

Description

Technical Field

This invention relates to processes for making crystalline semiconductor material and, more particularly, to methods and apparatus for growing ingots of group III-V and group II-VI semiconductor compounds from which monocrystalline wafers can be cut.

Background of the Invention

One of the most significant developments in semiconductor technology has been the increased use and importance of compound semiconductors. Particularly significant are the group III-V compounds composed of elements of groups III and V of the periodic table such as gallium arsenide and indium phosphide. Single crystals of such materials are used, for example, for making lasers, light-emitting diodes, microwave oscillators and light detectors. Also important are the II-VI materials such as cadmium sulfide which may be used for making light detectors and other devices.

Most commercial use of compound semiconductors requires the growth of large single-crystal ingots from which monocrystalline wafers can be cut for the subsequent fabrication of useful devices. The U.S. patent of Gault, No. 4,404,172, granted September 13, 1983, describes a particularly useful method of crystal growth known as the vertical gradient freeze (VGF) method. According to this method, raw semiconductor material is placed in a vertically extending crucible including a small cylindrical seed well portion at its bottom end which snugly contains a monocrystalline seed crystal. Initially, the raw material and a portion of the seed crystal are melted. The power to the system is then reduced in such a manner that solidification, or freezing, proceeds vertically upwardly from the seed crystal, with a crystal orientation of the grown ingot corresponding to that of the seed crystal.

The U.S. patent of Shahid, No. 4,966,645, granted October 30, 1990, points out that ingots grown by the VGF method should preferably be grown in the $\langle 111 \rangle$ direction, while the wafers from which devices are to be made should be oriented in the $\langle 100 \rangle$ crystallographic direction. Fulfillment of both of these conditions requires slicing of the ingot at an angle of 35.3 degrees with respect to its central axis which, if the ingot is cylindrical with a circular cross-section, results in elliptically shaped wafers. The Shahid patent US-A-4 966 645 points out that, by growing ingots to have an elliptical cross-section, one can obtain circularly shaped wafers which can more efficiently be converted to useful devices. For taking best advantage of this

improvement, the seed crystal should be properly rotationally oriented within the seed well of the crucible. Specifically, the seed crystal should be oriented such that the line of intersection of the $\{100\}$ plane with the $\{111\}$ plane is parallel to the major axis of the ellipse of the crucible in which the ingot is to be grown.

After any semiconductor ingot is grown, it is customary to me on its outer surface a axially extending flat surface portion known as a "reference flat". The reference flat bears a specified relationship to the crystalline orientation of the ingot so that, after the wafers are made, the resulting flat portion on the periphery of each wafer can be used as a reference for properly orienting devices to be defined in the wafer. Crystal orientation can be determined in a number of ways, such as etching to expose crystalline planes of a semiconductor, and by various x-ray and optical diffraction techniques. Providing a reference flat on the periphery of each wafer, of course, obviates the need for such crystallographic determination methods prior to use of each wafer.

While the improvement of the Shahid patent US-A-4 966 645 significantly increases the efficiency with which compound semiconductor wafers can be made, there is a long-felt need in the industry for ways of reducing further the cost of making such wafers, and considerable effort to that end has been expended.

Patent Abstracts of Japan, Vol. 11, No. 200 (C-431) (2647), 27.06.1987, JP-A-62-021 786 shows a crystal holder for use with the horizontal Bridgeman method of growing crystals in which the crucible and seed crystal are horizontally located. The crystal holder has a V-groove which meshes with a V-shaped outer surface of the seed crystal. The purpose of this configuration is to release pressure on the seed crystal due to differences in the thermal expansion coefficients of the holder and the seed crystal. That is, the V-shaped holder allows the crystal to move upwardly due to thermal expansion forces.

FR-A-2175594 describes a vertical method for growing crystals. In one embodiment, the lower surface of the seed crystal has a conical indent which fits over a conical projection of the crucible.

