crucible. An improved melting process is accordingly proposed, starting with melting by means of a side heater. The melt is then heated further in the bottom region of the crucible, which drives the melt movement and is thereby intended to lead to the degassing of the melt.

It has been found, however, that the occurrence of voids cannot be completely avoided by means of the described methods for carrying out the melting phase.

In accordance with US6340390B1 the pressure in the chamber of the crystal pulling installation during crystal pulling is kept below 95 mbar and below the pressure prevailing during the melting phase. The low pressure during crystal pulling is intended to lead to continuous degassing of the melt and thus to avoidance of the incorporation of gas bubbles into the growing single crystal. However, the pressure is an important parameter for the entire crystal quality. By way of example, the oxygen content of the single crystal and, consequently, the precipitation capability and thus the gettering capability are altered. Reducing the macroscopic voids by correspondingly setting the pressure is therefore associated with disadvantages. Moreover, the effect described is not always obtained in practice.

Therefore, embodiments of the invention seek to ~~was based on the object of~~ further reduce~~ing~~ the frequency of macroscopic voids in silicon single crystals without influencing the other crystal properties.

According to a first aspect of the invention, there is provided ~~The object is achieved by means of~~ a method for pulling a single crystal composed of silicon from a melt contained in a crucible, wherein the single crystal, during pulling, is surrounded by a heat shield, the lower end of which is at a distance h from the surface of the melt, wherein a gas flows downward in the region between the single crystal and the heat

shield, outward between the lower end of the heat shield and the melt and then upward again in the region outside the heat shield, wherein the internal diameter D_{HS} of the heat shield at the lower end thereof is at least 55 mm greater than the diameter D_{SC} of the single crystal, ~~and~~ wherein the radial width B_{HSU} of the heat shield at the lower end thereof is not more than 20% of the diameter of the single crystal wherein single crystal, crucible and heat shield are arranged in a chamber, and wherein the quotient of the flow rate of the gas and the pressure prevailing in the chamber is in the range of 20 to 500 (l/h)/mbar, and wherein the distance between the lower end of the heat shield and the melt is in the range of 10 to 40 mm.

According to a second aspect of the invention, there is provided a single crystal composed of silicon having a diameter of at least 100 mm, a crystal orientation (100) or (111), a dopant concentration of an element of the third or fifth main group of the periodic system of $1 \cdot 10^{17}$ to $1 \cdot 10^{20}$ cm^{-3} and an oxygen concentration of $4 \cdot 10^{17}$ to $9 \cdot 10^{17}$ cm^{-3}, wherein the concentration of voids having a diameter of at least 50 µm in the single crystal is not more than 50 m^{-3}.

The invention is described in greater detail below with reference to figures.

Figure 1 shows the schematic construction of a crystal pulling installation which can be used for the method according to the invention.

Figure 2 shows a schematic arrangement for pulling a single crystal and illustrates the geometrical variables which play a part in the context of the invention.

Figure 1 schematically shows a crystal pulling installation in accordance with the prior art during the crystal pulling process. A crucible 4, generally composed of quartz glass, contains the silicon melt 11. The crucible 4 is stabilized by a supporting crucible 5 and is heated either by side heaters 7 or by bottom heaters 8 or by both. The silicon single crystal 9 is pulled upward from the melt 11 at a predetermined rate (pulling rate, illustrated by arrow 14) with rotation (arrow 15), wherein the crucible 4 is likewise rotated (arrow 16) and is slowly moved along upward (arrow 17), for the purpose of keeping the position of the melt surface constant. Crucible 4 and single crystal 9 can be caused to effect rotation in the same direction or in opposite directions about the common axis of rotation. The convection in the melt can optionally be influenced by a magnetic field generated by electromagnets 6. The convection in the melt is indicated by an arrow.

