

Description

This invention pertains to high purity dopant mixtures for single crystal silicon manufacture. The novel materials of this invention are eminently suited for use in batch or continuous, Czochralski crystal pulling processes (for making single crystal silicon). The novel materials of this invention are made by a process which comprises chemical vapor deposition in a fluidized bed.

Single crystal silicon for electronic use is commonly prepared with relatively minute quantities of an element of Group III or Group V. The elements employed are usually selected from boron, phosphorus, arsenic or antimony. When incorporated in silicon, these elements change the electrical conductivity of the silicon by occupying normal silicon-atom positions in the crystalline lattice. The Group V elements (with five valence electrons) have one electron which is weakly bonded to the dopant element and maybe easily excited into the conduction band. Hence, the Group V elements are known as electron donors, and silicon predominantly doped therewith is called n-type. Boron has three electrons which participate in covalent bonding, i.e., one less than silicon. Little energy is required to excite a valence electron into the fourth bond, and its introduction creates a hole in the valence band. Boron is an electron acceptor, and acceptor doped silicon is termed p-type.

Because only relatively minute amounts of dopant elements are employed, it is not possible to weight with the requisite accuracy the amount of dopant to be added to a normal sized batch of silicon to be doped. Accordingly, alternate procedures are commonly utilized in an attempt to produce doped silicon having the required dopant concentration. None of these procedures is entirely satisfactory. Generally speaking these procedures fall within three main categories.

One type of current practice comprises melting the dopant and silicon in an appropriate crucible, e.g., quartz. The mass obtained is cooled and then pulverized, sieved and blended. Due to differential freezing during cooling, dopant concentration variations occur both on the micro and macro levels. These variations are not entirely removed by the crushing and blending procedures. Furthermore, impurities can be introduced during the crushing and blending operations. Consequently, a few test pulls are made with the doped alloy, the conductivity measured, and the conductivity values obtained are used to back calculate the dopant concentration level achieved. (Typically, the amount of useful material prepared by this method is about 50%.)

A second general technique for making dopant alloys comprises making a single crystal from a heavily doped melt. The single crystal ingot is sliced, and the slices are characterized analytically to determine dopant concentration. The slices are then crushed and blended. As with the first technique discussed above, maintenance of purity and homogeneity can be significant problems in this process.

In the third method, a small diameter (e.g., a 6.4mm (1/4") doped single crystal rod) is pulled either by a float zone technique or from a doped melt. (For float zone operation, gaseous dopants are introduced into the chamber during the pulling process.) The concentration profile of the dopant is characterized analytically, and then small slugs are cut from the single crystal rod. These slugs are used as dopants for batch Czochralski pullers.

Because of non-homogeneity in all the above methods a single analytical characterization of a sample does not characterize the entire batch. Thus, variations in product are the rule, rather than the exception. Silicon wafer manufacturers have identified the variability in dopant concentration as a significant problem in their crystal growing processes. The materials provided by this invention have much less variability in dopant concentration than materials of the prior art. Furthermore, the process of this invention is less susceptible to the introduction of impurities than the prior art methods mentioned above. Consequently the dopant alloys of this invention are a significant improvement over materials which are available in current practice.

The document DE-A 2,503,452 describes a two step process for the preparation of spherical semiconductor particles wherein, for example, silicon particles obtained by comminuting larger silicon particles (e. g. cutting pieces from a silicon rod and, hence obtaining cylinder-like silicon nuclei) are coated first with a dopant alloy containing silicon and a dopant element and thereafter coating a further layer containing silicon and another dopant element of counteracting dopant type. The first layer contains for example a p dopant, and the second layer an n dopant or vice versa. Such particles having a pn transition at the interface of the doped layers are used as materials for preparing sun collector cell semiconductor materials.

The present invention comprises a silicon composition in the form of spherical or substantially spherical particles characterized by having

- (a) a center portion of spherical or substantially spherical particles of high purity silicon; and
- (b) a layer on said center portion, said layer comprising a p or n carrier substance.

The invention is also concerned with a dopant alloy composition in free flowing particulate form consisting essentially of spherical or substantially spherical particles of a narrow size distribution and characterized by being comprised of

(a) a center portion of spherical or substantially spherical particles of high purity silicon; and

5 (b) a relatively thin layer around said center portion composed of high purity silicon alloyed with a p or n carrier substance,

said dopant alloy being suitable for batch and continuous Czochralski processes for preparing doped, single crystalline silicon.

