segment 164 includes a leg segment housing 170 that defines a leg chamber 172 within the housing 170. The leg segment 164 includes insulation 174 within the chamber 172. The insulation 174 is supported by a ledge 155 that extends from the housing 170. The void 166 is below the insulation 174 and is also radially inward to the insulation 174. The insulation 174 may be separated from the leg segment housing 170 by a gap 154 to reduce thermal conduction. The leg segment housing 170 may have openings that allow inert gas (e.g., argon gas) to enter the housing and fill the void 166.

[0028] The leg segment housing 170 may be made of graphite or a graphite shell having molybdenum sheets within the shell to block radiation. Alternatively, the leg segment housing may be made of graphite capped with silicon carbide. The insulation 174 may be made of carbon (e.g., carbon-based rigid insulation), felt or layered molybdenum.

[0029] As shown in FIG. 2, the leg segment 164 comprises a foot 182 that extends radially inward from the leg segment 164 toward the distal end 168 of the leg segment 164. The void 166 extends at least partially into the foot 182 (and extends through the entire foot in the embodiment of FIG. 2). The foot 182 comprises a foot housing 184 that defines a foot chamber 186. The foot housing 184 includes a floor 190, radially inward sidewall 192 and sloped top 194. The radially inward sidewall 192 is substantially parallel to the pull axis A (FIG. 1). In the embodiment shown in FIG. 2, there is no insulation disposed within the foot chamber 186. In other embodiments, the foot chamber 186 includes an amount of insulation or other material (e.g., graphite) therein.

[0030] Another embodiment of the heat shield is shown in FIG. 3. The components shown in FIG. 3 that are analogous to those of FIG. 2 are designated by the corresponding reference number of FIG. 2 plus “100” (e.g., part 182 becomes 282). The heat shield 251 includes a leg segment 264 and a foot 282 that extends from the leg segment 264. The heat shield 251 includes a void 266 formed within a leg segment housing 270. The heat shield 251 includes insulation 274 within a leg chamber 272 formed within the leg segment 264. The void 266 extends below the insulation 274 and is also radially inward to the insulation 274.

[0031] The foot 282 includes a radially inward lower sidewall 283 and a radially inward upper sidewall 285. The radially inward lower sidewall 283 and radially inward upper sidewall 285 angle toward each other and form an apex 287 which is the most radially inward portion of the heat shield 251. In the illustrated embodiment, the apex 287 is an inner wall that is substantially parallel to the pull axis A (FIG. 1).

[0032] As shown in FIG. 3, the foot 282 does not include a void formed therein. The foot 282 may be made of graphite.

[0033] Referring again to FIG. 1, the ingot puller apparatus 100 includes a cooling jacket 132. That cooling jacket 132 at least partially overlaps the heat shield 151 along the pull axis A (FIG. 1). The cooling jacket 132 is radially inward to the heat shield 151. The cooling jacket defines a central passage 134 for receiving

CLAIMS

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

a puller housing defining a growth chamber;

a crucible disposed within the growth chamber for containing the melt of silicon;

a pulling mechanism for pulling the ingot from the melt along a pull axis; and

a heat shield disposed within the growth chamber, the heat shield defining a central passage for receiving the ingot as the ingot is pulled by the pulling mechanism, the heat shield having a leg segment that extends downward relative to the pull axis, the leg segment comprising:

a leg segment housing that defines a leg chamber;

insulation disposed within the leg chamber; and

a foot at a distal end of the leg segment that extends radially inward;

wherein the leg segment has a void formed therein, the void extending above the foot and below the insulation.

2. The ingot puller apparatus as set forth in claim 1 wherein the void is at a distal end of the leg segment.

3. The ingot puller apparatus as set forth in claim 1 wherein the void is radially inward to the insulation.

4. The ingot puller apparatus as set forth in claim 1 wherein the void is radially inward to the insulation and also extends below the insulation.

5. The ingot puller apparatus as set forth in any one of claims 1 to 4 wherein the insulation is made of carbon, felt, or layered molybdenum.

6. The ingot puller apparatus as set forth in any one of claims 1 to 5 wherein the leg segment housing is made of graphite.

7. The ingot puller apparatus as set forth in any one of claims 1 to 6 wherein the void is at least partially disposed within the foot.

8. The ingot puller apparatus as set forth in claim 7 wherein the foot comprises a foot housing that defines a foot chamber, there being no insulation disposed within the foot chamber.

9. The ingot puller apparatus as set forth in claim 7 or claim 8 wherein the foot comprises a foot housing, the foot housing having a radially inward sidewall that is parallel to the pull axis.

10. The ingot puller apparatus as set forth in claim 7 or claim 8 wherein the foot comprises a radially inward lower sidewall and a radially inward upper sidewall, the radially inward lower sidewall and radially inward upper sidewall angling toward each other and forming an apex, the apex being the most radially inward portion of the heat shield.

11. The ingot puller apparatus as set forth in claim 10 wherein the foot does not include a void formed therein.

12. The ingot puller apparatus as set forth in any one of claims 1 to 11 comprising a cooling jacket that at least partially overlaps the heat shield along the pull axis, the cooling jacket being radially inward to the heat shield, the cooling jacket defining a central passage for receiving the ingot as the ingot is pulled by the pulling mechanism.

13. An ingot puller apparatus for growing a monocrystalline silicon ingot from a melt of silicon, the apparatus comprising:

a housing defining a growth chamber;

a crucible disposed within the growth chamber for containing the melt of silicon;

a pulling mechanism configured to pull the ingot from the melt along a pull axis;

a heat shield disposed within the growth chamber, the heat shield defining a central passage for receiving the ingot as the ingot is pulled by the pulling mechanism, the heat shield having a leg segment that extends along the pull axis, the leg segment comprising:

a leg segment housing that defines a leg chamber;

insulation disposed within the leg chamber; and

a foot at a distal end of the leg segment that extends radially inward, the foot comprising:

a radially inward lower sidewall; and

a radially inward upper sidewall, the radially inward lower sidewall and radially inward upper sidewall angling toward each other and forming an apex, the apex being the most radially inward portion of the heat shield,

wherein the leg segment has a void formed therein.

14. The ingot puller apparatus as set forth in claim 13 wherein the foot does not include a void formed within the foot.

15. The ingot puller apparatus as set forth in claim 13 or claim 14 wherein the foot comprises graphite.

16. The ingot puller apparatus as set forth in any one of claims 13 to 15 wherein the apex is an inner wall that is parallel to the pull axis.

17. The ingot puller apparatus as set forth in any one of claims 13 to 16 comprising a cooling jacket that at least partially overlaps the heat shield along the pull axis, the cooling jacket being radially inward to the heat shield, the cooling jacket defining a central passage for receiving the ingot as the ingot is pulled by the pulling mechanism.