# Claims

1. A silicon electromagnetic casting apparatus comprising a reaction vessel, a conductive crucible disposed within the interior of the reaction vessel; and an induction coil installed on the outer circumference of the conductive crucible;
characterized in that:
a hard structure formed from an electrical insulating material being fitted onto the outer peripheral surface of the conductive crucible when utilizing a prescribed gas to maintain a constant pressure in the interior of the reaction vessel while a silicon disposed within the conductive crucible is solidified into a silicon ingot subsequent to being melted into a molten silicon by induction heating by applying a terminal voltage to the induction coil wherein a solidification interface is formed between the molten silicon and the silicon ingot.

2. The silicon electromagnetic casting apparatus according to claim 1 wherein the hard structure is fitted onto the outer peripheral surface of the conductive crucible at a position of the height of the solidification interface.

3. The silicon electromagnetic casting apparatus according to claim 1 or 2 wherein the conductive crucible has an inner cross sectional width or diameter of 35 cm or more.

4. The silicon electromagnetic casting apparatus according to claim 1 or 2 wherein the conductive crucible has a square-shaped cross section with an inner side dimension of 35 cm and an outer side dimension of 41.6 cm, the conductive crucible divided into 60 segments, the hard structure forming a beam around the outer peripheral surface of the conductive crucible, the beam having a length of 41.6 cm, which is an inner side opposite to the outer peripheral side of the conductive crucible, a thickness of 10 cm and a width of 3 cm.

5. The silicon electromagnetic casting apparatus according to claim 1 or 2 wherein the conductive crucible has a circular-shaped cross section with an inner diameter of 600 mm and an outer diameter of 660 mm, the conductive crucible divided into 60 segments, the hard structure forming an annulus around the outer peripheral surface of the conductive crucible, the annulus having a thickness of 2 mm and a width of 50 mm.

6. The silicon electromagnetic casing apparatus according to claim1 or 2 wherein the hard structure comprises a fibre reinforced plastic having a Young's Modulus of 10 gigapascals or greater.

7. The silicon electromagnetic casting apparatus according to claim 1 or 2 wherein the induction coil comprises a plurality of induction coils, the plurality of induction coils arranged one above another and each one of the plurality of induction coils operating at a different frequency.

8. The silicon electromagnetic casting apparatus according to claim 7 wherein a magnetic shield is disposed between each one of the plurality of induction coils.

9. The silicon electromagnetic casting apparatus according to claim 1 or 2 wherein the induction coil comprises a first and a second induction coil, the first induction coil arranged above the second induction coil and the first and second induction coils operating at a different frequency with the second induction coil operating at a frequency higher than the frequency of the first induction coil.

10. The silicon electromagnetic casting apparatus according to claim 9 wherein the hard structure is disposed adjacent to the bottom of the second induction coil.

11. A process for producing a silicon ingot from a silicon mass, the process comprising the steps of supplying the silicon mass into a conductive crucible disposed within a reaction vessel, the conductive crucible having at least one induction coil surrounding a partial exterior height of the conductive crucible;
characterized by:
fitting a hard structure formed from an electrical insulating material onto the outer peripheral surface of the conductive crucible; supplying a prescribed gas to the interior of the reaction vessel to maintain a constant pressure; applying a terminal voltage to each one of the at least one induction coil; supplying a different induction frequency to each of the at least one induction coil; and forming a silicon ingot in the conductive crucible after the silicon mass is melted to form a molten silicon by induction heating where a solidification interface forms between the molten silicon and the silicon ingot within the conductive crucible.

12. The process for producing a silicon ingot from a silicon mass according to claim 11 wherein the step of fitting the hard structure onto the outer peripheral

surface of the conductive crucible further comprises locating the hard structure onto the outer peripheral surface of the conductive crucible at the height adjacent to where a solidification interface forms between the molten silicon and the silicon ingot within the conductive crucible.

13. The process for producing a silicon ingot from a silicon mass according to claim 11 or 12 wherein the at least one induction coil comprises a first and a second induction coil arranged with the first induction coil above the second induction coil, further comprising the step of supplying a higher induction frequency to the second induction coil than to the first induction coil.

14. A silicon ingot formed by an electromagnetic casting process comprising the steps of supplying a silicon mass into a conductive crucible disposed within a reaction vessel, the conductive crucible having at least one induction coil surrounding a partial exterior height of the conductive crucible;
characterized by:
fitting a hard structure formed from an electrical insulating material onto the outer peripheral surface of the conductive crucible; supplying a prescribed gas to the interior of the reaction vessel to maintain a constant pressure; applying a terminal voltage to each one of the at least one induction coil; supplying a different induction frequency to each of the at least one induction coils; and forming the silicon ingot in the conductive crucible after the silicon mass is melted to form a molten silicon by induction heating.

