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METHOD OF AND APPARATUS FOR PRODUCING SEMICONDUCTOR MATERIAL

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Fig. 1

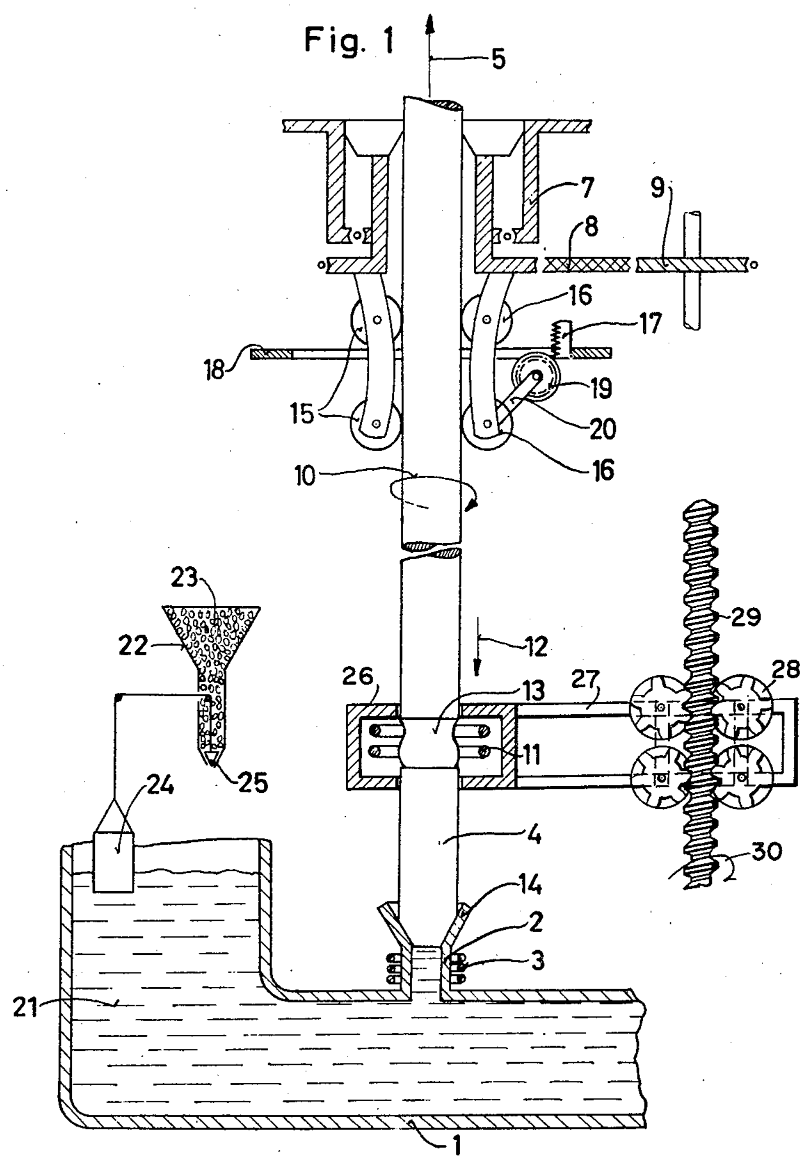

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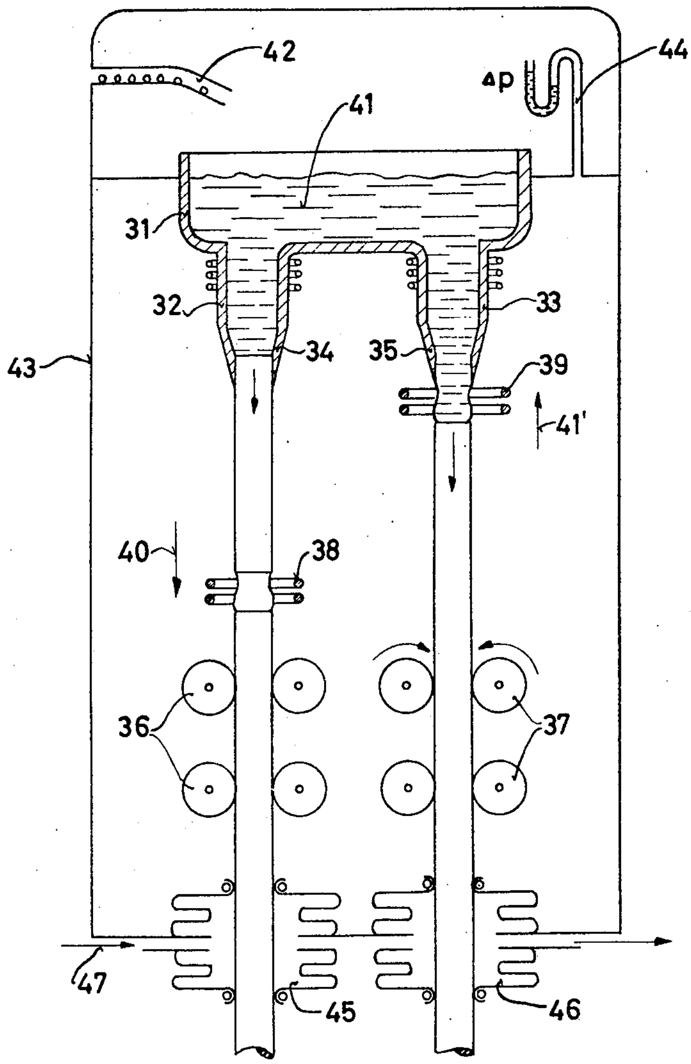
Fig. 2



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METHOD OF AND APPARATUS FOR PRODUCING SEMICONDUCTOR MATERIAL

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10 Claims. (Cl. 148—1.5)

This invention is concerned with a method of and apparatus for producing semiconductor material by drawing rodlike bodies from a melt and applying zone melting to said bodies, all in one working operation.

Copending application of Karl Siebertz Serial No. 409,420 filed February 10, 1954, having a common assignee, which describes a method of and apparatus for successively melting and solidifying semiconductor material in zones, applied primarily for purification purposes to an elongated preferably rodlike substantially perpendicularly disposed body fastened at its opposite ends, the melting zone being so small that it is supported by the adjacent solidified portions by adhering thereto. The advantage of the procedure is that it does not require a crucible, thereby avoiding contaminations which would otherwise result from the crucible material. The disadvantage—with the rod fastened at its ends—is that only one melting zone can be processed at any time. The procedure is, as compared with zone melting in a crucible, time consuming because it must be repeatedly applied while zone melting by means of a crucible, for example, a carbon well permits simultaneous processing of several melting zones. The simultaneous processing of several melting zones is in principle also possible with the rodlike body perpendicularly held at its ends provided that the rod is additionally supported at intermediate points, but these additional supports must be removed at the instant of passage of the melting zones through the corresponding regions.

The thought underlying the invention resides in recognition of the fact that the purification according to the zone melting process is the more effective the more the structure of the body to be purified approaches that of a monocrystal, the purification being most effective in the case of an ideal monocrystal.

The invention utilizes this fact by applying the zone melting described in the previously mentioned copending application directly and immediately upon drawing of crystals, especially monocrystals, from a crucible, thus combining the zone melting with the drawing in one working operation. The invention thereby contemplates to support the crystal, preferably a monocrystal, drawn from the crucible, at two widely separated points and to subject intervening areas to the zone melting. The operation according to the invention results not only in the advantage already mentioned, of accelerating the purification by the zone melting, but, in a particular embodiment, in giving the possibility to operate the zone melting in a continuous process. The supporting points are thereby to be altered, steadily or abruptly, in accordance with the length of the crystal drawn from the crucible. The speed at which the melting zone is drawn is to be matched to a certain extent with the speed at which the crystal is drawn from the crucible. However, inasmuch as the speed of drawing depends in part on the thickness of the rod, it will in some cases be necessary or suitable to interrupt or to slow down the crystal drawing at least

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for some intervals until the melting zones have been drawn once or several times through a predetermined portion of the rod-shaped crystal.

