate is completely located within the 2nd chamber, the 2nd partition is closed.

When the 2nd chamber is completely sealed with the 2nd partition after location of the base plate within the 2nd chamber, a 1st purge process is carried out to purge the 2nd chamber with nitrogen (N₂) gas.

Once the 2nd chamber is substantially filled with nitrogen gas, a 3rd partition is opened between the 2nd chamber and a 2nd interchamber during which time the base plate is moved through the open 3rd partition to the 2nd interchamber by the moving means.

In the 2nd interchamber, nitrogen (N₂) gas is in mixture with hydrogen (H₂) gas. That is, the 2nd interchamber is provided as a buffer zone to conduct conversion from a gas atmosphere of the 2nd chamber to a gas atmosphere of the subsequent 3rd chamber.

Subsequently, a 4th partition between the 2nd interchamber and a 3rd chamber is opened during which time the base plate is moved to the 3rd chamber by the moving means. Once the base plate is completely located within the 3rd chamber, the 4th
partition is closed.

When the 3rd chamber is completely sealed with the 4th partition after location of the base plate within the 3rd chamber, a heating process is carried out to heat the silicon filament under a hydrogen atmosphere in the 3rd chamber.

Under a hydrogen atmosphere in the 3rd chamber, the silicon filament is maintained at a high temperature by applying a high voltage thereacross or by an external heater. For example, the 3rd chamber is heated to keep the temperature of the silicon filament at from about room temperature to about 600°C, or at about 200 to about 600°C.

After the 3rd chamber is completely purged with hydrogen gas and maintained at a high temperature sufficient for silicon deposition, a 5th partition is opened between the 3rd chamber and a 3rd interchamber during which time the base plate is moved to the 3rd interchamber by the moving means. Once the base plate is completely located within the 3rd interchamber, the 5th partition is closed.

In the 3rd interchamber, hydrogen (3/4) gas is in mixture with a silicon precursor gas. That is, the 3rd interchamber is provided as a buffer zone to conduct conversion from a gas atmosphere of the 3rd chamber to a gas atmosphere of the subsequent 4th chamber.

When the gas atmosphere of the 3rd interchamber reaches the same pressure as in the 4th chamber, a 6th partition between the 3rd interchamber and a 4th interchamber is opened during which time the base plate driven by the moving means passes through the open 6th partition and is located within the 4th chamber.

In the 4th chamber, a silicon precursor compound, such as SiHCl₃, SiH₂Cl₂, SiCl₄, etc., is reacted with hydrogen to deposit silicon on the heated silicon filament in a chemical vapor deposition (CVD) manner.

Once the silicon deposition is completed in the 4th chamber, a 7th partition between the 4th chamber and a 4th interchamber is opened during which time the moving means-driven base plate is moved to the 4th interchamber. When the base plate is completely located within the 4th interchamber, the 7th partition is closed.

After location of the base plate within the 4th interchamber, when the 4th
interchamber is completely sealed with the 4th partition, the 4th interchamber is purged with hydrogen gas, so that a mixture of the silicon precursor gas and hydrogen is present in the 4th interchamber. That is, the 4th interchamber is provided as a buffer zone to conduct conversion from a gas atmosphere of the 4th chamber to a gas atmosphere of the subsequent 5th chamber.

When the gas atmosphere of the 4th interchamber reaches the same pressure as in the 5th chamber, an 8th partition between the 4th interchamber and a 5th chamber is opened during which time the moving means-driven base plate passes through the open 8th partition and is located within the 5th chamber.

In order to slowly cool the silicon filament on which the deposition has been completed in the 5th chamber, hydrogen gas of room temperature may be continuously fed in.

After the silicon filament is sufficiently cooled in a hydrogen atmosphere, a 9th partition between the 5th chamber and a 5th interchamber is opened during which time the moving means-driven base plate is moved to the 5th interchamber. Once the base plate is completely located within the 5th interchamber, the 9th partition is closed.

After location of the base plate within the 5th interchamber, when the 4th interchamber is completely sealed with the 9th partition, the 5th interchamber is purged with nitrogen gas, so that a mixture of hydrogen and nitrogen gases is present in the 5th interchamber. That is, the 5th interchamber is provided as a buffer zone to conduct conversion from a gas atmosphere of the 5th chamber to a gas atmosphere of the subsequent 6th chamber.

When the gas atmosphere of the 5th interchamber reaches the same pressure as in the 6th chamber, a 10th partition between the 5th interchamber and a 6th chamber is opened during which time the moving means-driven base plate passes through the open 10th partition and is located within the 6th chamber.

After location of the base plate within the 6th chamber, when the 6th chamber is completely sealed with the 10th partition, a 2nd purge process is carried out to purge the 6th chamber with nitrogen (N₂) gas.

