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DEVICE FOR MOUNTING SEMICONDUCTOR RODS IN APPARATUS
FOR CRUCIBLE-FREE ZONE MELTING

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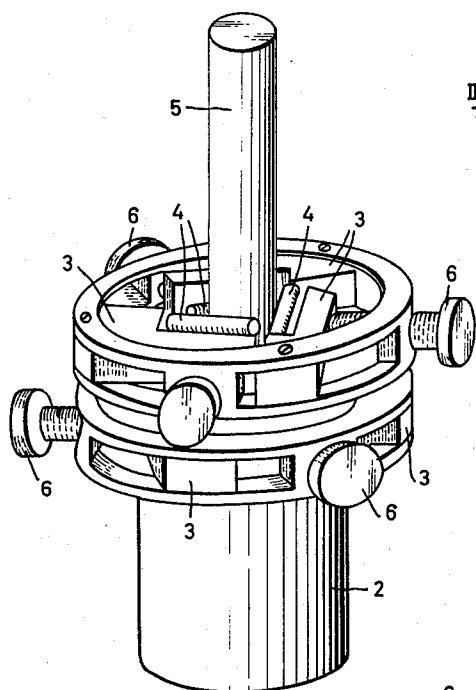


Fig. 1

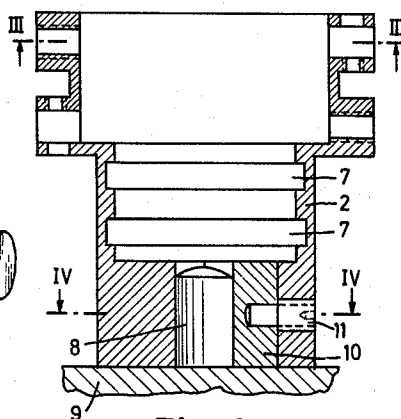


Fig. 2

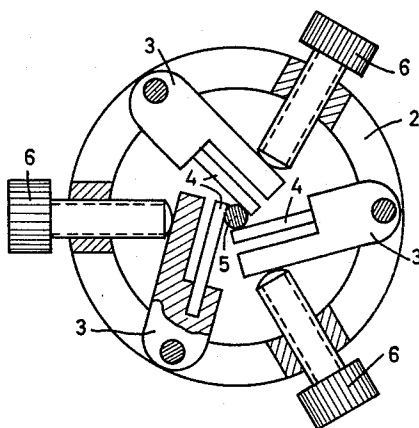


Fig. 3

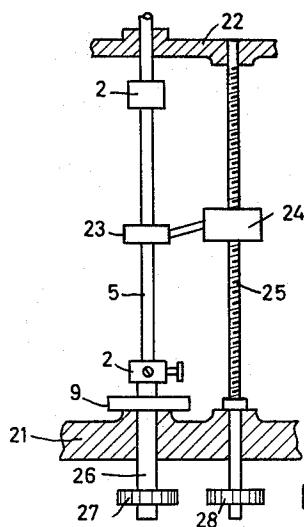


Fig. 5

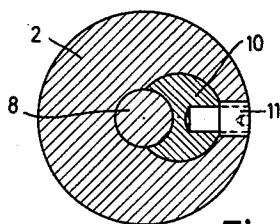


Fig. 4

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3,191,924 DEVICE FOR MOUNTING SEMICONDUCTOR RODS IN APPARATUS FOR CRUCIBLE-FREE ZONE MELTING

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8 Claims. (Cl. 269—156)

My invention relates to apparatus for the processing of rod-shaped bodies of silicon or other semiconductor material by crucible-free zone melting, for such purposes as purifying the semiconductor material, doping it with beneficial impurity atoms, converting it into a monocrystal or modifying its cross-sectional size, to thereby obtain a product desired for the manufacture of rectifiers, transistors, photodiodes and other electronic semiconductor devices.

