

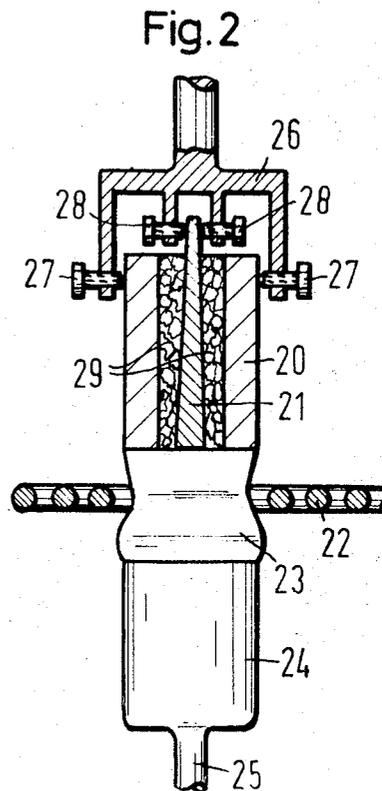
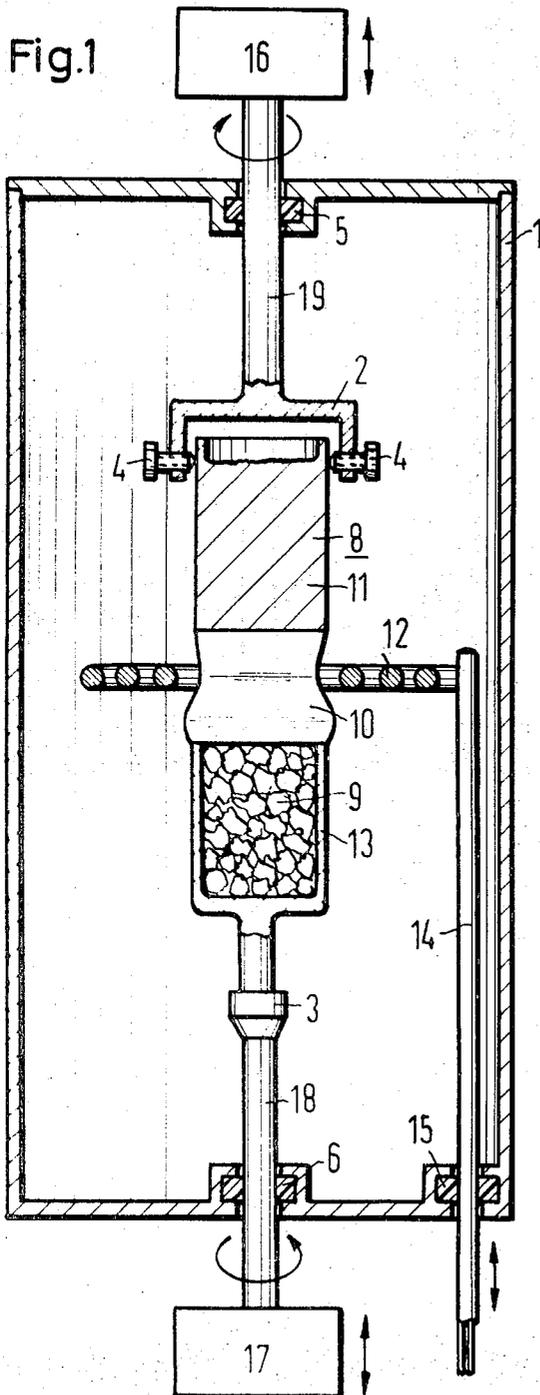
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METHOD OF PRODUCING HOMOGENEOUS RODS OF SEMICONDUCTOR MATERIAL

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METHOD OF PRODUCING HOMOGENEOUS RODS OF SEMICONDUCTOR MATERIAL

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8 Claims

ABSTRACT OF THE DISCLOSURE

A perpendicular tube of semiconductor material is filled with crystalline semiconductor waste and/or dopant. A molten zone is guided through the tube and the filling, whereby the filling fuses with the tube.

The present invention relates to a method for producing, by melting, homogeneous rods of semiconductor material.

