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SEED PULLING APPARATUS HAVING DIAGONAL FEED AND GAS DOPING

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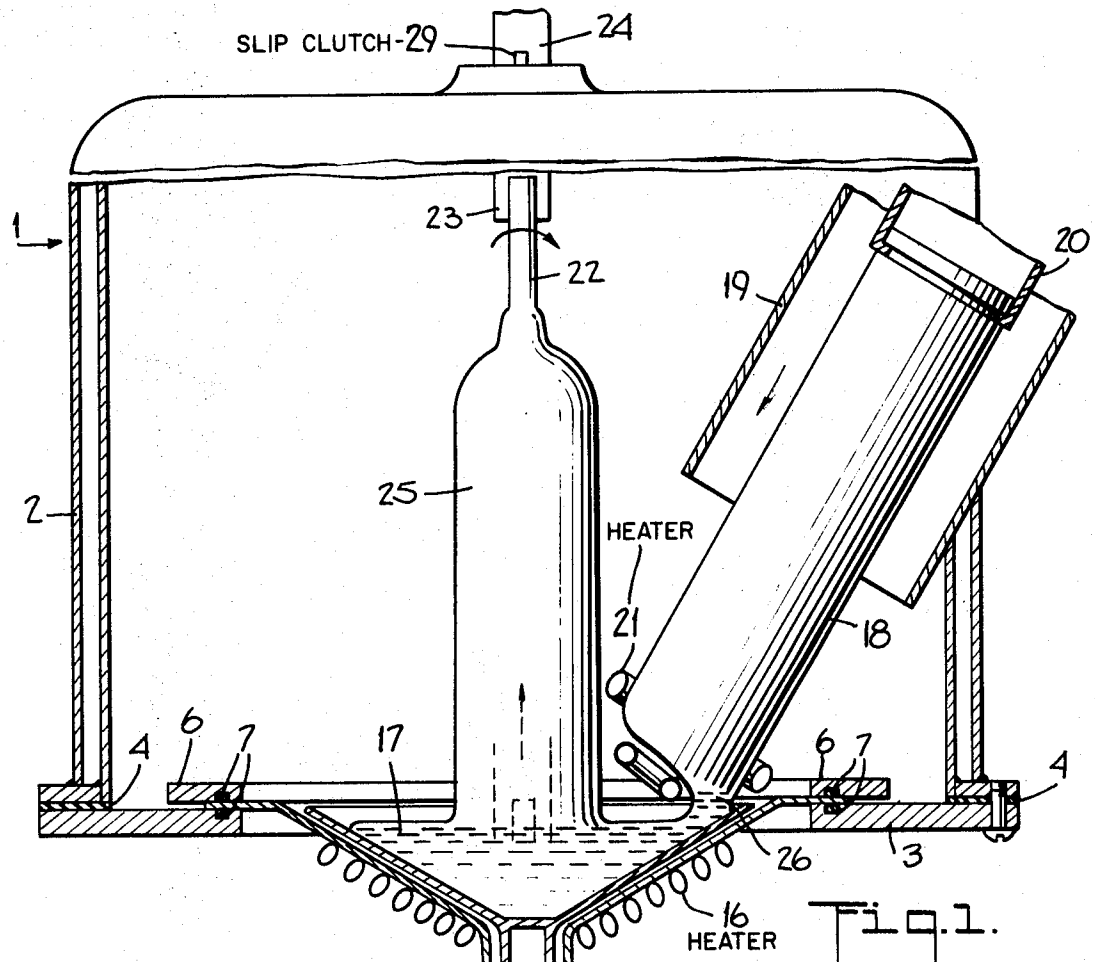


Fig. 1.

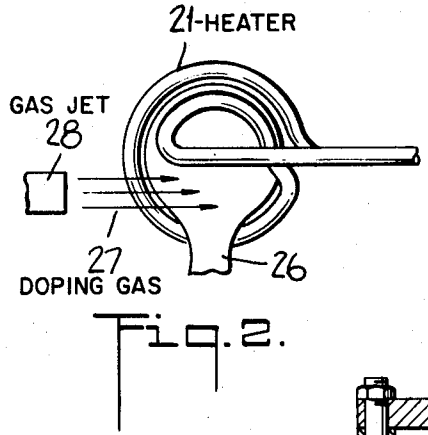


Fig. 2.