Once the 6th chamber is substantially filled with nitrogen gas, an 11th partition
is opened between the 6th chamber and a 6th interchamber, during which time the moving means-driven base plate is moved through the open 11th partition to the 6th interchamber.

In the 6th interchamber, nitrogen gas (N\textsubscript{2}) from the 6th chamber is in mixture with air. That is, the 6th interchamber is provided as a buffer zone to conduct conversion from a gas atmosphere of the 6th chamber to a gas atmosphere of the subsequent 7th chamber.

Next, a 12th partition is opened between the 6th interchamber and a 7th chamber during which time the moving means-driven base plate is moved to the 7th chamber. Once the base plate is completely located within the 7th chamber, the 12th partition is closed.

From the 7th chamber, the base plate on which the silicon deposition has been completed can be harvested.

As described above, the preparation method of polysilicon of the present invention is designed to perform the silicon deposition by the Siemens process including purging, deposition, and cooling within one enclosure, in a continuous manner, with the consequent minimization of manual operations, and thus allows for the automation of the Siemens process. In addition, the method of the present invention can remarkably increase the production of polysilicon in unit time thanks to its capacity of loading a plurality of silicon filaments with each cycle of operation.

In addition, because the reactor of the present invention is provided with many chambers set forth to perform respectively designated processes therein while the base plate travels among the chambers, the chambers need not be purged with new gas for every process, significantly reducing purge time periods and amount. Therefore, the present invention can produce polysilicon on a mass scale, with a significant reduction in production cost.

A better understanding of the present invention may be obtained through the following examples which are set forth to illustrate, but are not to be construed as limiting the present invention.
<EXAMPLES>

EXAMPLE 1

The process of producing polysilicon using the CVD reaction shown in FIG. 2 was simulated with PolySim™ (STR, Russia). In this regard, 10 silicon filaments were loaded in each round of operation (5 silicon U rods, each corresponding to 2 silicon filaments). One silicon U rod weighed 140 kg and one filament was 2,500 mm long.

Atmospheres, processes and operation time periods according to chamber were summarized in Table 2, below.

<table>
<thead>
<tr>
<th>Chamber</th>
<th>Process</th>
<th>Atmosphere</th>
<th>Time (unit: hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st chamber(10)</td>
<td>Silicon filament installment</td>
<td>air</td>
<td>0.5</td>
</tr>
<tr>
<td>1st interchamber(10a)</td>
<td>Gas atmosphere substitution</td>
<td>air ↔ N₂</td>
<td>0.5</td>
</tr>
<tr>
<td>2nd chamber(20)</td>
<td>1st purge</td>
<td>N₂</td>
<td>0.5</td>
</tr>
<tr>
<td>2nd interchamber(20a)</td>
<td>Gas atmosphere substitution</td>
<td>N₂ ↔ H₂</td>
<td>0.5</td>
</tr>
<tr>
<td>3rd chamber(30)</td>
<td>Filament ignition</td>
<td>H₂</td>
<td>0.5</td>
</tr>
<tr>
<td>3rd interchamber(30a)</td>
<td>Gas atmosphere substitution</td>
<td>H₂ ↔ Si precursor</td>
<td>0.5</td>
</tr>
<tr>
<td>4th chamber(40)</td>
<td>Deposition</td>
<td>Si precursor, H₂</td>
<td>60</td>
</tr>
<tr>
<td>4th interchamber(40a)</td>
<td>Gas atmosphere substitution</td>
<td>Si precursor ↔ H₂</td>
<td>0.5</td>
</tr>
<tr>
<td>5th chamber(50)</td>
<td>Cooling</td>
<td>H₂</td>
<td>10</td>
</tr>
<tr>
<td>5th interchamber(50a)</td>
<td>Gas atmosphere substitution</td>
<td>H₂ ↔ N₂</td>
<td>0.5</td>
</tr>
<tr>
<td>6th chamber(60)</td>
<td>2nd purge</td>
<td>N₂</td>
<td>0.5</td>
</tr>
</tbody>
</table>
The simulated process of Example 1 was found to produce polysilicon in an amount of 280 kg per hour from one silicon U rod (280 kg/ea·hr). This corresponds to an annual production of 11,200 ton/year if the process is carried out for 8,000 hrs per year (ratio of operation of about 91%).

**EXAMPLES 2 TO 10**

The same process as in Example 1 was repeated, with the exception for different numbers and lengths of the silicon filaments to be loaded in each round of operation.

For each case, the expected productivity is summarized in Table 3, as converted to annual production if the process is carried out for 8,000 hrs a year (ratio of operation of about 91%).