When performing the crucible-free zone melting operation, also called floating-zone melting, a molten zone of axially narrow size, preferably produced by an induction heater coil surrounding the rod, is caused to travel lengthwise of the rod-shaped body being processed. Impurities are thus transported to one end of the rod, and are partially caused to evaporate into the vacuum in which the zone melting is carried out in most cases. When using the method for producing a monocrystal, a crystal seed is fused to one end of the semiconductor rod to be processed, and the melting zone is repeatedly caused to travel through the length of the rod, always starting from the fusion junction. In most cases the rod-shaped body is vertically mounted and has its ends clamped in two holders which keep the rod in proper position during zone melting operation.

The rod holders known for such purposes tend to cause damage to the semiconductor rod or to shift it from the accurate position when the rod expands due to the heat applied thereto. The known holder devices also require the exchange of a fitting sleeve for adapting it to different rod diameters; and some holding devices also tend to dissipate disagreeably much heat to the adjacent parts of the processing apparatus.

It is an object of my invention, to obviate such shortcomings.

According to my invention, the device for holding the semiconductor rod at each end within the zone melting apparatus comprises a hollow carrier body in which three pins are pivotally mounted in each of two parallel planes that extend substantially perpendicularly to the rod axis. The pins consist of refractory material, preferably a high-melting metal, that does not diffuse appreciably into the semiconductor substance of the rod. The holder device further comprises structure for elastically pressing the three pins in each of the two planes against the semiconductor rod, thus securely holding the rod in the correct vertical position.

The foregoing and more specific objects and features of my invention will be described presently with reference to the embodiment of a holder device according to the invention illustrated by way of example on the accompanying drawing, in which:

FIG. 1 is a perspective view of the holder device.

FIG. 2 is an axial section through part of the device.

FIG. 3 is a sectional view onto the plane denoted by III—III in FIG. 2.

FIG. 4 is a cross section along the line IV—IV in FIG. 2; and

FIG. 5 shows schematically two holder devices according to FIGS. 1 to 4 as components of a zone-melting apparatus.

Referring first to the zone melting apparatus shown in FIG. 5, there is shown a base plate 21 and a top plate 22 which form part of a rigid frame structure within a vacuum envelope (not shown) and serve to support two holder devices 2 coaxially spaced from each other for accommodating a semiconductor rod 5 between them. The lower holder 2 is mounted on a plate 9 joined with a shaft 26. A gear 27 on shaft 26 permits rotating the lower holder 2 and thus the lower portion of the semiconductor rod during zone-melting performance. An inductance-heater coil 23 surrounds the rod 5 and is mounted on a support 24 in threaded engagement with a spindle 25 which, during zone melting, is kept in rotation by means of another gear 28. As a result, the inductance coil travels from the lower holder 2 to the upper holder thus passing a melting zone lengthwise through the rod. The inductance coil is then deenergized and returned toward the bottom holder 2, and the zone melting operation is repeated, the zone always travelling in the same direction while the inductance heater is energized for melting operation. The two holder devices 2 are designed as described presently with reference to FIGS. 1 to 4.

The holder comprises a cylindrical carrier body in which a total of six arms 3 are pivotally mounted, each three of them being located in one of two parallel planes axially spaced from the other. The pivot points of the arms 1 in each plane are 60° displaced from those in the other plane. Rigidly fastened to the arms are molybdenum pins 4 in point engagement with the silicon rod 5. Set screws 6 are provided for turning the arms 3 in the direction toward the rod 5. The arms thus press the molybdenum pins 4 firmly but somewhat elastically against the rod so that the rod is virtually rigidly secured to the holder. Due to the angular displacement of the arm pivots in the two planes, the points of engagement between the molybdenum pins 4 and the semiconductor rod 5 are likewise 60° displaced in one plane relative to the other. This readily affords an accurate centering of the semiconductor rod 5 with respect to the rotational axis of the holder 2.

