

SINGLE CRYSTAL FURNACE HEATING STRUCTURE AND SINGLE CRYSTAL FURNACE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims a priority to the Chinese patent application No. 202310952401.6 filed in China on July 31, 2023, a disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present application relates to the field of single crystal furnace, and in particular, to a single crystal furnace heating structure and a single crystal furnace.

BACKGROUND

[0003] Currently, in the production of single crystal silicon, both the melting of polycrystalline silicon and the normal growth of single crystal silicon rely on a heating structure. The heating structure is the most important core component of a hot zone in a Czochralski single crystal furnace. As the demand for the diameter of a crystal ingot continues to increase, a size standard of the equipment employed for growing the crystal ingot also increases correspondingly. With the increase in the size of the hot zone in the Czochralski single crystal furnace, the heating structure used in the single crystal furnace also becomes larger. The main function of the heating structure is to provide heat to the polycrystalline silicon material in a quartz crucible, so that the initial solid raw material melts into a liquid state, and to provide a temperature gradient required for single crystal silicon growth, thereby maintaining the normal growth of the single crystal silicon and ensuring a crystal formation yield of the single crystal silicon.

[0004] Currently, during the crystal growth process, the crystal ingot lifts continuously, but a position and area of a heating zone provided by the heating structure cannot be adjusted. This limitation hinders achieving a uniform axial temperature gradient throughout the crystal ingot.

SUMMARY

[0005] The present application provides a single crystal furnace heating structure and a single crystal furnace, which solve the problem that a heating area of the heating structure remains constant and adversely affects the uniformity of the axial temperature gradient of the crystal ingot.

[0006] The technical solutions adopted in the embodiments of the present application include: a single crystal furnace heating structure, including: an insulating baseplate;

a plurality of heating units, wherein the plurality of heating units is arranged around an edge of the insulating baseplate;

a power supply unit, configured to apply an electrical signal to the heating units;

a conductive block, movably connected between adjacent heating units, to allow the plurality of heating units to be connected in series and allow the plurality of heating units to cooperate with the power supply unit to form a loop;

an insulating connecting assembly, wherein one end of the insulating connecting assembly is connected to the conductive block, and the other end of the insulating connecting assembly is configured to be connected to a crucible support shaft, the insulating connecting assembly is configured to move up and down along with the crucible support shaft, to drive the conductive block to move up and down to change a length of a heating area of the heating unit in a first direction, and the first direction is an axial direction of the crucible support shaft.

[0007] Optionally, each of the heating units includes one heating plate.

[0008] Optionally, each of the heating units includes at least two heating plates arranged at intervals, and at least two heating plates in the same heating unit are connected in series.

[0009] Optionally, each of the heating units includes a conductive connector arranged at an end of the heating plate distal to the insulating baseplate, and the conductive connector is connected between two adjacent heating plates.

[0010] Optionally, the conductive connector is a graphite buckle.

[0011] Optionally, in the first direction, a thickness of each heating plate gradually decreases along a direction away from the insulating baseplate.

[0012] Optionally, the insulating connecting assembly includes an insulating bearing sleeve and a connecting component connected between the conductive block and the insulating bearing sleeve, the insulating bearing sleeve is drivingly connected to the crucible support shaft, to allow the insulating connecting assembly to move up and down along with the crucible support shaft, and not rotate along with the crucible support shaft when the crucible support shaft rotates.

[0013] Optionally, the connecting component includes:

a first insulating ring, wherein the conductive block is connected to an outer circumferential surface of the first insulating ring;

a second insulating ring, sleeved inside the first insulating ring, and fixedly connected to an exterior of the insulating bearing sleeve;

a plurality of connecting rods, connected between the first insulating ring and the second insulating ring.

[0014] Optionally, the power supply unit includes a positive electrode pin and a negative electrode pin, wherein the positive electrode pin and the negative electrode pin are respectively connected to distinct heating units.

