

Apparatus and Method For Pulling A Single Crystal Of Semiconductor Material

The invention provides an apparatus for pulling a single crystal of semiconductor
5 material from a melt contained in a crucible, and also a method for pulling a single
crystal of semiconductor material wherein the apparatus is used.

Prior art/problems

Single crystals of semiconductor material are frequently produced by the CZ method,
10 wherein a single crystal growing on a seed crystal is pulled upwardly away from a melt
which is contained in a crucible. On the industrial scale, single crystals of
semiconductor material such as silicon, in particular, are produced in this way, before
being subsequently processed further into semiconductor wafers and later on into
electronic components.

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An apparatus for employing the CZ method generally comprises a crucible, which is
held by a raiseable and lowerable crucible shaft, and a raiseable and lowerable pulling
shaft, which is used to pull the growing single crystal away from the melt. The
constituents of such an apparatus further include one device each for rotating the
20 pulling shaft and for rotating the crucible shaft. Single-crystalline growth requires an
ultra low-jitter environment, and this is the reason why particular importance attaches
to the devices for performing the rotational movements of the pulling shaft and of the
crucible shaft.

25 An apparatus is shown in EP 0 466 457 A1 wherein the device for rotating the pulling
shaft comprises a motor which drives a gearwheel, this gearwheel engaging into a
worm wheel which is mounted on the pulling shaft. The device for rotating the crucible
shaft comprises a motor which drives the crucible shaft directly.

30 An apparatus of this kind no longer satisfies the present-day demands for the
provision of an ultra low-jitter environment. In particular there is no assurance that
comparatively longwave vibrations are adequately suppressed.

It is an object of the present invention to provide an apparatus and a method for pulling single crystals of semiconductor material, where the devices of the apparatus for rotating the pulling shaft and the crucible shaft are designed in such a way as to provide assurance of low-jitter operation of these devices.

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The object of the invention is achieved by an apparatus for pulling a single crystal of semiconductor material from a melt contained in a crucible, having a device for rotating a pulling shaft and having a device for rotating a crucible shaft, characterized by a double worm gear between a drive and the pulling shaft and by a further double worm gear between a further drive and the crucible shaft.

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The apparatus not only achieves the object but also represents a space-saving and maintenance-friendly solution for bringing about the rotation of the pulling shaft and of the crucible shaft. The two double worm gears are notable for comparatively low play and for comparatively pronounced smooth running. Longwave vibrations, which may be brought about in particular by low rotary speeds of the crucible shaft, of less than 1 rpm, and/or following a change in the rotational direction of the crucible shaft, are effectively suppressed.

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The inventors have found out that it is necessary to install one double worm gear in each case between the pulling shaft and the drive that places it in rotation and between the crucible shaft and the further drive that places it in rotation, respectively. With an arrangement of this kind, the respective drive, preferably an electric motor, whose shaft drives the first worm of the respective double worm gear has a position lateral to the axis of rotation of the pulling shaft (or lateral to the axis of rotation of the crucible shaft, respectively) with a sufficient distance from the respective axis of rotation. The respective drive is preferably mounted rigidly on a housing plate of the respective double worm gear. There is therefore no spring mounting of the respective drive. The shaft of the respective drive is preferably arranged parallel to the pulling shaft (or crucible shaft, respectively). The first worm of the respective double worm gear engages into a respective first worm wheel, which is mounted coaxially on the shaft of the second worm of the respective double worm gear. The second worm of the respective double worm gear engages in turn into the respective second worm

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wheel of the respective double worm gear, with the respective second worm wheel being mounted coaxially on the pulling shaft (or crucible shaft, respectively).

5 It is preferred, furthermore, for the pulling shaft and the crucible shaft to be divided, respectively, into an upper portion and a lower portion and for the two portions to be connected in each case via a coupling bellows. Furthermore, at least in the case of the pulling shaft, the coupling bellows are configured in such a way that they provide the upper portion of the pulling shaft with electrical isolation from the lower portion of the pulling shaft. This enables simple implementation of the detection of the surface of
10 the melt via a current circuit which comprises the lower portion of the crucible shaft.

The drive of the crucible shaft is preferably designed in such a way that the direction of rotation of the crucible shaft can also be reversed.

15 The invention is elucidated in more detail below with reference to two drawings.

Brief description of the figures

Fig. 1 shows, as an example, an apparatus for pulling a single crystal by the CZ
20 method that can be utilized for implementing the invention.

Fig. 2 shows features of an apparatus according to the invention.

List of reference symbols used

- 25 **1** single crystal
 2 chamber
 3 heat insulation material
 4 gas inlet
 5 gas outlet
30 **6** heater
 7 melt
 8 crucible
 9 housing plate

- 10** apparatus for pulling
- 11** growing single crystal
- 12** supporting device
- 13** crucible shaft
- 5 **14** pulling shaft
- 15** mounting device
- 16** seed crystal holder
- 17** seed crystal
- 18** magnetic field generation coil
- 10 **19** controller
- 20** device for rotating the pulling shaft
- 21** device for rotating the crucible shaft
- 22** drive
- 23** driveshaft
- 15 **24** first worm
- 25** first worm wheel
- 26** second worm
- 27** second worm wheel
- 28** upper portion of the pulling shaft
- 20 **29** lower portion of the pulling shaft
- 30** bellows coupling
- 31** further drive
- 32** further driveshaft
- 33** further first worm
- 25 **34** further first worm wheel
- 35** further second worm
- 36** further second worm wheel
- 37** lower portion of the crucible shaft
- 38** upper portion of the crucible shaft
- 30 **39** further bellows coupling
- 40** further housing plate
- D** axis of rotation

