

WHAT IS CLAIMED IS:

1. A method for producing a monocrystalline silicon ingot having a neck and a main body suspended from the neck, the method comprising:

contacting a seed crystal with a silicon melt held within a crucible;

pulling a neck from the silicon melt;

measuring a pull rate at which the neck is pulled from the silicon melt;

calculating a moving average from the measured pull rate;

comparing the moving average of the measured pull rate to a target range; and

pulling an ingot main body from the melt if the moving average is within the target range, the main body being suspended from the neck.

2. The method as set forth in claim 1 wherein a main body is not grown from the melt if the moving average is outside the target range.

3. The method as set forth in claim 2 wherein the neck is lowered into the melt if the moving average is outside the target range.

4. The method as set forth in claim 2 or claim 3 wherein the neck is a first neck, the method further comprising:

pulling a second neck from the silicon melt if the main body is not grown from the first neck;

measuring a pull rate at which the second neck is pulled from the silicon melt;

calculating a moving average from the measured pull rate of the second neck;

comparing the moving average of the measured pull rate of the second neck to the target range; and

pulling an ingot main body from the melt if the moving average of the measured pull rate of the second neck is within the target range, the main body being suspended from the second neck.

5. The method as set forth in any one of claims 1 to 4 wherein the target range comprises a maximum moving average.

6. The method as set forth in any one of claims 1 to 4 wherein the target range comprises a minimum moving average.

7. The method as set forth in any one of claims 1 to 4 wherein the target range is bound by a minimum moving average and a maximum moving average.

8. The method as set forth in any one of claims 1 to 7 wherein the moving average is time-averaged.

9. The method as set forth in claim 8 wherein the calculated moving average is a moving average over at least the previous 5 seconds of neck growth, or at least the previous 30 seconds of neck growth, at least the previous 1 minute of neck growth, at least about the previous 2 minutes of neck growth, at least about the previous 5 minutes of neck growth, at least about the previous 10 minutes of neck growth or from about the

previous 5 seconds to about the previous 25 minutes of neck growth, about the previous 30 seconds to about the previous 20 minutes of neck growth, or about the previous 2 minutes to about the previous 10 minutes of neck growth.

10. The method as set forth in any one of claims 1 to 7 wherein the moving average is length-averaged.

11. The method as set forth in claim 10 wherein the moving average is a moving average over at least about the previous 0.2 mm of neck grown, at least about the previous 1 mm of neck grown, at least about the previous 2 mm of neck grown, at least about the previous 4 mm of neck grown, at least about the previous 10 mm of neck grown, at least about the previous 20 mm of neck grown, from about the previous 0.2 mm to about the previous 50 mm of neck grown, or about the previous 4 mm to about the previous 20 mm of neck grown.

12. The method as set forth in any one of claims 1 to 11 wherein comparing the moving average of the measured pull rate to a target range is performed for only a portion of the neck.

13. The method as set forth in any one of claims 1 to 11 wherein comparing the moving average of the measured pull rate to a target range is performed for the entire length of the neck.

14. The method as set forth in any one of claims 1 to 13 wherein the ingot main body has a diameter of at least about 200 mm or at least about 300 mm.

15. The method as set forth in any one of claims 1 to 14 wherein the ingot main body has a resistivity of less than about 20 mohm-cm.

16. The method as set forth in any one of claims 1 to 15 wherein the ingot main body is nitrogen-doped, the ingot main body comprising nitrogen at a concentration of at least about 1×10^{13} atoms/cm³.

17. The method as set forth in any one of claims 1 to 16 further comprising operating a heating system while measuring the pull rate, the heating system being operated at an average power while pulling the neck, the output power of the heating system being within about +/-0.5 kW of the average power while measuring the pull rate.

18. The method as set forth in any one of claims 1 to 16 further comprising operating a heating system while measuring the pull rate, the heating system being operated at an average power while pulling the neck, the output power of the heating system being within about +/-0.25 kW of the average power while measuring the pull rate.

19. A method for controlling the quality of a neck used to support an ingot main body, the neck being pulled from a silicon melt, the method comprising:

measuring a pull rate at which the neck is pulled from the silicon melt;

calculating a moving average of the pull rate from the measured pull rate;

comparing the moving average of the measured pull rate to a target range; and

sending a signal to terminate neck growth if the moving average falls outside of the target range.