[0015] Embodiments of the present application further provide a single crystal furnace, including the above-mentioned single crystal furnace heating structure, and further including a crucible and a crucible support shaft for supporting the crucible, wherein the insulating connecting assembly of the single crystal furnace heating structure is connected to the crucible support shaft.

[0016] The beneficial effects of the present application are as follows: the single crystal furnace heating structure disclosed in the present application includes the plurality of heating units, wherein the plurality of heating units is arranged around the edge of the insulating baseplate. Adjacent heating units are connected by conductive blocks to form a series structure. The conductive blocks are connected to the crucible support shaft through the insulating connecting assembly. The insulating connecting assembly can move up and down along with the crucible support shaft, thereby driving the conductive blocks to move up and down. Accordingly, it changes the connection position of the conductive blocks and the corresponding heating units, thereby changing the length of the heating area of the heating unit in the axial direction of the crucible support shaft, which can improve the uniformity of the axial temperature gradient of the crystal ingot. As a result, the Oxygen Interstitial (OI) at different lengths of the crystal ingots can be adjusted during a body stage of the crystal growth process, achieving precise control of the oxygen interstitial. Meanwhile, during a crystal ingot growth process, as the crystal ingot increases in length, the length of the heating area can be adjusted to reduce changes in a relative position between the heating area and the crystal ingot in the axial direction of the crystal ingot. Accordingly, it ensures that the growth environment at the solid-liquid-gas triple phase point during crystal growth is always the optimal growth environment, thereby achieving controllability of crystal bulk defects of the crystal ingot and growing a crystal ingot without bulk micro-defects.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. 1 shows a schematic diagram of a single crystal furnace heating structure according to an embodiment of the present application;

[0018] FIG. 2 shows a schematic diagram of a single crystal furnace according to an embodiment of the present application;

[0019] FIG. 3 shows a schematic diagram of a bearing sleeve according to an embodiment of the present application;

[0020] FIG. 4 shows a comparative schematic diagram of the oxygen interstitial during a crystal ingot growth process.

DETAILED DESCRIPTION

[0021] To make the objectives, technical solutions and advantages of the embodiments of the present disclosure clearer, the technical solutions of the embodiments of the present disclosure will be clearly and thoroughly described below in conjunction with the drawings of the embodiments of the present disclosure. Obviously, the described embodiments are only a part of the embodiments of the present disclosure, not all of the embodiments. Based on the described embodiments of the present disclosure, all other embodiments obtained by those of ordinary skill in the art without creative efforts shall fall within the protection scope of the present disclosure.

[0022] Unless otherwise defined, the technical terms or scientific terms used in the present disclosure shall have the common meanings understood by those of ordinary skill in the art to which the present disclosure pertains. The "first", "second" and similar expressions used in the present disclosure do not indicate any order, quantity or importance, but are merely used to distinguish different components. Likewise, terms such as "a", "an" or "the" do not imply a numerical limitation, but indicate the presence of at least one. The terms "comprising", "including", or similar expressions mean that the elements or items preceding the term encompass the elements or items listed thereafter and their equivalents, without excluding other elements or items. Terms such as "connect" or "connection" and similar expressions are not limited to physical or mechanical connections, but may include electrical connections, whether direct or indirect. The terms "up", "down", "left", "right" and the like are only used to indicate relative positional relationships. When the absolute position of the described object changes, the relative positional relationship may also change accordingly.

[0023] Referring to FIGs. 1 and 2, the present embodiment provides a single crystal furnace heating structure, including:

- an insulating baseplate 2;
- a plurality of heating units 1, wherein the plurality of heating units 1 is arranged around an edge of the insulating baseplate 2;
- a power supply unit, configured to apply an electrical signal to the heating units;
- a conductive block 4, movably connected between adjacent heating units 1, to allow the

plurality of heating units 1 to be connected in series and allow the plurality of heating units 1 to cooperate with the power supply unit to form a loop;

an insulating connecting assembly, wherein one end of the insulating connecting assembly is connected to the conductive block 4, and the other end of the insulating connecting assembly is configured to be connected to a crucible support shaft 30, the insulating connecting assembly is configured to move up and down along with the crucible support shaft, to drive the conductive block 4 to move up and down to change a length of a heating area of the heating unit 1 in a first direction, and the first direction is an axial direction of the crucible support shaft 30.