Summary of the Invention

In accordance with the invention as set out in claim 1, the crystal orientation of the ingot to be grown is controlled by providing matching meshing portions in the crucible and in the seed crystal. For example, the meshing portion of the crucible may be a projecting wall portion and the meshing portion of the seed crystal may be a slot adapted to fit snugly over the wall portion. When the seed crystal

is meshed in this manner with the crucible, its orientation is fixed, and the crystal orientation of the ingot to be grown is likewise fixed. One may then use a crucible having an elliptical cross-section in accordance with the Shahid patent US-A-4 966 645 and be assured that the grown crystal will have the proper orientation such that, when the ingot is sliced to make circular wafers, the resulting wafers will have the proper crystallographic orientation; for example, to ensure that the surface of the wafers are oriented in the $\langle 100 \rangle$ crystallographic direction.

In a preferred form of the invention, one or more reference flats are made in the inner surface of the crucible. The reference flat extends axially along the major portion of the crucible such that a reference flat is formed along the usable portion of the ingot. With the seed crystal locked in place, one can ensure that the reference flat is an accurate indicator of the crystallographic orientation of the ingot. The provision of this feature avoids the need for grinding a reference flat in the ingot after it has been produced.

The invention can be used in any of various ways to reduce the effort and operator skill needed for growing ingots of desired crystal orientation. These and other objects, features and benefits of the invention will be understood from a consideration of the following detailed description taken in conjunction with the accompanying drawing.

Brief Description of the Drawing

FIG. 1 is a schematic view of apparatus for making semiconductor crystalline ingots in accordance with the prior art VGF method;
 FIG. 2 is a view taken along lines 2-2 of FIG. 1;
 FIG. 3 is a view of part of an ingot made with the apparatus of FIG. 1;
 FIG. 4 is a top view of a crucible in accordance with one embodiment of the invention;
 FIG. 5 is a view of a wafer sliced from an ingot made in the crucible of FIG. 4;
 FIG. 6 is a schematic view of an etched pit in a monocrystalline semiconductor seed crystal that may be used for determining crystallographic orientation;
 FIG. 7 is a schematic illustration of part of the seed well portion of the crucible of FIG. 3 together with a seed well cap portion in accordance with the invention;
 FIG. 8 is a view taken along lines 8-8 of FIG. 7; and
 FIG. 9 is a schematic view of a method for making seed crystals in accordance with an embodiment of the invention.

Detailed Description

The aforementioned Gault patent US-A-4 404 172 and related prior art literature describe in detail the apparatus to be used and procedural steps to be followed in successfully growing monocrystalline III-V semiconductor ingots in accordance with the vertical gradient freeze (VGF) method. For the sake of brevity, and for the purpose of emphasizing the improvements which constitute the present invention, such details will not be repeated, it being understood that the preferred method of implementing the invention is through the use of the VGF method. It should also be understood that while terms such as "monocrystalline" and "single crystal" are used to describe ingots, most ingots contain defects or localized departures from monocrystallinity, and successful growing methods are those that reduce or minimize (not necessarily eliminate) such defects.

Referring now to FIG. 1, the VGF method employs a vertically extending crucible 12 having a major portion 13, a cylindrical seed well portion 14 and a transition portion 15. A cylindrical monocrystalline seed crystal 16 of the semiconductor material to be grown, such as indium phosphide, is placed in the cylindrical seed well portion 14. The crucible is then nearly filled with raw material from which the ingot is to be made, such as polycrystals 17 of indium phosphide. There may also be included in the crucible a quantity of boric oxide for encapsulating the molten group III-V material, and there may also be included elemental group V material for maintaining stoichiometry of the ingot during its growth.

Heat is controllably applied to the raw material by a heater 20 which surrounds the crucible 12. All of the raw material 17 and part of the upper portion of seed crystal 16 is melted and then the power to the heater is reduced to give a predetermined temperature gradient within the crucible that causes recrystallization, or freezing, first at the interface of the melt and the seed crystal. The freezing progresses upwardly until the entirety of the molten raw material has been recrystallized into an ingot. If the process is executed with perfection, the ingot will be of a single crystal having a crystallographic orientation identical of that of the seed crystal 16. During melting and subsequent freezing of the semiconductor material, an over-pressure of gas, which may or may not include vapors of the group V element material, may be applied to the upper surface of the melt to retard the escape of vaporized group V material from the melt.

