[0012]

Accordingly, there has been a need for a single crystal pulling apparatus provided with a crucible unit that makes it possible to avoid the problems relating to the graphite crucible that arise from the silicification (SiC formation) and the wall thickness decrease resulting from the oxidizing abrasion.

[0013]

In view of the foregoing circumstances, embodiments~~it is an object~~ of the present invention ~~to~~ provide a single crystal pulling apparatus that can suppress the heat escape from the crucible rotating shaft to outside the furnace more effectively, that can moreover use the component parts of the single crystal pulling apparatus such as the crucibles, the tray, and the crucible rotating shaft, as they are, and that can keep the manufacturing cost low, and to provide a low heat conductive member used for the single crystal pulling apparatus.

In view of the foregoing circumstances, embodiments~~it is another object~~ of the present invention ~~to~~ provide a single crystal pulling apparatus that makes it possible to avoid the problems relating to the graphite crucible that arise from the silicification (SiC formation) and the wall thickness decrease resulting from the oxidizing abrasion.

SOLUTION TO PROBLEM

[0014]

According to a first aspect of the present invention, there is~~In order to accomplish the foregoing objects, the present invention~~ provides~~d~~ a single crystal pulling apparatus comprising: a crucible unit including a crucible and a tray for securing and holding the crucible from below; and a crucible rotating shaft for supporting the tray from below and for elevating and lowering the tray and the crucible while rotating the tray and the crucible, characterized by having a gap portion formed between the crucible and the tray and/or between the tray and the crucible rotating shaft.

[0015]

Here, the single crystal pulling apparatus according to embodiments of the present invention also includes a single crystal pulling apparatus in which germanium melt or the like may be accommodated directly in a graphite crucible, in addition to the silicon single crystal pulling apparatus having a quartz crucible for accommodating silicon melt and a graphite crucible for retaining the quartz crucible.

[0016]

With the above-described aspecteonfiguration, heat escape can be suppressed because the gap portion is formed at least one of between the crucible and the tray and between the tray and the crucible rotating shaft. Specifically, part of the heat quantity transferred from the heater to the crucible escapes out of the furnace through the tray and the crucible rotating shaft. At this time, (1) when the gap portion is formed between the crucible and the tray, the heat escape from the crucible to the tray is suppressed; (2) when the gap portion is formed between the tray and the crucible rotating shaft, the heat escape from the tray to the crucible rotating shaft is suppressed; and (3) when the gap portion is formed between the crucible and the tray and also between the tray and the crucible rotating shaft, both the heat escape from the crucible to the tray and the heat escape from the tray to the crucible rotating shaft are suppressed. Accordingly, the heat conduction in the downward direction from the crucible rotating shaft is reduced in any of the above cases (1) through (3), and as a result, the heat quantity leaking from the crucible rotating shaft to the outside of the furnace can be reduced. Thus, the heat quantity that leaks from the crucible rotating shaft out of the furnace can be reduced by forming the gap portion at least one of between the crucible and the tray and between the tray and the crucible rotating shaft, and as a result, it becomes possible to maintain the heat quantity that is applied to the melt of the metal material, such as silicon, in the crucible, and to keep the temperature in the crucible higher than the melting point of the metal material.

In other words, since the heat quantity that leaks from the bottom portion of the crucible rotating shaft is reduced by forming the gap portion, it becomes unnecessary to take the heat loss into account so that the heater does not need to generate a large amount of heat.

[0017]

In addition, since the gap portion has a greater effect on preventing the heat escape than the low heat conductive member, the present invention can suppress the heat escape more effectively than the conventional example in which the low heat conductive member is interposed in the crucible rotating shaft.

[0018]

In order to form the gap portion, it is sufficient that, for example, a thin member be interposed on the joint surface between the crucible and the tray and/or on the joint surface between the tray and the crucible rotating shaft. With such a configuration, the component parts of the single crystal pulling apparatus, such as the crucibles, the tray, and the crucible rotating shaft, can be used as they are, and the manufacturing cost can be kept low.

[0019]

In an embodiment of the present invention, it is preferable that the gap portion formed between the crucible and the tray be positioned below a bottom portion of the crucible.

[0020]

With the above-described embodiment~~configuration~~, the amount of heat escape from the bottom portion of the crucible can be lessened. As a result, it is possible to prevent the temperature of the melted material in the bottom portion of the crucible from decreasing, and it is possible to prevent the convection of the melted material that results from the temperature difference from the melted material in an upper portion of the crucible.

[0021]

In an embodiment of the present invention, it is preferable that the gap portion formed between the tray and the crucible rotating shaft be positioned below a bottom portion of the tray.

