

WATER-COOLING DEVICE AND SINGLE CRYSTAL FURNACE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims a priority to the Chinese patent application No. 202310635809.0 filed in China on May 31, 2023, a disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present application relates to the technical field of single crystal ingot manufacturing, and in particular, to a water-cooling device and a single crystal furnace.

BACKGROUND

[0003] In related art, during a crystal lifting process for electronic-grade large-diameter semiconductor crystals, a water-cooling device is typically arranged in the area where crystal growth has been completed, in order to improve a crystal growth speed and defect control. For the development of crystal ingots used in epitaxial products that require a bulk micro defect (BMD) density exceeding $5E8$, nitrogen doping is commonly adopted. To achieve a high BMD concentration, the nitrogen doping concentration is generally exceeds $1E14$ atom/cm³. However, an excessive nitrogen concentration may cause the formation of numerous large-sized oxygen precipitates at a high temperature (1000-1200°C), resulting in significant stress and associated dislocation defects during the cooling process of the crystal. When these defects appear on the surface of an epitaxial silicon wafer substrate, they may propagate into an epitaxial layer as the epitaxial layer grows, resulting in epitaxial (EPI) stacking faults. Furthermore, to form a high density of BMDs, there must first be a sufficient residual vacancy concentration within the crystal, and it is also necessary to extend the dwell time of the crystal in the nucleation temperature range (600-850°C) as long as possible.

SUMMARY

[0004] To solve the above technical problems, the present application provides a water-cooling device and a single crystal furnace, which solve the problem of how to extend a dwell time of a crystal in a temperature range of 600-850°C to pull crystal ingots with a high-density of BMDs.

[0005] To achieve the above object, the technical solutions adopted in the embodiments of the

present application include the following: a water-cooling device, applied within a single crystal furnace, comprising a water-cooling jacket; wherein along an axial direction of the water-cooling jacket, the water-cooling jacket comprises a first end and a second end opposite to each other; when the water-cooling jacket is arranged in the single crystal furnace, the second end is arranged adjacent to a crucible in the single crystal furnace;

along a direction from the first end to the second end, the water-cooling jacket comprises a first portion and a second portion, wherein the first portion comprises cooling zones and non-cooling zones arranged at intervals.

[0006] Optionally, the non-cooling zone is provided with at least one through hole.

[0007] Optionally, an area of the cooling zone is smaller than an area of the non-cooling zone.

[0008] Optionally, the area of the non-cooling zone is greater than or equal to 80% of a total area of the first portion.

[0009] Optionally, in a circumferential direction of the water-cooling jacket, a circumferential length of one of the cooling zones is less than a circumferential length of one of the non-cooling zones.

[0010] Optionally, an inner surface of the cooling zone is provided with a first coating, and an emissivity of the first coating is less than 0.3.

[0011] Optionally, a first cooling channel extending along the axial direction of the water-cooling jacket is provided on a side wall of the cooling zone, and a second cooling channel communicating with the first cooling channel is provided on a side wall of the second portion.

[0012] Optionally, the side wall of the second portion is arranged as a hollow structure to form the second cooling channel.

[0013] Optionally, an inner surface of the second portion is provided with a second coating, and an emissivity of the second coating is greater than 0.8.

[0014] Embodiments of the present application further provide a single crystal furnace, including the above-mentioned water-cooling device.

[0015] The beneficial effects of the present application are as follows: the water-cooling jacket is segmented along its axial direction, and a cooling zone and a non-cooling zone are provided on the first portion, thereby reducing the cooling area of the first portion and thus lowering the cooling efficiency of the first portion. Accordingly, it can extend the dwell time of the crystal in the BMD nucleation temperature range of 600–850°C, thereby enhancing the BMD nucleation density.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 is a schematic diagram of a water-cooling device in an embodiment of the present application;

[0017] FIG. 2 is a schematic diagram showing a temperature distribution inside a crystal in the related art

[0018] FIG. 3 is a schematic diagram showing a temperature distribution inside a crystal in an embodiment of the present application;

[0019] FIG. 4 is a schematic diagram of a single crystal furnace in an embodiment of the present application.