The cylindrical seed crystal 16 is preferably formed such that its upper surface 18 lies in the $\{111\}$ crystallographic plane, in which case a direction perpendicular to the surface 18, as indicated

by arrow 19, constitutes the $\langle 111 \rangle$ direction. Under these circumstances, single crystal semiconductor material growing from surface 18 of crystal 16 will grow vertically upwardly in the $\langle 111 \rangle$ crystallographic direction indicated by arrow 19. As is known, growth in this direction reduces stresses between the inner surface of the crucible and the ingot during growth, thus minimizing defects in the ingot. However, to obtain optimum crystal orientation for the wafers, the wafers would have to be cut at a severe angle; with cylindrical ingots, this would yield elliptical wafers.

Referring to FIG. 2, it can be seen that, in accordance with the teachings of the aforementioned Shahid patent US-A-4 966 645, the cross-section of the major portion of crucible 12 has a generally elliptical shape. The reason for this shape is to grow elliptically shaped ingots which, when sliced at an appropriate angle with respect to the central axis of the ingot, give wafers having generally circular peripheries. The ellipse defined by the cross-section of the crucible has a major axis x and a minor axis y , as shown in FIG. 2. FIG. 3 shows a side view of the ingot having a central axis 21 and a minor elliptical axis y which corresponds to the direction of FIG. 2. With indium phosphide and other materials having a zinc-blend crystal structure, a growth of the ingot in the $\langle 111 \rangle_B$ direction requires slicing at an angle θ with respect to central axis 21 of about 35.3 degrees for yielding wafers that are desirably oriented in the $\langle 100 \rangle$ crystallographic direction. The slicing, as shown by the arrow 23, will yield wafers having a circular periphery if the angle θ is an angle having a sine equal to y/x , where y and x are the ingot thicknesses along the minor and major axes, respectively. Thus, in the indium phosphide example, parameters x and y are chosen such that the sine of 35.3 degrees equals y/x .

As mentioned above, it is customary, prior to slicing wafers from the ingot, to grind axially extending reference flats in the ingot. With indium phosphide, a primary flat maybe ground so as to correspond to the (011) plane and the secondary flat as the $(0\bar{1}\bar{1})$ plane. In accordance with the invention, this grinding is avoided by simply forming the flat, or flats, in the crucible prior to ingot fabrication.

This is illustrated in FIG. 4 which is a sectional view of a crucible 12' containing a primary flat 26 and a secondary flat 27. The seed crystal is oriented in the seed well 14 such that, when the ingot is grown, it has a flat portion corresponding with primary flat 26 which is used as a primary reference flat for the ingot and another axially extending flat corresponding to secondary flat 27 which will constitute a secondary flat for the ingot. For indium phosphide, the ingot is grown such that primary flat

26 is parallel to the major axis of the crucible ellipse and corresponds to the (011) plane, and secondary flat 27 is parallel to the minor axis and corresponds to the $(0\bar{1}\bar{1})$ plane. Referring to FIG. 5, after the ingot has been sliced as described previously for yielding circular wafers, the wafers each contain primary and secondary reference flats 26' and 27' which may thereafter be used, in a known manner, for properly orienting devices to be formed in the wafer.

For the reference flats 26 and 27 of FIG. 4 to be properly determinative of the crystal orientation of the ingot, it is necessary that the seed crystal be properly rotationally oriented within the seed well. Specifically, in the case of indium phosphide, the line of intersection of the $\{100\}$ plane with the $\{111\}$ plane should be aligned so as to be parallel to the major axis (x) of the crucible ellipse. A number of methods are known for making this determination, one example being the etch method, described for example, in the paper, "Review of Chemical Polishing of Semiconductors," B. Tuck, *Journal of Materials Science*, Vol. 10, (1975), pp. 321-339. Referring to FIG. 6, a pit etched in indium phosphide will have a triangular shape defined by planar facets 30, each being located in the $\{111\}$ planes and inclined to the $(111)_B$ plane at 70.5 degrees. The edges of the pit are aligned along the $\langle 110 \rangle$ directions. Thus, one of the edges 31 of seed crystal 16' should be oriented to be parallel with the major axis of the ellipse defined by the crucible.