[0022]

With the above-described embodiment~~configuration~~, the heat transfer from the bottom portion of the tray to the crucible rotating shaft is prevented even if the heat from the bottom portion of the crucible is easily conducted to the tray, so it practically means that the amount of heat escape from the bottom portion of the crucible is lessened. Accordingly, even when the gap portion is formed below the bottom portion of the tray, it is possible to prevent the temperature of the melted material in the bottom portion of the crucible from decreasing, and it is possible to prevent the convection of the melted material that results from the temperature difference from the melted material in an upper portion of the crucible.

[0023]

In an embodiment of the present invention, it is preferable that a low heat conductive member be interposed at least one of on a joint surface between the crucible and the tray and on a joint surface between the tray and the crucible rotating shaft, the low heat conductive member having a lower heat conductivity in a direction perpendicular to a main surface (i.e., in a thickness direction) than that in the main surface.

[0024]

With the above-described embodiment~~configuration~~, the crucible and the tray do not make direct contact with each other, and the tray and the crucible rotating shaft do not make direct contact with each other either. This means that the escaping heat inevitably passes through the low heat conductive member, and as a result, the low heat conductive member suppresses heat conduction. Therefore, the heat escape to the crucible rotating shaft can be delayed, and the heat quantity loss of the crucible can be prevented.

[0025]

Furthermore, with the embodiment~~configuration~~ in which the low heat conductive member is interposed on the joint surface between the crucible and the tray and/or on the joint surface between the tray and the crucible rotating shaft, it is possible to use the component parts of the single crystal pulling apparatus, such as the crucibles, the tray, and the crucible rotating shaft, as they are, and it is unnecessary to process the crucible rotating shaft to form grooves, holes, and the like for interposing the low heat conductive member, unlike the conventional example. Therefore, the manufacturing cost can be kept low.

[0026]

It should be noted that the low heat conductive member is not particularly limited as long as it can reduce heat conduction. However, it is preferable that the low heat conductive member be made of a material that has sufficient resistance against the compressive stress originating from the weight of the components that are placed thereabove, such as the crucibles and the tray. It is sufficient that the material have substantially the same level of strength as that of the artificial graphite for the crucible and the like, and it is preferable that the material have a compressive strength of 80 MPa or higher. The range of the "low heat conductivity" for the low heat conductive member should be a thermal conductivity coefficient of 10 W/m·K or less under a room temperature condition, preferably 5 W/m·K or less.

[0027]

In an embodiment~~addition, in the present invention~~, it is preferable that the low heat conductive member comprise a one-dimensional carbon fiber-reinforced carbon composite material or a two-dimensional carbon fiber-reinforced carbon composite material.

[0028]

the price of the low heat conductive member, it is preferable to use the one-dimensional carbon fiber-reinforced carbon composite material or the two-dimensional carbon fiber-reinforced carbon composite material as the raw material for the low heat conductive member.

[0030]

In an embodiment of the present invention, it is preferable that the carbon fiber-reinforced carbon composite material be formed in a substantially annular shape.

The shape of the carbon fiber-reinforced carbon composite material may be any shape, such as a circular shape or an annular shape, but an annular shape is preferable. The reason is that when the carbon fiber-reinforced carbon composite material is formed in a substantially annular shape, it is ensured to form the gap portion below the bottom portion of the crucible lower side or below the bottom portion of the tray. Moreover, it becomes possible to secure and support the crucible stably. Furthermore, the contact area is smaller when the carbon fiber-reinforced carbon composite material is in an annular shape than when in a circular shape. Therefore, the heat escape prevention effect can be further enhanced.

[0031]

~~The present invention also provides a low heat conductive member used for a single crystal pulling apparatus, characterized by being interposed at least one of on a joint surface between the crucible and the tray and on a joint surface between the tray and the crucible rotating shaft, and being used for suppressing heat conduction from the crucible to the crucible rotating shaft~~In a second aspect, there is provided a low heat conductive member used for suppressing heat conduction from the crucible to the crucible rotating shaft in the above single crystal pulling apparatus, characterized by comprising a one-dimensional carbon fiber-reinforced carbon composite material or a two-dimensional carbon fiber-reinforced carbon composite material, and having a flat shape.

In an embodiment of the present invention, it is preferable that the low heat conductive member comprise a one-dimensional carbon fiber-reinforced carbon composite material or a two-dimensional carbon fiber-reinforced carbon composite material.

In an embodiment~~addition~~, it is preferable that the low heat conductive member be formed in a substantially annular shape.

[0032]

In the single crystal pulling apparatus according to embodiments of the present invention, it is preferable that the crucible unit comprise: a quartz crucible including a straight trunk portion, a bottom portion, and a curved surface-shaped portion connected from the bottom portion to the straight trunk portion; and a graphite tray for retaining the quartz crucible from below.

[0033]

By the crucible unit that does not use a graphite crucible as described above, it is made possible to avoid the problems relating to the graphite crucible that arise from the silicification (SiC formation) and the wall thickness decrease resulting from the oxidizing abrasion, which were problems in the past.