[0020] 1 First portion; 2 Second portion; 11 Cooling zone; 12 Non-cooling zone; 100 Crystal; 101 Position corresponding to 1200°C; 102 Position corresponding to 1000°C; 103 Position corresponding to 850°C; 104 Position corresponding to 600°C; 3 Flange; 5 Furnace body; 6 Crucible assembly; 7 Heating component; 8 Support shaft; 9 Reflector; 10 Water-cooling jacket.

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 will be clearly and fully described below in conjunction with the accompanying drawings. It is evident that the described embodiments are only a part of the embodiments of the present disclosure, and not all of them. Based on the embodiments described herein, all other embodiments that can be obtained by those of ordinary skill in the art without creative effort shall fall within the protection scope of the present disclosure.

[0022] Unless otherwise defined, the technical or scientific terms used in this disclosure should have the usual meanings understood by those of ordinary skill in the art to which this disclosure belongs. The terms "first", "second" and similar expressions used herein do not indicate any order, quantity or importance, but are merely used to distinguish different components. Similarly, words such as "one", "an" or "the" do not imply a numerical limitation, but rather indicate the presence of at least one. Terms such as "comprise" or "include" mean that the elements or objects appearing before the words encompass the elements or objects listed after the words and their equivalents, without excluding other elements or objects. The terms "connected," "coupled," or similar expressions are not limited to physical or mechanical connections, but may include electrical connections, whether direct or indirect. Terms such as "upper", "lower", "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] In recent years, with the advancement of miniaturization in semiconductor device manufacturing, the requirements for silicon wafers have become increasingly stringent. In specific terms, not only are wafer surface defects required to be minimal or ideally nonexistent, but they are also required to contain sufficient bulk micro defects (BMDs) to protect the wafer area where electronic components are arranged from contamination by heavy metal impurities. Heavy metal impurities in silicon wafers have become a significant factor affecting the quality of semiconductor devices. Therefore, it is essential to minimize the content of heavy metal impurities throughout the silicon wafer production process. It is currently known that when sufficient number of BMDs form within a silicon wafer, these BMDs exhibit an Intrinsic Gettering (IG) effect, which enables them to capture heavy metal impurities and significantly alleviate the problem of poor semiconductor device quality caused by heavy metal impurities. In recent years, there has been a growing demand for silicon wafers with BMD densities equal to or greater than $1 \times 10^8/\text{cm}^3$. Therefore, when silicon wafers are supplied to electronic component manufacturers, it is necessary for the substrate silicon wafers to contain a sufficient number of BMD nuclei to achieve a high BMD density.

[0024] Epitaxial silicon wafers are formed by growing a single crystal layer, commonly referred to as an epitaxial layer, onto a silicon wafer through a vapor deposition reaction. Because the epitaxial layer has high crystalline integrity and is nearly defect-free, epitaxial silicon wafers are currently widely used as substrate materials for semiconductor devices. However, during the epitaxial growth process, as the silicon wafers are exposed to high temperatures exceeding 1000°C , the relatively small BMD nuclei are eliminated. As a consequence, epitaxial silicon wafers fail to provide a sufficient number of BMD nuclei, resulting in an inability to generate a sufficient density of BMDs when manufacturing semiconductor devices using these epitaxial silicon wafers. This, in turn, causes a suboptimal quality of the resulting semiconductor devices.

[0025] Referring to FIGs. 1 to 4, the embodiments of the present application provide a water-cooling device, applied within a single crystal furnace, including a water-cooling jacket; wherein along an axial direction of the water-cooling jacket, the water-cooling jacket comprises a first end and a second end opposite to each other; when the water-cooling jacket is arranged in the single crystal furnace, the second end is arranged adjacent to a crucible in the single crystal furnace;

along a direction from the first end to the second end, the water-cooling jacket comprises a first portion 1 and a second portion 2, wherein the first portion 1 comprises cooling zones 11 and non-cooling zones 12 arranged at intervals.