[0024] For a single crystal furnace, design of a heater is one of the core aspects of hot zone design. The heaters are divided into peripheral ring heaters and bottom heaters, wherein the peripheral ring heaters are responsible for the main heat output of the single crystal furnace, which play a crucial role in both a polysilicon melting stage and a subsequent body growth stage. The shape the heater and the size of heating area directly affect a temperature field in a crystal pulling furnace, and thereby influencing the quality of a crystal ingot. In this embodiment, a plurality of heating units 1 is arranged around an edge of the insulating baseplate 2, that is, the heating units 1 constitute the peripheral ring heater.

[0025] The insulating connecting assembly can move up and down along with the crucible support shaft 30, thereby driving the conductive block 4 to move up and down to change the connection position of the conductive block 4 and the corresponding heating unit 1. Accordingly, it changes the length of the heating area of the heating unit 1 in the axial direction of the crucible support shaft 30, which can improve the uniformity of the axial temperature gradient of the crystal ingot. As a result, the oxygen interstitial of the crystal ingot with different lengths can be adjusted during a body growth stage of the crystal growth process, achieving precise control of the oxygen interstitial. In addition, during a crystal ingot growth process, as the crystal ingot increases in length, the length of the heating area can be adjusted to reduce changes in a relative position between the heating area and the crystal ingot in the axial direction of the crystal ingot. Accordingly, it ensures that the growth environment at the solid-liquid-gas triple phase point during crystal growth is always the optimal growth environment, thereby achieving controllability of crystal bulk defects of the crystal ingot and growing a crystal ingot without bulk micro-defects.

[0026] It should be noted that during the crystal ingot growth process, as the crystal ingot increases in length, the amount of silicon melt continuously decreases. To maintain a same solidification rate, the silicon melt needs to be maintained at the same temperature. However, different volumes of silicon melt require different amounts of heat to maintain the same

temperature. It should be noted that, to maintain a constant temperature field, more heat is required when there is less silicon melt. In this case, the power of the heating unit needs to be increased. However, just increasing the power of the heating unit will change the temperature field of the crystal ingot growth environment, causing fluctuations at a solid-liquid interface and leading to non-uniform crystal ingot growth. In this embodiment, by adjusting the length of the heating area, specifically, by reducing the length of the heating area as the crystal ingot increases in length during a crystal growth process, heat is generated at the corresponding position to the residual silicon melt. By adjusting the power of the heating unit, the temperature of the silicon melt is maintained constant, ensuring the uniformity of the oxygen interstitial in the crystal ingot and the constant heat field of the hot zone environment within the single crystal furnace. This ensures that the growth environment at the solid-liquid-gas triple phase point during crystal growth is always the optimal growth environment, thereby achieving controllability of crystal bulk defects of the crystal ingot and growing a crystal ingot without bulk micro-defects.

[0027] FIG. 4 is a schematic diagram of the oxygen interstitial during the crystal ingot growth process. The horizontal axis represents the length of the crystal ingot, and the vertical axis represents the oxygen interstitial at the corresponding axial position of the crystal ingot. The curve labeled 100 represents the change in the oxygen interstitial of the crystal ingot with the increase in the length of the crystal ingot in a traditional technical solution where a heating area remains constant. The curve labeled 200 represents the change in the oxygen interstitial of the crystal ingot as the increase in the length of the crystal ingot while reducing the length of the heating area in this embodiment. By comparing the two curves, it is obvious that by adopting the single crystal furnace heating structure in this embodiment, the length of the heating area of the heating unit 1 in the axial direction of the crystal ingot is changed with the change in the length of the crystal ingot, thereby improving the uniformity of the oxygen interstitial in the crystal ingot.