In addition, the manufacturing is made easy, and moreover, the cost can be reduced. Specifically, the graphite crucible of the conventional example is manufactured by hollowing-out processing a graphite block into a closed-end cylindrical shape and further finishing-processing the interior thereof. For this reason, the manufacturing has been troublesome. On the other hand, the graphite tray has the advantage that the manufacturing is not troublesome because it has a dish-like shape and does not have a straight trunk portion. In addition, it has another advantage that the cost of the material can be reduced since it does not have the straight trunk portion.

[0034]

In an embodiment of the present invention, it is preferable that the tray retain at least the bottom portion of the quartz crucible.

[0035]

It is sufficient that the tray retain at least the bottom portion of the quartz crucible.

[0036]

In an embodiment of the present invention, it is preferable that the tray retain the bottom portion and the curved surface-shaped portion of the quartz crucible.

[0037]

With the embodiment~~configuration~~ in which the curved surface-shaped portion of the quartz crucible is retained in addition to the bottom portion as described above, the deformation of the quartz crucible resulting from softening of the quartz crucible can be prevented when it is heated by the heater. Thus, in the single crystal pulling apparatus that uses a later-described interposed member, the risk of contact between the quartz crucible and the interposed member is reduced. As a result, there is no risk that a trouble is caused during the manufacturing process by causing the quartz crucible and the interposed member to make contact with each other.

[0038]

In an embodiment of the present invention, it is preferable that an outer peripheral surface of the tray and an outer peripheral surface of the straight trunk portion of the quartz crucible be substantially flush with each other. This allows the gap between the quartz crucible and the interposed member to be arranged in a narrower condition easily.

[0039]

In an embodiment of the present invention, it is preferable that the single crystal pulling apparatus further comprise a crucible unit-heating device for heating the crucible unit, the crucible unit-heating device comprising: a heater disposed so as to surround an outer periphery of the crucible unit; and a cylindrical-shaped interposed member interposed between the crucible unit and the heater, the interposed member made of a carbonaceous material and

disposed so as to surround the outer periphery of the crucible unit.

[0040]

With the above-described embodiment~~configuration~~, the heat from the heater heats the quartz crucible through the interposed member made of graphite. At this time, because the interposed member has a cylindrical shape without slits, the quartz crucible is heated while variation in heat generation of the heater is alleviated by the interposed member. As a result, the quartz crucible is heated uniformly.

[0041]

In an embodiment of the present invention, it is preferable that the interposed member be disposed so as to be spaced with a microgap from the quartz crucible.

[0042]

The size of the microgap M is, for example, from about 1 mm to about 3 mm in the case of using a 22-inch size quartz crucible. The reason is as follows. If the gap is too narrow, the interposed member may make contact with the quartz crucible even when the quartz crucible is deformed very slightly. If the gap is too wide, the heat transfer from the heater may become insufficient.

ADVANTAGEOUS EFFECTS OF INVENTION

[0043]

According to embodiments of the present invention, the heat quantity that leaks from the crucible rotating shaft out of the furnace can be reduced by forming the gap portion at least one of between the crucible and the tray and between the tray and the crucible rotating shaft, and as a result, it becomes possible to maintain the heat quantity that is applied to the melt of the metal material, such as silicon, in the crucible, and to keep the temperature in the crucible higher than the melting point of the metal material. In other words, since the heat quantity that leaks from the bottom portion of the crucible rotating shaft is reduced

by forming the gap portion, it becomes unnecessary to take the heat loss into account so that the heater does not need to generate a large amount of heat.

[0044]

In addition, since the gap portion has a greater effect on preventing the heat escape than the low heat conductive member, embodiments of the present invention can suppress the heat escape more effectively than the conventional example in which the low heat conductive member is interposed in the crucible rotating shaft.

[0045]

Furthermore, in order to form the gap portion, it is sufficient that, for example, a thin member be interposed on the joint surface between the crucible and the tray and/or on the joint surface between the tray and the crucible rotating shaft. With such a configuration, the component parts of the single crystal pulling apparatus, such as the crucibles, the tray, and the crucible rotating shaft, can be used as they are, and the manufacturing cost can be kept low.

BRIEF DESCRIPTION OF DRAWINGS

[0046]

[Fig. 1] Fig. 1 is a cross-sectional view illustrating a primary portion of a silicon single crystal pulling apparatus according to Embodiment 1-1.

[Fig. 2] Fig. 2 is a cross-sectional view illustrating a primary portion of a silicon single crystal pulling apparatus according to Embodiment 1-2.

[Fig. 3] Fig. 3 is a view for illustrating a crucible bottom portion.

[Fig. 4] Fig. 4 is a cross-sectional view illustrating a primary portion of a silicon single crystal pulling apparatus according to Embodiment 1-3.

[Fig. 5] Fig. 5 is a cross-sectional view illustrating a primary portion of a silicon single crystal pulling apparatus according to Embodiment 2.