Aug. 22, 1967 R. E. LORENZINI 3,337,303

CRYSTAL GROWING APPARATUS

Filed March 1, 1965 3 Sheets-Sheet 1

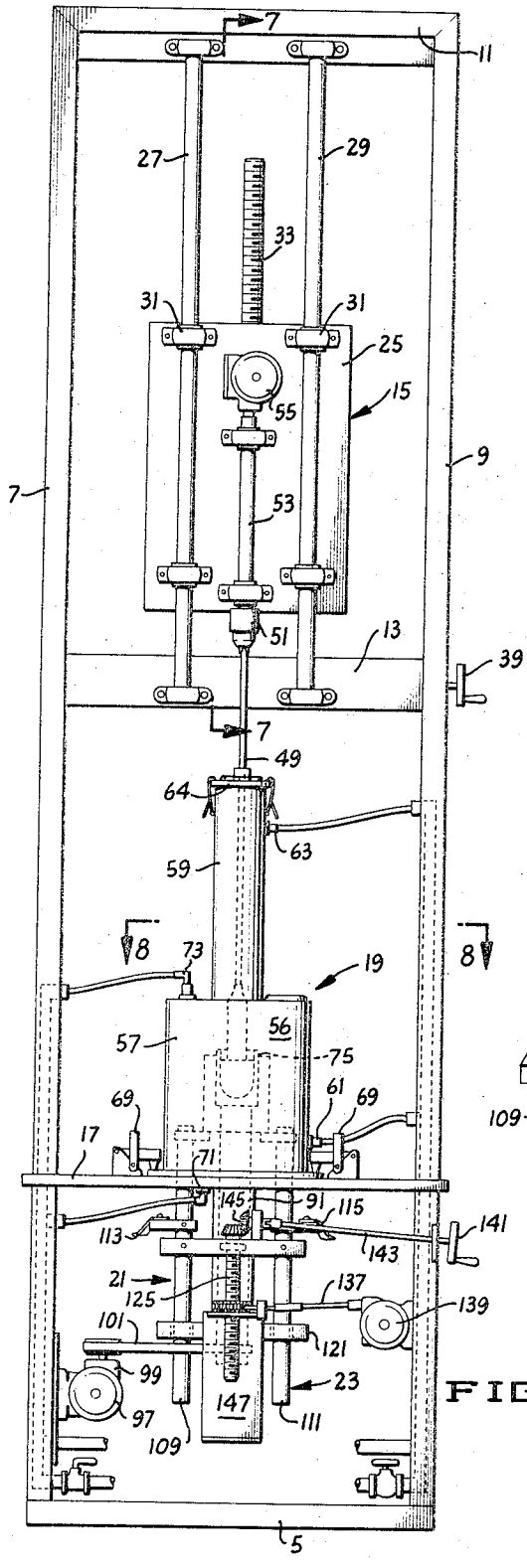


FIG-1.

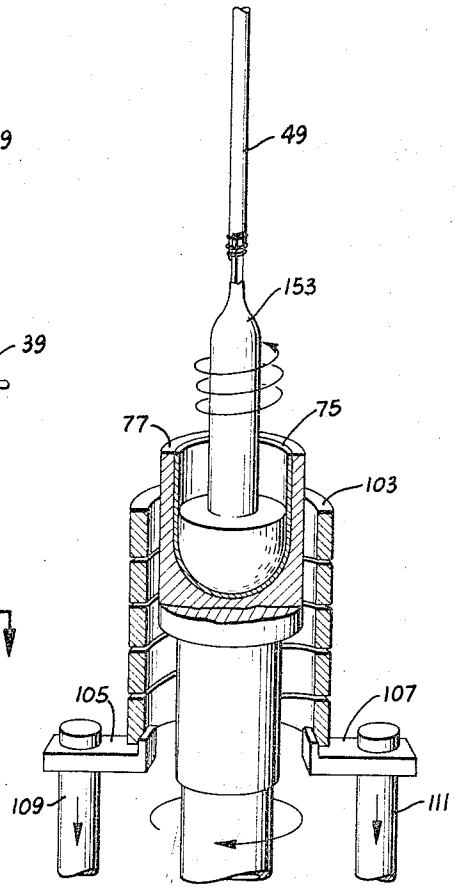


FIG-2.