All parts of the holder device, with the exception of the molybdenum pins, are made of a highly alloyed steel containing about 19% chromium and about 9% nickel, such a steel being available in the trade as V2A-steel. This has the advantage that all parts, when being heated, will thermally expand uniformly. The particular alloy steel mentioned is preferable because of its particularly slight thermal conductance. Consequently, the heat dissipation is slight, and the portion of the holder device 2 that is in contact with other parts of the zone melting apparatus, for example with the base plate 21 according to FIG. 5, conducts only little heat to such other parts. This prevents thermally distorting or damaging the connecting parts.

As shown in FIG. 2, additional thermal resistance can be obtained by providing localities of reduced cross section between the molybdenum pins 4 and the surface where the holder structure 2 is in contact with further parts of the zone melting apparatus. Such locations of reduced heat conductance are formed for example by undercutting at 7.

When the semiconductor 5 is heated, due to the heat supplied to the melting zone, it will slightly expand longitudinally. The molybdenum pins 4 are capable of elastically yielding to such elongation without change in position of the semiconductor rod and without breaking or damaging the rod.

The holder device according to the invention affords the clamping of rod-shaped bodies whose diameters differ within a rather large range. In particular, very thin bodies, such as used as crystal seeds for example, can

readily be held in the same device. In this respect, the holder device according to the invention is superior to holders which, as heretofore used in apparatus of this kind, are provided with ceramic sleeves for reducing the heat conductance and in which the semiconductor rod is clamped fast by means of resilient metal strips. With such known devices the ceramic sleeve must be dimensioned in accordance with the diameter of the particular rod to be processed because otherwise no reliable attachment can be secured. Nevertheless it happens frequently in such devices that the resilient metal strips become annealed and softened and that the ceramic sleeves are broken or cracked by thermal expansion so that considerable trouble is encountered during the zone melting process.

The heat transfer from the semiconductor rod to the holder structure 2 due to heat conductance is very slight because the molybdenum pins touch the rod practically only at points and because molybdenum is a relatively poor heat conductor. Other refractory metals, such as tungsten or tantalum may also be employed, but the use of molybdenum in contact with silicon has the further advantage that, at the processing temperatures, no noticeable contamination of the semiconductor material due to diffusion of the molybdenum will occur.

The above-described features also have the effect that the heat, transmitted by radiation, cannot become detrimentally effective at the location where the holder device is joined with other parts of the zone melting apparatus. According to FIG. 4, the holder device is attached to a pin 8 of the plate 9. The attachment is effected with the aid of an insert 10 which is pressed against the pin 8 of plate 9 by a pressure screw 11. It has been found that such fastening reliably prevents loosening of the holder device during operation of the apparatus.

It will be obvious to those skilled in the art, upon studying this disclosure, that holder devices according to my invention can be modified with respect to structural details, without departing from the essential features of my invention and within the scope of the claims annexed hereto.

I claim:

1. A holder device for securing a semiconductor rod in a fixed position during floating zone melting thereof, said holder device comprising a hollow carrier structure having an axis, two groups of three pins of refractory metal pivotally mounted individually on said structure so as to be displaceable toward said axis, the pins of each of said groups respectively being uniformly distributed about said axis in one of two respective axially spaced planes perpendicular to said axis, the pins of one group being angularly spaced from the pins of the other group about said axis, and adjusting means on said carrier structure for separately adjusting the pins of each of said groups of pins respectively so that a rod at the portion held by each said group of pins may be displaced laterally with respect to said axis whereby a semiconductor rod inserted in said holder device so that the axis of the rod is substantially coincident with the axis of said carrier structure is clamped between said pins.

2. A holder device for securing a semiconductor rod in a fixed position during floating zone melting thereof, said holder device comprising a hollow carrier structure having an axis, two groups of three molybdenum pins of elongated shape, each pin having one end pivotally mounted on said structure and a free end extending from the mounted end inwardly and movable toward and away from said axis, the pins of each of said groups respectively being uniformly distributed about said axis in one of two respective axially spaced planes perpendicular to said axis, the pins of one group being angularly spaced from the pins of the other group about said axis, and individual adjusting members on said carrier structure for individually adjusting the distance of said pins from said axis whereby they come into tangential engagement with

a semiconductor rod that is inserted in said device and whose axis is substantially coincident with the axis of said carrier structure.