10 The invention also relates to a fluidized bed process for preparing a composition according to any of the claims 1 to 9, said process comprising passing a stream of deposition gas comprising a binary hydride of a p or n carrier substance or a mixture of said hydride and silane through a fluidized bed of spherical or substantially spherical particles of high purity silicon maintained at a temperature above the decomposition temperature of said silane and said hydride, whereby said carrier substance or an alloy of silicon and said carrier substance is deposited on said particles of high purity silicon.

15 The products of this invention are of two general types. Both types have a nucleus or center portion of high purity silicon, and a p or n carrier substance deposited on the silicon nucleus. In the first type, the deposit containing the p or n carrier substance is an alloy of the carrier substance or substances with silicon. In the second type, the layer on the silicon nucleus is substantially silicon-free. Thus in the second type, the layer deposited on the central silicon nucleus is the p or n carrier substance per se, or a mixture of such substances. The p or n substance in both type of products is selected from boron, phosphorus, arsenic, and antimony (B, P, As and Sb).

20 Each of the two types of products contains a subset of products. In the subsets, the layer of the p or n substance, or the layer of p or n substance(s) alloyed with silicon, is covered with a relatively thin layer of silicon. This optional layer may serve to protect the p or n carrier substance layer from abrasion, and/or from contamination from the environment. It may also make the p or n carrier element layer adhere better to the central silicon nucleus, and thereby protect it from spalling off. This latter utility may be desirable when the p or n element is not present as an alloy with silicon.

25 The products of this invention are produced by a fluidized bed process which comprises chemical vapor deposition of a p or n substance in a bed of silicon particles. The chemical vapor deposition technique employed depends on the type of product to be made. For the first type of product, the fluidized bed of silicon particles is contacted, under reaction conditions, with a source of silicon and a source of p or n substance. Thus, for example, the gaseous mixture may comprise silane as the silicon source, and diborane as a boron source. Preferably, these materials are admixed with a carrier gas such as hydrogen. The process is conducted at a temperature high enough to thermally decompose the silane and, for example, diborane, thus causing a layer of silicon and, for example, boron to be deposited on the silicon particles. For the second type of product the silicon source is omitted. The p or n substance is deposited on the silicon particles in the absence or substantial absence of silicon.

30 As indicated above, the process of this invention utilizes bead-like particulate silicon as a starting material. Polysilicon produced in a fluidized bed process has this form. Accordingly, the products of this invention are made from spherical or substantially spherical silicon particles, preferably from polysilicon formed in a fluidized bed and are not formed from particles made by comminuting larger surfaces by a crushing or similar process. The latter type of particles typically have irregular planar faces. Thus, the entire product can be made using a succession of deposition steps using fluidized bed techniques. For example, the polysilicon kernels or nuclei can be formed by chemical vapor deposition of silicon on fluidized silicon seed particles. Next, the polysilicon particles so produced can be fluidized, and a coating of silicon and, for example, boron, or boron per se, added atop the core of silicon. Optionally, a layer of silicon can then be deposited on the layer having the boron or other carrier substance.

35 The various deposition steps described can be conducted in the same fluidised bed reactor, but it is not necessary to do so. Preferably, the alloy layer or layer of carrier element is deposited in a second reactor, i.e. a reactor different from the one in which the polysilicon nucleus or inner portion is prepared.

This invention has several advantages over existing dopant production methods:

(1) It produces substantially homogenous dopant alloy with lessened concentration variation.

(2) The physical form of the dopant alloy (substantially uniform spherical free flowing particles) makes it ideally suited for continuous Czochralski pulling systems.

40 (3) It can produce very high purity doped material.

(4) Compared to prior art processes, a single sample analysis from a batch is more capable of certifying the dopant concentration of the whole batch.

45 (5) High yields can be achieved in the process.

(6) Energy consumption per kilogram amount of dopant produced is much lower.

(7) It is a more efficient and economical process.

(8) The product has lessened tendency to segregate according to size.

The drawing in Figure 1 is an illustration, not to scale, of an illustrative particle of this invention. Particle 1 is composed of a polysilicon nucleus 10. That nucleus is overlayed with layer 12, which comprises a mixture of (i) polysilicon and (ii) a p or n type carrier material, e.g., boron or phosphorus. Superimposed on the alloy layer is outer layer 14, which is polysilicon. It envelops or enwraps the alloy layer, and the protects it from abrasion or from contamination. This layer is optional. Thus, layer 12 may be the outer layer, and layer 14 may be absent. The relative sizes of the layers in the drawing are not limiting, and are for purposes of illustration only.