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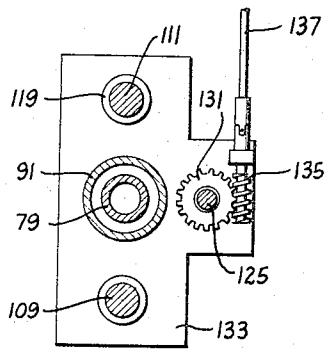


FIG. 5

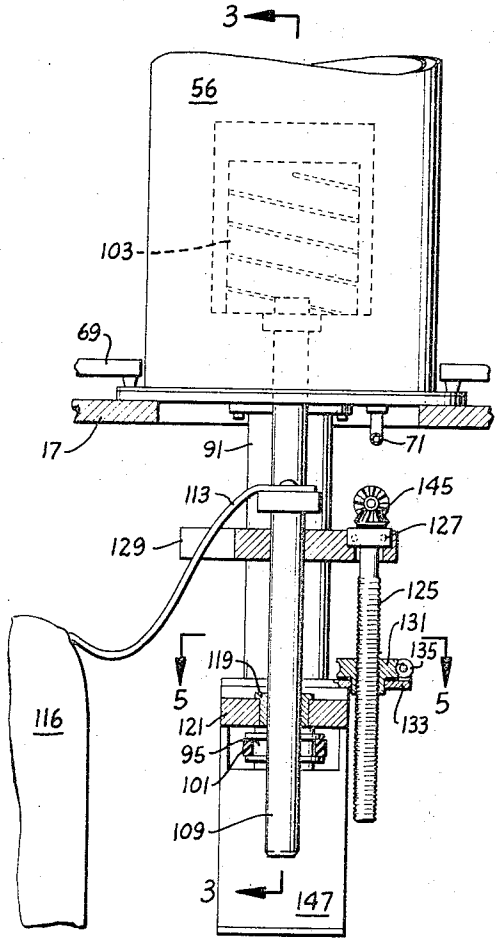


FIG. 4

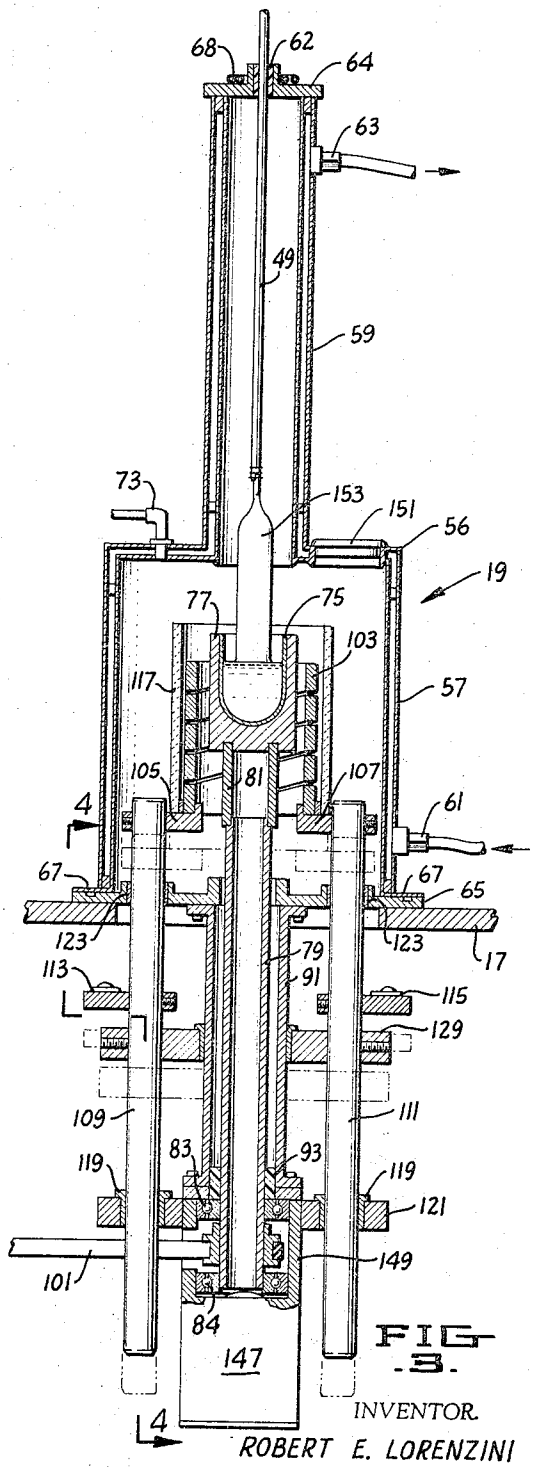


FIG. 3.