In accordance with another feature of the invention, the level of operator skill needed for rotationally orienting the seed crystal in the seed well is significantly reduced by using meshing portions in the seed crystal and in the seed well of the crucible as shown in FIG. 7. Only a portion 14' of the seed well of the crucible is shown in FIG. 7. Rigidly attached at the bottom is a cap 32 containing a wall portion 33 that projects upwardly from the cap. The seed crystal 35 contains a slot 36 which is indicative of the crystal orientation of the seed crystal 35. The seed crystal 35 is placed into the seed well 14' such that the slot 36 meshes with the wall portion 33 and fits snugly over it, and when so positioned, the seed crystal is properly rotationally oriented within the seed well for crystal growth as described above.

Referring to FIG. 8 which is a view taken along lines 8-8 of FIG. 7, the wall portion 33 may fit snugly into a slot in the crucible seed well portion 14'. Thus, after the crucible is made, a slot is cut in the bottom of the seed well portion which is carefully oriented with respect to the major and minor axes of the elliptical portion of the crucible. The wall portion 33 fits snugly in the slot and holds the cap 32 to the crucible by friction. In this manner,

crucibles can be produced of material such as boron nitride with interchangeable cap portions being used to define the wall portion 33. It can be appreciated that fitting the seed crystal 35 into the meshing seed well shown in FIG. 7 requires considerably less operator skill than would be required if the operator had to determine the crystal orientation of the seed crystal using a method such as that shown in FIG. 6.

If slot 36 is cut to be parallel with the line of intersection of the {100} plane with the {111} plane of the seed crystal 35, then wall portion 33 should be parallel with the major axis of the crucible ellipse. Alternatively, slot 36 can be cut to be parallel to the <112> direction, in which case wall portion 33 should be parallel to the minor axis of the ellipse. Referring to FIG. 8, a number of seed crystals 35 can be cut by "coring" in a known manner from a block of crystalline indium phosphide 38. The slots in the various seed crystals can be made by making slots 39 in the block 38, which bear a predetermined relationship to the crystal orientation of block 38. Then, when seed crystals 35 are cored from the block, they will contain slots 36 which are used in the manner depicted in FIG. 7.

While the invention has been discussed in the context of using the VGF method for making indium phosphide, it is to be understood that it is applicable to the growth of other semiconductor crystals, particularly group III-V and group II-VI semiconductors. The method of using one or more reference flats extending axially along the inner surface of a crucible may be used in conjunction with crucibles for making cylindrical ingots as well as elliptically shaped ingots, and it is not essential that the meshing feature of the seed crystal be used in any such embodiments. Various methods of interlocking or meshing the seed crystal with the crucible other than that specifically shown could alternatively be used. For example, a wall projection could be made in the seed crystal with a meshing slot formed in the crucible. The use of the meshing feature could be used in conjunction with cylindrical crucibles that may or may not have reference flats, as well as in conjunction with elliptically shaped crucibles that may or may not incorporate reference flats.

Claims

1. A method for making wafers of a semiconductor material comprising the steps of: orienting a semiconductor seed crystal (35) in a crucible having a vertically extending central axis such as to give a specific crystalline structure to a ingot to be grown; including semiconductor raw material (17) in the crucible in contact with

the seed crystal; melting the raw material and part of the seed crystal; solidifying the molten seed crystal and raw material so as to grow a crystalline semiconductor ingot having a central axis corresponding to that of the crucible; the orienting step comprising the steps of locating the seed crystal to be coaxial with the central axis of the crucible and rotationally orienting the seed crystal with respect to the central axis of the crucible such that the crystal structure of the seed crystal bears a predetermined angular relationship with the central axis of the ingot to be grown; and slicing the ingot at an angle with respect to the central axis of the ingot to make wafers of a selected crystal structure; CHARACTERIZED BY

making a first meshing portion (33) in part of the crucible; and

making a second meshing portion (36) in the seed crystal such that the second meshing portion matches the first meshing portion, such that the second meshing portion bears a selected relationship to the crystalline orientation of the seed crystal, and such that a meshing of the first and second meshing portions constrains angular rotation of the seed crystal around the central axis;

the step of orienting the seed crystal comprising the step of meshing the second meshing portion with the first meshing portion such that the seed crystal is constrained to conform to said predetermined angular relationship.

