

Description

Title of Invention:

METHOD FOR PRODUCING POLYSILICON ROD

5 Technical Field

[0001]

The present invention relates to a method for manufacturing a polysilicon rod.

10 Background Art

[0002]

In the manufacture of polysilicon used as a raw material for semiconductor elements, photovoltaic cells, and the like, for example, a method is known in which a raw material gas of chlorosilanes and hydrogen is injected into a reaction furnace to deposit a polysilicon rod.

[0003]

For example, Patent Literature 1 discloses a method for manufacturing a polysilicon rod in which a chlorosilane flow rate is set to 460 kg of chlorosilane per square meter of silicon surface per hour ($\text{kg}/(\text{h}\cdot\text{m}^2)$) within 15 hours from the start of deposition, and is maintained constant over the remaining required charging time. Further, Patent Literature 2 discloses a method for manufacturing a polysilicon rod in which the

amount of raw material gas is maintained at a constant
flow rate in an initial stage of a deposition reaction, and
thereafter the flow rate is gradually increased so that a
maximum flow rate is 3 times to 6 times the initial flow
rate.

Citation List

[Patent Literature]

[0004]

10 [Patent Literature 1]

Published Japanese Translation of PCT
International Application, *Tokuhyo*, No. 2010-540395

[Patent Literature 2]

Japanese Patent Application Publication, *Tokukai*,
15 No. 2014-028747

Summary of Invention

Technical Problem

[0005]

20 In general, in methods for manufacturing a
polysilicon rod, including the methods described in the
above-described Patent Literature 1 and Patent Literature
2, a polysilicon rod deposited in an initial period of a
growth period may have a low resistivity value. Further,
25 in the initial period of the growth period, a rod diameter

of the polysilicon rod is small, and depending on the degree to which a mixed gas is introduced into the reactor, there is a possibility that the polysilicon rod sways and collapses.

5 [0006]

An object of one aspect of the present invention is to improve a resistivity value of a polysilicon rod deposited in an initial period of a growth period, while preventing collapse of the polysilicon rod in the initial
10 period of the growth period.

Solution to Problem

[0007]

In order to attain the object, a method for producing a polysilicon rod in accordance with an aspect
15 of the present invention is a method for producing a polysilicon rod by supplying a raw material gas containing chlorosilanes to a silicon core wire erected inside a reaction furnace and heated by energization, to thereby deposit polysilicon on a surface of the silicon core
20 wire so as to grow the polysilicon into a polysilicon rod having a diameter of not less than 80 mm, wherein the raw material gas is introduced into the reaction furnace such that the number of gas exchanges in a growth start period of the polysilicon rod is not less than 8 times and
25 less than 35 times, the number of gas exchanges being

an amount of the raw material gas introduced into the reaction furnace relative to a volume of the reaction furnace, the growth start period lasting until one hour elapses from a start of deposition of the polysilicon on the surface of the silicon core wire.

Advantageous Effects of Invention

[0008]

According to one aspect of the present invention, it is possible to improve a resistivity value of a polysilicon rod deposited in an initial period of a growth period, while preventing collapse of the polysilicon rod in the initial period of the growth period.

Brief Description of Drawings

[0009]

Fig. 1 is a schematic view illustrating a production apparatus for producing a polysilicon rod in accordance with Embodiment 1 of the present invention.

Fig. 2 is a graph illustrating an example of the diameter of a polysilicon rod during deposition, versus deposition time.

Fig. 3 is a graph illustrating a relationship between deposition time and the amount of gas introduction for Examples and Comparative Examples of the present invention.

Fig. 4 is a graph illustrating a relationship between deposition time and the number of gas exchanges for Examples and Comparative Examples of the present invention.

5 Fig. 5 is a graph illustrating measurement results of the resistivity value of a polysilicon rod for Examples and Comparative Examples of the present invention.

Description of Embodiments

10 [0010]

 The following description will discuss an embodiment of the present invention in detail. Note that the following description provides examples of a production apparatus 1 and a production method for producing a polysilicon rod S1 in accordance with an
15 embodiment of the present invention, and the technical scope of the present invention is not limited to the examples described in the Description of Embodiments section and illustrated in the drawings.

20 [0011]

 [Overview of method for producing polysilicon rod]

 As a method for producing a polysilicon rod S1, there is a production method that involves supplying, to a silicon core wire (not shown) erected inside a reaction
25 furnace 10 and heated by energization, a raw material gas

G1 containing chlorosilanes to thereby deposit polysilicon on a surface of the silicon core wire so as to grow the polysilicon into a polysilicon rod S1. In such a method for producing a polysilicon rod S1, the polysilicon rod S1 deposited in a growth start period T1 (see Fig. 2) of the polysilicon rod, which is a period until one hour elapses from the start of deposition of polysilicon on the surface of the silicon core wire, may have a low resistivity value. Further, in the growth start period T1, a rod diameter of the polysilicon rod S1 is small, and depending on the degree to which the raw material gas G1 is introduced into the reaction furnace 10, there is a possibility that the polysilicon rod S1 sways and collapses.