<table>
<thead>
<tr>
<th>Ex. No.</th>
<th>Length of Si Filament (unit: mm)</th>
<th>No. of silicon U rod to be loaded in one round of operation</th>
<th>Productivity (unit: kg/ea·hr)</th>
<th>Annual Production (unit: ton/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1,500</td>
<td>1</td>
<td>168</td>
<td>1,344</td>
</tr>
<tr>
<td>3</td>
<td>1,500</td>
<td>4</td>
<td>168</td>
<td>5,376</td>
</tr>
<tr>
<td>4</td>
<td>1,500</td>
<td>12</td>
<td>168</td>
<td>16,128</td>
</tr>
<tr>
<td>5</td>
<td>2,000</td>
<td>1</td>
<td>224</td>
<td>1,792</td>
</tr>
<tr>
<td>6</td>
<td>2,000</td>
<td>4</td>
<td>224</td>
<td>7,168</td>
</tr>
<tr>
<td>7</td>
<td>2,000</td>
<td>12</td>
<td>224</td>
<td>21,504</td>
</tr>
<tr>
<td>8</td>
<td>2,500</td>
<td>1</td>
<td>280</td>
<td>2,240</td>
</tr>
<tr>
<td>9</td>
<td>2,500</td>
<td>4</td>
<td>280</td>
<td>8,960</td>
</tr>
</tbody>
</table>
Compared to the conventional batch-type Siemens process with an annual polysilicon production of up to about 400 ton/year from one reactor, the production method of polysilicon according to the present invention was observed to remarkably increase the production capacity.

<Description of symbols>
10, 10a, 20, 20a, 30, 30a, 40, 40a, 50, 50a, 60, 60a, 70: chamber
G1, G2, G3, G4, G5, G6, G7, G8, G9, G10, G11, G12: partition
80: base plate
90: silicon filament
100: conveyer belt
110: inlet 120: outlet
130: enclosure 200: CVD Reactor
WHAT IS CLAIMED IS:

1. A chemical vapor deposition (CVD) reactor, comprising:
a base plate movable by a moving means; and
a tunnel-shaped enclosure provided with a plurality of chambers divided by
switchable partitions between adjacent chambers.

2. The chemical vapor deposition reactor of claim 1, wherein the moving
means is a conveyer belt, and the base plate being movable in a moving direction of
the conveyer belt.

3. The chemical vapor deposition reactor of claim 1, wherein the base plate to
be loaded with a plurality of silicon filaments.

4. The chemical vapor deposition reactor of claim 1, wherein respective gas
atmospheres of the plural chambers are independently controlled.

5. The chemical vapor deposition reactor of claim 1, wherein the partitions are
opened and closed so as to allow the base plate to pass through the plurality of
chambers sequentially.

6. The chemical vapor deposition reactor of claim 5, when the base plate
moves from one chamber to adjacent another, the partition between the adjacent
chambers is opened, and while the base plate stays within one chamber, the either
partitions of the chamber which the base plate is placed on are kept to be closed.

7. The chemical vapor deposition reactor of claim 1, wherein the plural
chambers include a 1st chamber, a 1st interchamber, a 2nd chamber, a 2nd interchamber,
..., an n-th chamber, an n-th interchamber, and an n+1-th chamber which are arranged the
order (wherein n is an integer of 3 or more).
8. The chemical vapor deposition reactor of claim 7, wherein the plurality of chambers include the 1st chamber with an air atmosphere, the 2nd chamber with a nitrogen atmosphere, the 3rd chamber with a hydrogen atmosphere, the 4th chamber with a mixture of silicon precursor compound and hydrogen gas atmospheres, the 5th chamber with a hydrogen atmosphere, the 6th chamber with a nitrogen atmosphere, and the 7th chamber with an air atmosphere.

9. The chemical vapor deposition reactor of claim 8, wherein the silicon precursor compound is selected from the group consisting of SiHCl₃, SiH₂Cl₂, SiCl₄, and a combination thereof.

10. The chemical vapor deposition reactor of claim 1, wherein the enclosure further comprises an inlet for introducing the base plate thereto, and an outlet for discharging the base plate therefrom.

11. The chemical vapor deposition reactor of claim 8, wherein the base plate is introduced to the 1st chamber, and recovered from the 7th chamber after completion of silicon deposition.

12. The chemical vapor deposition reactor of claim 1, wherein the chemical vapor deposition reactor is used for producing polysilicon.

13. A method for preparing polysilicon, comprising:

   loading a silicon filament on a movable base plate;
   installing a base plate in an enclosure provided with a plurality of chambers, the chambers being divided by switchable partitions between adjacent chambers; and
   performing a chemical vapor deposition (CVD) reaction, as the silicon filament-loaded base plate sequentially passing through the plurality of chambers within the enclosure.
14. The method of claim 13, wherein the plurality of chambers include a 1st chamber, a 1st interchamber, a 2nd chamber, a 2nd interchamber, ..., an nth chamber, an nth interchamber, and an n+1th chamber which are arranged order (wherein n is an integer of 3 or more).