[0028] The specific structural form of the heating unit 1 can be determined according to actual needs. As long as the conductive block 4 can move up and down synchronously under the drive of the insulating connecting assembly when the crucible support shaft 30 is moves up and down, it is possible to change the length of the heating area of the heating unit in the axial direction of the crucible support shaft 30.

[0029] In an exemplary embodiment, each of the heating units 1 includes a heating plate 11.

[0030] In an exemplary embodiment, each of the heating units 1 includes at least two heating plates 11 arranged at intervals, and at least two heating plates 11 in a same one of the heating units are connected in series.

[0031] The number of the heating plates 11 can be determined according to actual needs. In this embodiment, each of the heating units 1 includes two heating plates 11, but the present application is not limited thereto.

[0032] For example, the number of the heating plates 11 in each of the plurality of heating units 1 is the same, so as to ensure the uniformity of the temperature applied to the crystal ingot in its circumferential direction.

[0033] It should be noted that the heating plate 11 has a first end connected to the insulating baseplate 2 and a second end arranged opposite to the first end. The heating plate 11 has a first surface facing the crucible support shaft 30. The corresponding portion on the heating plate 11 between the conductive block 4 and the second end serves as the heating area for heating the crucible. The conductive block 4 can move up and down in the axial direction of the crucible support shaft 30. That is, by moving the conductive block 4, the length of the heating area in the axial direction of the crucible support shaft 30, as well as the distance between the heating area and the bottom of the single crystal furnace can be changed. This allows, during the crystal growth process, as the crystal ingot grows, the change of the relative position between the heating area and the crystal ingot in the axial direction of the crystal ingot to be reduced, thereby improving the uniformity of the axial temperature gradient of the crystal ingot. As a result, the oxygen interstitial of the crystal ingot with different lengths can be adjusted during a body stage of the crystal growth process, achieving precise control of the oxygen interstitial. In addition, during a crystal ingot growth process, as the crystal ingot increases in length, the length of the heating area can be adjusted to reduce changes in a relative position between the heating area and the crystal ingot in the axial direction of the crystal ingot. This ensures that the growth environment at the solid-liquid-gas triple phase point during crystal growth is always the optimal growth environment, thereby achieving controllability of crystal bulk defects of the crystal ingot and growing a crystal ingot without bulk micro-defects.

[0034] In an exemplary embodiment, each of the heating units 1 includes a conductive connector 12 arranged at an end of heating plate 11 distal to the insulating baseplate 2, and the conductive connector 12 is connected between two adjacent heating plates 11.

[0035] When each of the heating units 1 includes at least two heating plates 11, the arrangement of the conductive connector 12 enables the series connection between the plurality of heating plates 11 in the same heating unit 1. This ensures that the heating power of each of the plurality of heating plates 11 in the same heating unit 1 is the same, and thus the temperature applied to the crystal ingot by each of the plurality of heating plates 11 in the same heating unit 1 is the same,

which is conducive to the uniformity of the temperature of the crystal ingot.

[0036] To ensure the uniformity of the temperature applied to the crystal ingot in its circumferential direction, the distance between the conductive connector 12 in each of the plurality of heating units 1 and the conductive block 4 is the same (it should be noted that the distance herein refers to the distance between the conductive connector 12 and the conductive block 4 in the axial direction of the crucible support shaft 30).

[0037] In an exemplary embodiment, each of the heating units 1 includes an adjacent first heating plate and second heating plate. The conductive connector 12 is a graphite buckle, with one end of the graphite buckle fixedly connected to the first heating plate and the other end of the graphite buckle cooperatively engaged with the slot on the second heating plate.

[0038] The arrangement of the graphite buckle enables a movable connection between the adjacent first heating plate and second heating plate, which facilitates the assembly and maintenance of the heating plate 11.

[0039] It should be noted that the specific structural form of the conductive connector 12 is not limited to the above description. For example, one end of the plurality of heating plates 11 within the same heating unit 1 can be connected into an integrated structure through the conductive connector 12. For example, the plurality of heating plates 11 within the same heating unit 1 and the conductive connector 12 are integrally injection molded.