[0012]

The method for producing a polysilicon rod S1 in accordance with an embodiment of the present invention achieves improvement of the resistivity value of the deposited polysilicon rod S1 while preventing collapse of the polysilicon rod S1 in the growth start period T1, by setting the number of gas exchanges in the reaction furnace 10 to a value determined through intensive studies conducted by the inventors of the present invention.

[0013]

[Configuration of production apparatus for producing polysilicon rod]

Fig. 1 is a schematic view illustrating the production apparatus 1 for producing a polysilicon rod S1 in accordance with Embodiment 1 of the present invention. As shown in Fig. 1, the production apparatus 1 for producing a polysilicon rod S1 includes a control section 2, a mixer 3, the reaction furnace 10, a supply pipe 20, supply nozzles 40, an electrode 50, and a discharge pipe 60.

[0014]

Note here that an inner diameter of each of the supply nozzles 40 and the number of the supply nozzles 40 provided in the reaction furnace 10 are not particularly limited. For example, the inner diameter of each of the supply nozzles 40 may be not less than 14 ϕ and not more than 18 ϕ , and the number of the supply nozzles 40 may be 10 to 30.

[0015]

The reaction furnace 10 is composed of a bottom part 11 on which the polysilicon rod S1 is placed, and a bell-jar type lid part 12 detachably connected to the bottom part 11. The reaction furnace 10 contains the raw material gas G1 for silicon deposition in a state where the lid part 12 is connected to the bottom part 11. The raw

material gas G1 is a mixed gas, and chlorosilanes and hydrogen (H_2) are mixed by the mixer 3 and introduced into the reaction furnace 10. The chlorosilanes may be, for example, a single gas of gaseous monochlorosilane

5 (SiH₃Cl), dichlorosilane (SiH₂Cl₂), trichlorosilane (SiHCl₃), or tetrachlorosilane (SiCl₄), or a mixture thereof.

[0016]

The bottom part 11 has formed therein inlets 111

10 for allowing the raw material gas G1 to flow into the reaction furnace 10 and an outlet 112 for allowing exhaust gas in the reaction furnace 10 after reaction to be discharged. From the inlets 111, respective through holes H1 extend so as to penetrate through the bottom

15 part 11. From the outlet 112, a through hole H2 extends so as to penetrate through the bottom part 11. In Fig. 1, two inlets 111 are formed in the bottom part 11 and one outlet 112 is formed in the bottom part 11; however, the numbers of inlets 111 and outlets 112 formed in the

20 bottom part 11 are not particularly limited.

[0017]

The supply pipe 20 is connected to ends of the through holes H1 on a side opposite to an interior of the reaction furnace 10, and supplies the raw material gas

25 G1 to the through holes H1. The supply nozzles 40 are

nozzles protruding into the reaction furnace 10 from the inlets 111. The supply nozzles 40 are provided on the bottom part 11 in order to cause the raw material gas G1 flowing in from the inlets 111 to reach an upper portion inside the reaction furnace 10 and to uniformly grow the polysilicon rod S1. A tip portion of each supply nozzle 40 is positioned higher than a topmost portion of the electrode 50 in order to prevent the raw material gas G1 from directly hitting the vicinity of the electrode 50. By adjusting the gas linear velocity at the tip of each supply nozzle 40, it is possible to prevent the polysilicon rod S1 from becoming prone to breakage. The supply nozzles 40 are preferably made of a material having high corrosion resistance to the raw material gas G1, and is made of carbon, for example.

[0018]

The electrode 50 is a member that electrically connects a power supply (not illustrated) and the silicon core wire. The deposition temperature of polysilicon is approximately not lower than 600°C. From the viewpoint of rapidly depositing polysilicon on the silicon core wire, the silicon core wire is heated by energization so that the silicon core wire is maintained at a temperature of approximately 900°C to 1000°C. At least one pair of electrodes 50 is provided on the bottom part 11. The

number of electrodes 50 is determined in accordance with the number of silicon core wires provided inside the reaction furnace 10.

[0019]

5 The discharge pipe 60 is a pipe for discharging, to the outside of the reaction furnace 10, gas formed in a silicon deposition step. The discharge pipe 60 extends between the outside of the reaction furnace 10 and an end of the through hole H2 opposite to the outlet 112.

10 The gas discharged from the silicon deposition step contains chlorosilanes, hydrogen (H_2), hydrogen chloride (HCl), by-products, and contaminants. The gas formed in the silicon deposition step and discharged is recovered and processed.

15 [0020]

 The control section 2 controls introduction of the raw material gas G1 into the reaction furnace 10. The control section 2 controls introduction of the raw material gas G1 into the reaction furnace 10 on the basis

20 of deposition time, the diameter of the polysilicon rod S1, the gas linear velocity at the tip of each supply nozzle 40, and the like. The function of the control section 2 may be implemented by a central processing unit (CPU) executing a program stored in a storage section (not illustrated).