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CRYSTAL GROWING APPARATUS

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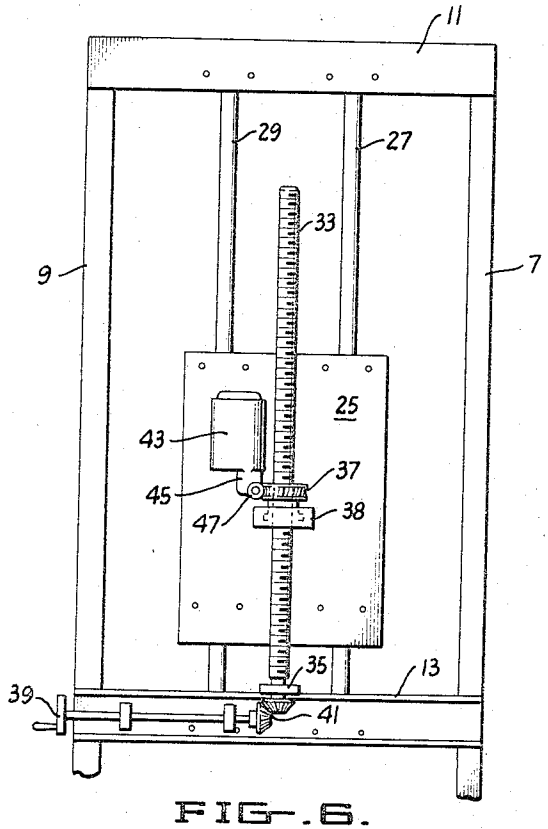


FIG. 6.

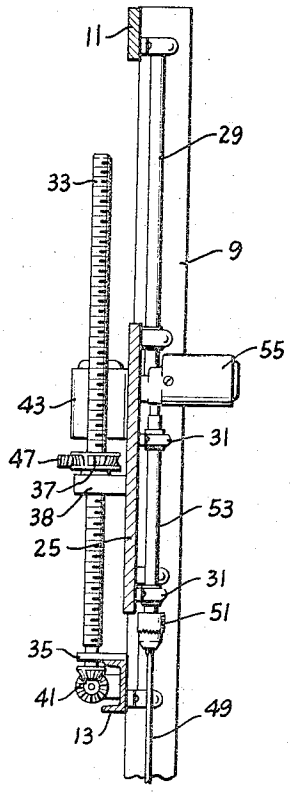


FIG. 7.

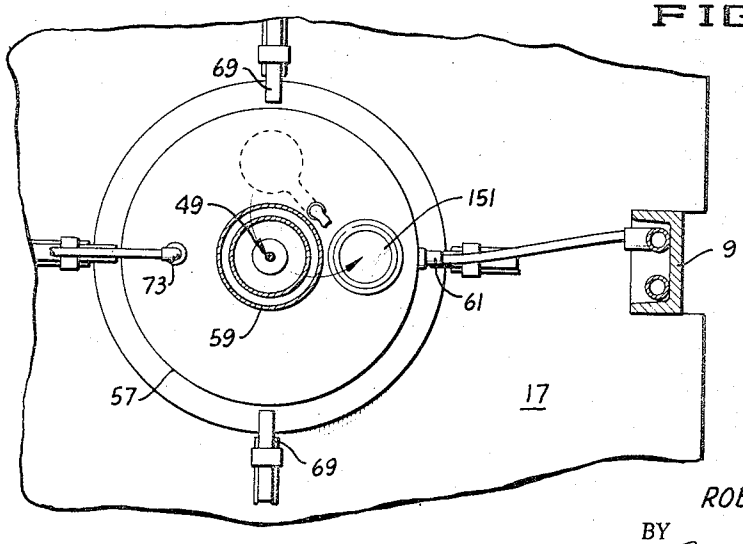


FIG. 8.

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3,337,303
CRYSTAL GROWING APPARATUS

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2 Claims. (Cl. 23—273)

This invention relates to a crystal growing furnace and, more particularly, relates to a furnace and growing method wherein large crystals of material such as silicon and germanium can be grown from a melt.

In many applications, particularly in the electronic industry wherein semiconductor materials such as silicon and germanium are utilized, it is important that crystalline materials be provided wherein the crystal is extremely pure with precisely controlled amounts of P or N doping materials. It is further important that such crystals have a minimum number of dislocations of the crystalline structure. From an economic standpoint, it is also desirable that large crystals be formed of uniform chemical composition and mechanical structure so that each crystal can be cut to provide a large number of uniform semiconductor elements.