20. The method as set forth in claim 19 wherein neck growth is terminated by lowering the neck into the melt.

21. The method as set forth in claim 19 wherein neck growth is terminated by increasing a pull rate of the neck to form an end cone and removing the neck from an ingot puller in which the neck was formed.

22. The method as set forth in any one of claims 19 to 21 wherein the neck has a resistivity of less than about 20 mohm-cm.

23. The method as set forth in any one of claims 19 to 22 wherein the neck is nitrogen-doped, the neck comprising nitrogen at a concentration of at least about 1×10^{13} atoms/cm³.

24. The method as set forth in any one of claims 19 to 23 further comprising operating a heating system at a power within about +/-0.5 kW of an average power while measuring the pull rate.

25. The method as set forth in any one of claims 19 to 23 further comprising operating a heating system at a power within about +/-0.25 kW of an average power while measuring the pull rate.

26. The method as set forth in any one of claims 19 to 25 wherein the target range comprises a maximum moving average.

27. The method as set forth in any one of claims 19 to 25 wherein the target range comprises a minimum moving average.

28. The method as set forth in any one of claims 19 to 25 wherein the target range is bound by a minimum moving average and a maximum moving average.

29. The method as set forth in any one of claims 19 to 28 wherein the moving average is time-averaged.

30. The method as set forth claim 29 wherein the calculated moving average is a moving average over at least the previous 5 seconds of neck growth, or at least the previous 30 seconds of neck growth, at least the previous 1 minute of neck growth, at least about the previous 2 minutes of neck growth, at least about the previous 5 minutes of neck growth, at least about the previous 10 minutes of neck growth or from about the previous 5 seconds to about the previous 25 minutes of neck growth, about the previous 30 seconds to about the previous 20 minutes of neck growth, or about the previous 2 minutes to about the previous 10 minutes of neck growth.

31. The method as set forth in any one of claims 19 to 29 wherein the moving average is length-averaged.

32. The method as set forth in claim 31 wherein the moving average is a moving average over at least about the previous 0.2 mm of neck growth, at least about the previous 1 mm of neck growth, at least about the previous 2 mm of neck growth, at least about the previous 4 mm of neck growth, at least about the previous 10 mm of neck growth, at least about the previous 20 mm of neck growth, from about the previous 0.2 mm to about the previous 50 mm of neck

grown, or about the previous 4 mm to about the previous 20 mm of neck grown.

33. The method as set forth in any one of claims 19 to 32 wherein comparing the moving average of the measured pull rate to a target range is performed for only a portion of the neck.

34. The method as set forth in any one of claims 19 to 32 wherein comparing the moving average of the measured pull rate to a target range is performed for the entire length of the neck.

35. The method as set forth in any one of claims 19 to 34 wherein the ingot main body has a diameter of at least about 200 mm or at least about 300 mm.

36. A system for producing a monocrystalline silicon ingot comprising:

- a crystal puller in which the silicon ingot is pulled;

- a crucible for holding a polycrystalline silicon melt within the crystal puller;

- a seed crystal chuck that secures a seed for contacting the silicon melt; and

- a control unit for controlling growth of a neck from which an ingot main body is suspended, the control unit regulating the pull rate of the neck, the control unit being configured to calculate a moving average of the pull rate and compare the moving average to a target moving average, the control unit terminating the neck when the pull rate is outside of the target moving average.

37. The system as set forth in claim 36 further comprising a termination mechanism for terminating neck growth, the termination mechanism being communicatively connected to the control unit.

38. The system as set forth in claim 37 wherein the termination mechanism produces a warning signal for alerting a technician.

39. The system as set forth in claim 37 wherein the warning signal causes an alarm to alert the technician.

40. The system as set forth in claim 36 wherein the control unit controls a heating system for heating the melt, the control unit being configured to maintain a power of the heating system within about ± 0.5 kW of an average power while calculating the moving average.

41. The system as set forth in claim 36 wherein the control unit controls a heating system for heating the melt, the control unit being configured to maintain a power of the heating system within about ± 0.25 kW of an average power while calculating the moving average.

42. The system as set forth in claim 36 comprising a sensor for measuring the neck pull rate.