25 [0021]

[Method for producing polysilicon rod]

The method for producing a polysilicon rod S1 in accordance with an embodiment of the present application is a method of supplying, to the silicon core wire erected inside the reaction furnace 10 and heated by energization, the raw material gas G1 containing chlorosilanes to thereby deposit polysilicon on the surface of the silicon core wire so as to grow the polysilicon into a polysilicon rod S1 having a diameter of not less than 80 mm. The method includes a step of introducing the raw material gas G1 into the reaction furnace 10.

[0022]

Fig. 2 is a graph illustrating an example of the diameter of a polysilicon rod S1 during deposition, versus deposition time. The diameter of the polysilicon rod S1 is not less than 80 mm, and is preferably 90 mm to 180 mm, in consideration of industrial utility value. The growth period is generally not less than 50 hours, and is preferably 60 hours to 150 hours. As illustrated in Fig. 2, the polysilicon rod S1 is deposited, for example, over approximately 100 hours until the polysilicon rod S1 has a diameter of approximately 130 mm. The following description is provided on the assumption that the time from the start of deposition of the polysilicon rod S1 to

the completion of the deposition (from 0 hours to 100 hours in Fig. 2) is a growth period T3 (entire growth period).

[0023]

5 In the present specification, unless otherwise specified, "the diameter of the polysilicon rod S1" indicates a diameter in a state in which polysilicon is deposited on the core wire, and the diameter of the polysilicon rod S1 includes the core wire. The diameter is
10 obtained by measuring a distance between a right end and a left end of the polysilicon rod S1 with use of a distance measuring instrument (not illustrated) provided outside the reaction furnace 10, through a viewing window (not illustrated) provided on a side surface of the
15 bell-jar type lid part 12 for observing the inside of the reaction furnace 10.

[0024]

(Number of gas exchanges)

<Growth start period T1>

20 As described above, the polysilicon rod S1 deposited in the growth start period (a period until one hour elapses from the start of deposition of polysilicon on the surface of the silicon core wire) T1 may have a low resistivity value. This is presumed to be due to the
25 following reason.

[0025]

Ordinarily, (1) during shutdown of the reaction furnace 10, the reaction furnace 10 is kept filled with a high-purity gas such as hydrogen or nitrogen, and (2) at the start of production of the polysilicon rod S1, the reaction furnace 10 is subjected to a purification treatment by the replacement of its internal air with the high-purity gas of these types and a raw material gas, and then polysilicon deposition is carried out.

[0026]

However, even if the above purification treatment is performed, it is difficult for all contaminants released from the inner wall and the like of the reaction furnace 10 and accumulated in the reaction furnace 10 during its shutdown to be discharged to the outside of the reaction furnace 10, and it is inevitable that some of the contaminants remain in the reaction furnace 10. As such, the contaminants remaining in the reaction furnace 10 are incorporated into the polysilicon to be deposited in the growth start period T1 of the polysilicon rod S1. It is presumed that the resistivity value of that portion decreases as a result.

[0027]

Further, in the growth start period T1, the diameter of the polysilicon rod S1 is small, and depending on the

degree to which the raw material gas G1 is introduced into the reaction furnace 10, there is a possibility that the polysilicon rod S1 sways and collapses. Specifically, in the growth start period T1, the polysilicon core wire has a small diameter of typically 5 mm to 15 mm, and when the growth start period T1 has elapsed, the diameter of the polysilicon rod S1 is as small as 6 mm to 18 mm.

[0028]

As a result of intensive studies, the inventors of the present invention have found that by setting, in the growth start period T1, the number of gas exchanges in the reaction furnace 10 to not less than 8 times and less than 35 times, preferably not less than 10 times and less than 30 times, it is possible to prevent collapse of the polysilicon rod S1 in the growth start period T1 and to improve the resistivity value of the deposited polysilicon rod S1.

[0029]

Conventionally, in the growth start period T1, the number of gas exchanges is ordinarily less than 8 times. However, the inventors of the present invention have found that by increasing the number of gas exchanges to not less than 8 times, contaminants generated from the reaction furnace 10 can be appropriately discharged.

Thus, the resistivity value of the polysilicon rod S1 deposited in the growth start period T1 can be significantly improved.

[0030]

5 On the other hand, as the number of gas exchanges is increased, the gas linear velocity at the tip of the supply nozzle 40 increases, and the load on the polysilicon rod S1 having a small diameter in the growth start period T1 increases. In connection with this, the
10 inventors of the present invention have found that by suppressing the number of gas exchanges to less than 35 times, it is possible to prevent the load from increasing to the extent that the polysilicon rod S1 collapses.

[0031]

15 Moreover, by thus increasing the number of gas exchanges to achieve a relatively large amount of gas introduction, the growth rate of the diameter of the polysilicon rod S1 increases, so that a diameter large enough to make it difficult for the polysilicon rod S1 to
20 collapse is reached earlier, and in turn the productivity of the polysilicon rod S1 is improved. It should be noted that in a case where the number of gas exchanges is not less than 35 times in the growth start period T1, the occurrence rate of collapse of the polysilicon rod S1
25 increases and productivity deteriorates.

