temperature before quench cooling (e.g., the flow path distance until quench cooling is reduced).

EXAMPLES

[0047] The processes of the present disclosure are further illustrated by the following Examples. These Examples should not be viewed in a limiting sense.

Example 1: Effect of Using an Fluid-Cooled Exhaust Tube that Extends into the Reaction Chamber

[0048] FIG. 5 shows occlusions in a conventional exhaust tube 52 (i.e., non-fluid cooled which does not extend into the reaction chamber (e.g., through the bottom of the housing)). The ingot puller system was operated in a continuous Czochralski pulling process in which polycrystalline silicon was added to the melt during ingot growth. The exhaust tube was composed of stainless steel and did not include a cooling-fluid channel formed therein. As shown in FIG. 5, the exhaust tube 52 was fully occluded with deposits D and the exhaust gas was unable to pass through the tube 52. An auger 49 within the exhaust tube 52 was powered but was not able to remove the deposits. The reactor was shut-down to clear the deposits.

[0049] FIG. 6 shows an exhaust tube 52 which was water cooled and extended into the reaction chamber to the extent shown in FIG. 1. The deposits D were more powder-like and where white-orange in color. The system of FIG. 6 did not include an auger. As may be seen from the Figures, use of a fluid-cooled exhaust tube which extended into the reactor chamber nearer the hot zone significantly reduced deposits on the exhaust tube.

CLAIMS:

1. A crystal pulling system for growing a monocrystalline ingot from a silicon melt, the system 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 containing the silicon melt;

an exhaust tube that extends through and outward from 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 inner wall;

an outer wall; and

a fluid channel defined between the inner wall and the outer wall for circulating cooling fluid to cool the exhaust gas within the exhaust flow path, the fluid channel extending through the bottom of the crystal pulling system housing.

2. The crystal pulling system as set forth in claim 1 comprising a bottom heat shield disposed within the crystal pulling system housing, the bottom heat shield having a thickness, the exhaust tube extending through the entire thickness of the bottom heat shield.

3. The crystal pulling system as set forth in claim 1 or claim 2 comprising an exhaust gas plenum, the exhaust gas plenum comprising a plenum housing, the plenum housing comprising a floor, top and a sidewall that extends

between the floor and top, wherein the exhaust tube extends into the plenum housing floor.

4. The crystal pulling system as set forth in claim 3 wherein the plenum housing is made of insulation.

5. The crystal pulling system as set forth in claim 3 or claim 4 wherein the exhaust gas plenum has an inlet, the inlet being disposed radially inward to a side heat shield that extends from a bottom heat shield, the side heat shield being radially inward to the housing sidewall.

6. The crystal pulling system as set forth in any one of claims 1 to 5 comprising a vacuum pump fluidly connected with the exhaust tube to draw exhaust gas through the exhaust flow path.

7. The crystal pulling system as set forth in any one of claims 1 to 6 wherein a portion of the exhaust tube extends downward from the bottom, the portion being fluid cooled.

8. The crystal pulling system as set forth in any one of claims 5 to 7 comprising a side heater that surrounds the crucible, the inlet of the exhaust gas plenum being disposed radially outward to the side heater.

9. The crystal pulling system as set forth in any one of claims 1 to 8 comprising a rotatable auger within the exhaust tube which clears deposits from an inner surface of the exhaust tube.

10. The crystal pulling system as set forth in any one of claims 1 to 9 further comprising a feed tube for adding polysilicon to the crucible.

11. The crystal pulling system as set forth in any one of claims 1 to 10 wherein the exhaust tube comprises baffles disposed within the inner wall and outer wall, the fluid channel being defined between the inner wall, outer wall and baffles.