[0040] For example, a surface of the conductive connector 12 distal to the insulating baseplate 2 is flush with an end surface of the heating plate 11 distal to the insulating baseplate 2, so as to maximize the size of the heating area of a heating component.

[0041] It should be noted that when the same heating unit 1 includes more than two heating plates 11, the advantage of using the graphite buckle is more apparent. Therefore, in some embodiments, optionally, the conductive connector 12 is a graphite buckle.

[0042] In an exemplary embodiment, in the first direction, a thickness of the heating plate 11 gradually decreases along a direction away from the insulating baseplate 2, that is, in the radial direction of the crucible support shaft 30, the thickness of the heating plate 11 gradually decreases along the direction away from the insulating baseplate 2.

[0043] During the crystal ingot growth process, as the crucible support shaft 30 rises, the conductive block 4 is driven upward by the insulating connecting assembly. As a result, the length of the heating area of the heating component (the length in the axial direction of the crucible support shaft 30) is reduced, thereby reducing the heating area accordingly. This may cause the problem of insufficient heating of the crucible.

[0044] To prevent insufficient heating due to a reduced heated area, in an implementation of this embodiment, in the radial direction of the crucible support shaft 30, the thickness of the heating plate 11 gradually decreases along the direction away from the insulating base plate 2. This means that a conductive cross-sectional area of the heating plate 11 gradually decreases in the vertical direction (i.e., the axial direction of the crucible support shaft 30). According to the resistance formula $R = \rho L / S$ (where ρ is the resistivity, L is the conductive length, i.e., the length between the end of the heating plate 11 distal to the insulating base plate 2 and the conductive block 4, and S is the conductive cross-sectional area), as the conductive block 4 moves and L gradually decreases. By appropriately reducing S , the resistance and power are maintained stable, thereby preventing the problem of insufficient heating.

[0045] For example, in the radial direction of the crucible support shaft 30, the thickness of the heating plate 11 is 20-30 mm, but the present application is not limited thereto.

[0046] In an embodiment, the thickness of the end of the heating plate 11 connected to the insulating baseplate 2 is 30 mm in the radial direction of the crucible support shaft 30, while the thickness of the end of the heating plate 11 distal to the insulating baseplate 2 is 20 mm in the radial direction of the crucible support shaft 30, but the present application is not limited thereto.

[0047] Referring to FIG. 2, exemplarily, in an initial state, that is, before the crystal ingot growing or at the beginning of the growth process, along the axial direction of the crucible support shaft 30, the heating component includes a first portion 101 and a second portion 102. An orthographic projection of the crucible support shaft 30 onto the heating component is located at the first portion 101, while an orthographic projection of the crucible onto the heating component is located at the second portion 102. In the radial direction of the crucible support shaft 30, the thickness of the first portion 101 remains constant along the direction away from the insulating baseplate 2, while in the radial direction of the crucible support shaft 30, the thickness of the second portion 102 gradually decreases along the direction away from the insulating baseplate 2.

[0048] In the axial direction of the crucible support shaft 30, the second portion 102 is at the closest relative distance to the crucible and plays a primary role in heating the crucible. Therefore, as the crucible rises along the crucible support shaft 30, the thickness of the second portion gradually decreases in the radial direction of the crucible support shaft 30, in a direction away from the insulating baseplate 2. This ensures stable resistance and power, thereby preventing the problem of insufficient heating.

[0049] For example, the heating plate 11 is made of graphite.

[0050] In an exemplary embodiment, the insulating connecting assembly includes an insulating

bearing sleeve 8 and a connecting component connected between the conductive block 4 and the insulating bearing sleeve 8, the insulating bearing sleeve 8 is drivingly connected to the crucible support shaft 30, to allow the insulating connecting assembly to move up and down along with the crucible support shaft, and not rotate along with the crucible support shaft 30 when the crucible support shaft 30 rotates.