[0032]

The number of gas exchanges is the amount of the raw material gas G1 introduced into the reaction furnace 10 per hour relative to the internal volume of the reaction furnace 10. The number is obtained by calculating (amount of the raw material gas G1 introduced into the reaction furnace 10)/(internal volume of the reaction furnace 10), and is expressed in units of times/h.

[0033]

In the growth start period T1 of the polysilicon rod S1, the linear velocity, per supply nozzle 40, of the raw material gas G1 introduced into the reaction furnace 10 is preferably not more than $40 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$. Thereby, the effect of preventing collapse of the polysilicon rod S1 can be further enhanced. The linear velocity, per supply nozzle 40, of the raw material gas G1 is more preferably not more than $35 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$.

[0034]

The lower limit of the linear velocity is appropriately determined in accordance with the inner diameter of each supply nozzle 40. For example, the lower limit value of the linear velocity is appropriately determined in a range of not less than $5.0 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$ and not more than $20.0 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$. By setting the linear velocity of each supply nozzle 40 to a value exceeding the

above range, the raw material gas G1 can be sufficiently distributed to the upper portion of the reaction furnace 10.

[0035]

5 The "linear velocity" is the gas linear velocity at the tip of the supply nozzle 40, calculated by (amount of gas introduction) / (nozzle cross-sectional area × number of nozzles).

[0036]

10 <Initial growth period T2>

 In the method for producing a polysilicon rod S1, during the growth period T3, even after the growth start period T1, the raw material gas G1 is introduced into the reaction furnace 10 until the polysilicon rod S1 grows to
15 have a desired diameter of not less than 80 mm. The amount of the raw material gas G1 introduced is increased macroscopically after the growth start period T1 until completion of polysilicon deposition. In the growth period T3, the maximum value of the number of
20 gas exchanges per hour is preferably not less than 80 times and not more than 100 times.

[0037]

 Note that, assuming that a given one hour in the growth period T3 is referred to as a given period TE and
25 the one hour immediately before the given period TE is

referred to as a given period TE-1, the amount of the raw material gas G1 introduced after the growth start period T1 may be such that, depending on the time that has elapsed from the start of deposition, there may temporarily be a period in which the introduced amount in the given period TE is maintained equal to the introduced amount in the given period TE-1, or a period in which the introduced amount in the given period TE is decreased from the introduced amount in the given period TE-1.

[0038]

In the growth period T3, even after the growth start period T1 has elapsed, contaminants remain in the reaction furnace 10 for a certain period following the growth start period T1, although in a small amount not as much as during the growth start period T1. Therefore, also in the certain period following the growth start period T1, there is a possibility that the contaminants remaining in the reaction furnace 10 are incorporated into the polysilicon to be deposited and decrease the resistivity value.

[0039]

The decrease in resistivity value is particularly likely to occur in an initial growth period T2 (see Fig. 2), which is the time from the end of the growth start period

T1 of the polysilicon rod S1 until the diameter reaches 30 mm.

[0040]

Therefore, in the initial growth period T2, it is more preferable that introduction of the raw material gas G1 into the reaction furnace 10 be carried out such that (1) an increase ratio per hour of the number of gas exchanges in the initial growth period T2 is within a range of not less than 0.6 and not more than 5.0, and (2) in one hour immediately before the diameter of the polysilicon rod S1 reaches 30 mm, the number of gas exchanges is increased to not less than 30 times and not more than 50 times. Thereby, also in the initial growth period T2, it is possible to further reduce incorporation of contaminants into polysilicon while continuing prevention of collapse of the polysilicon rod S1. The "increase ratio per hour of the number of gas exchanges" is calculated by "(number of gas exchanges in a given period TE)/(number of gas exchanges in a given period TE-1)".

[0041]

By performing gas exchange within the above-described range in the initial growth period T2, suppression of the resistivity value while preventing collapse of the polysilicon rod S1 is also possible in the initial growth period T2 following the growth start period

T1 in which the number of gas exchanges is set to not less than 8 times and less than 35 times.

[0042]

5 In the initial growth period T2, gas exchange is performed with the increase ratio of the number of gas exchanges being within a range of not less than 0.6 and not more than 5.0, more preferably within a range of not less than 0.7 and not more than 3.5, and particularly preferably within a range of not less than 0.8 and not
10 more than 3.4.

[0043]

Further, in the initial growth period T2, in a case where the increase ratio of the number of gas exchanges is not less than 0.6, the number of gas exchanges in the
15 given period TE may be made smaller than the number of gas exchanges in the given period TE-1. However, such a decrease period is kept temporary, and in one hour immediately before the diameter of the polysilicon rod S1 reaches 30 mm, it is necessary to increase the number of
20 gas exchanges to not less than 30 times and not more than 50 times, more preferably not less than 35 times and not more than 45 times.

