fluid at the pull cable. An exhaust flue carries away fluid discharged from the one or more nozzles.

[0008] Yet another aspect of the present disclosure is directed to a cleaning tool for cleaning a pull cable of an ingot puller apparatus. The cleaning tool includes a frame and a chamber that extends through the frame for receiving the pull cable. One or more nozzles direct a pressurized fluid toward the pull cable. The tool includes an extendable handle for raising and lowering the one or more nozzles into an upper chamber of the ingot puller apparatus.

[0009] A further aspect of the present disclosure is directed to a method for cleaning a pull cable of an ingot puller apparatus. The ingot puller apparatus includes a crystal puller housing that defines a growth chamber for pulling a silicon ingot from a silicon melt. The crystal puller housing includes a lower dome-shaped segment and an upper cylindrical-shaped segment that is removably connected to the lower dome-shaped segment. The pull cable is positioned within a chamber of a cleaning tool. Pressurized fluid is directed toward the pull cable. The pressurized fluid that is directed toward the pull cable is removed through an exhaust plenum of the cleaning tool for processing the pressurized fluid.

[0010] Various refinements exist of the features noted in relation to the above-mentioned aspects of the present disclosure. Further features may also be incorporated in the above-mentioned aspects of the present disclosure as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to

any of the illustrated embodiments of the present disclosure may be incorporated into any of the above-described aspects of the present disclosure, alone or in any combination.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a cross-section of an ingot puller apparatus during ingot growth;

[0012] FIG. 2 is a schematic of an ingot puller apparatus having an upper segment and lower segment that is removably connected to the upper segment;

[0013] FIG. 3 is a perspective view of a cleaning tool for cleaning the pull cable of an ingot puller apparatus;

[0014] FIG. 4 is another perspective view of the cleaning tool without the guides being shown;

[0015] FIG. 5 is a top view of the main body of the cleaning tool;

[0016] FIG. 6 is a front view of the cleaning tool;

[0017] FIG. 7 is a top view of the cleaning tool; and

[0018] FIG. 8 is a side view of the cleaning tool.

[0019] Corresponding reference characters indicate corresponding parts throughout the drawings.

[0029] According to the Czochralski single crystal growth process, a quantity of solid-phase silicon such as polycrystalline silicon, or “polysilicon”, is initially charged to the crucible assembly 102. The semiconductor or solar-grade solid silicon that is introduced into the crucible assembly 102 is melted by heat provided from one or more heating elements. Once the melt 104 is fully formed, the seed crystal 122 is lowered and contacted with the surface 111 of the melt 104. The pulling mechanism 114 is operated to pull the seed crystal 122 from the melt 104. The resulting ingot 113 includes a crown portion 142 in which the ingot transitions and tapers outward from the seed crystal 122 to reach a target diameter. The ingot 113 includes a constant diameter portion 145 or cylindrical “main body” of the crystal which is grown by increasing the pull rate. The main body 145 of the ingot 113 has a relatively constant diameter. The ingot 113 includes a tail or end-cone (not shown) in which the ingot tapers in diameter after the main body 145. When the diameter becomes small enough, the ingot 113 is then separated from the melt 104.

[0030] The crystal growth process may be a batch process in which solid silicon is initially added to the crucible assembly 102 to form a silicon melt without additional solid-silicon being added to the crucible assembly 102 during crystal growth. In other embodiments, the crystal growth process is a continuous Czochralski process in which an amount of silicon is added to the crucible assembly during ingot growth.

[0031] The ingot puller apparatus 100 includes a side heater 135 and a susceptor 106 that encircles the

by valves in one or more supply conduits integrated into the source of pressurized fluid. After contact with the pull cable 118, the fluid enters an exhaust flue 276 (FIG. 5) which carries away the fluid. The exhaust flue 276 includes an exhaust plenum 279 within the main body 220 of the tool 200 and also includes an exhaust tube 281 that is in fluid communication with the exhaust plenum 279. The exhaust plenum 279 is defined by the top 223, floor 225, and one or more sidewalls 229 of the main body 220. The exhaust tube 281 is in fluid communication with the exhaust plenum 279 and extends downward from the main body 220.

