

Method for producing semiconductor wafers from monocrystalline silicon

5 The subject of the invention is a method for producing semiconductor wafers of monocrystalline silicon.

Semiconductor wafers of monocrystalline silicon are produced on the industrial scale. A large number of such semiconductor wafers come about from the removal of the semiconductor wafers from the cylindrical section of a monocrystal which has been
10 pulled from a melt which was contained in a crucible. This method for producing the single crystal is also referred to as the CZ method. The semiconductor wafers produced are typically processed further into electronic components.

Prior Art / Problem

15 Certain applications, especially in the field of power electronics, require semiconductor wafers of comparatively high diameter, containing interstitial oxygen (referred to below simply as oxygen) in comparatively low concentration within comparatively narrow limits. In this description the concentration of oxygen is
20 understood to be comparatively low if the value thereof as determined by the new ASTM is not more than 5×10^{17} atoms/cm³.

DE 10 2010 028 924 A1 describes how the concentration of oxygen in the single crystal can be reduced by exposing the melt to a horizontal magnetic field and by
25 lowering the rotational velocity of the crucible.

Recommendations in JP 9 175 895 A2, furthermore, include that the rotational velocity of the crucible be increased periodically, starting from a base rotational velocity, and that the base rotational velocity and the amplitude of the increase be raised as a
30 function of the length of the single crystal grown.

It has now been ascertained that, while such teachings, if observed, do allow the concentration of oxygen in the single crystal to be lowered to a comparatively low

value, there is nevertheless comparatively sharp variation in the concentration over the length of the single crystal.

It is therefore an object of the invention to diminish axial fluctuations in the oxygen
5 concentration.

The object of the invention is achieved by means of a method for producing semiconductor wafers of monocrystalline silicon, comprising
pulling a cylindrical section of a single silicon crystal from a melt contained in a
10 crucible;
subjecting the melt to a horizontal magnetic field;
rotating the crucible at a rotational velocity and in a rotational direction during the pulling of the cylindrical section of the single crystal; and
removing the semiconductor wafers of monocrystalline silicon from the cylindrical
15 section of the single crystal, wherein
the amount of rotational velocity, averaged over time, is less than 1 rpm and the rotational direction is changed continually and the amplitude of the rotational velocity before and after the change in the rotational direction is not less than 0.5 rpm and not more than 3.0 rpm.

20 By employing the invention it is possible to reduce axial fluctuations in the concentration of oxygen in the cylindrical section of the single crystal, expressed as the difference between maximum concentration and minimum concentration, by more than half.

25 The invention can be utilized independently of the diameter of the cylindrical section of the single crystal. The concentration of oxygen in the cylindrical section of the single crystal is not more than 5×10^{17} atoms/cm³. The method of the invention is used preferably to produce semiconductor wafers having a diameter of at least 200 mm,
30 more preferably at least 300 mm.

For the object to be achieved, the rotational velocity of the crucible as a time average (average rotational velocity) must be less than 1 rpm, preferably not more than

0.7 rpm. The direction of the average rotational velocity of the crucible may match or be opposite to the direction of the rotational velocity of the single crystal. The directions preferably match. Furthermore, the rotational direction of the crucible must be changed continually, preferably periodically. The length of a period is preferably 10
 5 to 100 s. Before and after the change in the rotational direction, the amplitude of the rotational velocity is not less than 0.5 rpm and not more than 3.0 rpm. Allowing the amplitude to overshoot the upper limit is not advisable, unless the aim is for a concentration of oxygen in the single crystal of more than 5×10^{17} atoms/cm³.

10 In the region of the phase boundary between the growing single crystal and the melt, the horizontal magnetic field has an intensity of preferably not less than 0.2 T and not more than 0.4 T.

The invention is described further below with reference to drawings.

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Brief Description of the Figures

Fig. 1 shows schematically the time profile of the rotational velocity of the crucible over a period.

20 **Fig. 2** shows the concentration of oxygen in two groups of single silicon crystals as a function of the axial position in the cylindrical section of the single crystals.

List of Reference Symbols Used

25 **1** Timing at the change in the rotational direction

Detailed description of working examples in accordance with the invention

30 As represented in fig. 1, the crucible during one period is accelerated in a rotational direction up to an amplitude A_1 and braked again and subsequently, up to the timing 1 of the change in the rotational direction, is accelerated in the opposite rotational direction to an amplitude A_2 and braked again. The amplitudes A_1 and A_2 are different

in their amount, so resulting in an average rotational velocity in one of the rotational directions.

Example:

- 5 Two groups of single silicon crystals with a diameter of 300 mm were pulled by the CZ method and semiconductor wafers were removed from the respective cylindrical section of the single crystals. A first group of the single crystals was pulled in accordance with the invention – that is, in particular, by changing the rotational direction of the crucible, during the pulling of the cylindrical section of the single crystal, with a period duration of 40 s and an amplitude of not more than 1.1 rpm. In contrast to this, the other group of single crystals was pulled under otherwise identical conditions without any change in the rotational direction of the crucible. For both groups, the average rotational velocity of the crucible was 0.6 rpm.
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- 15 Determining the oxygen concentrations as a function of a relative axial position P in the cylindrical section of the single crystals produced the outcome represented in fig. 2. Accordingly, when the method of the invention is employed, it is possible to expect the oxygen concentration to remain within a comparatively narrow corridor. In the present case, all of the data points (solid circles), assigned to single crystals pulled in accordance with the invention, lay within the corridor delimited by dashed lines, with an oxygen concentration of 4.4×10^{17} atoms/cm³ to approximately 4.9×10^{17} atoms/cm³.
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- 25 The description above of illustrative embodiments should be understood as an example. The disclosure therein enables a skilled person, on the one hand, to understand the present invention and the advantages associated with it, and on the other hand, within the understanding of the skilled person, also embraces obvious alterations and modifications to the structures and methods described. The intention is therefore that all such alterations and modifications, and also equivalents, should be covered by the scope of protection of the claims.
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What is claimed is:-

1. A method for producing semiconductor wafers of monocrystalline silicon,
comprising
 - 5 pulling a cylindrical section of a single silicon crystal from a melt contained in a crucible;
subjecting the melt to a horizontal magnetic field;
rotating the crucible at a rotational velocity and in a rotational direction during the
pulling of the cylindrical section of the single crystal; and
 - 10 removing the semiconductor wafers of monocrystalline silicon from the cylindrical
section of the single crystal, characterized in that
the amount of rotational velocity, averaged over time, is less than 1 rpm and the
rotational direction is changed continually and the amplitude of the rotational velocity
before and after the change in the rotational direction is not less than 0.5 rpm and not
15 more than 3.0 rpm.
2. The method as claimed in claim 1, characterized in that the rotational direction is
changed periodically with a period length of 10 to 100 s.
- 20 3. The method as claimed in claim 1 or claim 2, characterized in that the amount of
the rotational velocity, averaged over time, is not more than 0.7 rpm.