It is, therefore, an object of the present invention to provide a crystal growing furnace assembly which is capable of growing large crystals of uniform chemical and mechanical structure from a melt of material such as silicon or germanium.

Another object of this invention is to provide a crystal growing furnace wherein a heating element is automatically lowered during crystal growth to maintain optimum temperature conditions within the melt from which the crystal is grown.

Another object of this invention is to provide a crystal growing furnace wherein there is substantially no possibility of contamination of the materials being grown.

Still another object of this invention is to provide a crystal growing furnace wherein the temperature of the crucible can be constantly monitored by a simple means.

Other objects and advantages of the invention will be apparent from the balance of the specification.

In the drawings forming a part of this application:

FIGURE 1 is a front view of a furnace assembly embodying the present invention.

FIGURE 2 is an enlarged perspective view of the crucible and heater.

FIGURE 3 is an enlarged, sectional view of a portion of the furnace shown in FIGURE 1.

FIGURE 4 is a section on the line 4—4 of FIGURE 3.

FIGURE 5 is a section on the line 5—5 of FIGURE 4.

FIGURE 6 is a back view of the crystal rotating and raising assembly.

FIGURE 7 is a sectional view of the line 7—7 of FIGURE 1.

FIGURE 8 is an enlarged plan view on the line 8—8 of FIGURE 1.

The furnace has a base member 5 with side members 7 and 9 and a top member 11. A cross member 13 supports the crystal elevation and rotation assembly, generally designated 15, while a bottom support plate 17, attached to the side members, supports the furnace proper, generally designated 19 and the electrode elevating and crucible rotating assemblies generally designated 21 and 23, respectively.

The crystal rotating and elevating assembly 15 is supported on a mounting plate 25 which, in turn, is mounted on rods 27 and 29 which are supported at their upper and lower ends by the top member 11 and cross member 13, respectively. Sleeves 31 are utilized to attach the plate 25 to the rods 27 and 29 so that the plate 25 can slide freely up and down the rods. A screw jack shaft 33 having a bottom thrust bearing 35 is journaled for rotation on the cross member 13 and is threaded on a pinion 37 which is fastened to the base plate 25 by bracket 38 which permits the pinion to rotate but to not move vertically with respect to plate 25. Thus, if the pinion is held and shaft 33 rotated or if the shaft is held and the pinion rotated, plate 25 will be raised and/or lowered. Shaft 33 can be rotated by means of handwheel 39 acting through the miter gears 41. The handwheel 39 is employed when a rapid vertical motion is desired such as in the initial setting up of a run. In order to provide for a slow withdrawal motion as a crystal is being formed, a motor 43 is attached to the plate 25 with a step down gear box 45 terminating in a worm 47 which engages pinion 37. In this way a rapid motion is provided for initial setup as well as a very slow withdrawal motion for use during crystal growth, the latter being programmed to a desired speed.

The crystal is grown on the bottom end of rod 49 which is held by a chuck 51 on shaft 53. A geared down motor 55 mounted on plate 25 is employed to rotate the shaft 53 and thus the rod 49. In this manner, the rod 49 on which the crystal is being grown can be rotated at any desired speed completely independent of the up and down motion of the carrier plate 25.

The chamber assembly 19 comprises a double walled vessel 56 having a large bottom portion 57 and a reduced top portion 59. Water is introduced between the two walls of the vessel through a connection 61 and is withdrawn through the upper portion at 63 to prevent the walls of the vessel from getting inconveniently hot. Rod 49 passes through a Teflon (polytetrafluoroethylene) bearing 62 in top plate 64. The top plate is preferably cooled by water tubes 68. A furnace bottom plate 65 rests on the bottom support plate 17 and the bottom of vessel 56 is provided with a gasket 67 and held in air-tight relationship with the furnace bottom plate by means of clamps 69. The vessel 56 is provided with a gas inlet 73 and a gas outlet 71 so that the interior of the vessel can be continuously flushed with an inert gas such as argon.