2. The method of claim 1 wherein:

one of said first meshing portion and said second meshing portion is a projecting wall portion and the other is a slot adapted to fit snugly over the projecting wall portion, preventing any rotation of the seed crystal around the central axis.

3. The method of claim 2 wherein:

the first meshing portion is the projecting wall portion;

and the step of making the second meshing portion comprises the step of making a slot in the seed crystal having a thickness sufficient to permit it to fit snugly over the projecting wall portion.

4. The method of claim 2 wherein:

the seed crystal is located at one end of the crucible;

and the solidification step comprises the step of growing the ingot from the seed crystal in a selected first crystallographic direction substantially coincident with the central axis of the crucible.



crucibles can be produced of material such as boron nitride with interchangeable cap portions being used to define the wall portion 33. It can be appreciated that fitting the seed crystal 35 into the meshing seed well shown in FIG. 7 requires considerably less operator skill than would be required if the operator had to determine the crystal orientation of the seed crystal using a method such as that shown in FIG. 6.

If slot 36 is cut to be parallel with the line of intersection of the {100} plane with the {111} plane of the seed crystal 35, then wall portion 33 should be parallel with the major axis of the crucible ellipse. Alternatively, slot 36 can be cut to be parallel to the <112> direction, in which case wall portion 33 should be parallel to the minor axis of the ellipse. Referring to FIG. 8, a number of seed crystals 35 can be cut by "coring" in a known manner from a block of crystalline indium phosphide 38. The slots in the various seed crystals can be made by making slots 39 in the block 38, which bear a predetermined relationship to the crystal orientation of block 38. Then, when seed crystals 35 are cored from the block, they will contain slots 36 which are used in the manner depicted in FIG. 7.

While the invention has been discussed in the context of using the VGF method for making indium phosphide, it is to be understood that it is applicable to the growth of other semiconductor crystals, particularly group III-V and group II-VI semiconductors. The method of using one or more reference flats extending axially along the inner surface of a crucible may be used in conjunction with crucibles for making cylindrical ingots as well as elliptically shaped ingots, and it is not essential that the meshing feature of the seed crystal be used in any such embodiments. Various methods of interlocking or meshing the seed crystal with the crucible other than that specifically shown could alternatively be used. For example, a wall projection could be made in the seed crystal with a meshing slot formed in the crucible. The use of the meshing feature could be used in conjunction with cylindrical crucibles that may or may not have reference flats, as well as in conjunction with elliptically shaped crucibles that may or may not incorporate reference flats.

Claims

1. A method for making wafers of a semiconductor material comprising the steps of: orienting a semiconductor seed crystal (35) in a crucible having a vertically extending central axis such as to give a specific crystalline structure to a ingot to be grown; including semiconductor raw material (17) in the crucible in contact with

the seed crystal; melting the raw material and part of the seed crystal; solidifying the molten seed crystal and raw material so as to grow a crystalline semiconductor ingot having a central axis corresponding to that of the crucible; the orienting step comprising the steps of locating the seed crystal to be coaxial with the central axis of the crucible and rotationally orienting the seed crystal with respect to the central axis of the crucible such that the crystal structure of the seed crystal bears a predetermined angular relationship with the central axis of the ingot to be grown; and slicing the ingot at an angle with respect to the central axis of the ingot to make wafers of a selected crystal structure; CHARACTERIZED BY

making a first meshing portion (33) in part of the crucible; and

making a second meshing portion (36) in the seed crystal such that the second meshing portion matches the first meshing portion, such that the second meshing portion bears a selected relationship to the crystalline orientation of the seed crystal, and such that a meshing of the first and second meshing portions constrains angular rotation of the seed crystal around the central axis;

the step of orienting the seed crystal comprising the step of meshing the second meshing portion with the first meshing portion such that the seed crystal is constrained to conform to said predetermined angular relationship.