Figure 2 is a flow diagram of an apparatus for producing product of this invention. As shown, polysilicon beads that have been prepared by a fluidized bed process are preferably introduced into a sieve device 11. A sieve device need not be used. However, if the starting particles are sieved, the product will be more homogeneous and the product particles will have less tendency to segregate according to size. Particles of a selected narrow size distribution, e.g. 500-600 μm , or 450-500 μm , or 600-650 μm are taken from the sieve device via line 13 for charging vessel 14. Polysilicon particles from the sieve that are not of the desired size are removed via line 12.

Particles from vessel 14 are fed through line 15 into fluidized bed reactor 16, which is externally heated by surrounding heater 17. A mixture of hydrogen and silane or other silicon source is fed into the reactor through line 13a. (This stream can be omitted if the p or n carrier substance is to be deposited *per se*, i.e. without silane.)

A source of p or n carrier substance, optionally mixed with a diluent gas such as hydrogen, is fed into the reactor through line 13b. The source may be any convenient, thermally decomposable compound of B, P, As or Sb. Of these compounds, hydrides and halides are preferred, especially the simple binary compounds such as diborane, B_2H_6 , phosphine, PH_3 , arsine, AsH_3 , stibine, SbH_3 , and their fluorine or chlorine analogs such as BF_3 , BCl_3 or PCl_3 .

The gases and vapors flow through distributor 16a into particle bed 16b with sufficient motive force to maintain the particles in fluidized suspension. The source of p or n carrier substance, and the silicon source if present, thermally decompose to provide a layer of carrier substance (with or without silane) on the fluidized bed particles.

Off gases, and any silicon fines produced by homogeneous decomposition of silane or other silicon source, are removed through line 18. The dust or fines are removed by filter 19. The filtered gases can be sent via line 20 to be recovered, flared or recycled. After the desired amount of p or n substance (with or without silicon) has been deposited, the flow(s) of hydride(s) or other source compound(s) are stopped.

Optionally, the flow of silicon source in hydrogen can be continued to deposit a coating of silicon of desired thickness.

After the desired deposition(s) are completed, the product materials are removed from the reactor and recovered for sale or use.

This invention provides in bead-like form, mixtures of polysilicon and a p or n carrier substance such as B, P, As, or Sb. As indicated above and described more fully below, this invention comprises a spherical or substantially spherical silicon nucleus substantially surrounded by layer which comprises the carrier substance. Preferably, a major portion of the particulate product is the center silicon nucleus. In this preferred embodiment, a relatively thin layer which has the carrier substance is on the central nucleus. It is to be understood however, that this invention also comprises products made from a relatively small nucleus and a relatively thick layer having the carrier element. Generally speaking, this type of product is not as readily made, and is more expensive than the product with the relatively thick nuclei. Hence, it is preferred that the product have a relatively thick silicon nucleus and a relatively thin layer of carrier substance (or carrier substance alloyed with silicon) on the silicon nucleus.

It is easier and more economical to make materials from undoped polysilicon; hence it is preferred that the dopant element not be within the central nucleus or core.

As mentioned above, a fluidized bed is used to deposit a layer of boron, phosphorus, arsenic, or antimony on a silicon particle, and the layer containing the carrier substance can be (i) an alloy of that substance with silicon, or (ii) the carrier substance *per se*. Thus, for purposes of illustration, this invention comprises particulate products having the following compositions:

EXAMPLES OF PRODUCTS OF THIS INVENTION

Product Type	Central Core	Examples of Layer of Carrier Substance	Optional Outer Layer
1	Silicon	Boron or phosphorus	-
2	Silicon	Boron or phosphorus with silicon	-
3	Silicon	Boron or phosphorus	Silicon
4	Silicon	Boron or phosphorus with silicon	Silicon

In the above table, the term "boron or phosphorus with silicon" signifies a layer of boron with silicon, or a layer of phosphorus with silicon. Arsenic or antimony can replace the boron or phosphorus.

In a preferred embodiment, this invention comprises a product selected from types 2 and 4, i.e., a silicon alloy composition in bead or bead-like form having a center and major portion of high purity silicon, and a layer enveloping the center kernel or nucleus composed of silicon alloyed with another element. The alloy layer has silicon in a major proportion, and a minor amount of a p or n carrier substance. Preferably, the spheres or spheroidal particles of this invention are roughly uniform in size.