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SEED PULLING APPARATUS HAVING DIAGONAL FEED AND GAS DOPING

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ABSTRACT OF THE DISCLOSURE

A means and method of producing a large diameter single crystal rod of semi-conductor material by the "seed-pulling" method comprising a hermetically-sealed chamber with means for introducing a bar of poly crystal material therein at an angle to the vertical so that a generally conical induction heating coil may be placed about the bar end within the chamber to heat it to a molten state; a rotating funnel-shaped receptacle located beneath the bar end for receiving the melted material flowing therefrom through a space between the heating coils; another conical heating coil for maintaining the melted material in the receptacle in a molten state so that a single crystal seed may be inserted into the melt to pull a single crystal rod therefrom. By feeding the poly crystal material to the melt at a predetermined rate while the rotating single crystal seed is being retracted at a predetermined rate a single crystal rod of any desired diameter may be produced, while requiring less heat input for producing and maintaining a melt than in prior devices of this type by virtue of the arrangement of the heating coils.

BACKGROUND OF THE INVENTION

The present invention relates to a means for growing single crystals from a poly crystal melt and more particularly to an apparatus which permits single crystal rods of any desired diameter to be pulled from a constantly fed poly crystal melt.

An important step in the manufacturing of semiconductors is the growing of high quality single crystals of the materials, such as silicon or germanium, to be used therein. By a "single crystal" is meant a material all parts of which are arranged on a molecular scale in the same repeting three-dimensional pattern.

There are many different techniques for growing these crystals because of the individual technique limitations depending on crystal form and tolerable operating temperatures. Each technique is designed to produce crystals only of certain structure such as thin film, long rod, bulk or large crystal. One of the commonest methods of growing crystals is the Czochralski method often called "pulling" a crystal and to which the present invention is directed. In this method a crucible of purified germanium, silicon or whatever basic material is being processed is placed in an inert gas atmosphere and heated to the melting point. The inert atmosphere prevents oxidation and contamination of the semiconductor. With just the right temperature a single crystal particle or "seed" of the material on the end of a shaft lowered into the melted material and withdrawn at just the right speed will "pull" a crystal, that is, cause it to grow, at the end of the seed. While this method is particularly suited for growing long, single

crystal rods, it is limited in the size of the diameters obtainable since the crystal is pulled from a given supply of poly crystal melt in the crucible, so that, in order to obtain a long rod, the diameter must be proportionately diminished. The present invention overcomes this limitation in this important crystal growing technique.

Also, the crucible for holding the melt has generally been of cylindrical shape with a cylindrical induction coil arranged about its lower end for supplying the heat, whereas the present arrangement provides an improved crucible and heating means requiring less power in the same operation.

SUMMARY OF THE INVENTION

The present invention provides a method and means wherein a supply of poly crystal material may be fed at a given rate into the melt so that single crystal rods of any desired diameter and length may be pulled therefrom. It has been found that by heating the end of a poly crystal bar by means of a conical induction coil and permitting the molten material to flow into the crucible through a space between the coils, the amount of melt may be continuously replenished at any desired rate. In addition, the melt is held in a conical crucible with a surrounding induction heating coil, by which arrangement in combination with the melting coil less heating is required than is used in the related prior art devices and gas doping is facilitated.

It is therefore an object of the present invention to provide an apparatus for producing single crystal rods of any desired diameter.

Another object of the present invention is to provide a method of growing single crystal rods of any desired dimension form a poly crystal melt in a crucible.

Another object of the present invention is to provide a method and means for pulling single crystals from a poly crystal melt which requires less heat than those of the prior art and which facilitates gas doping.

A further object of the present invention is to provide an apparatus of this type in which the poly crystal material in the melt is constantly replenished.