[0044]

25 The time from the start of deposition of polysilicon on the surface of the silicon core wire until the end of the

initial growth period T2, in other words, the time from the start of polysilicon deposition until the diameter of the polysilicon rod S1 reaches 30 mm, is ordinarily 10 hours to 30 hours.

5 [0045]

In the initial growth period T2, the linear velocity, per supply nozzle 40, of the raw material gas G1 introduced into the reaction furnace 10 is preferably not less than $15 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$ and not more than 150
10 $\text{Nm}^3/(\text{s}\cdot\text{m}^2)$. Thereby, the effect of preventing collapse of the polysilicon rod S1 can be further enhanced. The linear velocity, per supply nozzle, of the raw material gas G1 is more preferably not less than $20 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$ and not more than $120 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$.

15 [0046]

(Example 1)

Example 1 of the present invention will be described with reference to Figs. 3 to 5. Fig. 3 is a graph illustrating a relationship between deposition time and
20 the amount of gas introduction for Examples and Comparative Examples of the present invention. More specifically, Fig. 3 is a graph illustrating, for each hour that elapses after the start of deposition, the amount of gas introduction into the reaction furnace 10 in that one
25 hour.

[0047]

Fig. 4 is a graph illustrating a relationship between deposition time and the number of gas exchanges for Examples and Comparative Examples of the present invention. More specifically, Fig. 4 is a graph illustrating, for each hour that elapses after the start of deposition, the number of gas exchanges in that one hour. Fig. 5 is a graph illustrating measurement results of the resistivity value of a polysilicon rod S1 for Examples and Comparative Examples of the present invention. In Figs. 3 to 5, a1-1 indicates a result of Example 1, and a1-2, b1-1, and b1-2 indicate results of Example 2, Comparative Example 1, and Comparative Example 2, respectively, described later.

[0048]

In Example 1, a polysilicon rod S1 was produced using the production apparatus 1 illustrated in Fig. 1. The reaction furnace 10 was designed to accommodate ten polycrystalline silicon rods (five pairs of inverted U-shaped polysilicon rods S1), and in Example 1, five pairs of inverted U-shaped silicon core wires having a height of 2000 mm were erected on the bottom part 11 of the reaction furnace 10.

[0049]

Each silicon core wire in the reaction furnace 10

was heated by energization so as to have a temperature of approximately 1000°C, and a mixed gas of trichlorosilane and hydrogen was used as the raw material gas G1 and introduced from the supply nozzles 40 to carry out a silicon deposition reaction by the Siemens process for 100 hours. The number of supply nozzles 40 was six, and the supply nozzles 40 were distributedly arranged at equal intervals over substantially the entire area of an upper surface of the bottom part 11.

[0050]

As a result, as shown in the graph of Fig. 2, the polysilicon rods S1 grew in diameter, so that polysilicon rods S1 having a diameter of 130 mm were obtained. This diameter is an average of the diameters of the ten polysilicon rods S1 produced, and in the present Example, subsequent physical properties of the polysilicon rods S1 were similarly evaluated based on an average of the ten polysilicon rods S1.

[0051]

In the production of the polysilicon rods S1, in the growth start period T1, which was a period until one hour elapsed from the start of deposition, the raw material gas G1 was introduced into the reaction furnace 10 at an amount of gas introduction of 243 Nm³/h as indicated by

a1-1 in Fig. 3.

[0052]

The number of gas exchanges in the growth start period T1 was 19 times as indicated by a1-1 in Fig. 4. At the end of the growth start period T1, the linear velocity, per supply nozzle 40, of the raw material gas G1 introduced into the reaction furnace 10 was $30.9 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$.

[0053]

When the growth start period T1 had elapsed, none of the growing polysilicon rods S1 had collapsed. When the growth start period T1 had elapsed, the diameter of the polysilicon rods S1 had reached 11 mm.

[0054]

In the initial growth period T2 following the growth start period T1 until the diameter of the polysilicon rods S1 reached 30 mm, the raw material gas G1 was introduced into the reaction furnace 10 at an amount of gas introduction as indicated by a1-1 in Fig. 3 and with the number of gas exchanges as indicated in Fig. 4. The elapsed time from the start of deposition until the diameter of the polysilicon rods S1 reached 30 mm was 21 hours.

[0055]

In the initial growth period T2, the increase ratio

per hour of the number of gas exchanges was within a range of 0.9 to 2.0. Further, in one hour immediately before the diameter of the polysilicon rods S1 reached 30 mm, the number of gas exchanges was increased to 45 times. In this initial growth period T2, the linear velocity, per supply nozzle 40, of the raw material gas G1 introduced into the reaction furnace 10 was within a range of $30.9 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$ to $72.7 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$. Also in this initial growth period T2, none of the polysilicon rods S1 collapsed.