Such methods are widely known. In one of these methods, the semiconductor material is first pyrolytically precipitated from a gaseous compound, upon heated rod shaped carrier bodies. The carrier bodies are usually of the same semiconductor material and may be more or less heavily doped. Following precipitation of semiconductor material, a rod is obtained whose interior is doped, but whose outer layers are not doped. The dopant is then uniformly distributed by means of the known, crucible-free zone melting process so that a low doping is now uniformly established over the entire cross section. A plurality of rod shaped carrier bodies can be produced from this rod, e.g. by pulling thin. Semiconductors can be precipitated from the gaseous phase, upon said carrier bodies. This process, which comprises the alternate steps of precipitation and zone melting, may be continued until the desired homogeneous doping is obtained. However, the method is relatively cumbersome, and has the additional disadvantage that cutoff parts of semiconductor material cannot be used.

The cutoff or waste pieces are, therefore, molten in a crucible and a rod is pulled therefrom, by the Czochralski method. The dopant necessary for the basic doping can also be placed into the crucible and becomes installed into the rod, during the pulling from the melt. The crucible method has the disadvantage, however, that the impurities which are present in the crucible will also become installed in the rod. Thus, for example, oxygen will penetrate to a considerable degree, into the semiconductor material when the crucible is made of quartz.

It is an object of the present invention to provide a method of the aforescribed type, which makes it possible to utilize the waste material and/or to obtain the desired doping in a simple manner, without having to accept the above-indicated shortcomings.

The invention is characterized by the fact that a substantially perpendicularly positioned tube of semiconductor material, which is held at both ends and has a sealed bottom, is provided with a filling of crystalline semiconductor pieces and optionally with doping material. The term "perpendicularly" used herein and in the claims also include substantially perpendicular. A molten zone is introduced through said tube into the filling and the parts lying on both sides of the molten zone are rotated, relative to one another, during the melting. The filling may consist of doped or undoped pieces of semiconductor material. If a filling, consisting of undoped pieces of semiconductor material is used, it is recom-

mended to place a rod which contains dopant, into the tube. This rod is at least almost as long as the tube. A rod containing only dopant and being at least almost of the same length as the tube, may also be inserted into said tube. The rod is, preferably, conical. The melting zone can be also moved from the melting point of a monocrystal, through the tube and the filling. Thus, the semiconductor rod may be transformed into a monocrystal, while simultaneously obtaining homogeneous qualities.

The invention will be disclosed in greater detail, with reference to the drawing, wherein:

FIG. 1, schematically, illustrates partly in section one embodiment of the invention; and

FIG. 2, schematically, illustrates partly in section a second embodiment.

The device of FIG. 1 has a vacuum tight housing 1. Two holders 2 and 3, between which a tube 8 of semiconductor material is clamped, are provided in the housing 1. The holder 2 has screws 4, which hold the tube 8 in its position. Holder 2 is connected with a shaft which leads through a packing seal 5 to a drive unit 16. The shaft 19 may be rotated by the drive unit as well as be shifted along its axis. This is indicated by the arrows. In a similar manner, holder 3 is connected to a drive unit 17, via a shaft 18, that is led through packing seal 6. The drive unit 17 rotates the shaft 18 into rotation and shifts it along its axis. The device also contains a high frequency coil 12, which is connected via a lead 14 through packing 15, with a high frequency generator (not shown), positioned outside the housing 1. The coil 12 produces, with the aid of HF energy, a melting zone 10. A part 11 of the rod to be produced is seen above the molten zone 10. Below the molten zone 10 is a portion 13 of the original tube. This portion 13 is filled with pieces 9 of semiconductor material, such as waste, for example.

The method is performed by first placing the high frequency coil 12 near the upper end of the tube 8. A part of the tube and of the filling is then molten, at the same time, parts 11 and 13 are turned, oppositely, relative to each other, at a r.p.m. of 5 to 100, preferably about 40 r.p.m. This provides a homogeneous distribution of the material in the rod being produced. If, for example, the tube 8 consists of undoped material and if pieces of doped semiconductor material are located among the filling 9, the rod will obtain a homogeneous distribution and an appropriate quantity of doping. According to the space filling degree of the filling 9 which is smaller than 1, the holders 2 and 3 must be moved toward each other from the top downward as the molten zone advances so that the diameter of the rod remains equal over the entire length. To this end, either the holders 2, 3 may be moved independently or both holders may be moved at the same time. This is effected by drives 16 or 17 or 16 and 17. The distance through which the holders must be moved, can be determined by a regulator, not shown in the drawing, which regulates the melting zone 10 to a constant volume. This type of regulating method is described, for example, in German Pat. No. 1,153,908. Here, the high frequency coil is a component of an oscillatory or resonant circuit, whose inductivity is fundamentally determined by the volume of the melting zone and by the coil, itself. A frequency impressed upon the resonant circuit, lines in the slope of the resonance frequency of the resonant circuit. If the inductivity of the resonance circuit is altered through an increase or a decrease in the volume of the melting zone, the resulting voltage change is used as a controlled quantity for shifting the holders 2, 3, via the drive units 16 and 17, respectively. This type of control ensures that the volume of the melting zone

