6 may stabilize as it moves toward the inner melt zone 22. The first and second weirs 20, 30 each have at least one opening defined therein to permit molten silicon to flow radially inward towards the growth region of the inner melt zone 22.

[0021] In the illustrated embodiment, the first weir 20, second weir 30 and sidewall 40 each have a generally annular shape. The first weir 20, second weir 30 and sidewall 40 may be part of three nested crucibles which are joined at the bottom or floor 45 of the crucible assembly 10 (i.e., the first and second weirs 20, 30 are the sidewalls of two crucibles nested within a larger crucible). The crucible assembly configuration depicted in Figures 1-6 is exemplary. In other embodiments, the crucible assembly 10 has a single layer floor (i.e., does not have nested crucibles) with the weirs extending upward from the floor 45. Optionally, the floor 45 may be flat rather than curved and/or the weirs 20, 30 and/or sidewall 40 may be straight-sided. Further, while the illustrated crucible assembly 10 is shown with two weirs, in other embodiments the crucible assembly may have a single weir or even no weirs.

[0022] A feeding tube 46 feeds solid-state silicon which may be, for example, polysilicon chips, granular polysilicon, or chunk polysilicon, or a combination thereof, into the outer melt zone 42. Chunk polysilicon is generally larger in size than chip polysilicon which is larger in size than granular polysilicon. For example, chunk polysilicon may generally have an average nominal size of at least 15 mm (e.g., ranging from 5 mm to 110 mm) while chip polysilicon may

42. In other embodiments, a single plate 31 is added (e.g., a plate that circumscribes the entire circumference of the outer melt zone 42).

[0026] In embodiments in which a plurality of plates 31 are added to the outer melt zone 42, the plates may be free-floating and not connected to each other. In other embodiments, the plates 31 may be connected. The plates 31 may be sized to minimize gaps between adjacent plates 31.

[0027] The plates 31 may be made of quartz or other material that allows the plates 31 to operate as described herein. The plates 31 are generally less dense than the melt 6 of silicon such that the plates float within the melt 6 after formation of the melt 6.

[0028] Referring now to Figure 4, each plate 31 has one or more openings or slots 49 that extend through the thickness of the plate 31. Once solid-state silicon is discharged through the feeding tube 46 into the outer melt zone 42 of the crucible assembly 10 and onto the one or more plates 31, the silicon melts and falls through the openings 49 and enters the melt 6. In the illustrated embodiment, the openings 49 are slots having a major axis that is generally parallel to the longitudinal axis A of the plate 31 (i.e., the openings 49 are spaced radially). Generally, the openings 49 may have any shape that allows the plates 31 to operate as described herein. Generally, the openings 49 may be sized to be smaller than the size of the type of polysilicon introduced into the outer melt zone (e.g., chunk, chips or granular).

[0029] The plates 31 have an inner edge 51 and an outer edge 53. The edges 51, 53 are rounded to match the contours of the outer melt zone 42 (i.e., the area bound by the first weir 20 and sidewall 40). The outer edge 53 is longer than the inner edge 51. First and second sides 57, 59 extend between the inner and outer edges 51, 53.

[0030] Each plate 31 has a width W_{31}. The width W_{31} of each plate 31 is less than the width W_{42} (Figure 3) of the outer melt zone 42 to allow the plates 31 to be disposed within the outer melt zone 42 without contacting the first weir 20 or the sidewall 40 (e.g., during meltdown and/or during ingot growth).

[0031] Once polycrystalline silicon is added to the crucible assembly 10 to form a charge 27 and the plates 31 have been added to the outer melt zone 42, the charge 27 is heated to a temperature above the melting temperature of silicon (e.g., about 1412°C) to melt the charge, and thereby form a silicon melt 6 (Figure 6) comprising molten silicon. The silicon melt 6 has an initial volume of molten silicon and has an initial melt elevation level, and these parameters are determined by the size of the initial charge 27. In some embodiments, the crucible assembly 10 comprising the silicon melt 6 is heated to a temperature of at least about 1425°C, at least about 1450°C or even at least about 1500°C. Once the initial melt 6 is formed, the plates 31 float on the melt 6 in the outer melt zone 42.

[0032] The ingot pulling apparatus 5 includes a pulling mechanism 114 (Figure 6) for growing and pulling the ingot 60 from the melt 6 within the inner melt zone 22. The pulling mechanism 114 includes a pulling cable 118, a

of impurities and also to control crystal melt interface shape.

[0035] After formation of the neck 52, an outwardly flaring seed-cone portion 54 (or “crown”) adjacent the neck 52 is grown. In general, the pull rate is decreased from the neck portion pull rate to a rate suitable for growing the outwardly flaring seed-cone portion 54. Once the seed-cone portion reaches the target diameter, the main body 56 or “constant-diameter portion” of the ingot 60 is grown. In some embodiments, the main body 56 of the ingot 60 has a diameter of about 150 mm, at least about 150 mm, about 200 mm, at least about 200 mm, about 300 mm, at least about 300 mm, about 450 mm, or even at least about 450 mm.

[0036] While the ingot 60 is pulled from the melt 6, solid polysilicon feedstock is added to the outer melt zone 42 through the tube 46 or other channel to replenish the melt 6 in the ingot growth apparatus 5. Solid polycrystalline silicon may be added from a polycrystalline silicon feed system 66 and may be continuously or intermittently added to the ingot puller apparatus 5 to maintain the melt level. Generally, polycrystalline silicon may be metered into the ingot puller apparatus 5 by any method available to those of skill in the art. The solid polysilicon added to the outer melt zone 42 may be silicon chips, chunk or granular.

[0037] In some embodiments, dopant is also added to the melt 6 during ingot growth. Dopant may be introduced from a dopant feed system 72. Dopant may be added as a gas or solid and may be added to the outer melt zone 42.