Other and further objects of the invention will be obvious upon an understanding of the illustrative embodiment about to be described, or will be indicated in the appended claims, and various advantages not referred to herein will occur to one skilled in the art upon employment of the invention in practice.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention has been chosen for purposes of illustration and description and is shown in the accompanying drawings, forming a part of the specification, wherein:

FIG. 1 is a cross section of the machine of the present invention; and

FIG. 2 is an end view of the heating coil used to melt the end of the poly crystal bar showing the space between the coil elements through which the melted material flows and the gas doping operation.

DETAILED DESCRIPTION OF DISCLOSURE

FIG. 1 shows a cross section of a preferred embodiment of the apparatus of the present invention for producing single crystal rods of semi-conducting material, such as silicon or germanium, from a poly crystal bar of similar material including means for continuous and uni-

form doping. The term "bar" herein shall be used exclusively in connection with the supply of unmelted poly crystal material and the term "rod" shall be used in connection with the supply of resolidified single crystal material merely in an attempt to avoid confusion between the two, and in no way should these terms be interpreted to indicate the relative diameters or other dimensional features of these members.

The apparatus is in the form of a stainless-steel water-cooled furnace chamber **1** which comprises a cylindrical housing **2** with a Mycalex ring **3** held gas-tight against the bottom of the cylinder **2** with an intermediate gasket **4**. The furnace chamber **1** is hermetically sealed and filled with an inert gas. The Mycalex ring **3** supports a stationary funnel-shaped member **5** made of quartz. This funnel-shaped member **5** is sealed with two O-rings **7** about the inner circumference of the ring **3** by an upper ring **6**. A second quartz funnel-shaped member **8** which acts as the crucible is arranged to rotate inside of the first quartz member **5**. This rotation is accomplished through a belt drive **9**, which acts upon a shaft **10** connected to the lower end of the inner funnel member **8** and rides in suitable bearings **11** on a machine mounting member **12**. A vacuum-type seal **13** is provided about the upper portion of the shaft **10** at the upper bearings **11** to seal the space between the two funnel-shaped members **5** and **8** which communicates with the interior of the chamber **1**. The outer quartz member **5** is sealed at point **14** and held in place on the mounting member **12** by means of a locknut **15**.

An induction heating coil **16** is disposed beneath the frusto-conical portion of the outer funnel member **8** outside of the furnace chamber **1** and at atmospheric pressure.

It will be noted that the coil **16** is also of conical or frusto-conical shape which will induce the heat energy into the melt **17** held in the crucible **8** across its entire lower surface. With this arrangement less heat is required to maintain the melt in the molten state as compared with the prior cylindrical arrangements wherein the applied heat must penetrate to the core of the melt from the outer circumference. The weight of the melt is also more evenly distributed when the rotational motion is applied to the crucible **8**.

The poly crystal bar **18** is fed at an angle to the vertical axis of the funnels **5** and **8** into the furnace chamber **1** through a tubular member **19** which passes through the cylindrical wall **2** of the furnace **1**. The bar **18** is held at its upper end by a suitable holder means **20** which is sealingly inserted into the tubular member **19** at its upper end. The lower end of the bar **18** is free to be inserted into a high frequency induction heating coil **21** located above and to one side of the funnel-shaped crucible **8**. This coil **21** is also of a generally conical shape having one or more elements disposed beneath the end of the bar **18**. It will again be seen that less heat is required to melt the bar **18** through to its core than if the heating coil was arranged to merely surround the outer circumference as in prior devices. Such an arrangement also supplies a small even stream **26** of molten material to the melt which may be easily controlled by the rate of insertion of the bar **18** into the coil **21**. In addition this molten portion of the material has a large outer surface area which is extremely conducive for accepting gas doping. The elements of the coil **21** are suitably spaced to permit the molten lower edge of the bar **18** to flow into the crucible **8** when melted by the energy from the induction coil **21**.

A single crystal seed **22** of the same material as that of the bar **18** and which is used to pull the rod **25**, is held in a crystal-holding chuck **23**. Thus chuck is mounted by means of a slip clutch **29** on a shaft **24** which is capable of rotational and controlled up and down movement.