Stated another way, this invention comprises as a preferred embodiment, a dopant alloy composition suitable for use in doping silicon with a dopant selected from p or n carrier substances such as B, P, As and Sb, the alloy being in free flowing form, and consisting essentially of spherical or spheroidal particles of a narrow size distribution, the particles having an inner nucleus of high purity silicon of spherical or substantially spherical shape, and a relatively thin layer around the nucleus of high purity silicon, and a relatively thin layer around the nucleus composed of high purity silicon alloyed with a p or n carrier substance such as boron, phosphorus, arsenic or antimony. The dopant alloy compositions of this invention are suitable for batch or continuous Czochralski processes for preparing doped, single crystal silicon.

Typically, the products of this invention have a relatively minor amount of carrier substance, e.g. B, P, As or Sb. Thus, the particulate products of this invention can have from 10 to 3000 ppm of one or more of these substances. More preferably, the amount of carrier substance is in the range of from 100 to 2000 ppm. It is to be understood that the concentration of the carrier substance in the products of this invention is not critical, and therefore this invention comprises materials having greater or lesser concentrations than specifically set forth above.

As stated above, the products of this invention are spherical or substantially spherical. Generally, they have a diameter within the range of from 100 to 2000 μm . More preferably, their diameter is within the range of from 300 to 700 μm , and most preferably from 500 to 600 μm . It is to be understood that the size of the particles is not critical, and products having smaller or larger particles than mentioned above are within this invention.

As indicated above, the layer containing the carrier substance can be comparatively thick or thin and thin layers are preferred because they are easier and more economical to prepare. Preferably, the layer with the carrier substance is less than 150 μm ; more preferably from 5 to 100 μm , and most preferably from 50 to 100 μm .

When the particulate products of this invention have an outer silicon layer atop the layer with the p or n carrier substance, the outer layer is preferably from 1 to 10 μm thick. It can be thicker or thinner since its size is not critical.

Another preferred embodiment of this invention is a process for producing silicon/dopant compositions (of the type described above) comprising:

A fluidized bed process for preparing a silicon composition in free flowing particulate form, said process comprising:

fluidizing a bed of spherical or substantially spherical particles of high purity elemental silicon, i.e., silicon particles having a purity sufficient for use in electronic devices, e.g., solar panels or semiconductors, with a motive gas comprising a source of a dopant element (B, P, As or Sb), e.g. comprising a binary hydride of a p or n carrier substances or a mixture of said hydride and silane;

said particle bed being maintained at a temperature above the decomposition temperature of said dopant element source and optionally of said silane, whereby said source is thermally decomposed and the dopant element (i.e., carrier substance) and optionally silicon is deposited on said spherical or substantially spherical particles of high purity silicon.

In this process, the dopant element source is a compound of the dopant element. Compounds with relatively low decomposition temperatures are preferred. Typical sources are hydrides and halides of the

dopant elements. Preferred compounds are binary hydrides and halides such as B_2H_6 , PH_3 , AsH_3 , SbH_3 , BCl_3 , PCl_3 and the like. The hydrides are highly preferred since they are generally thermally decomposable at lower temperatures, and the hydrogen by-product is easier to handle from the reactor materials of construction viewpoint, than a halogen-containing stream.

To prepare products of Types 2 and 4 -- see the Table above --, the motive gas which passes through the fluidized bed also contains a source of silicon. Various compounds such as silicon hydrides, silicon halides and silicon-hydrogen-halogen compounds can be used. By way of illustration, silane, SiH_4 , dichlorosilane, $SiCl_2H_2$ can be used as well as the fluoro-, or bromoanalogs of these compounds. Silane is highly preferred because of its lower decomposition temperature, and the hydrogen by-product is easier to handle than a halogen material.

Typically, the silane or other silicon source, and the hydride or other source of dopant element, are admixed with a gas prior to passage through the bed of fluidized particles. Hydrogen is a typical diluent gas; however, other inert gases such as helium, argon, and the like can also be used. It is known in the art that the use of such a diluent gas has many advantages. For example, the hydrogen or other gas dilutes the compounds that are to be thermally decomposed and thereby promotes good mixing with the bed particles. It also provides motive force to maintain the particles in fluidized suspension. Use of such gases dilutes the silane concentration, thereby lowering the rate of formation of silicon dust or fines by homogeneous decomposition of silane.

For the purpose of this invention, the silane in hydrogen concentration used to prepare the layer of silicon/dopant alloy is preferably in the range of 1-8 mole %, more preferably 4 to 6 mole percent. Other silicon sources are preferably employed in these ranges. The amount of silane or other silicon source introduced is sufficient to provide a silicon/dopant layer of desired thickness. The concentration of the source of B, P, As or Sb, is selected to provide the desired amount of p or n substance deposited on the particle bed, as discussed below.