2. The method of claim 1 wherein:

one of said first meshing portion and said second meshing portion is a projecting wall portion and the other is a slot adapted to fit snugly over the projecting wall portion, preventing any rotation of the seed crystal around the central axis.

3. The method of claim 2 wherein:

the first meshing portion is the projecting wall portion;

and the step of making the second meshing portion comprises the step of making a slot in the seed crystal having a thickness sufficient to permit it to fit snugly over the projecting wall portion.

4. The method of claim 2 wherein:

the seed crystal is located at one end of the crucible;

and the solidification step comprises the step of growing the ingot from the seed crystal in a selected first crystallographic direction substantially coincident with the central axis of the crucible.



5. The method of claim 4 further comprising the steps of:

constraining growth of a major portion of the ingot such that, in a section taken perpendicularly to the first crystallographic direction, the outer surface of the ingot is substantially elliptical.

6. The method of claim 5 wherein:

the slicing step comprises the step of repeatedly cutting the ingot at a sufficient angle with respect to the first direction to yield wafers each having a substantially circular outer periphery.

7. The method of claim 6 wherein:

the first crystallographic direction is the (111) crystallographic direction;

and the angle at which the ingot is cut is substantially 35.3 degrees with respect to the first direction.

8. The method of claim 6 wherein:

the semiconductor is taken from the group consisting of a group III-V semiconductor material and a group II-VI semiconductor material.

9. The method of claim 1 wherein:

the method of growing the ingot comprises the step of including the seed crystal in a seed well at the lower end of the crucible;

and the solidification step comprises the step of progressively freezing the molten material in a upward direction from the seed crystal to form a ingot having a central axis coincident with the central axis of the crucible.

10. The method of claim 3 wherein:

the step of making the slot in the seed crystal comprises the step of making a plurality of slots in a crystal body and then cutting the body into a plurality of seed crystals each having a slot therein.

Patentansprüche

1. Verfahren zur Herstellung von Wafern eines Halbleitermaterials umfassend die Schritte:

Ausrichten eines Halbleiter-Impfkristalls (35) in einem Schmelztiegel mit einer sich vertikal erstreckenden Mittenachse, um so einem zu erzeugenden Block eine spezielle kristalline Struktur zu verleihen, umfassend ein Halbleiter-Rohmaterial (17) im Schmelztiegel in Kontakt mit dem Impfkristall, Schmelzen des Rohmaterials und eines Teils des Impfkristalls, Verfestigen des geschmolzenen Impfkristalls und Rohmaterials, um so einen kristallinen

Halbleiterblock zu erzeugen mit einer Mittenachse, die derjenigen des Schmelztiegels entspricht, wobei der Schritt des Ausrichtens die Schritte des Anordnens des Impfkristalls in koaxialer Weise zur Mittenachse des Schmelztiegels und das Ausrichten der Drehung des Impfkristalls in Bezug auf die Mittenachse des Schmelztiegels derart umfaßt, daß die Kristallstruktur des Impfkristalls ein vorbestimmtes Winkelverhältnis zur Mittenachse des zu erzeugenden Blockes aufweist, und Schneiden des Blockes in Scheiben unter einem Winkel in Bezug auf die Mittenachse des Blockes, um Wafer einer ausgewählten Kristallstruktur herzustellen,

gekennzeichnet durch

das Herstellen eines ersten Eingriffsabschnitts (33) in einem Teil des Schmelztiegels und das Herstellen eines zweiten Eingriffsabschnitts (36) im Impfkristall, so daß der zweite Eingriffsabschnitt an den ersten Eingriffsabschnitt derart angepaßt ist, daß der zweite Eingriffsabschnitt ein ausgewähltes Verhältnis zur kristallinen Orientierung des Impfkristalls aufweist und derart, daß ein Ineinandergreifen des ersten und zweiten Eingriffsabschnitts die winkelmäßige Drehung des Impfkristalls um die Mittenachse erzwingt,

wobei der Schritt des Ausrichtens des Impfkristalls den Schritt des Ineinandergreifens des zweiten Eingriffsabschnitts mit dem ersten Eingriffsabschnitt derart umfaßt, daß der Impfkristall gezwungen wird, mit dem vorbestimmten Winkelverhältnis in Einklang zu geraten.