15. The method of claim 14, wherein the step of performing a chemical vapor deposition (CVD) reaction as the silicon filament-loaded base plate sequentially passing through the plurality of chambers within the enclosure, includes:

- loading the base plate to the 1st chamber;
- purging the 2nd chamber with nitrogen;
- heating the silicon filament in the 3rd chamber;
- reacting a silicon precursor compound with hydrogen to deposit silicon on the silicon filament in the 4th chamber;
- cooling the silicon filament in the 5th chamber;
- purging the 6th chamber with nitrogen; and
- harvesting the silicon-deposited silicon filament from the 7th chamber.

16. The method of claim 15, wherein the silicon precursor compound is selected from the group consisting of SiHCl₃, SiH₂Cl₂, SiCl₄, and a combination thereof.

17. The method of claim 13, when the base plate moves from one chamber to adjacent another, the partition between the adjacent chambers is opened, and while the base plate stays within one chamber, the either partitions of the chamber which the base plate is placed on are kept to be closed.

18. The method of claim 13, wherein a plurality of the silicon filaments are loaded to the base plate.
FIG. 1

: Step requiring worker's operation

FIG. 2
# INTERNATIONAL SEARCH REPORT

## A. CLASSIFICATION OF SUBJECT MATTER

C23C 16/44(2006.01)i, C23C 16/22(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

- C23C 16/44; H01L 21/205; C23C 16/54; B03C 11/00; C23C 16/50; B05D 3/06; C23C 16/00; C23C 16/22

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

- Korean utility models and applications for utility models
- Japanese utility models and applications for utility models

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

- eKOMPASS (KIPO internal) & keywords: chemical vapor deposition, Siemens, reactor, partition, and polysilicon

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>JP 2003-059844 A (ANELVA CORP.) 28 February 2003 See paragraphs [0015H0018], [0021]; claim V, and figure 1.</td>
<td>1, 2</td>
</tr>
<tr>
<td>Y</td>
<td>US 2007-0251455 A1 (WAN et al.) 01 November 2007 See paragraphs [0049]; claims 1, 14; and figure 2.</td>
<td>3, 12, 13, 18</td>
</tr>
<tr>
<td>A</td>
<td>US 2010-0080902 A (ARIFUDDIN et al.) 01 April 2010 See paragraphs [0022], [0023]; claims 1, 2; and figure 1.</td>
<td>1-18</td>
</tr>
<tr>
<td>A</td>
<td>US 2011-0151137 A (REVANKAR et al.) 23 June 2011 See paragraph [0019] and claims 1, 13.</td>
<td>1-18</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C. See patent family annex.

- "A" Special categories of cited documents:
  - "AA" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier application or patent but published on or after the international filing date
  - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  - "O" document referring to an oral disclosure, use, exhibition or other means
  - "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search

14 October 2014 (14.10.2014)

Date of mailing of the international search report

17 October 2014 (17.10.2014)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongna-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer

BAE, Geum Tae

Telephone No. +82-42-481-5580

Form PCT/ISA/210 (second sheet) (July 2009)
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP 2003-059844 A</td>
<td>28/02/2003</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CN 101432460 A</td>
<td>13/05/2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CN 101432460 B</td>
<td>31/07/2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 2013376 A2</td>
<td>14/01/2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 2013376 A4</td>
<td>24/03/2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 2530184 A2</td>
<td>05/12/2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 2530184 A3</td>
<td>07/08/2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2009-535505 A</td>
<td>01/10/2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO 20084722 A</td>
<td>10/11/2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RU 2008142471 A</td>
<td>10/06/2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RU 2442844 C2</td>
<td>20/02/2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 8647432 B2</td>
<td>11/02/2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 2012-0180720 Al</td>
<td>19/07/2012</td>
<td>CN 102597308 A</td>
<td>18/07/2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 2492369 Al</td>
<td>29/08/2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 2492369 A4</td>
<td>12/03/2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 05460236 B2</td>
<td>02/04/2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2011-089165 A</td>
<td>06/05/2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KR 10-2012-0056883 A</td>
<td>04/06/2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KR 10-2014-0006091 A</td>
<td>15/01/2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KR 10-2014-0013062 A</td>
<td>04/02/2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 2011-048790 Al</td>
<td>28/04/2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 2010-0080902 Al</td>
<td>01/04/2010</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 2011-0151137 Al</td>
<td>23/06/2011</td>
<td>CN 102140678 A</td>
<td>03/08/2011</td>
</tr>
</tbody>
</table>