The foregoing and other objects and features of the invention will appear from the description which is rendered below with reference to the accompanying schematic drawings, wherein—

Fig. 1 shows an embodiment for drawing a crystal rod from a crucible in upward direction; and

Fig. 2 illustrates an embodiment for effecting the drawing of a crystal rod in downward direction.

Referring now to Fig. 1, numeral **1** indicates a crucible made for example of graphite, containing molten silicon or germanium **21**. The crucible **1** is provided with an extension **2** which is separately heated by means of a coil **3**. The crystal **4** is in known manner drawn from the extension **2** in the direction of the arrow **5**. Rollers **15** and **16** movably journalled in a bearing **7** are provided to support the upper end of the crystal **4**. Numeral **8** indicates a belt extending from a drive roller **9** for rotating the rollers **15** and **16** to rotate the crystal rod **4** in the direction of the arrow **10**. The crystal drawing is otherwise effected in known manner.

In accordance with the invention, there is provided a heating device **11**, formed as an annulus, adapted to melt a narrow zone of the crystal rod **4**. This heating device **11** may be disposed within a casing **26** provided with arms **27** carrying worm wheels **28** meshing with a worm **29**, and may be displaced, for example, downwardly, in the direction of the arrow **12**, by rotating the worm **29** in the direction of the arrow. The consequently produced melting zone **13** is thereby drawn downwardly along the solidified portion of the drawn monocrystal, effecting purification, and contaminations are deposited at the lower end engaging the flaring mouth **14** of the extension **2**. The process is likewise employed in Fig. 2 though by opposite movement.

The pair of rollers **15—16** also serve for moving the crystal rod **4** upwardly. There is provided, for this purpose, a ratchet **17** supported on an annular carrier **18** which may be displaced downwardly, by suitable not illustrated means, to rotate a gear wheel **19** for correspondingly rotating the rollers **16** through the medium of a link **20**, thereby advancing the crystal rod **4** upwardly.

The operation is as follows:

The heating coil **3** is in suitable manner connected to a current source, heating the neck of the extension **2**. The crystal rod **4** is now drawn from the crucible **1** in known manner. The drawing operation is thereupon interrupted and the heating coil **3** is at the same time disconnected. A portion of the melt within the extension **2**, at least within the flaring mouth **14**, accordingly solidifies. The crystal rod **4** is thus fixedly supported at the bottom while being held at the top by the roller pairs **15—16**. The heating coil **11** is thereupon moved from the upper end downward to the flaring mouth **14** of the extension **2**, the melting zone **13** moving along the rod **4**. This operation may be repeated, if desired. Upon conclusion of the zone melting, the heating coil is again connected to current. As soon as the material in the extension **2** and at least in part of the flaring mouth **14** has melted, the crystal drawing is continued, followed by zone melting, etc.

Upon remelting the material contained in the flaring mouth **14** of the extension **2**, the contaminations collected therein, extracted in the zone melting, will enter into the melt **21** in the crucible **1**, resulting in continually enriching the melt with contamination products. This effect is in part counteracted by continuously delivering to the melt **21** purified semiconductor material **23** from the supply receptacle **22**, such delivery being automatically effected by means of a float 24 controlling a valve 25 disposed at the bottom of the receptacle 22. If desired, the contaminated melt may be drawn off at another point of the crucible, shown broken away at the right side, before delivering the new melt material.

It is in this manner possible to draw in a continuous process crystal rods 4 of desired length and uniform purity as well as crystalline structure. Portions of the crystal rod produced may be cut off at the upper end as desired or required.

The embodiment described above may be modified in several ways. Thus, several supporting means corresponding to the pairs of rollers 15—16 may be provided, and several melting zones such as 13 may be arranged for simultaneous drawing relative to the crystal rod. The heating coil 3 may under some circumstances be omitted and its function may be effected by the heating coil 11. Additional supporting elements may be disposed at the lower end, and means may be provided for moving all supporting elements in the direction of drawing for the purpose of effecting a continuous drawing operation while simultaneously applying the zone melting.