The exact conditions utilized to deposit the layer having the dopant element are important, but not critical. Generally, it is desirable to use good fluidized bed process techniques, as they apply to the equipment to be used, and the nature or type of product to be prepared. For commercial operations, the objective to prepare the product at acceptable cost will also be borne in mind.

Preferably, the spherical or substantially spherical silicon particulate used as a starting material has a narrow size distribution, e.g., a range of 150 μm or less, preferably 50 to 100 μm .

The particles are substantially free of the planar surfaces and surface boundaries found in materials prepared by comminuting larger particles.

The process of this invention is conducted using a temperature above the thermal decomposition temperatures of the silicon source and the source of the p or n carrier substance(s). When silane is used as the silicon source, preferred temperatures are between 600 and 700 $^{\circ}C$; more preferably from 620 $^{\circ}$ to 650 $^{\circ}C$. The decomposition temperature of the source of the p or n carrier substance is preferably below such temperatures. The preferred process pressure is ambient pressure, but higher or lower pressures can be employed if desired. The flow of gases will be selected to maintain the bed of particles in a fluidized state. A flow rate (U) at or slightly above the minimum flow (U_{min}) to keep the bed fluidized will be selected. Typically, the rate of flow can be defined by the relationship $U/U_{min} = 2.0$ to 3.0. Somewhat higher or lower rates can be used.

For a given reactor, there will be a preferred bed height range; this will define a range for preferred operation. Thus for example, for a particular reactor, the initial bed height might be within a certain preferred range, e.g., 0.46 to 0.61m (1.5 - 2 feet), and the final bed height after the product is made should not exceed a given preferred value, e.g., 1.5 x the starting bed height. Within such parameters, one can determine the range of the amount by weight of the dopant element layer to be deposited.

For any specific reactor to be utilized, there will be a range of acceptable motive gas flow rates. This range will in part determine the diameters of the starting material and of the product so that the bed will remain fluidized during operation.

Generally, an objective of a process of this invention will be the preparation of a product having a given concentration of dopant element (C_{DP}). In this regard, an operator can apply the relationship:

$$C_{DP} = C_{DL} \times \left(1 - \frac{D_1}{D_2} \right)^3$$

where:

- C_{DP} is the concentration of dopant element in the final product;
 C_{DL} is the concentration of dopant in the dopant layer deposited; and
 D_1 and D_2 are respectively, the initial and final diameters of the particle.

- 5 Using this relationship, the operator can determine how much dopant is to be added per any selected thickness of the dopant layer.

To illustrate this invention and not to limit it, a desirable product of this invention can be produced by using a fluidized bed of silicon particles having a diameter within the range of 500-600 μm and an average of 550 μm . As an example, an initial bed of such particles will weigh 25 to 41 kg and a typical final bed
 10 weight will be 40-60 kg.

Typical product particles will have a dopant layer of 50 μm thickness (i.e., a diameter increase of one hundred μm . Using the illustrative particles mentioned above, the product particle size will be 600 - 700 μm for an average of 650 μm .

Illustrative but non-limiting operating conditions are:

- 15 bed temperature 620°-650° C.;
 feed gas temperature 325°-375° C.;
 U/U_{min} 1.5-3.5;
 SiH_4 concentration in feed gas ~ 406%;
 SiH_4 conversion ~ 50-90%;
 20 Diborane concentration - 30-40 ppm

EXAMPLE 1

About 6 kg of high purity polysilicon particles having an average size of 550 μm and a size range of
 25 500-600 μm were charged to a fluidized bed reactor having an internal diameter of about 12.1cm (4.75 inches). (These particles were in bead or bead-like form, and have been prepared by a fluidized bed process comprising thermal decomposition of silane with deposition of silicon on a bed of polysilicon seed particles. After operation of the fluidized bed process, the product was sieved to obtain the 500-600 μm sized starting material used in this example.)

30 The bed was maintained at a temperature of 630-640° C, while being fluidized with a flow of silane in hydrogen, (silane concentration was about 5 mole %) admixed with about 35 ppm B_2H_6 . The source of the diborane comprised a mixture of 1060 ppm (molar) B_2H_6 in hydrogen. The average flow of hydrogen was about $14.4 \cdot 10^{-2} \text{ m}^3$ per min (5.1 scfm). The flow of gases was maintained for about 3.5 hours. The silane conversion was 82%.

35 Material balance indicated that the thickness of the silicon/boron layer deposited on the polysilicon particles was about 24 μm . Inspection of etched cross-sections of several particles indicated that the layer of silicon and boron had grown very uniformly, with an average thickness of about 25 μm ; confirming the thickness expected by material balance.