remains constant and that the rod to be produced, has the same cross section, at each location.

If the tube and the filling are made of silicon, a melting temperature of about 1420° C. is established. The tube may be 20 to 80 mm. thick and have a wall thickness of 1 to 5 mm. The speed of the melting zone is preferably 0.5 to 5 mm. per minute.

The method was described with reference to an embodiment which shows the melt being moved from the top down. It is also possible to move the melt, from below upward, through the tube and the filling. This creates a rod which issues from below, while the tube, respectively, the remnant of the tube is situated above the melt. The tube can be efficiently held by a holding device so that the filling 9 does not sink into the melt; as it must be firmly pounded or pressed into the tube.

FIG. 2 shows another embodiment of the invention. Only the essential parts are illustrated, while the drive members, the housing, etc. were omitted for the sake of simplicity. The device has a tube 20, which is held in holder 26 by two screws 27. A core 21 which contains doping material is situated in the tube 20. The core 21 is positioned in the holder 20 by screws 28. The tube may also contain a filling 29 of doped and undoped pieces of semiconductor material. The melting coil of this example was given numeral 22; the molten zone numeral 23 and the rod shaped part numeral 24. A crystal 25 with a small diameter which is fused to the lower end of the rod shaped part 24 may, for example, be a monocrystal.

In this embodiment, the melting zone is led through the tube, from below upward. Since the distribution coefficient of most dopants, such as, for example, gallium, arsenic, antimony, is less than 1, meaning that less dopant is dissolved in solid semiconductor material than in liquid semiconductor material, this would cause the doping of the rod to increase constantly from below, upward. The dopant core 21 is, therefore, constructed in the shape of a cone, with a diameter ratio from below to the top of 3:1 to 2:1. The dopant core consists, preferably, of alloys of semiconductor material with the dopant, such as of Si/P, Si/As, Si/Sb, Si/Ga, etc. The allowing ratio may be varied within wide scopes, according to the level of the basic doping that is already present in the semiconductor rod and according to the weight ratio, between core and rod.

If boron is used for doping, a core comprising an Si/B alloy will be used and will not be conically shaped, since the distribution coefficient of boron in silicon, is approximately equal to 1.

In FIG. 2, the core is shown positioned concentrically to the tube. This is not necessary, however, since zone melting produces a mixing effect, which results in a uniform distribution of the material in the rod.

What is claimed is:

1. A method of producing rods of semiconductor material by zone melting, which comprises holding, perpendicularly to the surface of the earth at both ends, a tube of semiconductor material, having a sealed bottom, said tube being filled with a filling of crystalline semiconductor material pieces and dopant, passing a melting zone comprising semiconductor material through said tube and filling while rotating the part of the tube above the melting zone relative to the part of the tube below the melting zone during the melting process, the tube and the filling being of the same material and being part of the melting zone, and the melting zone being moved over the entire length of the tube.

2. The method of claim 1, wherein a filling of doped semiconductor pieces is within said tube.

3. The method of claim 1, wherein a filling of non-doped semiconductor pieces is within said tube.

4. The method of claim 3, wherein a core is inserted into the filling, said core containing dopant and being of almost as long as said tube.

5. The method of claim 4, wherein the core is conical and has a diameter ratio from bottom to top of 3:1 to 2:1.

6. The method of claim 1, wherein the melting zone is moved through the tube and the filling from the fusion point of a monocrystal located below the tube.

7. The method of claim 1, wherein the molten zone is moved from the top down through the filling and the tube.

8. The method of claim 1, wherein the molten zone is moved from the bottom up through the tube and the filling.

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