feeder 264 includes a third dopant receptacle 259. The third dopant receptacle 259 includes one or more sidewalls 261 and has a floor 263 (which is the sidewall of the first dopant receptacle 229) which define a second dopant receptacle inner chamber 265. The third receptacle 259 has an outlet 266 that is aligned with a third cup opening 268. In the illustrated embodiment, the third receptacle 259 is L-shaped.

[0057] The third dopant receptacle 259 holds a third batch of dopant 270. Once the dopant mechanism 250 is rotated through the points at which the first dopant batch 247 is discharged (Figure 9) and the second dopant batch 249 is discharged (Figure 10) and as it approaches the position shown in Figure 11, the third dopant batch 270 is discharged through the outlet 266 and third cup opening 268.

[0058] Another embodiment of the dopant feeder is shown in Figures 12-16. The components shown in Figures 12-16 that are analogous to those of Figures 3-6 are designated by the corresponding reference number of Figures 3-6 plus “200” (e.g., part 123 becomes 323). In addition to first, second, and third dopant receptacles 329, 331, 359, the dopant feeder 364 includes a fourth dopant receptacle 375 (shown with dashed lines for illustration). The fourth dopant receptacle 375 includes one or more sidewalls 377 and has a first end or floor 379. The fourth dopant receptacle 375 includes a fourth dopant receptacle inner chamber 381. In the illustrated embodiment, the fourth receptacle 375 extends through the second opening 324 of the cup 337. In other embodiments, the fourth receptacle 375 is within the profile of the sidewall 315. The fourth

receptacles” 829, 831. The dopant cup 637 may include projections 805 (upper row embodiment) and/or ridges 807 (one in the upper row embodiment and two in the bottom row embodiment) that limit release of the dopant batches.

[0069] To dope the silicon melt by use of one of the dopant feeders described herein, the rotation mechanism is actuated to rotate the first dopant receptacle to release the first batch of dopant from the first dopant receptacle to cause the first batch of dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt. After the first batch of dopant is released from the first dopant receptacle, the rotation mechanism is operated to rotate the second dopant receptacle to release the second batch of dopant from the second dopant receptacle and cause the second batch of dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt. Depending on the number of batches loaded in the dopant feeder and its configuration (e.g., number of dopant receptacles), the rotation mechanism may be rotated further to add additional batches to the melt during ingot growth. In this respect, the rotation mechanism may include one or more stops 181 (Figure 33) which limit rotation to ensure only a single batch is added during operation of the rotation mechanism. The stops may be pushed away to allow the next batch of dopant to be added. In some embodiments, the rotation mechanism may be arranged to prevent reverse rotation.

[0070] In some embodiments, the silicon melt is initially doped with a dopant of a first type (e.g., P-type or N-type). This initial dopant may be added by use of the dopant feeder of the present disclosure or by other

CLAIMS:

1. An ingot puller apparatus for producing a doped single crystal silicon ingot, the ingot puller apparatus comprising:

an ingot puller outer housing;

an ingot puller inner chamber formed within the ingot puller outer housing;

a crucible disposed within the ingot puller inner chamber;

a dopant feeder for adding dopant to the crucible, the dopant feeder comprising;

a first dopant receptacle for holding a first batch of dopant, the first dopant receptacle having a first dopant receptacle outlet;

a second dopant receptacle for holding a second batch of dopant, the second dopant receptacle having a second dopant receptacle outlet; and

a rotatable dopant cup, the first dopant receptacle and the second dopant receptacle being disposed within the rotatable dopant cup, the rotatable dopant cup comprising:

a sidewall;

a first dopant cup opening formed in the sidewall, the first dopant cup opening being aligned with the first dopant receptacle outlet;

a second dopant cup opening, the second dopant cup opening being aligned with the second dopant receptacle outlet; and

a tube disposed below the dopant feeder for transporting the first and second batches of dopant to the crucible.

2. The ingot puller apparatus as set forth in claim 1 wherein the first dopant receptacle is a tube and the second dopant receptacle is a tube.

3. The ingot puller apparatus as set forth in claim 1 wherein the dopant feeder comprises a third dopant receptacle for holding a third batch of dopant, the third dopant receptacle being disposed within the rotatable dopant cup.

4. The ingot puller apparatus as set forth in claim 3 wherein the dopant feeder comprises a fourth dopant receptacle for holding a fourth batch of dopant, the fourth dopant receptacle being disposed within the rotatable dopant cup.