15. The silicon ingot according to claim 14 wherein the fitting of the hard structure onto the outer peripheral surface of the conductive crucible locates the hard structure onto the outer peripheral surface of the conductive crucible at the height adjacent to where a solidification interface forms between the molten silicon and the silicon ingot within the conductive crucible.

## Claims

1. A silicon electromagnetic casting apparatus comprising a reaction vessel, a conductive crucible disposed within the interior of the reaction vessel; and an induction coil installed on the outer circumference of the conductive crucible; characterized in that:
a hard structure formed from an electrical insulating material being fitted onto the outer peripheral surface of the conductive crucible when utilizing a prescribed gas to maintain a constant pressure in the interior of the reaction vessel, a silicon disposed within the conductive crucible is solidified into a silicon ingot subsequent to being melted into a molten silicon by induction heating by applying a terminal voltage to the induction coil wherein a solidification interface is formed between the molten silicon and the silicon ingot and the hard structure is fitted onto the outer peripheral surface of the conductive crucible at a position of the height of the solidification interface.

2. The silicon electromagnetic casting apparatus according to claim 1 wherein the conductive crucible has an inner cross sectional width or diameter of 35 cm or more.

3. The silicon electromagnetic casting apparatus according to claim 1 wherein the conductive crucible has a square-shaped cross section with an inner side dimension of 35 cm and an outer side dimension of 41.6 cm, the conductive crucible being divided into 60 segments, the hard structure forming a beam around the outer peripheral surface of the conductive crucible, the beam having a length of 41.6 cm, which is an inner side opposite to the outer peripheral side of the conductive crucible, a thickness of 10 cm and a width of 3 cm.

4. The silicon electromagnetic casting apparatus according to claim 1 wherein the conductive crucible has a circular-shaped cross section with an inner diameter of 600 mm and an outer diameter of 660 mm, the conductive crucible divided into 60 segments, the hard structure forming an annulus around the outer peripheral surface of the conductive crucible, the annulus having a thickness of 2 mm and a width of 50 mm.

5. The silicon electromagnetic casing apparatus according to any preceding claim wherein the hard structure comprises a fibre reinforced plastic having a Young's Modulus of 10 gigapascals or greater.

6. The silicon electromagnetic casting apparatus according to any preceding claim, wherein the induction coil comprises a first and a second induction coil, the first induction coil arranged above the second induction coil, a magnetic shield positioned between the first and second induction coils, and the first and second induction coils operating at a different frequency with the second induction coil operating at a frequency higher than the frequency of the first induction coil, the hard structure disposed adjacent to the bottom of the second induction coil.

7. A process for producing a silicon ingot from a silicon mass, the process comprising the steps of supplying the silicon mass into a conductive crucible disposed within a reaction vessel, the conductive crucible having at least one induction coil surrounding a partial exterior height of the conductive crucible;
characterized by:
fitting a hard structure formed from an electrical insulating material onto the outer peripheral surface of the conductive crucible; supplying a prescribed gas to the interior of the reaction vessel to maintain a constant pressure; applying a terminal voltage to each one of the at least one induction coil; supplying a different induction frequency to each of the at least one induction coil; and forming a silicon ingot in the conductive crucible after the silicon mass is melted to form a molten silicon by induction heating where a solidification interface forms between the molten silicon and the silicon ingot within the conductive crucible.

8. The process for producing a silicon ingot from a silicon mass according to claim 7 wherein the step of fitting the hard structure onto the outer peripheral surface of the conductive crucible includes locating the hard structure onto the outer peripheral surface of the conductive crucible at the height adjacent to where a solidification interface forms between the molten silicon and the silicon ingot within the conductive crucible.

9. The process for producing a silicon ingot from a silicon mass according to claim 7 or 8 wherein the at least one induction coil comprises a first and a second induction coil arranged with the first induction coil above the second induction coil, including the step of supplying a higher induction frequency to the second induction coil than to the first induction coil.

10. A silicon ingot formed by an electromagnetic casting process comprising the steps of supplying a silicon mass into a conductive crucible disposed within a reaction vessel, the conductive crucible having at least one induction coil surrounding a partial exterior height of the conductive crucible;
characterized by:
fitting a hard structure formed from an electrical insulating material onto the outer peripheral surface of the conductive crucible; supplying a prescribed gas to the interior of the reaction vessel to maintain a constant pressure; applying a terminal voltage to each one of the at least one induction coil; supplying a different induction frequency to each of the at least one induction coils; and forming the silicon ingot in the conductive crucible after the silicon mass is melted to form a molten silicon by induction heating.

11. The silicon ingot according to claim 10 wherein the fitting of the hard structure onto the outer peripheral surface of the conductive crucible locates the hard structure onto the outer peripheral surface of the conductive crucible at the height adjacent to where a solidification interface forms between the molten silicon and the silicon ingot within the conductive crucible.