Boron concentration determined by resistivity measurements (using Hall effective equipment) on three
 40 float zoned single crystals were 137.5, 137.0 and 131.0 ppma.

The particles had a low, acceptable surface dust content (less than about 0.1%).

If desired, the particles produced above, could be coated with a thin, e.g., 1-10 μm thick outer layer, by continuing the silane/hydrogen feed until the outer silicon layer of desired thickness was deposited.

The process of this example can be modified to prepare products having a diameter of 100 to 2000
 45 μm , boron in concentrations of about 10 ppma, 750 ppma, 1500 ppma or 3000 ppma. The deposited silicon/boron alloy layer can be from 5 to 100 μm thick; preferably 50-100 μm .

The above process can be repeated using a silane/hydrogen mixture of 1-6 mole percent silane, a bed temperature of 620-650° C. and a U/U_{min} of 1.5-3.5. Typical diborane conversions are 25-60%. The process can be repeated using PH_3 instead of diborane, to produce similar particles having phosphorus concentra-
 50 tions of 10 and 300 ppma. Similar products with arsenic or antimony can be obtained using arsine or stibine as the source of the carrier substance as illustrated below.

EXAMPLE 2

55 In this example, the initial bed particle size range was 500-600 μm . The inlet silane concentration in hydrogen was about 5 mole percent. The phosphorus source was PH_3 in hydrogen; 2607 ppm molar. The inlet PH_3 concentration was 145 ppm. The operating temperature was about 690° C.

The phosphorus concentration was determined by resistivity measurements (using Hall effect equipment) of six single crystal slices from two float zoned single crystal samples (three slices from each crystal) to be 478.4, 508.6, 484.0, 444.8, 476.6, and 526.2 ppma.

Material balance indicated that the new CVD layer of silicon incorporating the phosphorus to be about 29 μm .

Examination of etched cross-sections of several particles indicated that the CVD layer was grown uniformly around the particles with an average thickness of about 30 microns.

The products produced by the process may be used as dopant alloys in batch or continuous Czochralski crystal pulling processes. The products are added to polysilicon and melted to produce a batch of product having a concentration of dopant element in a selected range.

Claims

1. A silicon composition in the form of spherical or substantially spherical particles characterized by having
 - (a) a center portion of spherical or substantially spherical particles of high purity silicon; and
 - (b) a layer on said center portion, said layer comprising a p or n carrier substance.
2. The composition of claims 1 wherein said layer is an alloy of silicon in predominantly major proportion with a minor amount of said p or n carrier substance.
3. The composition of claim 1 or claim 2 further being characterized in that the spherical or substantially spherical particles of said composition are relatively uniform in size and substantially free of planar surfaces and surface boundaries of the type obtained by comminuting larger particles.
4. The composition of any of the claims 1 to 3 wherein said layer on the center portion is relatively thin compared to said center portion.
5. The composition of any of the claims 1 to 4 further being characterized by an outer coat of essentially pure silicon, said outer coat being substantially thinner than said thin layer of silicon alloy.
6. The composition of any of the claims 1 to 5 further being characterized by being suitable for use as a dopant alloy for batch and continuous Czochralski processes for preparing doped, single crystalline silicon.
7. A dopant alloy composition in free flowing particulate form consisting essentially of spherical or substantially spherical particles of a narrow size distribution and characterized by being comprised of
 - (a) a center portion of spherical or substantially spherical particles of high purity silicon; and
 - (b) a relatively thin layer around said center portion composed of high purity silicon alloyed with a p or n carrier substance,
 said dopant alloy being suitable for batch and continuous Czochralski processes for preparing doped, single crystalline silicon.
8. The dopant alloy composition of claim 7 further being characterized by an outer coat of essentially pure silicon, said outer coat being substantially thinner than said thin layer of silicon alloy.
9. The composition of any of the claims 1 to 8 wherein the p or n carrier substance is selected from the group consisting of B, P, As and Sb.
10. A fluidized bed process for preparing a composition according to any of the claims 1 to 9, said process comprising passing a stream of deposition gas comprising a binary hydride of a p or n carrier substance or a mixture of said hydride and silane through a fluidized bed of spherical or substantially spherical particles of high purity silicon maintained at a temperature above the decomposition temperature of said silane and said hydride, whereby said carrier substance or an alloy of silicon and said carrier substance is deposited on said particles of high purity silicon.



The phosphorus concentration was determined by resistivity measurements (using Hall effect equipment) of six single crystal slices from two float zoned single crystal samples (three slices from each crystal) to be 478.4, 508.6, 484.0, 444.8, 476.6, and 526.2 ppma.