[0040] The exhaust tube 281 also may be used as a handle for raising and lowering the main body 220 within the upper chamber 165 (FIG. 2) of the ingot puller apparatus 100 (i.e., for raising and lowering the one or more nozzles 252, 254 relative to the pull cable 118). The handle 281 may be extendable. For example, the handle 281 may include a telescoping portion 284 (FIG. 4) that slides within an outer portion 286 to retract or extend the handle 281. The cleaning tool 200 may include a lock 288 to fix the telescoping portion 284 relative to the outer portion 286 (e.g., when positioning the tool 200 below the upper chamber 165 and inserting the pull cable 118 through the slot 233 (FIG. 3) into the chamber 214).

[0041] The exhaust tube 281 may be fluidly connected to one or more filters and/or a vacuum source such as by connection to the exhaust tube port 291. The exhaust tube 281 defines a fluid passageway that extends from its inlet 293 (FIG. 4) to the exhaust tube port 291.

CLAIMS:

1. A cleaning tool for cleaning a pull cable of an ingot puller apparatus, the cleaning tool comprising:

a frame comprising a main body;

a chamber that extends through the main body for receiving the pull cable;

one or more nozzles for directing a pressurized fluid at the pull cable;

an exhaust flue for carrying away fluid discharged from the one or more nozzles; and

one or more outer guides that guide the cleaning tool within an upper chamber of the ingot puller apparatus during cleaning of the pull cable, the one or more outer guides being disposed radially outward from the main body, each of the one or more outer guides comprising a roller for contacting an inner surface of an upper chamber of the ingot puller apparatus.

2. The cleaning tool as set forth in claim 1 wherein the main body comprises a floor and a top, the chamber extending through the floor and the top.

3. The cleaning tool as set forth in claim 2 wherein the exhaust flue comprises:

an exhaust plenum within the main body; and

an exhaust tube that extends from the main body, the exhaust tube being in fluid communication with the exhaust plenum.

4. The cleaning tool as set forth in any one of claims 1 to 3 wherein the cleaning tool has an extendable

handle for raising and lowering the one or more nozzles into an upper chamber of the ingot puller apparatus.

5. The cleaning tool as set forth in claim 4 wherein the extendable handle comprises an exhaust tube that carries away fluid discharged from the one or more nozzles.

6. The cleaning tool as set forth in any one of claims 1 to 5 wherein the one or more nozzles comprises a first nozzle and a second nozzle.

7. An ingot puller system for manufacturing a single crystal silicon ingot and for cleaning the system after use, the ingot puller system comprising:

an ingot puller apparatus comprising:

a crucible assembly for holding a silicon melt;

a crystal puller housing that defines a growth chamber for pulling a silicon ingot from the silicon melt, the crucible assembly being disposed within the growth chamber, the crystal puller housing comprising:

a lower dome-shaped segment; and

an upper cylindrical-shaped segment that is removably connected to the lower dome-shaped segment; and

a pulling mechanism comprising a pull cable; and

the cleaning tool as set forth in any one of claims 1 to 6.

8. A cleaning tool for cleaning a pull cable of an ingot puller apparatus, the cleaning tool comprising:

a frame;

a chamber that extends through the frame for receiving the pull cable;

one or more nozzles for directing a pressurized fluid toward the pull cable; and

an extendable handle for raising and lowering the one or more nozzles into an upper chamber of the ingot puller apparatus, the extendable handle comprising a telescoping portion that enables the extendable handle to be extended and retracted.

9. The cleaning tool as set forth in claim 8 wherein the extendable handle comprises an exhaust tube, the exhaust tube having a fluid passageway through which fluid discharged from the one or more nozzles passes.

10. The cleaning tool as set forth in any one of claims 8 to 9 comprising one or more outer guides that guide the cleaning tool within an upper chamber of the ingot puller apparatus during cleaning of the pull cable.