5. The ingot puller apparatus as set forth in claim 1 wherein the dopant feeder comprises a dopant feeder housing, the first dopant receptacle and second dopant receptacle being disposed within the dopant feeder housing.

6. The ingot puller apparatus as set forth in claim 5 wherein the dopant feeder housing is external to the ingot puller outer housing.

7. The ingot puller apparatus as set forth in claim 1 comprising a handle for an operator to rotate the first and second dopant receptacles.

8. The ingot puller apparatus as set forth in claim 7 comprising a shaft connected to the handle and

one or more bearings through which the shaft extends that enable the shaft to rotate.

9. The ingot puller apparatus as set forth in claim 1 wherein the dopant feeder comprises a funnel that is disposed below the first and second dopant receptacles for collecting the first and second batches of dopant, the funnel being connected to the tube.

10. A method for producing a single crystal silicon ingot from a silicon melt held within a crucible, the method comprising:

adding solid-state silicon to the crucible, the crucible being disposed within an ingot puller inner chamber;

heating the solid-state silicon to cause the silicon melt to form in the crucible;

pulling the single crystal silicon ingot from the silicon melt;

rotating a dopant cup, a first dopant receptacle and a second dopant receptacle being disposed within the dopant cup, the dopant cup comprising:

a sidewall;

a first dopant cup opening formed in the sidewall; and

a second dopant cup opening; and

wherein rotating the dopant cup causes:

the first dopant receptacle to rotate to release a first batch of solid-phase dopant from the first dopant receptacle and through a first dopant receptacle outlet to cause the first batch of solid-phase

dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt, the first dopant cup opening being aligned with the first dopant receptacle outlet; and

the second dopant receptacle to rotate to release a second batch of solid-phase dopant from the second dopant receptacle and through a second dopant receptacle outlet to cause the second batch of solid-phase dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt and after the first batch of solid-phase dopant is released from the first dopant receptacle, the second dopant cup opening being aligned with the second dopant receptacle outlet, the first dopant receptacle and the second dopant receptacle being disposed within a dopant feeder housing, the dopant feeder housing being external to an ingot puller outer housing.

11. The method as set forth in claim 10 further comprising adding a dopant of a first type to the crucible before pulling the single crystal silicon ingot from the silicon melt, the first type being p-type or n-type, wherein the first batch of solid-phase dopant released from the first dopant receptacle and the second batch of solid-phase dopant released from the second dopant receptacle are each a second type that is opposite that of the first type.

12. The method as set forth in claim 10 wherein the first dopant receptacle and the second dopant receptacle are part of a dopant feeder for adding dopant to the crucible.

13. The method as set forth in claim 12 wherein the first dopant receptacle is a tube and the second dopant receptacle is a tube.

14. The method as set forth in claim 10 wherein the dopant feeder comprises a third dopant receptacle disposed in the dopant cup for holding a third batch of solid-phase dopant, wherein rotating the dopant cup causes the third dopant receptacle to rotate to release the third batch of solid-phase dopant from the third dopant receptacle and cause the third batch of solid-phase dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt and after the second batch of solid-phase dopant is released from the second dopant receptacle.

15. The method as set forth in claim 14 wherein the dopant feeder comprises a fourth dopant receptacle disposed in the dopant cup for holding a fourth batch of solid-phase dopant, wherein rotating the dopant cup causes the fourth dopant receptacle to release the fourth batch of solid-phase dopant from the third dopant receptacle and cause the fourth batch of solid-phase dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt and after the third batch of solid-phase dopant is released from the third dopant receptacle.

16. The method as set forth in claim 10 comprising operating a handle to rotate the first and second dopant receptacles.

17. The method as set forth in claim 16 wherein the handle is connected to a shaft, the shaft extending

through one or more bearings that enable the shaft to rotate.

18. The method as set forth in claim 10 wherein the dopant feeder comprises a funnel that is disposed below the first and second dopant receptacles, the funnel being connected to a dopant tube, wherein the first batch of solid-phase dopant falls through the funnel upon being released from the first dopant receptacle and the second batch of solid-phase dopant falls through the funnel upon being released from the second dopant receptacle.