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 - (a) a center portion of spherical or substantially spherical particles of high purity silicon; and
 - (b) a layer on said center portion, said layer comprising a p or n carrier substance.
2. The composition of claims 1 wherein said layer is an alloy of silicon in predominantly major proportion with a minor amount of said p or n carrier substance.
3. The composition of claim 1 or claim 2 further being characterized in that the spherical or substantially spherical particles of said composition are relatively uniform in size and substantially free of planar surfaces and surface boundaries of the type obtained by comminuting larger particles.
4. The composition of any of the claims 1 to 3 wherein said layer on the center portion is relatively thin compared to said center portion.
5. The composition of any of the claims 1 to 4 further being characterized by an outer coat of essentially pure silicon, said outer coat being substantially thinner than said thin layer of silicon alloy.
6. The composition of any of the claims 1 to 5 further being characterized by being suitable for use as a dopant alloy for batch and continuous Czochralski processes for preparing doped, single crystalline silicon.
7. A dopant alloy composition in free flowing particulate form consisting essentially of spherical or substantially spherical particles of a narrow size distribution and characterized by being comprised of
 - (a) a center portion of spherical or substantially spherical particles of high purity silicon; and
 - (b) a relatively thin layer around said center portion composed of high purity silicon alloyed with a p or n carrier substance,said dopant alloy being suitable for batch and continuous Czochralski processes for preparing doped, single crystalline silicon.
8. The dopant alloy composition of claim 7 further being characterized by an outer coat of essentially pure silicon, said outer coat being substantially thinner than said thin layer of silicon alloy.
9. The composition of any of the claims 1 to 8 wherein the p or n carrier substance is selected from the group consisting of B, P, As and Sb.
10. A fluidized bed process for preparing a composition according to any of the claims 1 to 9, said process comprising passing a stream of deposition gas comprising a binary hydride of a p or n carrier substance or a mixture of said hydride and silane through a fluidized bed of spherical or substantially spherical particles of high purity silicon maintained at a temperature above the decomposition temperature of said silane and said hydride, whereby said carrier substance or an alloy of silicon and said carrier substance is deposited on said particles of high purity silicon.



Patentansprüche

1. Siliciumzusammensetzung in Form von kugelförmigen oder im wesentlichen kugelförmigen Teilchen, dadurch gekennzeichnet, daß sie
 - (a) einen Mittelteil aus kugelförmigen oder im wesentlichen kugelförmigen Teilchen aus Silicium von hoher Reinheit und
 - (b) auf diesem Mittelteil eine Schicht aufweist, die eine p oder n Trägersubstanz umfaßt.
2. Zusammensetzung nach Anspruch 1, in der die Schicht eine Legierung aus Silicium in einem überwiegend größeren Anteil mit einer kleineren Menge der p oder n Trägersubstanz ist.
3. Zusammensetzung nach Anspruch 1 oder 2, die außerdem dadurch gekennzeichnet ist, daß die kugelförmigen oder im wesentlichen kugelförmigen Teilchen der Zusammensetzung eine verhältnismäßig einheitliche Größe aufweisen und im wesentlichen frei sind von planen Oberflächen sowie Oberflächengrenzen des Typs, wie man sie bei der Zerkleinerung größerer Teilchen erhält.
4. Zusammensetzung nach einem der Ansprüche 1 bis 3, in der die Schicht auf dem Mittelteil im Vergleich zu diesem verhältnismäßig dünn ist.
5. Zusammensetzung nach einem der Ansprüche 1 bis 4, die außerdem durch eine äußere Ummantelung aus im wesentlichen reinem Silicium gekennzeichnet ist, die wesentlich dünner als die dünne Schicht aus Siliciumlegierung ist.
6. Zusammensetzung nach einem der Ansprüche 1 bis 5, die außerdem dadurch gekennzeichnet ist, daß sie zur Verwendung als Legierung für Dotierungszwecke für diskontinuierliche und kontinuierliche Czochralski-Verfahren zur Herstellung von dotierten Siliciumeinkristallen geeignet ist.
7. Legierungszusammensetzung zu Dotierungszwecken in frei fließender partikulärer Form, die im wesentlichen aus kugelförmigen oder überwiegend kugelförmigen Teilchen mit enger Größenverteilung besteht und dadurch gekennzeichnet ist, daß sie aus
 - (a) einem Mittelteil aus kugelförmigen oder im wesentlichen kugelförmigen Teilchen aus Silicium von hoher Reinheit und
 - (b) einer verhältnismäßig dünnen Schicht um diesen Mittelteil besteht, die aus hoch reinem, mit einer p oder n Trägersubstanz legiertem Silicium zusammengesetzt ist,
 wobei die Legierung für Dotierungszwecke für diskontinuierliche und kontinuierliche Czochralski-Verfahren zur Herstellung von dotiertem Siliciumeinkristallen geeignet ist.
8. Legierungszusammensetzung zu Dotierungszwecken nach Anspruch 7, die weiterhin durch eine äußere Ummantelung aus im wesentlichen reinem Silicium gekennzeichnet ist, die erheblich dünner als die dünne Siliciumlegierungsschicht ist.
9. Zusammensetzung nach einem der Ansprüche 1 bis 8, in der die p oder n Trägersubstanz aus der aus B, P, As und Sb bestehenden Gruppe ausgewählt ist.
10. Fließbettverfahren zur Herstellung einer Zusammensetzung nach einem der Ansprüche 1 bis 9, bei dem ein binäres Hydrid einer p oder n Trägersubstanz oder eine Mischung aus diesem Hydrid und Silan umfassendes Abscheidegas durch ein Fließbett aus kugelförmigen oder im wesentlichen kugelförmigen Teilchen aus hoch reinem Silicium geleitet wird, das auf einer Temperatur über der Zersetzungstemperatur des Silans und des Hydrids gehalten wird, wodurch diese Trägersubstanz oder eine Legierung aus Silicium und der Trägersubstanz auf die Teilchen aus hoch reinem Silicium abgeschieden wird.

