

Induction heating coil and method for melting granules composed of semiconductor material

The invention relates to an induction heating coil and a method
5 for melting granules composed of semiconductor material on a plate with outlet tube. An induction heating coil of this type is required, in accordance with DE 102 04 178 A1, in order to be able to produce a single crystal of semiconductor material with granules as raw material.

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Figure 4 shows a known induction heating coil in an arrangement during the production of a single crystal. The granules melted with the aid of the induction heating coil flow through an opening in the center of the plate with formation of a funnel-
15 shaped film of semiconductor material into a melt. The melt forms a reservoir which, controlled by a pulling coil, crystallizes on a single crystal whilst increasing the volume thereof. For the crystal growth to proceed without any disturbances it is important, inter alia, for the film and the
20 adjoining melt to remain liquid. In order to preclude uncontrolled freezing of the film and the melt, a radiant heating system is present. However, such a radiant heating system is complicated and not very efficient because the majority of the radiation impinging on the film is reflected
25 and thus remains ineffective. Furthermore, the film and the melt cannot be heated uniformly because the respective angles of incidence of the radiation differ significantly.

It is an object of the present invention to achieve uniform
30 heating of the film and of the adjoining melt more simply and more effectively.

The invention relates to an induction heating coil for melting granules composed of semiconductor material on a plate with an
35 outlet tube, comprising a coil body provided with current-

guiding slots and having an upper and a lower side and having a passage opening for granules in a region of the coil body that lies outside the center, and current-carrying segments which project in the center of the lower side of the coil body and
5 which are electrically conductively connected by a web at a lower end.

The invention also relates to a method for melting granules composed of semiconductor material on a plate with an outlet
10 tube by means of an induction heating coil, comprising forming a film of molten semiconductor material, which wets the outlet tube, and a melt of semiconductor material with a free surface which is surrounded by the film, wherein the film and the melt are heated in the region of the free surface by means of
15 current-carrying segments which project in the center of the underside of the induction heating coil and which are electrically conductively connected by a web at a lower end.

According to the invention, the induction heating coil for
20 melting the granules is also used for inductively heating the film and the adjoining upper region of the melt and for keeping them liquid. This achieves the aim of ensuring a continuous and controllable melt flow from the plate to the single crystal. For this purpose, the coil body has current-carrying segments
25 which project in the center of the lower side of the coil body and protrude into the channel delimited by the film of semiconductor material toward the side and by the melt at the bottom. The segments are preferably configured in such a way that inductive heating of the film and of the melt is
30 particularly effective in the region of the free surface of the melt that is surrounded by the film. A shape of the segments on the basis of which the volume of the channel is almost completely filled by the segments is particularly preferred. Therefore, the segments are formed for example as two segments
35 which form the shape of a truncated cone and which are

electrically conductively connected to one another by a web at their lower end.

This and further features of the invention are illustrated in greater detail below with the aid of figures. Figure 1 shows, in a schematic longitudinal sectional illustration, a preferred embodiment of the induction heating coil according to the invention in an arrangement during operation. Figures 2 and 3 show the induction heating coil in plan view and in cross-sectional illustration. Figure 4 is an illustration which corresponds to figure 1 and which represents the prior art. Features of identical type are identified by the same reference numerals.

The induction heating coil is formed in such a way that the radiofrequency current essentially flows through the coil body 1 and the segments 2 (figures 2 and 3). The segments are electrically conductively connected to one another by a thin web 3 at their lower end. The coil body has radially directed current-guiding slots 4 which constrain a current flow on a meandering path through the coil body. The path leads from coil connections 5 at the edge of the coil body 1 to the segments 2 in the coil center, through the segments and through the coil body again back to the coil connections. It is ensured in this way that all regions of the surface of the plate are covered equally by the electromagnetic field, which induces there the current for melting granules and for maintaining the molten state.

The coil body 1 has in an outer region at least one passage opening 6 for feeding granules composed of semiconductor material onto the rotating plate. The passage opening is preferably formed by one of the current-guiding slots 4, which is widened in a section for this purpose.