Fig. 2 shows a modification in which the semiconductor crystal, if desired a monocrystal, is drawn downwardly from a melt 41 contained in a crucible 31. Rods are continuously drawn downwardly from the extensions 32 and 33. These rods may be supported at their ends by means corresponding to the elements described in connection with Fig. 1. In the present case, there are provided tapering extensions 34 and 35. The functions of the pairs of rollers 36 and 37 shown in Fig. 2 correspond to those of the rollers 15—16 of Fig. 1. The melting zones produced by the heating coils 38 and 39 are moved relative to the two rods, by suitable not illustrated means, in opposite directions as indicated by arrows 40 and 41'. Contaminations are in this manner respectively transported to the lower end of the left hand crystal rod and to the upper end of the right hand rod. The right hand crystal rod is produced for further processing, while the left hand rod serves for regaining melt material which is delivered to the crucible 31 along the path 42. The apparatus is encased in a housing 43 containing a suitable protective gas, preferably under pressure, to avoid dropping off of melt at the openings of the extensions 34 and 35. Numeral 44 indicates a manometer and 45 and 46 are locks or gates for the protective gas flowing in the direction of the arrow 47 to prevent ingress of air into the housing 43.

The arrangement according to Fig. 1 may be modified to provide for dual rod operation by employing features analogous to those incorporated in Fig. 2.

Changes may be made within the scope and spirit of the appended claims.

We claim:

1. A method of producing elongated generally rod-shaped semi-conductor crystal bodies, comprising drawing a crystal body from a melt contained in a crucible while supporting said drawn crystal body at its ends, one end of said crystal body being in operative contact relation with the melt while subjecting said one end to heating, subjecting an intermediate area of said crystal body immediately upon conclusion of the drawing thereof to zone melting, and moving relative to said crucible the consequently produced melting zone along the solidified portion of the drawn crystal, effecting purification and causing deposit of contaminations at the end of said crystal body in contact with the melt.

2. A method according to claim 1, comprising continuously delivering melt material to said crucible.

3. A method according to claim 1, comprising alternately drawing and zone melting said crystal body.

4. A method according to claim 1, comprising continuously drawing said crystal body and continuously zone melting portions of said drawn crystal body at a speed adapted to the speed of drawing.

5. A method according to claim 1, comprising drawing said crystal body from said crucible in upward direction.

6. A method according to claim 1, comprising drawing said crystal body from said crucible in downward direction.

7. A method according to claim 5, comprising heating said crystal body during said drawing at a point adjacent the melt in said crucible, said crystal body solidifying at said point so that the solidified body is supported adjacent the melt during the subsequent zone melting thereof.

8. A method according to claim 6, comprising heating said crystal body during said drawing at a point adjacent the melt in said crucible, said crystal body solidifying at said point so that the solidified body is supported adjacent the melt during the subsequent zone melting thereof.

9. Apparatus for producing semiconductor crystal bodies, comprising a crucible adapted to contain molten semiconductor material, a funnel-shaped extension projecting upwardly from said crucible, means for vertically upwardly drawing an elongated generally rodlike crystal body from said melt contained in said crucible, means for heating the material in said extension during drawing of said crystal body, the material in said extension partially solidifying to serve as a support for said drawn crystal body at the lower end thereof with such lower end in operative contact relation with the melt in said crucible, means for supporting the drawn crystal body at the upper end thereof, and vertically movable heating means concentric with said rodlike crystal body and intermediate the ends of said body for subjecting said body to zone melting immediately after the drawing thereof from said melt.

10. Apparatus for producing semi-conductor crystal bodies, comprising a crucible containing molten semi-conductor material, means for vertically drawing an elongated generally rodlike crystal body from said melt contained in said crucible, guide rollers in engagement with said drawn crystal body, said guide rollers forming part of said drawing means, means for rotating said guide rollers about the axis of said crystal body to rotate such body, means for positively rotating a predetermined guide roller to move said crystal body relative to said melt with one end of said body in operative contact relation with said melt, heating means comprising a heating coil concentric with the rodlike crystal body and intermediate the ends thereof for subjecting said crystal body to zone melting immediately after concluding the drawing of said body from said melt, and means for moving said heating means longitudinaly of said crystal body.

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