Fig. 1 shows, as an example, an apparatus 10 for pulling a single crystal 1 of semiconductor material from a melt 7, which can be utilized in the invention. The apparatus comprises a chamber 2, a heater 6, a crucible 8, a crucible shaft 13, a pulling shaft 14, and a magnetic field generation coil 18. One internal wall of the chamber 2 is provided with a heat insulation material 3. In the upper part of the chamber 2 there is a gas inlet 4, through which an inert gas such as argon is introduced, and at the lower part of the chamber 2 there is a gas outlet 5. The crucible 8 supports an internal crucible which is filled with the melt 7 of semiconductor material. Around the crucible 8 is the heater 6, to melt solid semiconductor material and maintain it in the melted state. The crucible shaft 13 extends from a lower end of the crucible 8 to the base of the chamber, and is mounted by a supporting device 12. The crucible shaft 13 can be raised and lowered and rotated by the supporting device 12. The pulling shaft 14 is held at the upper end by a holding device 15 and, with the aid of the holding device 15, can be raised and lowered and rotated around an axis of rotation D. The supporting device 12 and the holding device 15 are controlled by a controller 19. By passing a current through the magnetic field generation coil 18 a magnetic field, for example a horizontal magnetic field, can be imposed on the melt 7. Furthermore, a heat shield (not shown in the drawing) can also be arranged around the growing single crystal 11. The reference numerals 16 and 17 denote a seed crystal holder and a seed crystal.

In accordance with the illustration in Fig. 2, the holding device 15 comprises a device 20 for rotating the pulling shaft 14, and the supporting device 12 comprises a device 21 for rotating the crucible shaft 13. The devices 20 and 21 are designed in accordance with the invention.

The device 20 for rotating the pulling shaft 14 comprises a drive 22 having a driveshaft 23 which drives a first worm 24. The first worm 24 engages into a first worm wheel 25, which is fixed coaxially on a shaft of a second worm 26. The second worm 26 engages into a second worm wheel 27, which is fixed coaxially on an upper portion 28 of the pulling shaft 14. The first and second worms 24, 26 and the first and second worm wheels 25, 27 together form a double worm gear. The drive 22 is mounted rigidly on a housing plate 9 of the double worm gear. Between the upper portion 28 of the pulling shaft 14 and a lower portion 29 of the pulling shaft 14 there is a first

bellows coupling 30 arranged, which performs electrical isolation of the upper portion 28 of the pulling shaft 14 from the lower portion 29 of the pulling shaft 14.

The device 21 for rotating the crucible shaft 13 comprises a further drive 31 having a
5 further driveshaft 32 which drives a further first worm 33. The further first worm 33 engages into a further first worm wheel 34, which is fixed coaxially on a shaft of a further second worm 35. The further second worm 35 engages into a further second worm wheel 36, which is fixed coaxially on a lower portion 37 of the crucible shaft 13. The further first and second worms 33, 35 and the further first and second worm
10 wheels 34, 36 together form a further double worm gear. The further drive 31 is mounted rigidly on a further housing plate 40 of the further double worm gear. Arranged between the lower portion 37 of the crucible shaft 13 and an upper portion 38 of the crucible shaft 13 is a further bellows coupling 39.

15 The description above of illustrative embodiments should be understood as a description of examples. The disclosure made accordingly on the one hand enables the skilled person to understand the present invention and the advantages associated with it, while on the other hand the understanding of the skilled person also encompasses obvious alterations and modifications of the methods and structures
20 described. The intention is therefore that all such alterations and modifications, and also equivalents, are covered by the scope of protection of the claims.

Claims

1. Apparatus for pulling a single crystal (1) of semiconductor material from a melt (7) contained in a crucible (8), having a device (20) for rotating a pulling shaft (14) and
5 having a device (21) for rotating a crucible shaft (13), characterized by a double worm gear between a drive (22) and the pulling shaft (14) and by a further double worm gear between a further drive (31) and the crucible shaft (13).
2. Apparatus according to Claim 1, characterized by a bellows coupling (30) between
10 an upper portion (28) and a lower portion (29) of the pulling shaft.
3. Apparatus according to Claim 1 or Claim 2, characterized by a further bellows coupling (39) between an upper portion (38) and a lower portion (37) of the crucible shaft (13).
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4. Apparatus according to any of Claims 1 to 3, characterized in that a driveshaft (23) of the drive (22) is arranged parallel to the pulling shaft (14).
5. Apparatus according to any of Claims 1 to 4, characterized in that the drive (22) is
20 mounted rigidly on a housing plate (9) of the double worm gear.
6. Apparatus according to any of Claims 1 to 5, characterized in that a further driveshaft (32) of the further drive (31) is arranged parallel to the crucible shaft (13).
- 25 7. Apparatus according to any of Claims 1 to 6, characterized in that the further drive (31) is mounted rigidly on a further housing plate (40) of the further double worm gear.
8. Method for pulling a single crystal of semiconductor material from a melt by the CZ method, characterized by the pulling of the single crystal of semiconductor material
30 using an apparatus according to any of Claims 1 to 7.