The induction heating coil is furthermore equipped with a cooling system comprising cooling channels 7 in the coil body 1, through which a coolant, for example water, flows. In order also to obtain intensive cooling of the segments 2, the cooling
5 channels are led to the segments and connected to one another via a tube bridge 8. The tube bridge reaches in the center of the upper side of the coil body 1 as far as the segments 2 and is for example soldered or welded thereto. The tube bridge 8 is singly or multiply wound, such that it has a sufficiently high
10 inductance. The radiofrequency current therefore essentially flows via the web 3 connecting the segments 2, and not via the tube bridge 8. By virtue of the current flow, the field line density is particularly high in the region of the web and the inductive heating of the melt that is directly opposite the web
15 during the production of a single crystal is particularly effective. Preferably the same electrical potential, particularly preferably ground potential, is present at the melt and the web.

20 A preferred relative arrangement of the induction heating coil and of the plate 9 during the production of a single crystal 10 is illustrated in figure 1. The segments 2 form a truncated cone and reach almost as far as the melt in the region of the web 3. The film 12 of molten semiconductor material flowing
25 from the outlet tube 11 of the plate 9 encloses a channel, the volume of which is almost completely filled by the current-carrying segments 2. Preferably, the angle of inclination of the outer surface of the segments and the angle of inclination of the inner surface of the outlet tube are identical. The
30 continuous flow of molten semiconductor material from the plate to the melt can additionally be improved by the truncated cone being positioned a little asymmetrically in the channel and one side thus being preferentially heated. As a result, a defined closed melt path forms at the beginning of the growth process,
35 when as yet little melt flow is required.

The plate 9 is preferably composed of the same semiconductor material as the granules 13 and is preferably embodied in a manner like the container which is described in DE 102 04 178 A1, and the content of which is hereby expressly incorporated.
5 However, it can also be embodied as a simple flat slab with a central outlet tube, particularly if it is used for melting granules for producing single crystals having comparatively small diameters. The reference numeral 14 denotes a funnel into
10 which the granules 13 are conveyed.

The invention is preferably used for producing single crystals composed of silicon. The semiconductor wafers cut from the single crystals are suitable for example for producing solar
15 cells or electronic components, for example power transistors and thyristors.

Example:

With an induction heating coil according to the invention in an arrangement in accordance with figure 1, single crystals
20 composed of silicon were produced without providing a radiant heating system for the channel and the adjoining melt. The pulled single crystals were free of dislocations and no loss of yield arose as a result of silicon solidifying in the film or
25 in the adjoining region of the melt.

Patent claims:

1. An induction heating coil for melting granules composed of semiconductor material on a plate having an outlet tube, said
5 heating coil comprising a coil body provided with current-guiding slots and having an upper and a lower side and having a passage opening for granules in a region of the coil body that lies outside the center, and current-carrying segments which project in the center of the lower side of the coil body and
10 which are electrically conductively connected by a web at a lower end.
2. The induction heating coil as claimed in claim 1, wherein at least one of the current-guiding slots is widened in order to
15 form the passage opening.
3. The induction heating coil as claimed in claim 1 or claim 2, wherein the segments form the shape of a truncated cone.
- 20 4. The induction heating coil as claimed in any of claims 1 to 3, wherein the angle of inclination of the outer surface of the current-carrying segments and the angle of inclination of the inner surface of the outlet tube are identical.
- 25 5. The induction heating coil as claimed in any of claims 1 to 4, characterized by a cooling system for cooling the coil body and the segments.
6. The induction heating coil as claimed in claim 5, wherein
30 the cooling system comprises a wound tube bridge through which coolant flows and which is in contact with the current-carrying segments in the center of the upper side of the coil body.
7. A method for melting granules composed of semiconductor
35 material on a plate with an outlet tube by means of an

induction heating coil, comprising forming a film of molten semiconductor material, which wets the outlet tube, and a melt of semiconductor material with a free surface which is surrounded by the film, wherein the film and the melt are
5 heated in the region of the free surface by means of current-carrying segments which project in the center of the underside of the induction heating coil and which are electrically conductively connected by a web at a lower end.

10 8. The method as claimed in claim 7, wherein granules composed of silicon are melted on a plate composed of silicon.

9. The method as claimed in claim 6 or claim 7, wherein the web and the melt are put at the same electrical potential.