11. A cleaning tool for cleaning a pull cable of an ingot puller apparatus, the cleaning tool comprising:

a frame comprising a main body;

a chamber that extends through the main body for receiving the pull cable;

one or more nozzles for directing a pressurized fluid toward the pull cable;

an extendable handle for raising and lowering the one or more nozzles into an upper chamber of the ingot puller apparatus; and

one or more outer guides that guide the cleaning tool within an upper chamber of the ingot puller apparatus during cleaning of the pull cable, the one or more outer guides being disposed radially outward from the main body, each of the one or more outer guides comprising a roller for contacting an inner surface of an upper chamber of the ingot puller apparatus.

12. An ingot puller system for manufacturing a single crystal silicon ingot and for cleaning the system after use, the ingot puller system comprising:

an ingot puller apparatus comprising:

a crucible assembly for holding a silicon melt;

a crystal puller housing that defines a growth chamber for pulling a silicon ingot from the silicon melt, the crucible assembly being disposed within the growth chamber, the crystal puller housing comprising:

a lower dome-shaped segment; and

an upper cylindrical-shaped segment that is removably connected to the lower dome-shaped segment; and

a pulling mechanism comprising a pull cable; and

the cleaning tool as set forth in claim 8.

13. The cleaning tool as set forth in claim 11 the main body comprises a floor and a top, the chamber extending through the floor and the top.

14. The cleaning tool as set forth in claim 13 comprising:

an exhaust flue for carrying away fluid discharged from the one or more nozzles, the exhaust flue comprising:

an exhaust plenum within the main body; and

an exhaust tube that extends from the main body, the exhaust tube being in fluid communication with the exhaust plenum.

15. The cleaning tool as set forth in claim 11 wherein the extendable handle comprises an exhaust tube that carries away fluid discharged from the one or more nozzles.

16. The cleaning tool as set forth in claim 11 wherein the one or more nozzles comprises a first nozzle and a second nozzle.

17. An ingot puller system for manufacturing a single crystal silicon ingot and for cleaning the system after use, the ingot puller system comprising:

an ingot puller apparatus comprising:

a crucible assembly for holding a silicon melt;

a crystal puller housing that defines a growth chamber for pulling a silicon ingot from

the silicon melt, the crucible assembly being disposed within the growth chamber, the crystal puller housing comprising:

a lower dome-shaped segment; and

an upper cylindrical-shaped segment that is removably connected to the lower dome-shaped segment; and

a pulling mechanism comprising a pull cable; and

the cleaning tool as set forth claim 11.

18. A method for cleaning a pull cable of an ingot puller apparatus, the ingot puller apparatus comprising a crystal puller housing that defines a growth chamber for pulling a silicon ingot from a silicon melt, the crystal puller housing comprising a lower dome-shaped segment and an upper cylindrical-shaped segment that is removably connected to the lower domed-shaped segment, the method comprising:

positioning the pull cable within a chamber of a cleaning tool;

directing pressurized fluid toward the pull cable; and

removing the pressurized fluid that is directed toward the pull cable through an exhaust plenum of the cleaning tool for processing the pressurized fluid.

19. The method as set forth in claim 18 comprising moving the cleaning tool relative to the pull cable while directing pressurized fluid toward the pull

cable and while removing the pressurized fluid through the exhaust plenum for processing the pressurized fluid.

20. The method as set forth in claim 19 comprising moving the cleaning tool through the upper cylindrical-shaped segment of the ingot puller apparatus.

21. The method as set forth in claim 20 comprising separating the upper cylindrical-shaped segment from the lower dome-shaped segment and moving the cleaning tool from a lower end toward an upper end of the upper cylindrical-shaped segment.

22. The method as set forth in claim 20 or claim 21 wherein the cleaning tool comprises one or more outer guides, the one or more outer guides guiding the cleaning tool within the upper cylindrical-shaped segment.

23. The method as set forth in any one of claims 18 to 22 wherein the pressurized fluid is air.

24. The method as set forth in any one of claims 18 to 23 wherein the pull cable comprises a plurality of tungsten wires.