[0051] Referring to FIG. 3, for example, the insulating bearing sleeve 8 includes a main sleeve 81 and a secondary sleeve 82. The secondary sleeve 82 is connected to the crucible support shaft 30 by means of an interference fit. The main sleeve 81 and the secondary sleeve 82 are cooperatively engaged, so that the entire insulating connecting assembly moves up and down with the crucible support shaft 30 as it is raised and lowered. However, when the crucible support shaft 30 rotates, as long as the crucible support shaft 30 rotates independently, the entire insulating connecting assembly does not rotate.

[0052] In an exemplary embodiment, the insulating connecting assembly includes an insulating connection portion and a connecting component connected between the conductive block 4 and the insulating bearing sleeve 8. The crucible support shaft 30 includes a rotating shaft and a lifting shaft sleeved outside the rotating shaft. The insulating connection portion is fixedly connected to an outer circumferential surface of the lifting shaft. Therefore, during the lifting process of the crucible driven by the lifting shaft, the entire insulating connecting assembly moves up and down along with the crucible support shaft 30. The lifting shaft and the rotating shaft are connected via a bearing, so that when the rotating shaft drives the crucible to rotate, the lifting shaft remains stationary relative to the rotating shaft, i.e., the lifting shaft does not rotate with the rotating shaft. In this case, the entire insulating connecting assembly does not rotate.

[0053] In an exemplary embodiment, the connecting component includes:

- a first insulating ring 5, wherein the conductive block 4 is connected to an outer circumferential surface of the first insulating ring 5;

- a second insulating ring 7, sleeved inside the first insulating ring 5, and fixedly connected to an exterior of the insulating bearing sleeve 8;

- a plurality of connecting rods 6, connected between the first insulating ring 5 and the second insulating ring 7.

[0054] For example, the plurality of conductive blocks 4 are evenly distributed on the outer circumferential surface of the first insulating ring 5.

[0055] For example, a threaded hole is provided on the outer circumferential surface of the first insulating ring 5, and the conductive block 4 is screwed onto the first insulating ring 5 through the

threaded hole.

[0056] For example, the plurality of connecting rods 6 are evenly distributed between the first insulating ring 5 and the second insulating ring 7, serving to enhance the overall strength and connection stability of the insulating assembly, thereby facilitating the movement of the conductive block 4 in the axial direction of the crucible support shaft 30.

[0057] For example, the conductive block 4 is a trapezoidal structure, and the length of one end of the conductive block 4 proximate to the first insulating ring 5 is smaller than the length of one end of the conductive block 4 distal to the first insulating ring 5.

[0058] In an exemplary embodiment, the power supply unit includes a positive electrode pin and a negative electrode pin, wherein the positive electrode pin and the negative electrode pin are connected to different heating units, respectively. Each of the electrode pins 3 (including the positive electrode pin and the negative electrode pin) is provided with a threaded hole for connecting to an electrode.

[0059] An embodiment of the present application further provides a single crystal furnace, including the single crystal furnace heating structure, and further including a crucible and a crucible support shaft 30 for supporting the crucible, wherein the insulating connecting assembly of the single crystal furnace heating structure is connected to the crucible support shaft 30.

[0060] Referring to FIG. 2, a single crystal furnace further includes:

- a furnace body;

- a furnace cover mounted on the furnace body;

- a crucible assembly arranged within an inner chamber of the furnace body, wherein the crucible assembly includes a concentrically arranged quartz crucible 10 and graphite crucible 20, wherein the quartz crucible 10 contains silicon melt;

- the single crystal furnace further includes a water cooling device, which includes a water-cooling jacket and a lifting structure for controlling the raising and lowering of the water-cooling jacket;

- the lifting structure passes through the furnace cover to connect with the water-cooling jacket, and controls the water-cooling jacket to be suspended above the silicon melt;

- a reflector sleeved on an exterior of the water-cooling jacket, with a gap between the reflector and the water-cooling jacket;

- a heating component arranged around the crucible assembly, configured to heat the crucible assembly; the heating component is fixed to the bottom of the furnace body through electrode bolts and is connected to a heating electrode at the bottom of the furnace body;

a heat-insulating layer, arranged between the heating component and a side wall of the furnace body, for preventing the heat of the heating component from radiating to the outside of the furnace body;

a crucible support shaft 30, supported and connected to the bottom of the graphite crucible 20 through a crucible tray 40; wherein an upper end of the crucible support shaft 30 is provided with a crucible tray, and a lower end of the crucible support shaft 30 extends through the bottom of the furnace body.