The improved machine of the present invention is operated in the following manner. The poly crystal bar **18** is inserted through the guiding tube **19** into the furnace **1** and its end is disposed within the high frequency induction coil **21** for pre-heating. The pre-heating may be accomplished by inserting a tantalum disc in the area so that the radiated heat will cause the poly crystal material to become conductive to a point where the high frequency power will take over and induce into the material directly The pre-heating step also decreases the overall amount of energy required for the melting and molten state maintaining operation.

The elements of the coil **21** are disposed the circumference of the bar **18** and beneath its end so as to melt the end of the bar **18** completely through its cross section. The melted material will be caused by gravity to flow between the spaced elements of the coil **21** into the inner funnel member or crucible **8**. This crucible **8** is rotating as the flow enters and mixes and distributes the material uniformly over its inner walls. The high frequency power oscillating through the lower induction coil **16** will provide sufficient heat to maintain the melt material **17** in a molten state and also to superheat it to the required temperature for producing the single crystal rod **25**.

The single crystal seed **22** is now immersed in the molten pool or melt **17** forming a fused junction between itself and the molten material **17**. The seed **22** will then be slowly drawn up and rotated in the opposite direction from the rotation of the molten material **17** in the quartz crucible **8**. This rotation acts to mix the molten material and the centrifugal effect causes an enlargement of the diameter of the resulting rod **25**. The slip clutch **29** is provided to protect against a freeze-up the material.

By controlling the speed at which the poly crystal bar **18** is fed into the system and the rate at which the single crystal rod **25** is drawn from the melt **17**, any desired diameter of single crystal rod **25** may be obtained. These two operations may be accomplished automatically once the necessary parameters are determined.

If it is desired to gas dope the single crystal rod **25**, this may be readily and uniformly accomplished by introducing the doping gas **27** from a source **28** into the area about the molten end of the poly crystal bar **18** and particularly against its lower surface as shown in FIG. 2. The arrangement of the end of the bar within the heating coil provides a molten surface of large area and diminished cross-section which is bombarded by the gas and is particularly conducive to providing a continuous uniform and predetermined degree of doping over the entire length of the recrystallized single crystal rod **25**.

It will thus be seen that an improved apparatus and method are provided for producing single crystal rods of semiconductor material from a poly crystal melt without limiting the diameter of the rod which may be obtained and requiring less energy for heating than the prior devices of this type while being extremely conductive to improved continuous and uniform gas doping.

As various changes may be made in the form, construction and arrangement of the parts and the steps of the method herein without departing from the spirit and scope of the invention and without sacrificing any of its advantages, it is to be understood that all matter herein is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. An apparatus for producing a single crystal rod from a melt of poly crystal comprising:

(a) a chamber;

(b) a tubular member in the wall of the chamber for introducing a bar of poly crystal material into the chamber at an angle with the vertical;

(c) a first heater inside the chamber for heating the end of the bar to the molten state;

(d) a conical receptacle in the chamber beneath the heater for receiving melted material from the bar;

(e) means to rotate the receptacle;

(f) a second heater of conical shape below the receptacle for maintaining the melted material in a molten state;

(g) a chuck having a seed crystal attached to its lowermost end, the chuck being movable in a vertical direction in order to insert the seed into the melted material to form a molten junction; and

(h) means to move the check vertically and to rotate it in a direction opposed to the direction of rotation of the receptacle so that retraction of the seed after formation of the molten junction draws the molten material with it and produces a single crystal rod.

2. An apparatus as claimed in claim **1** in which the first and second heaters comprise high frequency induction coils.

3. An apparatus as claimed in claim **2** in which at least a portion of the first induction coil is disposed beneath the end of the bar.

4. An apparatus as claimed in claim **2** in which the elements of the first coil are spaced from one another.

5. An apparatus as claimed in claim **2** which further comprises means for introducing a doping gas into the area about the molten end of the bar.

6. An apparatus as claimed in claim **2** in which the chuck is mounted on a shaft which is attached to the means for rotating the seed through a slip clutch.

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