

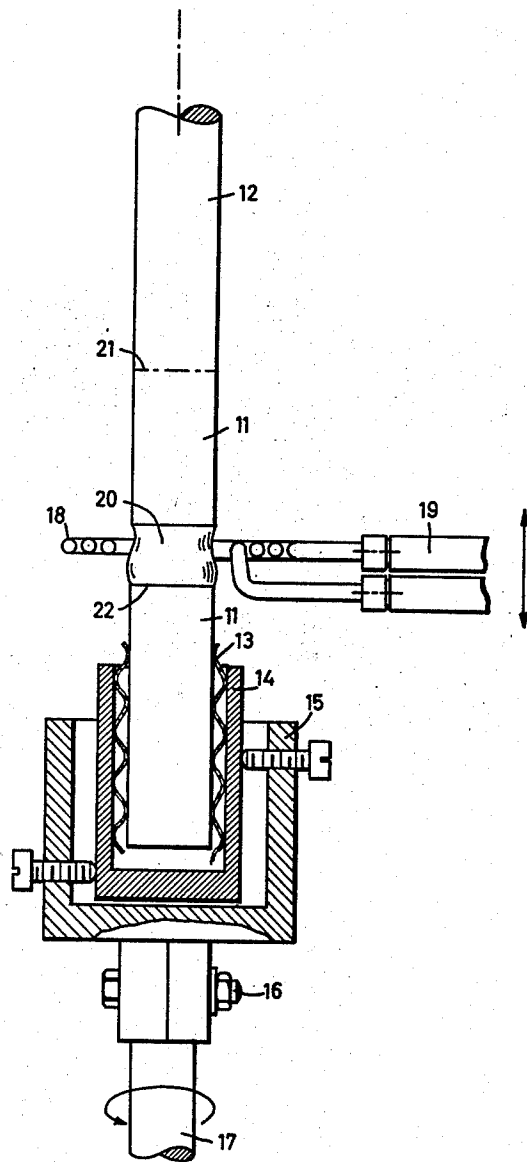
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K. REUSCHEL

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METHOD FOR PRODUCING MONOCRYSTALLINE SEMICONDUCTOR MATERIAL

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METHOD FOR PRODUCING MONOCRYSTALLINE SEMICONDUCTOR MATERIAL

Konrad Reuschel, Pretzfeld, Germany, assignor to Siemens-Schuckertwerke Aktiengesellschaft, Erlangen, Germany, a corporation of Germany

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5 Claims. (Cl. 252—62.3)

My invention relates to an improvement in the method disclosed in the copending, co-assigned application of Ludwig Sporrer, Serial No. 23,429, filed April 20, 1960, now Patent No. 3,134,700.

The method facilitates the production of a monocrystalline hyperpure semiconductor rod for electronic purposes from a polycrystalline rod by a floating, i.e. crucible-free, zone melting procedure, carried out with the aid of a seed crystal fused to the rod being processed. The melting zone is repeatedly passed in a given direction through the semiconductor rod each time starting from the fusing junction of the seed crystal. The commencement of the zone pass which immediately follows the fusing-together of seed and rod, is located away from the fusion point into the seed crystal.

The instant improvement resides in that the melting zone, after fusion-joining the seed crystal with the semiconductor rod, is placed away from the fusion point into the seed crystal, and the first zone pass is commenced at the displaced location.

The main object and advantage of the improved method is that undesired crystal dislocations which occur when fusing the seed crystal to the semiconductor rod, are eliminated prior to commencing the zone melting process proper.

A preferred embodiment of the invention will be described below with reference to the drawing, which illustrates the essential portion of an apparatus suitable for carrying out the novel method.

A monocrystalline seed 11 is coaxially fused to a semiconductor rod 12, both consisting of semiconductor substance such as silicon. The seed crystal 11 is mounted in a holder which comprises an inner ceramic cylinder 14 and an outer centering cup 15. A number of crimped or wavy leaf-springs 13, of molybdenum, are uniformly distributed over the periphery of the seed crystal between the seed and the cup 14. The holder can be rotated by means of a shaft 17 secured by screw bolt 16 to centering cup 15. The upper portion of rod 12, and its holder, are not illustrated. A heating device is provided for melting an axially narrow zone 20 of the rod, the heating device comprising an inductance coil 18 energized by alternating current. The coil is preferably designed as a flat spiral made of copper tubing, through which cooling water is passed during the heating operation. The coil ends are mounted on terminals 19. During zone melting operation the heating device is displaced upwardly and downwardly as indicated by the arrow A.

For performing the method of the invention, the seed 11 is first fused together with the semiconductor rod 12 at a location indicated by a dot-and-dash line 21. During the initial melting operation, the melting zone remains stationary for a relatively long period of time. Such a "stationary" melting zone, as a rule, causes undesired changes in the crystal lattice structure of the adjacent seed portion. As soon as the melt of seed and rod has become merged and liquefied into a single zone extending diametrically through the entire rod, the seed 11 is placed in rotation by means of the shaft 17. After termination of this initial melting operation, the melting zone is moved downwardly into the seed 11 by moving the heater coil 18 downwardly to a location 22 at which

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the crystalline structure is virtually no longer affected by the initial melting operation and hence has a higher degree of perfection. Immediately thereafter, the melting zone is again passed upwardly through the initial melting location 21, thus initiating the first zone pass longitudinally through the semiconductor rod 12.

It will be recognized that according to the invention the melting zone is shifted from the range of crystal dislocations, namely from the initial melting location 21 at the end of the seed, into a region of the seed where no such dislocations are present. The first zone pass is then commenced at the latter location 22, before any new "stationary" melting zone can form further lattice defects. It has therefore been found preferable to commence the first zone pass immediately without any delay as soon as the melting zone has been shifted sufficiently far into the crystal seed.