[0026] The water-cooling jacket is segmented along its axial direction, and a cooling zone and a

non-cooling zone are provided on the first portion, thereby reducing the cooling area of the first portion and thus lowering the cooling efficiency of the first portion. Accordingly, it can extend the dwell time of the crystal 100 in the BMD nucleation temperature range of 600–850°C, thereby enhancing the BMD nucleation density.

[0027] It should be noted that the arrangement of the non-cooling zone 11 in the first portion 1 allows the water-cooling jacket to achieve maximum cooling efficiency only at the bottom (i.e., at the second end). Compared with the traditional water-cooling jacket, it can reduce the stress generation within the crystal 100 and thus alleviate the problem of cracking of the crystal 100 caused by excessively rapid cooling.

[0028] It should be noted that the specific structural forms of the non-cooling zone 12 and the cooling zone 11 can be various, as long as the cooling area of the first portion 1 can be reduced and thereby lowering the cooling zone efficiency of the first portion 1. The structural forms of the non-cooling zone 12 and the cooling zone 11 in the embodiments of the present application are described in detail below.

[0029] In an exemplary embodiment, the cooling zones 11 and the non-cooling zones 12 are arranged at intervals along the circumferential direction of the water-cooling jacket.

[0030] During the crystal ingot pulling process, the crystal ingot is located in the crystal ingot lifting area at the middle part of the water-cooling jacket. The cooling zones 11 and the non-cooling zones 12 are arranged at intervals along the circumferential direction of the water-cooling jacket, which is beneficial to the temperature uniformity of the crystal ingot in the circumferential direction.

[0031] To effectively reduce the cooling efficiency of the first portion 1, the total area of the non-cooling zone 12 is greater than the total area of the cooling zone 11.

[0032] In a specific embodiment, in a circumferential direction of the water-cooling jacket, a circumferential length of one of the cooling zones 11 is less than a circumferential length of one of the non-cooling zones 12, so that the area of each non-cooling zone 12 is greater than the area of each cooling zone 11.

[0033] The larger the area of the non-cooling zone 12 and the smaller the area of the cooling zone 11, the lower the cooling efficiency of the first portion.

[0034] It should be noted that, to increase the dwell time of the crystal in the temperature range of 600–850°C, the length L1 of the first portion in the axial direction of the water-cooling jacket should not exceed a certain limit. For example, the maximum length of L1 should not exceed 30 cm. Specifically, L1 may measure 20 cm, 25 cm, or up to the maximum of 30 cm, among other

possible values. In addition, within the L1 portion, the area of the non-cooling zone should be as large as possible while ensuring the water-cooling effect of the second portion. For example, the area ratio of the non-cooling zone should be greater than or equal to 80%, but the present application is not limited thereto.

[0035] For example, the first portion comprises at least two cooling zones 11, with each of these cooling zones having identical areas, thereby improving the temperature uniformity of the water-cooling jacket for the crystal ingot, as well as the temperature uniformity of the silicon melt.

[0036] In an exemplary embodiment, the non-cooling zone 12 is provided with at least one through hole.

[0037] The provision of the through holes can effectively reduce the cooling area of the first portion 1, thereby lowering the cooling efficiency of the first portion 1 and increasing the dwell time of the crystal in the temperature range of 600-850°C during the pulling process.

[0038] In an embodiment, the non-cooling zone 12 is provided with a through hole, and the through hole completely covers the non-cooling zone 12.

[0039] It should be noted that, in order to avoid adversely affecting the axial gradient change of the crystal, the dwell time of the crystal in the temperature range of 600-850°C should not be excessively long. Therefore, a flange 3 is provided at the first end, and a connecting area 4 is provided between the flange 3 and the first portion 1. That is, the first portion does not directly extend through a first end of the water-cooling jacket, but the present disclosure is not limited thereto.

[0040] In an exemplary embodiment, the non-cooling zone 12 is provided with a plurality of through holes, which, compared to a single through hole, can enhance the overall connection stability of the water-cooling jacket.