Revendications

1. Composition de silicium présentant la forme de particules sphériques ou essentiellement sphériques, caractérisée en ce qu'elle possède:
 - (a) une partie centrale des particules sphériques ou essentiellement sphériques en silicium de haute pureté;
 - (b) une couche sur ladite partie centrale, ladite couche comprenant une substance porteuse p ou n.



2. Composition selon la revendication 7, dans laquelle ladite couche est un alliage de silicium en proportion prédominante avec des quantités mineures de ladite substance porteuse p ou n.
3. Composition selon la revendication 1 ou la revendication 2, caractérisée en outre en ce que les particules sphériques ou essentiellement sphériques de ladite composition sont de taille relativement uniforme et essentiellement dépourvues de surfaces planaires et de surfaces de bordure du type obtenu en fractionnant de plus grandes particules.
4. Composition selon l'une quelconque des revendications 1 à 3, dans laquelle ladite couche sur la partie centrale est relativement mince par rapport à ladite partie centrale.
5. Composition selon l'une quelconque des revendications 1 à 4, caractérisée en outre par une couche extérieure de silicium essentiellement pur, ladite couche extérieure étant essentiellement plus mince que ladite couche mince d'alliage de silicium.
6. Composition selon l'une quelconque des revendications 1 à 5, caractérisée en outre en ce qu'elle convient pour une utilisation comme alliage dopant pour des procédés Czochralski discontinus et continus de fabrication de silicium monocristallin dopé.
7. Composition d'alliage dopant sous forme de particules à écoulement libre, constituée essentiellement de particules sphériques ou essentiellement sphériques à granulométrie étroite, et caractérisée en ce qu'elle est constituée de:
- (a) une partie centrale de particules sphériques ou essentiellement sphériques en silicium de haute pureté;
 - (b) une couche relativement mince autour de ladite partie centrale, composée de silicium de haute pureté allié à une substance porteuse p ou n,
- ledit alliage dopant convenant pour des procédés Czochralski discontinus et continus de fabrication de silicium monocristallin dopé.
8. Composition d'alliage dopant selon la revendication 7, caractérisée en outre par un revêtement extérieur de silicium essentiellement pur, ledit revêtement extérieur étant essentiellement plus mince que ladite couche mince d'alliage de silicium.
9. Composition selon l'une quelconque des revendications 1 à 8, dans laquelle la substance porteuse p ou n est choisie parmi le groupe constitué de B, P, As, et Sb.
10. Procédé à lit fluidisé pour la fabrication d'une composition selon l'une quelconque des revendications 1 à 9, ledit procédé comportant le passage d'un courant de gaz de dépôt comportant un hydrure binaire d'une substance porteuse p ou n ou un mélange dudit hydrure et de silane à travers un lit fluidisé de particules sphériques ou essentiellement sphériques en silicium de haute pureté, maintenu à une température supérieure à la température de décomposition dudit silane et dudit hydrure, grâce à quoi ladite substance porteuse ou un alliage de silicium et de ladite substance porteuse est déposé sur lesdites particules de silicium de haute pureté.