19. A method for producing a single crystal silicon ingot from a silicon melt held within a crucible, the method comprising:

adding solid-state silicon to the crucible, the crucible being disposed within an ingot puller inner chamber;

heating the solid-state silicon to cause the silicon melt to form in the crucible;

pulling the single crystal silicon ingot from the silicon melt;

rotating a first dopant receptacle to release a first batch of dopant from the first dopant receptacle and cause the first batch of dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt, the first dopant receptacle being disposed within a dopant cup, the dopant cup comprising a sidewall, a first dopant cup opening formed in the sidewall, and a second dopant cup opening, the dopant cup being rotated to cause the first batch of dopant to fall through a first dopant receptacle outlet and from the first dopant

receptacle, the first dopant cup opening being aligned with the first dopant receptacle outlet; and

rotating a second dopant receptacle to release a second batch of dopant from the second dopant receptacle and cause the second batch of dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt and after the first batch of dopant is released from the first dopant receptacle, the second dopant receptacle being disposed within the dopant cup, the dopant cup being rotated to cause the second batch of dopant to fall through a second dopant receptacle outlet and from the second dopant receptacle, the second dopant cup opening being aligned with the second dopant receptacle outlet.

20. The method as set forth in claim 19 comprising:

rotating a third dopant receptacle to release a third batch of dopant from the third dopant receptacle and cause the third batch of dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt and after the second batch of dopant is released from the second dopant receptacle, the third dopant receptacle being disposed within the dopant cup, the dopant cup being rotated to cause the third batch of dopant to fall from the third dopant receptacle; and

rotating a fourth dopant receptacle to release a fourth batch of dopant from the fourth dopant receptacle and cause the fourth batch of dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt and after the third batch of dopant is released from the third dopant receptacle, the fourth dopant receptacle being disposed within the dopant cup, the

dopant cup being rotated to cause the fourth batch of dopant to fall from the fourth dopant receptacle.

21. The method as set forth in claim 19 wherein the first batch of dopant is a first batch of solid-phase dopant and the second batch of dopant is a second batch of solid-phase dopant.

22. A method for producing a single crystal silicon ingot from a silicon melt held within a crucible, the method comprising:

adding solid-state silicon to the crucible, the crucible being disposed within an ingot puller inner chamber;

heating the solid-state silicon to cause the silicon melt to form in the crucible;

pulling the single crystal silicon ingot from the silicon melt;

rotating a dopant cup, a first dopant receptacle and a second dopant receptacle being disposed within the dopant cup, the dopant cup comprising:

a sidewall;

a first dopant cup opening formed in the sidewall; and

a second dopant cup opening; and

wherein rotating the dopant cup causes:

the first dopant receptacle and the second dopant receptacle to rotate simultaneously in a first step to release a first batch of solid-phase dopant from the first dopant receptacle and through a first dopant receptacle outlet to cause the first batch of solid-phase dopant to

enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt, the first batch of solid-phase dopant being released only from the first dopant receptacle, the first dopant cup opening being aligned with the first dopant receptacle outlet; and

the first dopant receptacle and the second dopant receptacle to rotate simultaneously in a second step to release a second batch of solid-phase dopant from the second dopant receptacle and through a second dopant receptacle outlet to cause the second batch of solid-phase dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt, the second batch of solid-phase dopant only being released from the second dopant receptacle, the second dopant cup opening being aligned with the second dopant receptacle outlet.

23. The method as set forth in claim 22 wherein a third dopant receptacle and a fourth dopant receptacle are disposed in the dopant cup, wherein rotating the dopant cup causes:

the third dopant receptacle to rotate simultaneously with the first dopant receptacle and the second dopant receptacle in a third step to release a third batch of solid-phase dopant from the third dopant receptacle and cause the third batch of solid-phase dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt and after the second batch of solid-phase dopant is released from the second dopant receptacle, the third batch of solid-phase dopant only being released from the third dopant receptacle; and

the fourth dopant receptacle to rotate simultaneously with the first dopant receptacle, the second

dopant receptacle, and the third dopant receptacle in a fourth step to release a fourth batch of solid-phase dopant from the fourth dopant receptacle and cause the fourth batch of solid-phase dopant to enter the silicon melt while pulling the single crystal silicon ingot from the silicon melt and after the third batch of solid-phase dopant is released from the third dopant receptacle, the fourth batch of solid-phase dopant only being released from the fourth dopant receptacle.

24. The method as set forth in claim 22 comprising operating a handle to rotate the first and second dopant receptacles.