[0041] The plurality of through holes may be arranged in various distribution patterns. For example, along the circumferential direction of the water-cooling jacket, a plurality of columns of through holes may be arranged side by side and at intervals.

[0042] The length of each through hole in the axial direction of the water-cooling jacket can be set according to actual needs.

[0043] The length of each through hole in the circumferential direction of the water-cooling jacket can also be set according to actual needs.

[0044] In the circumferential direction of the water-cooling jacket, the spacing between two adjacent columns of through holes can be set according to actual needs. For example, the spacing between two adjacent columns of through holes may be half the width of the through hole in the

circumferential direction of the water-cooling jacket, but the present application is not limited thereto.

[0045] For example, the plurality of columns of through holes include a first column of through holes and a second column of through holes that are adjacent to each other, and an orthographic projection of one through hole in the first column of through holes onto the second column of through holes completely coincides with a respective through hole in the second column of through holes.

[0046] For example, the plurality of columns of through holes include a first column of through holes and a second column of through holes that are adjacent to each other, and an orthographic projection of one through hole in the first column of through holes onto the second column of through holes partially overlaps with a respective through hole in the second column of through holes.

[0047] In an exemplary embodiment, an inner surface of the cooling zone 11 is provided with a first coating, and an emissivity of the first coating is less than 0.3, but the present application is not limited thereto.

[0048] The provision of the first coating can reduce the amount of heat absorbed by the cooling zone 11, thereby lowering the cooling efficiency of the cooling zone 11.

[0049] It should be noted that the first coating is made of a silicon-based ceramic material, and its emissivity can be controlled by setting the shade of its color. The darker the color, the higher the emissivity and the greater the heat absorption capacity. The lighter the color, the lower the emissivity and the smaller the heat absorption capacity.

[0050] For example, the color of the first coating is white, but the present not limited thereto.

[0051] In the related art, to address the issue of reduced BMD density in epitaxial silicon wafers, nitrogen doping is typically performed during the monocrystalline silicon ingot pulling process to obtain stable BMD nuclei. However, an excessive nitrogen concentration may cause the formation of a large number of large-sized oxygen precipitates at high temperatures (1000-1200°C), resulting in significant stress and associated dislocation defects during the cooling process of the crystal. When these defects appear on the surface of an epitaxial silicon wafer substrate, they may propagate into an epitaxial layer as the epitaxial layer grows, resulting in epitaxial (EPI) stacking faults. Furthermore, to form a high density of BMDs, there must first be a sufficient residual vacancy concentration within the crystal, and it is also necessary to extend the dwell time of the crystal in the nucleation temperature range (600-850°C) as long as possible.

[0052] In the related art, the crystal pulling speed is increased to reduce the dwell time of the

crystal in the temperature range of 1000-1200°C where large-sized oxygen precipitation is formed. However, this approach will also reduce the time the crystal in the BMD nucleation temperature range of 600-850°C, which is unfavorable for the formation of high-density BMD nuclei.

[0053] To avoid EPI stacking fault when doping with high nitrogen concentrations, the dwell time of the crystal in the temperature range of 1000-1200°C where large oxygen precipitates form during cooling should be minimized as much as possible. Compared to the water-cooling jacket in the related art, this embodiment enhances the cooling efficiency of the second portion. Specifically, this can be achieved by increasing the cooling area of the second portion, but the present application is not limited thereto.

[0054] For example, the cooling area of the second portion may be increased by increasing the length of the second portion in the axial direction of the water-cooling jacket.

[0055] It should be noted that as the length of the second portion in the axial direction of the water-cooling jacket increases, the total length of the water-cooling jacket in the axial direction increases, thereby reducing the distance between the water-cooling jacket and the surface of the silicon solution. For example, the length of the second portion in the axial direction of the water-cooling jacket increases by 10-20 cm, but the present application is not limited thereto.

[0056] For example, in the axial direction of the water-cooling jacket, the length of the second portion is greater than or equal to 10 cm, such as 12 cm, 15 cm, etc., but the present application is not limited thereto.