[0056]

Further, during a period following the initial growth period T2 and lasting until 100 hours from the start of deposition, the number of gas exchanges was gradually increased so as to reach a maximum value of 95 times at 42 hours from the start of deposition, and thereafter the raw material gas G1 was introduced into the reaction furnace 10 at an increase ratio per hour of the number of gas exchanges in a range of not less than 0.0 and not more than 1.5. In the last one hour at the end of growth, the number of gas exchanges was set to 0 times. The growth was ended when 100 hours had elapsed from the start of deposition as described above, and the polysilicon rods S1 having a diameter of approximately 130 mm were obtained.

[0057]

After the production of the polysilicon rods S1 described above, a core rod with a diameter of 19 mm was drilled out from each of the obtained polysilicon rods S1 in a direction perpendicular to a longitudinal direction of the polysilicon rod S1 so as to include a core wire portion. The resistivity value of the core rod in a longitudinal direction thereof was measured to thereby obtain the resistivity value of the polysilicon rod S1 in a radial direction thereof. The result is shown in Fig. 5 as a1-1. On the horizontal axis in Fig. 5, for example, "core wire + 2 cm" indicates a state in which polysilicon was deposited around the core wire so as to have a thickness of approximately 1 cm (i.e., a diameter larger by 2 cm than the diameter of the core wire).

[0058]

Regarding the resistivity value of a1-1 in Fig. 5, a resistivity value X_{a1-1} of the polysilicon rods S1 having a diameter X at the end of the growth start period T_1 , which was when one hour had elapsed from the start of polysilicon deposition, was as high as approximately 1700 (Ωcm). Further, a resistivity value Y_{a1-1} of the polysilicon rods S1 at the end of the initial growth period T_2 , when the diameter of the polysilicon rods S1 had reached 30 mm (diameter Y), was approximately 3600

(Ωcm). Thus, a high resistivity value was favorably maintained.

[0059]

(Comparative Example 1)

5 Comparative Example 1 of the present invention will be described with reference to Figs. 3 to 5. In Comparative Example 1, production of a polysilicon rod S1 was carried out in the same manner as in Example 1 except that the amounts of the raw material gas G1
10 introduced in the growth start period T1 and the initial growth period T2 were changed as described below. Comparative Example 1 is a method for producing a polysilicon rod S1 according to an amount of gas introduction that is conventionally generally
15 implemented.

[0060]

In Comparative Example 1, the amount of the raw material gas G1 introduced in the growth start period T1 was decreased to $88 \text{ Nm}^3/\text{h}$ as indicated by b1-1 in Fig.
20 3, and the number of gas exchanges in the growth start period T1 was reduced to 7 times as indicated by b1-1 in Fig. 4. At the end of the growth start period T1, the linear velocity, per supply nozzle 40, of the raw material gas G1 introduced into the reaction furnace 10 was 9.7
25 $\text{Nm}^3/(\text{s}\cdot\text{m}^2)$.

[0061]

In the initial growth period T2, the raw material gas G1 was introduced into the reaction furnace 10 at an amount of gas introduction as indicated by b1-1 in Fig. 3 and with the number of gas exchanges as indicated in Fig. 4. The elapsed time from the start of deposition until the diameter of polysilicon rods S1 reached 30 mm was 21 hours.

[0062]

In the initial growth period T2, the increase ratio per hour of the number of gas exchanges was within a range of 0.9 to 1.6. Further, in one hour immediately before the diameter of the polysilicon rods S1 reached 30 mm, the number of gas exchanges was increased to 27 times. In the initial growth period T2, the linear velocity, per supply nozzle 40, of the raw material gas G1 introduced into the reaction furnace 10 was within a range of $9.7 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$ to $37.8 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$.

[0063]

In the production of the polysilicon rods S1 of Comparative Example 1, when the growth start period T1 had elapsed, none of the polysilicon rods S1 had collapsed. When the growth start period T1 had elapsed, the diameter of the polysilicon rods S1 had reached approximately 11 mm.

[0064]

When the subsequent initial growth period T2 had elapsed, none of the polysilicon rods S1 had collapsed. When the initial growth period T2 had elapsed, the diameter of the polysilicon rods S1 had reached approximately 30 mm.

[0065]

In the same manner as in Example 1, a core rod was drilled out from each of the obtained polysilicon rods S1, and the resistivity value of the core rod in a longitudinal direction thereof was obtained. The result is shown in Fig. 5 as b1-1. A resistivity value Xb1-1 of the polysilicon rods S1 having a diameter X at the end of the growth start period T1 was approximately 480 (Ωcm), which was approximately 28% lower than that in Example 1. Further, a resistivity value Yb1-1 of the polysilicon rods S1 at the end of the initial growth period T2, when the diameter of the polysilicon rods S1 had reached 30 mm (diameter Y), was approximately 980 (Ωcm), which was approximately 27% lower than that in Example 1.

[0066]

(Comparative Example 2)

Comparative Example 2 of the present invention will be described with reference to Figs. 3 to 5. In Comparative Example 2, production of a polysilicon rod

S1 was carried out in the same manner as in Example 1 except that the amount of the raw material gas G1 introduced in the growth start period T1 was changed as described below.