2. Verfahren nach Anspruch 1, bei welchem der erste Eingriffsabschnitt oder der zweite Eingriffsabschnitt ein vorstehender Wandabschnitt und der andere ein Schlitz ist, der über den vorstehenden Wandabschnitt genau paßt, wodurch eine Drehung des Impfkristalls gegenüber der Mittenachse verhindert wird.

3. Verfahren nach Anspruch 2, bei welchem der erste Eingriffsabschnitt der vorstehende Wandabschnitt ist und der Schritt des Herstellens des zweiten Wandabschnittes den Schritt des Herstellens eines Schlitzes im Impfkristall, der eine ausreichende Dicke zum engen Passen über den vorstehenden Wandabschnitt aufweist, umfaßt.

4. Verfahren nach Anspruch 2, bei welchem der Impfkristall an einem Ende des Schmelztiegels angeordnet ist und der Schritt des Verfestigens den Schritt des Erzeugens des Blockes vom Impfkristall aus in einer ausgewählten kristallografischen Richtung im wesentlichen überein-



stimmend mit der Mittenachse des Schmelzriegels umfaßt.

5. Verfahren nach Anspruch 4, ferner umfassend die Schritte des Begrenzens des Erzeugens eines Hauptabschnittes des Blockes derart, daß in einem senkrecht zur ersten kristallografischen Richtung gewählten Abschnitt, die äußere Oberfläche des Blockes im wesentlichen elliptisch ist. 5 10
6. Verfahren nach Anspruch 5, bei welchem der Schritt des Schneidens in Scheiben den Schnitt des wiederholten Schneidens des Blockes unter einem geeigneten Winkel in Bezug auf die erste Richtung umfaßt, um Wafer zu erhalten, die jeweils im wesentlichen kreisförmigen äußeren Umfang haben. 15
7. Verfahren nach Anspruch 6, bei welchem die erste kristallografische Richtung die kristallografische $\langle 111 \rangle$ Richtung ist und der Winkel, unter welchem der Block geschnitten wird, im wesentlichen 35,3 Grad in Bezug auf die erste Richtung beträgt. 20 25
8. Verfahren nach Anspruch 6, bei welchem der Halbleiter aus der Gruppe gewählt wird, die besteht aus Gruppe III-V Halbleitermaterial und/oder Gruppe II-VI Halbleitermaterial. 30
9. Verfahren nach Anspruch 1, bei welchem: das Verfahren des Erzeugens des Blockes den Schritt des Einschließens des Impfkristalls in einer Zuchtmulde am unteren Ende des Schmelzriegels umfaßt und der Verfestigungsschritt den Schritt des fortschreitenden Einfrierens des geschmolzenen Materials in einer vom Impfkristall aufwärts gerichteten Richtung umfaßt, um einen Block zu bilden mit einer mit der Mittenachse des Schmelzriegels übereinstimmenden Mittenachse. 35 40
10. Verfahren nach Anspruch 3, bei welchem der Schritt des Herstellens des Schlitzes im Impfkristall den Schritt des Herstellens einer Vielzahl von Schlitzten in einem Kristallkörper und dann das schneiden des Körpers in eine Vielzahl von Impfkristallen, die jeder einen Schlitz in sich haben, umfaßt. 45 50

Revendications

1. Un procédé pour fabriquer des tranches d'un matériau semiconducteur, comprenant les étapes suivantes :
on oriente un cristal germe de semiconducteur