[0057] The second portion 2 absorbs heat to sufficiently dissipate the heat radiated from the melt and ensure the crystal growth rate, thereby reducing the dwell time in the temperature range of 1000-1200°C.

[0058] FIG. 2 is a schematic diagram of the axial temperature distribution of the crystal in the related art, and FIG. 3 is a schematic diagram of the axial temperature distribution of the crystal formed after adopting the water-cooling device in the embodiments of the present application.

[0059] In FIG. 2 and FIG. 3, the area between the reference numerals 101 and 102 represents a temperature range of 1000-1200°C, and the area between the reference numerals 103 and 104 represents a temperature range of 600-850°C.

[0060] It can be seen from FIGs. 2 and 3 that, after adopting the water-cooling device of the embodiment of the present application, the pulling distance of the crystal in the temperature range of 1000-1200°C has been reduced, while the pulling distance of the crystal in the temperature range 600-850°C has been increased. In FIG. 2, the pulling distance of the crystal in the temperature range of 1000-1200°C is 73 mm, whereas in FIG. 3, the pulling distance of the crystal

in the temperature range of 1000-1200°C is reduced to 59 mm. In FIG. 2, the pulling distance of the crystal in the temperature range of 600-850°C is 172 mm, whereas in FIG. 3, the pulling distance of the crystal in the temperature range of 600-850°C is increased to 320 mm.

[0061] It should be noted that, corresponding to the axial temperature distribution of the crystal in FIG. 2, the bottom end of the water-cooling jacket is 35 cm with respect to the silicon solution. Corresponding to the axial temperature distribution of the crystal in FIG. 3, the bottom end of the water-cooling jacket is 2-3 cm with respect to the silicon solution. The length L2 of the second portion in the axial direction of the water-cooling jacket is 10 cm, and the length L1 of the first portion in the axial direction of the water-cooling jacket is 30 cm. The non-cooling zone is provided in through holes, and the area of the through holes accounts for 80% of the total area of the first portion.

[0062] In an exemplary embodiment, a first cooling channel extending along the axial direction of the water-cooling jacket is provided on a side wall of the cooling zone 11, and a second cooling channel communicating with the first cooling channel is provided on a side wall of the second portion 2.

[0063] The first cooling channel and the second cooling channel contain a cooling medium, which may be cooling water, but the present application is not limited thereto.

[0064] The first cooling channel is only distributed in the cooling zone 11, thereby lowering the cooling efficiency of the first portion 1.

[0065] It should be noted that, the larger the area of the non-cooling zone, the lower the cooling zone efficiency of the first portion, which consequently extends the dwell time of the crystal in the temperature range of 600-850°C. However, it is essential that the area of the cooling zone ensures an adequate supply of cooling medium to the second portion in order to maintain its cooling efficiency. Therefore, in some embodiments, the area of the non-cooling zone accounts for less than or equal to 80% of the total area of the first portion, but the present application is not limited thereto.

[0066] For example, the second portion 2 serves exclusively as the cooling zone 11, effectively absorbing heat and ensuring the crystal growth rate.

[0067] To enhance the cooling efficiency of the second portion 2, in an exemplary embodiment, the second portion 2 is configured with an integral hollow structure; that is, an internal space of the side wall of the second portion 2 serves as the second cooling channel and is filled with the cooling medium. Compared with the arrangement of multiple cooling channels, this can increase the cooling area while simultaneously reducing costs.

[0068] To enhance the cooling efficiency of the second portion 2, in an exemplary embodiment, an inner surface of the second portion 2 is provided with a second coating, and an emissivity of the second coating is greater than 0.8.

[0069] For example, the second coating is made of a silicon-based ceramic material, and its emissivity can be controlled by setting the shade of its color. The darker the color, the higher the emissivity and the greater the heat absorption capacity. The lighter the color, the lower the emissivity and the smaller the heat absorption capacity.

[0070] For example, the color of the second coating is black, but the present application is not limited thereto.

[0071] To enhance the cooling efficiency of the second portion 2, in an exemplary embodiment, a concave-convex structure is provided on the inner wall of the second portion 2 to increase the cooling area.

