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# Device and method for pulling a single crystal

The invention relates to a device for pulling a silicon single crystal, comprising an element, which annularly surrounds the single crystal growing at a crystallization boundary and has a face directed at the single crystal. The invention furthermore relates to a method for pulling a silicon single crystal, in which the single crystal is pulled at a pull rate V selected in such a way that the ratio V/G takes the value $1.3 * 10^{-3}$ $cm^2min^{-1}K^{-1}$ ± 10%, where G is the axial temperature gradient in the region of the crystallization boundary.

It is, for example in DE-4414947 A1, described that silicon semiconductor wafers separated from a single crystal may have a so-called stacking fault ring. The occurrence of a stacking fault ring is closely connected with the pull rate V and the axial temperature gradient G in the region of the crystallization boundary. According to the empirically found formula $V/G = 1.3 * 10^{-3}$ $cm^{-2}min^{-1}K^{-1}$, it is possible to specify a lower pull rate, above which a stacking fault ring just starts to occur.

The prior art furthermore describes that the stacking fault ring separates regions of the semiconductor wafer which are characterized by the presence of different defect types and defect densities (E. Dornberger and W.v. Ammon, Journal Of The Electrochemical Society, Vol. 143, No. 5, 1996). This literature reference also discloses that, with the customarily employed pulling method, the temperature gradient in the region of the crystallization boundary is not constant, but changes in the radial direction, viewed from the crystal axis.

The object of the present invention is to avoid substantially a variation in the axial temperature gradient in the region of the crystallization boundary in the radial direction.

This object is achieved by a device for pulling a silicon single crystal, comprising an element, which

annularly surrounds the single crystal growing at a crystallization boundary and has a face directed at the single crystal, and is characterized in that the element surrounds the single crystal substantially level with the crystallization boundary and has the property of reflecting heat radiation radiated by the single crystal or of radiating heat radiation.

This object is furthermore achieved by a method for pulling a silicon single crystal, in which the single crystal is pulled at a pull rate V selected in such a way that the ratio V/G takes the value $1.3 * 10^{-3}$ $cm^2min^{-1}K^{-1}$ ± 10%, where G is the axial temperature gradient in the single crystal in the region of the crystallization boundary, which is characterized in that the single crystal is thermally affected by an element surrounding it substantially level with the crystallization boundary.

The standardization of the axial temperature gradient G in the region of the crystallization boundary, which can be achieved with the aid of the invention, makes it possible to produce semiconductor wafers with definitively adjustable defect characteristics.

The invention will be explained in more detail below with reference to a figure. Only those features are represented which contribute to comprehension of the invention. The figure schematically shows a view of the longitudinal section through a growing single crystal. Only the right-hand half is shown on account of axial symmetry.

The single crystal 1 grows at a crystallization boundary 2. The material needed for the growth is delivered by a melt 3. Around the single crystal, a heat shield 4 known per se is arranged. In the region of the crystallization boundary, this shield is connected to an element 5 which extends to within a distance D from the single crystal. The distance D is preferably from 10 to 50 mm. The element 5 has a face 6 directed at the single crystal 1 and extends over a height H in the pull direction. The height H is preferably from 25 to 100 mm. The face 6 is inclined relative to the long axis 7 of the

single crystal, preferably in the direction of the single crystal. The angle $\alpha$ is preferably from 0 to 60°. The face need not necessarily be plane, but may, for example, also be of concave or convex design.

The element 5 is arranged substantially level with the crystallization boundary 2, so that the region of the crystallization boundary can be thermally affected using the element. In the context of the invention, the region of the crystallization boundary is counted as the crystallization boundary 2 and a region extending up to 2 mm into the single crystal.

In order to make it possible to standardize the axial temperature gradient in the radial direction using the element, this element must reflect well the heat radiation radiated by the single crystal, or be capable of applying heat to the single crystal. In the first case, the element 5, or at least its face 6, consists of a material having a high reflection factor for heat radiation, for example made of molybdenum or polished graphite. In the second case, the element 5 is designed as a heating element, preferably a resistive heater. To further improve the radial homogeneity of G, active cooling may be carried out above the element, for example by providing an active cooling instrument, as described for example in US-5,567,399, above the element.

The element 5 need not be connected to a heat shield 4. It may also be fastened to a frame independently of a heat shield.

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Patent claims:

1. Device for pulling a silicon single crystal, comprising an element, which annularly surrounds the single crystal growing at a crystallization boundary and has a face directed at the single crystal, characterized in that the element surrounds the single crystal substantially level with the crystallization boundary and has the property of reflecting heat radiation radiated by the single crystal or of radiating heat radiation.

2. Device according to Claim 1, characterized in that the element is connected to the lower edge of a heat shield surrounding the single crystal.

3. Device according to Claim 1 or Claim 2, characterized in that the face of the element is inclined at a specific angle with respect to the single crystal relative to the long axis of the single crystal.

4. Device according to one of Claims 1 to 3, characterized in that the element has a height H which is from 25 to 100 mm long.

5. Device according to one of Claims 1 to 4, characterized in that the element extends to within a distance D of from 10 to 50 mm from the single crystal.

6. Method for pulling a silicon single crystal, in which the single crystal is pulled at a pull rate V selected in such a way that the ratio V/G takes the value $1.3 * 10^{-3}$ $cm^2min^{-1}K^{-1}$ ± 10%, and G is the axial temperature gradient in the single crystal in the region of the crystallization boundary, characterized in that the single crystal is thermally affected by an element surrounding it substantially level with the crystallization boundary.

7. Method according to Claim 6, characterized in that heat radiation from the single crystal is reflected using the element.

8. Method according to Claim 6, characterized in that the single crystal is exposed to heat radiation using the element.

9. Method according to one of Claims 6 to 8,

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characterized in that there is active cooling above the element.

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