

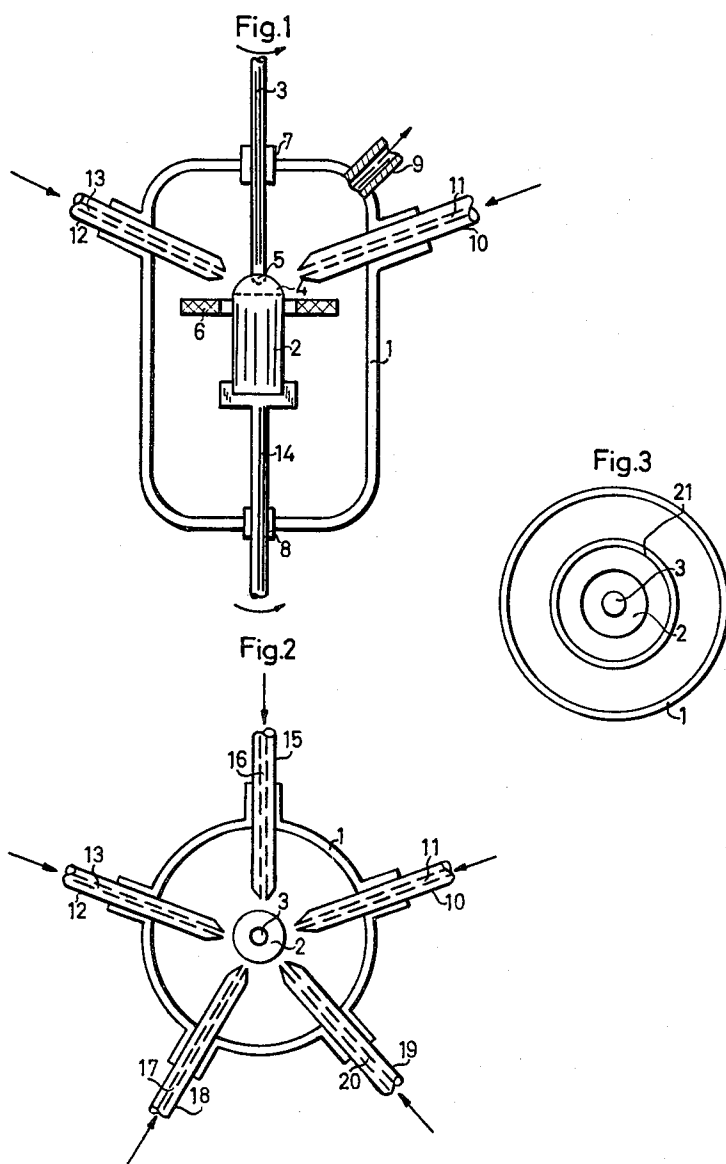
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PRODUCTION OF HIGHLY PURE SINGLE CRYSTAL SEMICONDUCTOR RODS

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PRODUCTION OF HIGHLY PURE SINGLE CRYSTAL SEMICONDUCTOR RODS

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9 Claims. (Cl. 23—223.5)

This invention is concerned with producing highly pure single crystal semiconductor rods, especially silicon rods, by separation of the semiconductor material in a glow-arc discharge, comprising dipping into a drop-shaped highly pure semiconductor melt a thin single crystal of the semiconductor material having a cross-sectional area which is small as compared with the surface area of the melt, and thereupon moving the single crystal from the melt, resulting in the drawing of a thin semiconductor rod, the drawing speed being such that substantially as much semiconductor material solidifies at the drawn rod as is newly formed at the surface of the molten zone by thermal decomposition of a highly pure gaseous compound of the semiconductor material.

When the molten zone is inductively heated to the decomposition temperature of the gaseous compound of the semiconductor material which is conducted into the reaction vessel, silicon from the gaseous compound will under some circumstances be deposited not only upon the surface of the molten zone but also upon colder parts.

The method according to the invention avoids this drawback. In accordance with a characteristic feature of the invention, the molten zone itself forms one electrode of one gas discharge or of a plurality of gas discharges, preferably glow-arc discharges, and the highly pure gaseous compound of the semiconductor material is injected in the direction of the molten zone.

The gaseous compound of the semiconductor material, subjected to the gas discharge, is decomposed and the semiconductor material to be obtained is precipitated upon the electrodes, that is, when using a direct current discharge according to the invention, upon the one electrode which is formed by the molten zone and connected as cathode.

The advantage of using a glow-arc discharge which constitutes a special form of the arc discharge is, that the discharge does not impact the cathode as a focal point but distributed over a relatively large area, resulting in a correspondingly large area of the zone of the semiconductor which is thereby brought to melting temperature and, accordingly, in a large-area reaction zone. The heat development at the cathode and also the decomposition of the reaction gas are moreover better effective in the high cathode drop of the glow-arc discharge.

The invention proposes to provide for advantageously uniform heating of the melting zone and uniform separation of the semiconductor material, a plurality of counter electrodes (anodes) disposed circularly distributed about the melting zone and connected with positive potential, resulting in a plurality of parallel effective glow arc discharges. In order to favor the separation at the melting zone, the gas stream containing the silicon compound is introduced into the reaction vessel so that it is advantageously confined to the immediate neighborhood of the counter electrodes and aimed in the direction of the melting zone. It is particularly advantageous to provide tubular counter electrodes and to introduce the reaction gas therethrough.

The various objects and features of the invention will appear from the description which is rendered below with reference to the accompanying drawing, in which

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FIG. 1 is a longitudinal sectional view of apparatus for practicing the invention;

FIG. 2 is a transverse sectional view of the apparatus assuming the use of five counter electrodes; and

FIG. 3 shows in transverse sectional view an embodiment in which a closed ring-shaped member is used as a counter electrode.