[0061] With the needs of advanced chip manufacturing processes, there are increasingly stringent requirements on the oxygen interstitial and defects in wafers, which puts higher requirements on the oxygen interstitial and defects in crystal ingots. The oxygen interstitial in the crystal ingot mainly originates from the reaction between the quartz crucible and the silicon melt. A reaction rate of this reaction is primarily influenced by the heating area of the heater. Therefore, the present application also discloses a crystal growth process method, which adjusts the heating area of the heater to control the oxygen interstitial of the crystal ingot with different lengths during a body stage of the crystal growth process to achieve precise control of the oxygen interstitial. At the same time, by adjusting the heating area of the heater at different crystal ingot lengths, it is ensured that the growth environment at the solid-liquid-gas triple phase points during crystal growth is always the optimal growth environment, thereby achieving controllability of crystal bulk defects of the crystal ingot and growing a crystal ingot without bulk micro-defects.

[0062] The process of crystal growth using the above-mentioned single crystal furnace is introduced as follows.

[0063] First, the crystal raw material is placed in the crucible assembly and melted by the high temperature generated by the heating component.

[0064] Then, the molten silicon is slightly cooled to achieve a certain degree of supercooling.

[0065] Next, a silicon single crystal (referred to as a seed crystal) fixed on the seed crystal axis is inserted into the melt surface. After the seed crystal fuses with the melt, the seed crystal is slowly lifted upward, and the crystal will grow at the lower end of the seed crystal.

[0066] Subsequently, the seed crystal is controlled to grow a thin neck approximately 100mm in length and 3mm–5mm in diameter, as so to eliminate the dislocation of atomic arrangement caused by the strong thermal shock of the high-temperature melt on the seed crystal. This process is known as dip process.

[0067] Then, the crystal diameter is enlarged to the size required by the process, generally 75mm to 300mm. This process is called shoulder process.

[0068] Then, the pulling speed is suddenly increased to perform an over shoulder process, forming an approximately right-angled shoulder.

[0069] Then, the body stage begins, where a single crystal column of a certain size is grown by controlling the hot zone temperature and a crystal lifting speed.

[0070] Finally, when most of the silicon melt has crystallized, the crystal is gradually tapered to form a conical tail, which is known as a tail process.

[0071] In this way, the single crystal growth process is basically completed, and after a period of insulation and cooling, the crystal can be removed.

[0072] As shown in FIGs. 1 and 2, the single crystal furnace heating structure disclosed in the embodiments of the present application defines the heating area of the heating component as the area on the heating plate 11 corresponding to the area between the conductive connector 12 and the conductive block 4. During a melting stage of the crystal growth process, the conductive block 4 is on the side of the heating unit 1 proximate to the insulating baseplate 2. At this time, the distance from the bottom of the conductive connector 12 to the upper end face of the conductive block 4 is at its maximum. The size of the heating area is the largest, and the length of the heating area in the axial direction of the crucible support shaft 30 is also at its maximum. The heat generated by the heating component will be evenly transmitted to the crucible assembly and the silicon material contained in the crucible assembly, achieving uniform melting and preventing the phenomenon of local expansion of the quartz crucible caused by uneven heating, thereby enabling fast melting. During the body stage of the crystal growth process, as the amount of silicon melt in the quartz crucible gradually decreases, the crucible support shaft 30 rises, thereby causing the conductive block 4 to rise. This reduces the length of the heating area in the axial direction of the crucible support shaft 30, as well as the size of the heating area, ensuring that the crystal ingot always grows in an appropriate temperature field.