3. A holder device for securing a semiconductor rod in a fixed position during floating zone melting thereof, said holder device comprising a hollow carrier structure having an axis, two groups of three rigid arms, each arm pivotally mounted on said structure near the perimeter thereof and extending inwardly from the pivot mounting, two groups of three elongated pins of refractory metal, each of said pins having one end attached to respective ones of said arms and extending from the attached end inwardly in generally transverse relation to said axis, the arms of each of said groups of arms and the respective attached pins being uniformly distributed about said axis in one of two respective axially spaced planes perpendicular to said axis, the pins of one group being angularly spaced from the pins of the other group about said axis, and individually adjustable setting members mounted on said carrier structure and engageable with said six arms for individually adjusting the distance of said pins from said axis whereby they come into tangential clamping engagement with a semiconductor rod inserted in said device so that its axis is substantially coincident with the axis of said carrier structure.

4. In a rod holder device according to claim 3, said individually adjustable setting members comprising six set screws in threaded engagement with said carrier structure and arranged in two groups of three, said screws being individually set in pressing engagement with said three arms in each of said two planes.

5. A holder device for securing a semiconductor rod in a fixed position during floating zone melting thereof, said holder device comprising a hollow carrier structure having an axis, two groups of three individually operable clamping units, each of said units having a pivot rotatably joining it with said carrier structure near the perimeter thereof, the pivots of each of said groups of units being uniformly distributed in one of two respective mutually spaced planes perpendicular to said axis, the pivots in one plane being angularly spaced 60° from those in the other plane, each of said units including an elongated pin of refractory metal movable toward and away from said axis, and six individual adjusting members mounted on said carrier structure and engageable with said respective six units for individually adjusting the distance of said respective pins from said axis whereby they come into tangential clamping engagement with a semiconductor rod inserted into said device with the axis substantially coinciding with the axis of said carrier structure.

6. A rod holder device according to claim 3, consisting entirely, except for said pins, of low heat-conductance alloy steel containing about 19% chromium and about 9% nickel.

7. A holder device for securing a semiconductor rod in a fixed position during floating zone melting thereof, said holder device comprising a hollow carrier structure having an axis, two groups of three pins of refractory metal pivotally mounted individually on said structure so as to be displaceable toward said axis, the pins of each of said groups respectively being uniformly distributed about said axis in one of two respective axially spaced planes perpendicular to said axis, the pins of one group being angularly spaced from the pins of the other group about said axis, said carrier structure having portions of reduced cross section adapted for mounting said carrier structure on a support spaced by said portions of reduced cross section from said pins whereby the conductance of heat from said pins to said support is minimized, and individual adjusting members mounted on said carrier structure for individually adjusting the distance of said pins from said axis whereby they come into tangential engagement with a semiconductor rod inserted in said device so that its axis is substantially coincident with the axis of said carrier structure.

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8. A holder device for securing a semiconductor rod in a fixed position during floating-zone melting thereof, said holder device comprising a hollow carrier structure having an axis, two groups of three individually operable clamping units respectively, each of said units having a pivot rotatably joining it with said carrier structure near the perimeter thereof, the pivots of each of said groups of units respectively being angularly spaced 120° from each other in one of two respectively mutually spaced planes perpendicular to said axis, each of the pivots of one of said groups of units being located angularly intermediate two of the pivots respectively of the other of said groups of units, each of said units including an elongated pin of refractory metal movable in the respective plane toward and away from said axis, and two groups of three individual adjusting members respectively mounted on said carrier structure and engageable individually with said respective two groups of three units for individually adjusting the distance of the respective pins from said axis whereby said pins come into tangential clamping en-

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agement with a semiconductor rod inserted in said device with its axis substantially coinciding with the axis of said carrier structure.

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