[0072] It should be noted that the specific structural forms of the concave-convex structure can be various, as long as the cooling area of the second portion 2 is increased. In this embodiment, several specific forms of the concave-convex structure are described below.

[0073] In an exemplary embodiment, the concave-convex structure comprises a plurality of protrusions and recesses extending along the circumferential direction of the water-cooling jacket, so that the concave-convex structure is wave-shaped.

[0074] In an exemplary embodiment, the concave-convex structure comprises a plurality of protrusions arranged at intervals on the inner wall of the second portion 2.

[0075] For example, the plurality of protrusions are evenly distributed on the second portion 2.

[0076] For example, the plurality of protrusions and the side wall of the second portion 2 are an integral structure, which not only simplifies the manufacturing process but also improves the connection stability between the plurality of protrusions and the second portion 2.

[0077] For example, the plurality of protrusions is formed by extending inward from corresponding positions on the inner wall of the second portion 2.

[0078] For example, a recess is formed between two adjacent protrusions; that is, the plurality of protrusions is formed by being recessed outward at corresponding positions on the inner wall of the second portion 2, thereby resulting in the formation of the protrusions at the corresponding positions.

[0079] For example, the inner wall of the second portion 2 comprises a first area and a second area arranged in a staggered manner. The first area extends inward to form the protrusion, therefore forming the concave-convex structure on the inner wall of the second portion 2, and/or the second

area is recessed outward, so that the inner wall of the second portion 2 forms the concave-convex structure.

[0080] For example, in order to prevent the protrusion from damaging the crystal ingot, the end of the protrusion distal to the inner wall of the second portion 2 is rounded.

[0081] For example, the diameter of the side wall of the water-cooling jacket gradually decreases from the first portion 1 to the second portion 2. That is, the water-cooling jacket has a tapered structure. The closer the distance between the side wall of the water-cooling jacket and the crystal ingot, the higher the cooling rate, conversely, the farther the distance between the side wall of the water-cooling jacket and the crystal ingot, the lower the cooling rate.

[0082] For example, in the radial direction of the water-cooling jacket, the thickness of the second portion 2 is greater than that of the first portion 1. The interior of the second portion 2 is entirely hollow to accommodate the cooling medium, thereby increasing the capacity of the cooling medium and thus increasing the cooling rate.

[0083] For example, the outer surface of the first portion 1 and the outer surface of the second portion 2 are on a same plane, while the inner surface of the first portion 1 and the inner surface of the second portion 2 form a stepped structure. The inner wall of the second portion 2 is protruded inward to prevent interference between the water-cooling jacket and other components.

[0084] For example, the water-cooling device further comprises a lifting structure, and the lifting structure is used to control vertical movement of the water-cooling jacket.

[0085] The lifting structure comprises a driving unit and a transmission unit. The transmission unit comprises two lifting rods. The first end of the water-cooling jacket comprises a flange 3. The flange 3 is connected to the lifting rod.

[0086] The driving unit may be a driving motor, but the present application is not limited thereto.

[0087] Referring to FIG. 4, an embodiment of the present application further provides a single crystal furnace, including the above-mentioned water-cooling device.

[0088] The single crystal furnace further comprises the aforementioned water-cooling device, which comprises a water-cooling jacket 10 and a lifting structure for controlling the vertical movement of the water-cooling jacket 10.

[0089] The lifting structure is configured to extend through the furnace cover to connect to the water-cooling jacket 10, and control the water-cooling jacket 10 to be suspended above the silicon solution.