5 [0067]

In Comparative Example 2, the amount of the raw material gas G1 introduced in the growth start period T1 was increased to 518 Nm³/h as indicated by b1-2 in Fig. 3, and the number of gas exchanges in the growth start
10 period T1 was increased to 40 times as indicated by b1-2 in Fig. 4. In the growth start period T1, the linear velocity, per supply nozzle 40, of the raw material gas G1 introduced into the reaction furnace 10 was 65.7 Nm³/(s·m²).

15 [0068]

In Comparative Example 2, when the growth start period T1 had elapsed, one pair (two rods) out of the 10 polysilicon rods S1 collapsed, and the fallen polysilicon rods S1 leaned on other polysilicon rods S1, resulting in
20 collapse of all polysilicon rods S1.

[0069]

(Example 2)

Example 2 of the present invention will be described with reference to Figs. 3 to 5. In Example 2,
25 production of a polysilicon rod S1 was carried out in the

same manner as in Example 1 except that the amounts of the raw material gas G1 introduced in the growth start period T1 and the initial growth period T2 were changed as described below.

5 [0070]

In Example 2, the amount of gas introduction in the growth start period T1 was decreased to 162 Nm³/h as indicated by a1-2 in Fig. 3, and the number of gas exchanges in the growth start period T1 was reduced to
10 13 times as indicated by a1-2 in Fig. 4. At the end of the growth start period T1, the linear velocity, per supply nozzle 40, of the raw material gas G1 introduced into the reaction furnace 10 was 20.6 Nm³/(s·m²).

[0071]

15 In the initial growth period T2, the raw material gas G1 was introduced into the reaction furnace 10 at an amount of gas introduction as indicated by a1-2 in Fig. 3 and with the number of gas exchanges as indicated in Fig. 4. The elapsed time from the start of deposition until the
20 diameter of the polysilicon rods S1 reached 30 mm was 21 hours.

[0072]

In the initial growth period T2, the increase ratio per hour of the number of gas exchanges was within a
25 range of 0.8 to 2.2. Further, in one hour immediately

before the diameter of the polysilicon rods S1 reached 30 mm, the number of gas exchanges was increased to 30 times. In this initial growth period T2, the linear velocity, per supply nozzle 40, of the raw material gas G1 introduced into the reaction furnace 10 was within a range of $20.6 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$ to $48.7 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$.

[0073]

In the production of the polysilicon rods S1 of Example 2, when the growth start period T1 had elapsed, none of the polysilicon rods S1 had collapsed. When the growth start period T1 had elapsed, the diameter of the polysilicon rods S1 had reached approximately 11 mm.

[0074]

When the subsequent initial growth period T2 had elapsed, none of the polysilicon rods S1 had collapsed. When the initial growth period T2 had elapsed, the diameter of the polysilicon rods S1 had reached approximately 30 mm.

[0075]

In the same manner as in Example 1, a core rod was drilled out from each of the obtained polysilicon rods S1, and the resistivity value of the core rod in a longitudinal direction thereof was obtained. The result is shown in Fig. 5 as a1-2. A resistivity value Xa1-2 of the polysilicon rods S1 having a diameter X at the end of the

growth start period T1 was as high as approximately 940 (Ωcm). Further, a resistivity value Ya1-2 of the polysilicon rods S1 at the end of the initial growth period T2, when the diameter of the polysilicon rods S1 had reached 30 mm (diameter Y), was approximately 2050 (Ωcm). Thus, a high resistivity value was favorably maintained.

[0076]

Aspects of the present invention can also be expressed as follows:

A method for producing a polysilicon rod (S1) in accordance with Aspect 1 of the present invention is a method for producing a polysilicon rod (S1) by supplying a raw material gas (G1) containing chlorosilanes to a silicon core wire erected inside a reaction furnace (10) and heated by energization, to thereby deposit polysilicon on a surface of the silicon core wire so as to grow the polysilicon into a polysilicon rod (S1) having a diameter of not less than 80 mm, wherein the raw material gas (G1) is introduced into the reaction furnace (10) such that the number of gas exchanges in a growth start period (T1) of the polysilicon rod is not less than 8 times and less than 35 times, the number of gas exchanges being an amount of the raw material gas (G1) introduced into the reaction furnace (10) relative to a volume of the reaction furnace (10), the growth start period lasting until one hour

elapses from a start of deposition of the polysilicon on the surface of the silicon core wire.

[0077]

5 As a result of intensive studies, the inventors of the present invention have found that by setting the number of gas exchanges in the reaction furnace (10) to not less than 8 times and less than 35 times per unit time, it is possible to prevent collapse of the polysilicon rod (S1) in the growth start period (T1) and to improve the resistivity
10 value of the deposited polysilicon rod (S1).

[0078]

 As such, with the above configuration, it is possible to improve the resistivity value of the polysilicon rod (S1) deposited in the growth start period (T1), while
15 preventing collapse of the polysilicon rod (S1) in the growth start period (T1).