Referring now to FIG. 1, the electrodes, serving as anodes in the glow-arc discharge, extend laterally of the melting zone at which is effected the decomposition of the highly pure gaseous compound of the semiconductor material. Sealed into the reaction vessel 1 which may, for example, be made of quartz, are the gas discharge conduit 9 and the counter electrodes (anodes), of which two are shown in schematic sectional view and designated by numerals 10 and 12. Within the vessel is arranged a polycrystalline rod 2 of semiconductor material, at the upper end of which is formed the melting zone 4 into which is dipped the single crystal seed 5. From this melt at which the continuously introduced gas mixture containing a gaseous semiconductor compound is decomposed, is drawn the thin single crystal rod 3. A coil 6 may be arranged in the reaction vessel, producing an electromagnetic field for supporting the melting zone. The thin semiconductor rod 3 may be disposed rotatably and axially movable so as to obtain desirable temperature distribution and continuous adjusted removal of the rod in accordance with the growth thereof.

Smooth, cylindrical semiconductor single crystal rods are in this manner produced which may be drawn from the reaction vessel by way of the schematically indicated sealing bushing 7. The mounting 14 of the relatively thick semiconductor body 2 is likewise carried to the outside by means of a sealing bushing 8.

FIG. 2 shows a transverse section of the arrangement employing, for example, five counter electrodes 10, 12, 15, 18 and 19 sealed into the reaction vessel, thus providing for a plurality of parallel effective glow-arc discharges. These counter electrodes are arranged circularly about the melting zone in order to obtain uniform heating and uniform separation of the desired semiconductor material. The uniform heating and material separation may be supported for example, by rotation of the melting zone. The counter electrodes are advantageously made of copper and may be water-cooled by suitable means (not shown) so as to prevent precipitation of semiconductor material thereon. In the illustrated example, the counter electrodes are tubular, providing ducts 11, 13, 16, 17 and 20 for directing the reaction gas to the melting zone so as to favor separation thereat.

FIG. 3 shows a further embodiment in which the counter electrode is formed by a closed ring-shaped member 21 which faces the melting zone, the single crystal being drawn therethrough. A suitable gas inlet must be provided for the reaction vessel. In order to secure in such case a uniform distribution of the heating and to avoid concentration and localization of the glow-arc discharge, the glow discharge is rotated by a magnetic field arranged substantially radially or perpendicularly to the direction of the current thereof. The potential gradient of the glow-arc discharge is thereby increased and the decomposition of silicon compound is favored, that is, the amount of semiconductor material separated in a time unit is increased.

It is understood, of course, that doping substances may be added to the gaseous semiconductor compound so as to permit drawing of a single crystal of defined conductivity type or, by intermittent addition of doping substance to the reaction gas, drawing of a semiconductor rod with desired pn-junctions.

Changes may be made within the scope and spirit of

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the appended claims which define what is believed to be new and desired to have protected by Letters Patent.

I claim:

1. The method of continuously growing in a continuous operation a highly pure relatively thin single crystal rod-like semiconductor body from a melt of said semiconductor material, comprising producing within a reaction vessel between one end of a main electrode consisting of said semiconductor material and at least one counter electrode a glow-arc discharge to form said melt at said one end of said main electrode in the form of a substantially drop-shaped molten zone, said electrodes being disposed to produce substantially uniform heating of such molten zone by said glow-arc discharge, dipping into said melt the end of a relatively thin seed member consisting of said semiconductor material and having a cross-sectional area which is small as compared with the surface area of said drop-shaped melt, directing onto said drop-shaped melt a highly pure gaseous compound of said semiconductor material to continuously supply the melt therewith, said gaseous compound decomposing thermally by the action of said glow-arc discharge to effect continuous deposit of said semiconductor material upon said drop-shaped melt, and continuously withdrawing said body from said drop-shaped melt to cause molten material to solidify thereon at a rate which corresponds substantially to the rate at which said semiconductor material is deposited on said melt by the thermal decomposition of said gaseous compound.

2. A method according to claim 1, wherein the glow-arc discharge is a direct current discharge, said drop-shaped melt forming the cathode for such discharge.

3. A method according to claim 2, wherein a plurality of glow-arc discharges are effected between said cathode formed by said drop-shaped melt and a plurality of counter electrodes arranged about said melt.

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4. A method according to claim 3, wherein said counter electrodes are tubular, said gaseous compound of the semiconductor material being supplied through said tubular counter electrodes.

5. A method according to claim 4, comprising the step of cooling said counter electrodes.

6. A method according to claim 1, wherein said glow-arc discharge is effected between said drop-shaped melt and a circular counter electrode disposed about said melt.

7. A method according to claim 1, comprising the step of rotating said main electrode carrying said drop-shaped melt.

8. A method according to claim 1, comprising the step of supporting said drop-shaped melt by an electromagnetic field.

9. A method according to claim 1, comprising the step of applying the effect of a magnetic field which is operative radially of the main electrode and perpendicularly of the direction of the glow-arc discharge.

References Cited in the file of this patent

UNITED STATES PATENTS

2,631,356	Sparks et al. _____	Mar. 17, 1953
2,768,074	Stauffer _____	Oct. 23, 1956
2,854,318	Rummel _____	Sept. 30, 1958
2,892,739	Rusler _____	June 30, 1959

FOREIGN PATENTS

1,125,277	France _____	July 9, 1956
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OTHER REFERENCES

Nelson: Article in "Transistors I," RCA Laboratories, pages 66-76, March 1956.