When processing semiconductor rods of about 12 to 15 mm. thickness, the crystal seed exhibits only negligibly slight crystal dislocations at a distance of approximately 3 cm. away from the initial melting location. It has been found that semiconductor rods which, for example, were produced with a programmed doping according to the disclosure in Hoffmann et al. U.S. application Serial No. 841,026, filed September 21, 1959, now Patent No. 2,970,111, could be converted to a monocrystal by a single zone pass when employing the present method.

The method of the invention has been found particularly advantageous in cases where a doped polycrystalline semiconductor rod is to be converted to a monocrystal. The invention is further advantageously applicable in the production of rods of predetermined doping, for example in accordance with said patent application Serial No. 841,026 in which a prescribed dope concentration is uniformly distributed over the rod volume by zone melting, while the semiconductor material is being simultaneously converted to a monocrystal. All of the disclosure of said application Serial No. 841,026 is included herein by reference.

The combined process for transforming the polycrystalline silicon rod into a monocrystalline rod with controlled doping can be carried out as follows:

A polycrystalline silicon rod having an impurity concentration predetermined by a controlled doping is placed in a chamber through which silicon tetrachloride and hydrogen are passed, the rod being heated by passing an electric current through it, to a temperature high enough to cause deposition of silicon on the rod. The deposited silicon is of higher purity than the original rod. The coated polycrystalline rod is then thinned in a zone melting procedure in which the rod holders are drawn apart, and is then subjected to the process described above, for conversion to a monocrystalline rod.

However, it is also feasible to carry out said deposition of purer silicon on the monocrystalline rod produced as described in the main body of this specification.

The method is further characterized as follows:

A method for producing a monocrystalline hyperpure semiconductor rod for electronic purposes from a polycrystalline rod by crucible free zone melting with the aid of a seed crystal fused to the rod, in which the melting zone is repeatedly passed in one direction longitudinally through the semiconductor rod, commencing each time from the fusion junction of the seed crystal, the commencement of a zone pass next following to the fusing-together of seed and crystal being displaced into the seed crystal. The method being characterized in that the melting zone, after fusing the seed crystal to the semiconductor rod, is moved from the fusion point away into the seed crystal, and that the first zone pass is commenced at the latter location, the melting zone being moved at

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least 2 cm., preferably 3 cm., from the fusion point away into the seed crystal.

I claim:

1. A crucible-free floating molten zone method for producing a monocrystalline semiconductor rod from a polycrystalline rod, comprising supporting the latter vertically, fusing a monocrystalline seed crystal to the lower end of said polycrystalline rod to form a liquid fused junction, setting the seed crystal in rotation, displacing the molten zone into the seed crystal to a location in the seed crystal removed from the fused junction, said location being in a monocrystal region having a higher degree of lattice perfection than in the region of said junction, immediately thereafter commencing the first zone pass by displacing the molten zone from said seed crystal location through said junction to said polycrystalline rod to transform said polycrystalline rod into a substantially dislocation-free monocrystalline rod.

2. The process of claim 1, the semiconductor being silicon.

3. A crucible-free floating molten zone method for producing a monocrystalline semiconductor rod from a polycrystalline rod, the polycrystalline rod being of silicon having a known impurity concentration obtained by controlled doping, and by thinning in a zone melting drawing operation, and having precipitated thereupon a coating of relatively purer silicon semiconductor material by heat decomposition of a silicon halide vapor in contact with the rod, comprising supporting the polycrystalline rod vertically, fusing a monocrystalline seed crystal to said polycrystalline rod to form a fused junction, displacing the molten zone into the seed crystal to a location in the seed crystal removed from the fused junction, so that said location is in a monocrystal region having a higher degree of lattice perfection than in the region of said junction, thereafter commencing the first zone pass by displacing the molten zone from said seed crystal location through said junction to said polycrystalline rod to transform said polycrystalline rod into a substantially dislocation-free monocrystalline rod.

4. A crucible-free floating zone method for producing a doped monocrystalline semiconductor rod from a polycrystalline rod, comprising supporting the latter vertically, said rod having a predetermined impurity concentration, precipitating upon said polycrystalline rod relatively purer semiconductor material of the same substance as the rod, fusing a monocrystalline seed crystal to the lower end of said polycrystalline rod to form a liquid fused junction,

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setting the seed crystal in rotation, displacing the molten zone into the seed crystal to a location in the seed crystal removed from the fused junction, said location being in a monocrystal region having a higher degree of lattice perfection than in the region of said junction, immediately thereafter commencing zone pass by displacing the molten zone from said seed crystal location through said junction along said polycrystalline rod to transform said polycrystalline rod into a substantially dislocation-free monocrystalline rod.

5. A crucible-free floating molten zone method for producing a doped monocrystalline semiconductor rod from a polycrystalline rod, comprising supporting the latter vertically, fusing a monocrystalline seed crystal to the lower end of said polycrystalline rod to form a liquid fused junction, setting the seed crystal in rotation, displacing the molten zone into the seed crystal to a location in the seed crystal removed from the fused junction, said location being in a monocrystal region having a higher degree of lattice perfection than in the region of said junction, immediately thereafter commencing zone passing by displacing the molten zone from said seed crystal location through said junction into and along said polycrystalline rod to transform said polycrystalline rod into a substantially monocrystalline rod, the first zone pass commencing from said location, said monocrystalline rod having a predetermined impurity concentration, precipitating upon said monocrystalline rod relatively purer semiconductor material of the same substance as the rod, and distributing the impurity concentration over the entire rod cross section by zone melting.

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MAURICE A. BRINDISI, *Primary Examiner*.

MARCUS U. LYONS, *Examiner*.