(35) dans un creuset ayant un axe central s'étendant verticalement, de façon à donner une structure cristalline spécifique à un lingot que l'on doit faire croître; on introduit dans le creuset une matière première (17) consistant en un semiconducteur, en contact avec le cristal germe; on fait fondre la matière première et une partie du cristal germe; on solidifie le cristal germe et la matière première en fusion, de façon à faire croître un lingot semiconducteur cristallin ayant un axe central qui correspond à celui du creuset; l'étape d'orientation comprenant les étapes qui consistent à positionner le cristal germe de façon coaxiale avec l'axe central du creuset, et à orienter le cristal germe en rotation, par rapport à l'axe central du creuset, de façon que la structure cristalline du cristal germe présente une relation angulaire prédéterminée avec l'axe central du lingot à faire croître; et on découpe le lingot sous un certain angle par rapport à l'axe central du lingot, pour former des tranches ayant une structure cristalline sélectionnée; CARACTERISE EN CE QUE

on forme une première partie d'accouplement (33) dans une partie du creuset; et

on forme une seconde partie d'accouplement (36) dans le cristal germe, de façon que la seconde partie d'accouplement s'adapte à la première partie d'accouplement, de façon que la seconde partie d'accouplement présente une relation sélectionnée vis-à-vis de l'orientation cristalline du cristal germe, et de façon qu'un accouplement des première et seconde parties d'accouplement empêche toute rotation angulaire du cristal germe autour de l'axe central;

l'étape d'orientation du cristal germe comprenant l'étape qui consiste à accoupler la seconde partie d'accouplement avec la première partie d'accouplement, de façon que le cristal germe soit contraint de se conformer à la relation angulaire prédéterminée.

2. Le procédé de la revendication 1, dans lequel :
une partie parmi la première partie d'accouplement et la seconde partie d'accouplement est une partie de paroi en saillie et l'autre est une encoche qui est adaptée de façon à s'ajuster étroitement sur la partie de paroi en saillie, en empêchant toute rotation du cristal germe autour de l'axe central.
3. Le procédé de la revendication 2, dans lequel :
la première partie d'accouplement est la partie de paroi en saillie;
et l'étape de formation de la seconde partie d'accouplement comprend l'étape qui



consiste à former dans le cristal germe une encoche ayant une épaisseur suffisante pour lui permettre de s'ajuster étroitement sur la partie de paroi en saillie.

cristal germe comprend l'étape qui consiste à former un ensemble d'encoches dans un corps cristallin et à découper ensuite ce corps en un ensemble de cristaux germes présentant chacun une encoche.

4. Le procédé de la revendication 2, dans lequel :
le cristal germe est placé à une extrémité du creuset;
et l'étape de solidification comprend l'étape qui consiste à faire croître le lingot à partir du cristal germe dans une première direction cristallographique sélectionnée, coïncidant pratiquement avec l'axe central du creuset. 5 10
5. Le procédé de la revendication 4, comprenant en outre l'étape suivante :
on contraint la croissance d'une partie principale du lingot à se dérouler d'une manière telle que, dans une section perpendiculaire à la première direction cristallographique, la surface extérieure du lingot soit pratiquement elliptique. 15 20
6. Le procédé de la revendication 5, dans lequel :
l'étape de découpage comprend l'étape qui consiste à découper le lingot de façon répétée sous un angle, par rapport à la première direction, qui est suffisant pour donner des tranches ayant chacune une périphérie extérieure pratiquement circulaire. 25 30
7. Le procédé de la revendication 6, dans lequel :
la première direction cristallographique est la direction cristallographique (111);
et l'angle sous lequel le lingot est coupé est pratiquement de 35,3 degrés par rapport à la première direction. 35 40
8. Le procédé de la revendication 6, dans lequel :
le semiconducteur est pris dans le groupe qui est formé par un matériau semiconducteur du groupe III-V et un matériau semiconducteur du groupe II-VI. 45
9. Le procédé de la revendication 1, dans lequel :
le procédé de croissance du lingot comprend l'étape qui consiste à inclure le cristal germe dans un puits de germe à l'extrémité inférieure du creuset;
et l'étape de solidification comprend l'étape qui consiste à solidifier progressivement la matière en fusion dans une direction ascendante, à partir du cristal germe, pour former un lingot ayant un axe central qui coïncide avec l'axe central du creuset. 50 55
10. Le procédé de la revendication 3, dans lequel :
l'étape de formation de l'encoche dans le