[0073] The resistance formula is $R = \rho L / S$, where ρ is the resistivity, which is a constant value, L is the conductive length, and S is the conductive cross-sectional area. According to the above resistance formula, the resistivity is a constant value, and the resistance depends on the conductive length L and the conductive cross-sectional area S . As the conductive block 4 rises, the conductive length of the heating area decreases. Although the conductive cross-sectional area S also decreases, the ratio of L to S increases, which means the resistance increases. At this time, in order to avoid insufficient heating due to the reduction of the heating area, the conductive cross-sectional area of the heating plate 11 (the heating plate 11 including a first surface facing the crucible and a second surface adjacent to the first surface; the conductive cross-sectional area of the heating plate 11

being the area of the portion of the second surface between the conductive connector 12 and the conductive block 4) gradually decreases in the vertical direction (i.e., the axial direction of the crucible support shaft 30). As the conductive block moves upward, L gradually decreases. By appropriately reducing S, the resistance and power are maintained stable, thereby preventing the problem of insufficient heating.

[0074] It should be understood that the above embodiments are merely exemplary implementations used to illustrate the principles of the present application, and the present application is not limited thereto. Those of ordinary skill in the art may make various modifications and improvements without departing from the spirit and essence of the present application, and such modifications and improvements shall also fall within the protection scope of the present application.

What is claimed is:

1. A single crystal furnace heating structure, comprising:
 - an insulating baseplate;
 - a plurality of heating units, wherein the plurality of heating units is arranged around an edge of the insulating baseplate;
 - a power supply unit, configured to apply an electrical signal to the heating units;
 - a conductive block, movably connected between adjacent heating units, to allow the plurality of heating units to be connected in series and allow the plurality of heating units to cooperate with the power supply unit to form a loop;
 - an insulating connecting assembly, wherein one end of the insulating connecting assembly is connected to the conductive block, and the other end of the insulating connecting assembly is configured to be connected to a crucible support shaft, the insulating connecting assembly is configured to move up and down along with the crucible support shaft, to drive the conductive block to move up and down to change a length of a heating area of the heating unit in a first direction, and the first direction is an axial direction of the crucible support shaft.
2. The single crystal furnace heating structure according to claim 1, wherein each of the heating units comprises at least two heating plates arranged at intervals, and at least two heating plates in the same heating unit are connected in series.
3. The single crystal furnace heating structure according to claim 1, wherein each of the heating units comprises one heating plate.
4. The single crystal furnace heating structure according to claim 3, wherein each of the heating units comprises a conductive connector arranged at an end of the heating plate distal to the insulating baseplate, and the conductive connector is connected between two adjacent heating plates.

5. The single crystal furnace heating structure according to claim 4, wherein the conductive connector is a graphite buckle.

6. The single crystal furnace heating structure according to claim 2 or 3, wherein, in the first direction, a thickness of each heating plate gradually decreases along a direction away from the insulating baseplate.

7. The single crystal furnace heating structure according to claim 1, wherein the insulating connecting assembly comprises an insulating bearing sleeve and a connecting component connected between the conductive block and the insulating bearing sleeve, the insulating bearing sleeve is drivingly connected to the crucible support shaft, to allow the insulating connecting assembly to move up and down along with the crucible support shaft, and not rotate along with the crucible support shaft when the crucible support shaft rotates.

8. The single crystal furnace heating structure according to claim 7, wherein the connecting component comprises:

a first insulating ring, wherein the conductive block is connected to an outer circumferential surface of the first insulating ring;

a second insulating ring, sleeved inside the first insulating ring, and fixedly connected to an exterior of the insulating bearing sleeve;

a plurality of connecting rods, connected between the first insulating ring and the second insulating ring.

9. The single crystal furnace heating structure according to claim 7, wherein the power supply unit comprises a positive electrode pin and a negative electrode pin, wherein the positive electrode pin and the negative electrode pin are respectively connected to distinct heating units.

10. A single crystal furnace, comprising the single crystal furnace heating structure according to any one of claims 1 to 9, and further comprising a crucible and a crucible support

shaft for supporting the crucible, wherein the insulating connecting assembly of the single crystal furnace heating structure is connected to the crucible support shaft.