[0079]

 A method for producing a polysilicon rod in accordance with Aspect 2 of the present invention may be
20 configured such that, in Aspect 1, in an initial growth period (T2) of the polysilicon rod (S1) following the growth start period (T1) of the polysilicon rod and lasting until the diameter of the polysilicon rod (S1) reaches 30 mm, introduction of the raw material gas (G1) into the reaction
25 furnace (10) is carried out such that (1) an increase ratio

per hour of the number of gas exchanges in the initial growth period (T2) of the polysilicon rod is within a range of not less than 0.6 and not more than 5.0, and (2) in one hour immediately before the diameter of the polysilicon rod (S1) reaches 30 mm, the number of gas exchanges is increased to not less than 30 times and not more than 50 times.

[0080]

At the start of deposition, since the diameter of the polysilicon rod (S1) is small, increasing the amount of gas introduction may lead to collapse of the polysilicon rod (S1). With the above-described configuration, the amount of gas introduction can be increased as the polysilicon rod (S1) grows by deposition to become thicker and stronger. This makes it possible to achieve both the prevention of collapse of the polysilicon rod (S1) and appropriate deposition on the polysilicon rod (S1).

[0081]

A method for producing a polysilicon rod in accordance with Aspect 3 of the present invention may be configured such that, in Aspect 1 or 2, in the growth start period (T1), the raw material gas (G1) is introduced by a supply nozzle (40) into the reaction furnace (10), and a linear velocity, per supply nozzle (40), of the raw material gas (G1) introduced into the reaction furnace (10) is not

more than $40 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$.

[0082]

In the growth start period (T1) of the polysilicon rod (S1), an excessively high linear velocity, per supply nozzle (40), of the raw material gas (G1) introduced into the reaction furnace (10) may cause collapse of the polysilicon rod (S1). With the above configuration, since the raw material gas (G1) is introduced at a linear velocity per supply nozzle (40) that allows the polysilicon rod (S1) to remain self-standing, the possibility of collapse of the polysilicon rod (S1) in the growth start period (T1) can be further reduced.

[0083]

A method for producing a polysilicon rod in accordance with Aspect 4 of the present invention may be configured such that, in any one of Aspects 1 to 3, in an entire growth period (growth period T3) of the polysilicon rod (S1), a maximum value of the number of gas exchanges per hour is not less than 80 times and not more than 100 times.

[0084]

With the above-described configuration, the raw material gas (G1) can be introduced into the reaction furnace (10) such that the polysilicon rod (S1) does not collapse during the entire growth period (growth period

T3) of the polysilicon rod.

[0085]

The present invention is not limited to the
embodiments, but can be altered by a skilled person in
5 the art within the scope of the claims. The present
invention also encompasses, in its technical scope, any
embodiment derived by combining technical means
disclosed in differing embodiments. Further, it is possible
to form a new technical feature by combining the
10 technical means disclosed in the respective embodiments.

Reference Signs List

[0086]

1: Production apparatus
15 10: Reaction furnace
40: Supply nozzle
G1: Raw material gas
S1: Polysilicon rod
T1: Growth start period
20 T2: Initial growth period
T3: Growth period (entire growth period)

Claims

[Claim 1]

5 A method for producing a polysilicon rod by
supplying, to a silicon core wire erected inside a reaction
furnace and heated by energization, a raw material gas
containing chlorosilanes to thereby deposit polysilicon on
a surface of the silicon core wire so as to grow the
polysilicon into a polysilicon rod having a diameter of not
10 less than 80 mm,

the method comprising:

introducing the raw material gas into the reaction
furnace such that the number of gas exchanges in a
growth start period of the polysilicon rod is not less than
15 8 times and less than 35 times, the number of gas
exchanges being an amount of the raw material gas
introduced into the reaction furnace relative to a volume
of the reaction furnace, the growth start period lasting
until one hour elapses from a start of deposition of the
20 polysilicon on the surface of the silicon core wire.

[Claim 2]

The method for producing a polysilicon rod as set
forth in claim 1, wherein in an initial growth period of the
25 polysilicon rod following the growth start period of the

polysilicon rod and lasting until the diameter of the polysilicon rod reaches 30 mm, introduction of the raw material gas into the reaction furnace is carried out such that (1) an increase ratio per hour of the number of gas exchanges in the initial growth period is within a range of not less than 0.6 and not more than 5.0, and (2) in one hour immediately before the diameter of the polysilicon rod reaches 30 mm, the number of gas exchanges is increased to not less than 30 times and not more than 50 times.

[Claim 3]

The method for producing a polysilicon rod as set forth in claim 1 or 2, wherein
in the growth start period, the raw material gas is introduced by a supply nozzle into the reaction furnace, and

a linear velocity, per supply nozzle, of the raw material gas introduced into the reaction furnace is not more than $40 \text{ Nm}^3/(\text{s}\cdot\text{m}^2)$.

[Claim 4]

The method for producing a polysilicon rod as set forth in claim 1 or 2, wherein in an entire growth period of the polysilicon rod, a maximum value of the number of

gas exchanges per hour is not less than 80 times and not more than 100 times.