Within the chamber 56 a quartz crucible 75 is mounted in a graphite holder 77 which, in turn, is mounted on a shaft 79, preferably of stainless steel. The upper portion of the shaft can advantageously be made of a ceramic material as at 81 for heat insulation. Shaft 79 is mounted for rotation between ball bearings 83 and 84. An outer tube 91 is mounted on furnace bottom plate 65 and at its lower end has a Teflon seal 93 to keep air from entering the furnace chamber through bearing 83. Shaft 79 also has a pulley 95 which is driven by motor 97 with speed reducer 99 acting through a belt 101. Thus motor 97 serves to rotate shaft 79 and thus the crucible 75. The reason for placing the bearings and seal far down on the shaft 79 is to get away from the extreme temperatures encountered in the top part of the shaft.

In order to heat the crucible, a graphite heating element 103 surrounds the crucible, the graphite heating element 103 being in the form of a double helix with opposite ends of the helix being attached to brackets 105 and 107 which are, respectively, attached to rods 109 and 111. The rods and brackets serve both to mechanically support the heater and to supply electricity thereto by means of the connections 113 and 115 which lead to a suitable source of low voltage, high amperage current such as transformer 116. A heat shield 117, suitably of a ceramic material, surrounds the heating element and is also supported on the brackets 105 and 107. The lower ends of the rods 109 and 111 pass through bearings 19 in a plate 121 which is attached to the tube 91. Similar bearings 123 are provided where the upper portions of the rod pass through the bottom plate 65. The bearings 119 and 123

are of an inert plastic material, such as Teflon so that the bearings serve the dual purpose of allowing the rods to slide up and down and also act as insulators. The heating assembly is provided with both a manual fast motion and an electrical slow motion similar to that employed for raising and lowering the crystal growth rod. Thus, a jack screw **125** is mounted in a thrust bearing **127** on an insulated arm **129** which is clamped to the rods **109** and **111**. The jack screw **125** also passes through the threaded bore of a pinion **131** which is mounted for rotation on a plate **133** attached to the lower end of outer tube **91**. A worm **135**, driven through shaft **137** by motor **139** serves to provide the desired slow, constant motion. A handwheel **141**, acting through shaft **143** and miter gears **145**, provides a manual, rapid motion for use in initially setting up a run.

An optical pyrometer **147** is mounted on bracket **149** at the bottom of the outer tube **91** and sights upwardly through the inner tube **79** to the bottom of the crucible support **77**. In this way a constant check can be run on the temperature of the crucible.

The vessel **56** may be provided with a double observation window **151** through which the operation can be observed and also through which samples can be periodically taken of the melt. The structure of this window forms the subject matter of a separate patent application and is not described here in detail.

In utilizing the apparatus, the crucible **75** would be first filled with the material to be crystallized such as hyperpure silicon to which has been added a small amount of a doping substance. A seed crystal of the material to be crystallized would then be attached to the lower end of the rod **49**. The chamber would be flushed with an inert gas and the heating element **103** brought substantially even with the top of the crucible. Current would then be turned on in the heating element **103** and the contents of the crucible liquefied. The rod **49** would be slowly rotated in one direction, while the crucible assembly would be rotated in the opposite direction, as is shown by the arrows in FIGURE 2 and the seed crystal then dipped into the melt utilizing the rapid, manual motion provided through handle **39**. Motor **43** would then be started, pulling the rod slowly away from the surface of the melt, causing a crystal **153** to form. Motor **139** would also be started causing the heating element to be slowly lowered corresponding with the lowering of the surface of the melt in crucible **75** as the crystal **53** is formed and withdrawn. Since the crystal is formed from

supercooled molten material at the surface of the melt, it is important that the heat source be lowered since if too high a surface temperature were maintained, no crystal would be formed.

Although I have described a specific embodiment of my invention and its method of operation, it will be understood by those skilled in the art that many departures can be made from the exact structure described without departing from the spirit of my invention. For instance, some or all of the electric motors may be eliminated and the device operated by hand. Further, instead of lowering the heating element, the crucible and crystal growth rod could be raised to achieve the same effect.

I claim:

1. A crystal growing furnace comprising in combination a double walled vessel including a top-hat portion down through which a seed crystal is introduced and a lower wider portion extending downwardly therefrom and surrounding a crucible, means for maintaining a flow of a cooling fluid between said walls, means for heating and rotating said crucible within said vessel, said crucible having a melt therein, means for rotating said seed crystal in the opposite direction from said crucible within said vessel and in contact with said melt, means for slowly withdrawing said seed crystal from said melt, means for maintaining a heating zone around said melt and means for lowering said heating zone as the surface of the melt is lowered due to a crystal being withdrawn therefrom.

2. The structure of claim **1** wherein an inert atmosphere is provided in the vessel to surround the melt and the crystal being grown.

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