

WHAT IS CLAIMED IS:

1. A method for producing a single crystal silicon ingot from a silicon melt held within a crucible, the method comprising:

adding polycrystalline silicon to the crucible, the crucible being disposed within an ingot puller inner chamber;

heating the polycrystalline silicon to cause a silicon melt to form in the crucible;

pulling a single crystal silicon ingot from the silicon melt;

providing a source of solid-phase boric acid;

producing a boron-containing gas from the solid-phase boric acid; and

contacting the boron-containing gas with a surface of the melt to cause boron to enter the melt as a dopant while pulling the single crystal silicon ingot from the melt.

2. The method as set forth in claim 1 comprising adding an n-type dopant to the crucible prior to pulling the single crystal silicon ingot from the melt.

3. The method as set forth in claim 2 wherein the n-type dopant is phosphorous.

4. The method as set forth in any one of claims 1 to 3 wherein the boron-containing gas is produced by:

liquefying the solid-phase boric acid to produce a boric acid liquid; and

evaporating the boric acid liquid to produce the boron-containing gas.

5. The method as set forth in any one of claims 1 to 4 wherein the solid-phase boric acid is disposed within the ingot puller inner chamber.

6. The method as set forth in claim 5 wherein the solid-phase boric acid is disposed within a capsule.

7. The method as set forth in any one of claims 1 to 4 wherein the solid-phase boric acid is disposed exterior to the ingot puller housing.

8. The method as set forth in claim 7 wherein the solid-phase boric acid is within a chamber of a vaporization unit.

9. An ingot puller apparatus for producing a doped single crystal silicon ingot, the ingot puller apparatus comprising:

an ingot puller outer housing;

an ingot puller inner chamber formed within the ingot puller outer housing;

a crucible disposed within the ingot puller inner chamber;

an outer feed tube that is at least partially disposed exterior to the ingot puller outer housing, the outer feed tube defining an outer feed tube chamber and having a distal end, proximal end and an outer feed tube axis that extends through the distal end and the proximal end;

an elongate member that is moveable within the outer feed tube chamber along the outer feed tube axis; and

a dopant receptacle coupled to the elongate member that is moveable between a loading position in which the dopant receptacle is disposed exterior to the ingot puller outer housing and a feed position in which the dopant receptacle is disposed within the ingot puller inner chamber.

10. The ingot puller apparatus as set forth in claim 9 wherein the dopant receptacle is a capsule that is separable from the elongate member.

11. The ingot puller apparatus as set forth in claim 10 wherein the capsule comprises:

an outer capsule housing; and

a weir disposed within the outer capsule housing, the weir forming a channel for dopant gas to pass through, the weir having an upper end and a lower end, the upper end and lower ends being open, an annular chamber disposed between the weir and the ingot puller outer housing for holding solid-phase dopant.

12. The ingot puller apparatus as set forth in any one of claims 9 to 11 comprising a tube disposed below the dopant receptacle to direct dopant gas to a surface of a melt.

13. The ingot puller apparatus as set forth in any one of claims 9 to 12 wherein the elongate member is a tube.

14. The ingot puller apparatus as set forth in any one of claims 9 to 13 further comprising a valve for sealing the ingot puller inner chamber when the elongate member is withdrawn from the ingot puller inner chamber.

15. The ingot puller apparatus as set forth in any one of claims 9 to 14 comprising a translation device for moving the dopant receptacle between the loading position and the feed position.

16. The ingot puller apparatus as set forth in claim 15 wherein the translation device is a magnetically coupled through-wall translation unit.

17. The ingot puller apparatus as set forth in claim 15 wherein the translation device is a bellows system.

18. An ingot puller apparatus for producing a doped single crystal silicon ingot, the ingot puller apparatus comprising:

an ingot puller outer housing;

an ingot puller inner chamber formed within the ingot puller outer housing;

a crucible disposed within the ingot puller inner chamber;

a dopant conduit having a gas inlet disposed exterior to the ingot puller inner chamber and a gas outlet disposed in the ingot puller inner chamber; and

a dopant vaporization unit disposed exterior to the ingot puller chamber and comprising:

a dopant chamber for holding solid-phase dopant;

a heating device for heating the solid-phase dopant and producing a dopant gas; and

an outlet through which the dopant gas passes, the outlet being in fluid communication with the dopant conduit.

19. The ingot puller apparatus as set forth in claim 18 further comprising an inlet for introducing a process gas, the inlet being in fluid communication with the dopant chamber, the process gas passing through the dopant chamber and through the outlet.