[0090] The single crystal furnace further comprises:

a furnace body 5;

a furnace cover mounted on the furnace body 5;

a crucible assembly 6, arranged in the inner chamber of the furnace body 5, wherein the crucible assembly 6 comprises a quartz crucible and a graphite crucible that are arranged in a sleeved manner, with the quartz crucible containing a silicon melt;

a reflector 9, sleeved on the outside of the water-cooling jacket 10, with a gap between the reflector 9 and the water-cooling jacket 10;

a heating component 7, arranged around the crucible assembly for heating the crucible assembly 6, wherein the heating component is fixed to the bottom of the furnace body 5 through an electrode bolt and is connected to the heating electrode at the bottom of the furnace body 5;

a thermal insulation layer 20, arranged between the heating component 7 and the side wall of the furnace body 5, and configured for preventing the heat of the heating component 7 from radiating to the outside of the furnace body 5;

a supporting shaft 8, supported and connected to the bottom of the graphite crucible, wherein an upper end of the supporting shaft 8 is provided with a crucible tray, and a lower end of the supporting shaft 8 extends through the bottom of the furnace body 5.

[0091] In the following, it describes the crystal pulling process using the above-mentioned single crystal furnace.

[0092] First, the crystal raw material is placed in the crucible assembly 6 and melted by the high temperature generated by the heating component 7.

[0093] Then, the silicon melt is slightly cooled to create a certain supercooling.

[0094] Next, a silicon single crystal (referred to as a seed crystal) fixed on the seed crystal shaft is inserted into the surface of the melt. After the seed crystal fuses with the melt, the seed crystal is slowly lifted, allowing the crystal to grow at the lower end of the seed crystal.

[0095] After this, the seed crystal is controlled to grow a thin neck with a length of about 100 mm and a diameter of 3 mm to 5 mm, so as to eliminate the dislocation of atomic arrangement caused by the intense thermal shock of the high-temperature solution on the seed crystal. This process is called necking process.

[0096] Then, the crystal diameter is enlarged to the size required by the process, generally 75mm to 300mm. This process is referred to as shoulder process.

[0097] Subsequently, the lifting speed is suddenly increased to perform a shoulder transition, making the shoulder approximately right-angled.

[0098] After that, the body process is entered, and a single crystal column of a certain size is grown by controlling the thermal field temperature and the crystal lifting speed.

[0099] Finally, when most of the silicon solution has completed crystallization, the crystals are gradually shrunk to form a tail-shaped cone, which is known as the tail process.

[0100] In this way, the single crystal pulling process is basically completed, and the crystal can be removed after a certain period of insulated cooling.

[0101] It should be understood that the above embodiments are merely exemplary embodiments for illustrating the principles of the present application, and the present application is not limited thereto. For those of ordinary skill in the art, various modifications and improvements may be made 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 water-cooling device, applied within a single crystal furnace, comprising a water-cooling jacket; wherein along an axial direction of the water-cooling jacket, the water-cooling jacket comprises a first end and a second end opposite to each other; when the water-cooling jacket is arranged in the single crystal furnace, the second end is arranged adjacent to a crucible in the single crystal furnace;

along a direction from the first end to the second end, the water-cooling jacket comprises a first portion and a second portion, wherein the first portion comprises cooling zones and non-cooling zones arranged at intervals.

2. The water-cooling device according to claim 1, wherein the non-cooling zone is provided with at least one through hole.

3. The water-cooling device according to claim 1, wherein an area of the cooling zone is smaller than an area of the non-cooling zone.

4. The water-cooling device according to claim 3, wherein the area of the non-cooling zone is greater than or equal to 80% of a total area of the first portion.

5. The water-cooling device according to claim 1, wherein, in a circumferential direction of the water-cooling jacket, a circumferential length of one of the cooling zones is less than a circumferential length of one of the non-cooling zones.

6. The water-cooling device according to claim 1, wherein an inner surface of the cooling zone is provided with a first coating, and an emissivity of the first coating is less than 0.3.

7. The water-cooling device according to claim 1, wherein a first cooling channel extending along the axial direction of the water-cooling jacket is provided on a side wall of the cooling zone, and a second cooling channel communicating with the first cooling channel is provided on a side wall of the second portion.

8. The water-cooling device according to claim 7, wherein the side wall of the second portion is arranged as a hollow structure to form the second cooling channel.

9. The water-cooling device according to claim 1, wherein an inner surface of the second portion is provided with a second coating, and an emissivity of the second coating is greater than 0.8.

10. A single crystal furnace, comprising the water-cooling device according to any one of claims 1 to 9.