Patent Claims

1. A method for pulling a single crystal (9) composed of silicon from a melt (11) contained in a crucible (4), wherein the single crystal (9), during pulling, is surrounded by a heat shield (2), the lower end (3) of which is at a distance (h) from the surface of the melt (11), wherein a gas flows (10) downward in the region between the single crystal (9) and the heat shield (2), outward between the lower end (3) of the heat shield (2) and the melt (11) and then upward again in the region outside the heat shield (2), wherein the internal diameter (D_{HS}) of the heat shield (2) at the lower end (3) thereof is at least 55 mm greater than the diameter (D_{SC}) of the single crystal (9), and wherein the radial width (B_{HSU}) of the heat shield (2) at the lower end (3) thereof is not more than 20% of the diameter (D_{SC}) of the single crystal (9).

2. The method as claimed in claim 1, wherein single crystal (9), crucible (4) and heat shield (2) are arranged in a chamber, and wherein the quotient of the flow rate of the gas and the pressure prevailing in the chamber is in the range of 20 to 500 (l/h)/mbar.

3. The method as claimed in claim 2, wherein the flow rate of the gas is in the range of 500 to 8000 l/h.

4. The method as claimed in claim 2, wherein the pressure is in the range of 10 to 80 mbar.

5. The method as claimed in any of claims 1 to 4, wherein crucible (4) and single crystal (9) are caused to effect rotation (15, 16) in opposite directions, and wherein the rotational speed of the crucible (4) is 0.25 to 25 revolutions per minute.

6. The method as claimed in any of claims 1 to 5, wherein the distance (h) between the lower end (3) of the heat shield (2) and the melt (11) is in the range of 10 to 40 mm.

7. The method as claimed in any of claims 1 to 6, wherein the internal diameter (D_{TI}) of the crucible (4) is two to four times as large as the diameter (D_{SC}) of the single crystal (9).

8. The method as claimed in any of claims 1 to 7, wherein the surface at the inner side of the crucible (4) is coated with a barium compound.

9. A single crystal composed of silicon having a diameter of at least 100 mm, a crystal orientation (100) or (111), a dopant concentration of an element of the third or fifth main group of the periodic system of $1 \cdot 10^{17}$ to $1 \cdot 10^{20}$ cm^{-3} and an oxygen concentration of $4 \cdot 10^{17}$ to $9 \cdot 10^{17}$ cm^{-3}, wherein the concentration of voids having a diameter of at least 50 µm in the single crystal is not more than 50 m^{-3}.

Claims

1. A method for pulling a single crystal composed of silicon from a melt contained in a crucible, wherein the single crystal, during pulling, is surrounded by a heat shield, the lower end of which is at a distance from the surface of the melt, wherein a gas flows downward in the region between the single crystal and the heat shield, outward between the lower end of the heat shield and the melt and then upward again in the region outside the heat shield, wherein the internal diameter of the heat shield at the lower end thereof is at least 55 mm greater than the diameter of the single crystal, wherein the radial width of the heat shield at the lower end thereof is not more than 20% of the diameter of the single crystal, wherein single crystal, crucible and heat shield are arranged in a chamber, and wherein the quotient of the flow rate of the gas and the pressure prevailing in the chamber is in the range of 20 to 500 (l/h)/mbar, and wherein the distance between the lower end of the heat shield and the melt is in the range of 10 to 40 mm.

2. The method as claimed in claim 1, wherein the flow rate of the gas is in the range of 500 to 8000 l/h.

3. The method as claimed in claim 1, wherein the pressure is in the range of 10 to 80 mbar.

4. The method as claimed in any of claims 1 to 3, wherein crucible and single crystal are caused to effect rotation in opposite directions, and wherein the rotational speed of the crucible is 0.25 to 25 revolutions per minute.

5. The method as claimed in any of claims 1 to 4, wherein the internal diameter of the crucible is two to four times as large as the diameter of the single crystal.

6. The method as claimed in any of claims 1 to 5, wherein the surface at the inner side of the crucible is coated with a barium compound.

7. A single crystal composed of silicon having a diameter of at least 100 mm, a crystal orientation (100) or (111), a dopant concentration of an element of the third or fifth main group of the periodic system of $1 \cdot 10^{17}$ to $1 \cdot 10^{20}$ cm^{-3} and an oxygen concentration of $4 \cdot 10^{17}$ to $9 \cdot 10^{17}$ cm^{-3}, wherein the concentration of voids having a diameter of at least 50 µm in the single crystal is not more than 50 m^{-3}.