includes the curved portion of the crucible 102 that extends below the sidewall 131. Within the crucible 102 is a silicon melt 104 (FIG. 3) having a melt surface 111 (i.e., melt-ingot interface).

[0018] In some embodiments, the crucible 102 is layered. For example, the crucible 102 may be made of a quartz base layer and a synthetic quartz liner disposed on the quartz base layer.

[0019] The susceptor 106 is supported by a shaft 105. The susceptor 106, crucible 102, shaft 105 and ingot 113 (Fig. 3) have a common longitudinal axis A or “pull axis” A.

[0020] The ingot puller apparatus housing 108 includes a housing bottom 116 and a housing sidewall 121 that extends upward from the bottom 116. The ingot puller apparatus 100 includes an insulation bottom layer 110 that extends upward from the housing bottom 116. The ingot puller apparatus 100 includes an insulation cap 125 to prevent contaminants from entering the growth chamber 152 from the insulation bottom layer 110. Side insulation 124 extends radially inward from the housing sidewall 121.

[0021] A pulling mechanism 114 is provided within the ingot puller apparatus 100 for growing and pulling an ingot 113 (FIG. 3) from the melt 104. Pulling mechanism 114 includes a pulling cable 118, a seed holder or chuck 120 coupled to one end of the pulling cable 118, and a silicon seed crystal 122 coupled to the seed holder or chuck 120 for initiating crystal growth. One end of the pulling cable 118 is connected to a pulley (not shown) or a drum (not shown), or any other suitable type of lifting

CLAIMS:

1. An ingot puller apparatus for growing a single crystal silicon ingot from a silicon melt, the apparatus comprising:

a housing defining a growth chamber, the housing having a bottom and a sidewall that extends from the bottom;

a crucible disposed within the growth chamber for holding the silicon melt;

an exhaust tube that extends from the growth chamber and to the bottom of the housing, the exhaust tube defining an exhaust flow path for discharging an exhaust gas from the growth chamber, the exhaust tube comprising:

an upper portion made of a first material; and

a lower portion coupled to the upper portion, the lower portion being made of a second material, the second material being different from the first material.

2. The ingot puller apparatus as set forth in claim 1 wherein the first material is graphite.

3. The ingot puller apparatus as set forth in claim 1 or claim 2 wherein the second material is metal.

4. The ingot puller apparatus as set forth in claim 3 wherein the second material is stainless steel.

5. The ingot puller apparatus as set forth in claim 1 wherein the first material is graphite and the second material is stainless steel.

6. The ingot puller apparatus as set forth in any one of claims claims 1 to 5 wherein the first material has a melting temperature greater than a melting temperature of the second material.

7. The ingot puller apparatus as set forth in any one of claims 1 to 6 wherein the lower portion includes a collar, the collar being received in the upper portion and wherein the collar is friction fit within the upper portion.

8. The ingot puller apparatus as set forth in any one of claims 1 to 7 wherein the ingot puller apparatus comprises a plurality of exhaust tubes, each exhaust tube comprising:

an upper portion made of the first material;

and

a lower portion coupled to the upper portion, the lower portion being made of the second material.

9. A method for selecting a length of a lower, metal portion of a compound exhaust tube of an ingot puller apparatus, the compound exhaust tube comprising an upper portion made of a first material and a lower portion coupled to the upper portion, the lower portion being made of a second material that is a metal, the second material being different from the first material, the compound exhaust tube extending upward from a bottom of a housing and through an insulation layer, the method comprising:

determining a threshold temperature for the lower, metal portion of the exhaust tube;

determining the radial position of the exhaust tube;

determining the axial temperature profile of the ingot puller apparatus at the radial position of the exhaust tube during a meltdown phase of ingot growth, the axial temperature profile decreasing from an upper portion of the insulation layer toward the housing bottom; and

selecting a length of the lower, metal portion of the exhaust tube such that an upper end of the lower, metal portion is at an axial position in which the temperature of the lower, metal portion is less than the threshold temperature during the meltdown phase of ingot growth.

10. The method as set forth in claim 9 wherein the axial temperature profile at the radial position of the exhaust tube is determined by measuring temperatures within the ingot puller apparatus during the meltdown phase.

11. The method as set forth in claim 9 wherein the axial temperature profile at the radial position of the exhaust tube is determined by modeling temperatures within the ingot puller apparatus during the meltdown phase.

12. The method as set forth in any one of claims 9 to 11 wherein the threshold temperature is related to the melting temperature of the second material of the lower, metal portion of the exhaust tube.

13. The method as set forth in any one of claims 9 to 11 wherein the threshold temperature is the melting temperature of the second material of the lower, metal portion of the exhaust tube.

14. The method as set forth in any one of claims 9 to 13 wherein the threshold temperature is a first threshold temperature, the length of the lower, metal portion of the exhaust tube being selected such that the entire length of the upper portion of the exhaust tube is above a second threshold temperature.

15. The method as set forth in claim 14 wherein the second threshold temperature is a maximum temperature at which at least some deposits form on the upper portion of the exhaust tube.

16. The method as set forth in claim 15 wherein the deposits are at least silicon oxides, silicon, and silicon carbides.

17. The method as set forth in any one of claims 14 to 16 wherein the first material of which the upper portion is made is graphite and the second threshold temperature is 1200°C.

18. The method as set forth in any one of claims 9 to 17 wherein the second material of which the lower portion is made is stainless steel.

19. The method as set forth in any one of claims 9 to 18 wherein the first material of which the upper portion is made is graphite.