Description

The present invention relates to p-n junction solar cells and more particularly to electrical contacts formed thereon.

Conventional screen printed solar cells have their main advantages lying with their simplicity of fabrication and the associated low production costs. However, there are numerous disadvantages. Screen printed contacts typically have a minimum metallisation width of about 150μm. The consequence is a fairly high degree of shading of the top surface of the solar cell, often in the vicinity of 12%. In addition, the high shading losses require a minimum spacing between fingers usually of at least 3mm. This results in the silicon surface requiring very heavy doping to give sufficiently good conductivity in the diffused layer so as to reduce the lateral resistance losses to respectable values. The unfortunate consequence of the heavy doping is a poor response of the solar cell to short wavelength light. This is because the high energy photons generate electron-hole pairs near the surface in the heavily doped region which recombine without contributing to the generated current. Another problem area for screen printed contacts is the associated high contact resistance that is established between the metallisation and the silicon surface. Optimisation of infra-red furnace firing conditions or subsequent immersion in hydrofluoric acid can reduce this problem although neither will totally eliminate it. Finally, any solar cell with the diffused layer confined to the top surface will suffer from a poor response to long wavelength light unless it has extremely long bulk minority carrier lifetimes. Solar cells fabricated on polycrystalline substrates are a good example of such solar cells. A MIS solar cell having a buried metal contact finger system provided in grooves in the semiconductor is described in DE-A-28 46 097. An etched vertical junction solar cell is described in Solar Cells, Volume 6, 1982, page 17-38.

The present invention proposes a buried contact through applying the metal to an already formed groove which results in numerous advantages over conventional contacts, which include:

(1) Grooves can be made to have their depth considerably greater than their width. This is the opposite to conventional contacts whose width is usually substantially greater than their depth. For instance, a standard screen printed contact will typically be 150μm wide and 20μm deep. In comparison, a groove filled contact of the same metal can be 30μm wide and 100μm deep giving the same cross sectional area for current handling but with only one fifth the shading loss. This factor alone gives a solar cell having buried contacts in accordance with the present invention an increase in output power of about 8%.

(2) For a given width groove, there remains considerable flexibility as to the depth, particularly if a laser scriber is being used. Consequently, for the example in (1) above, the 30μm wide groove could just as easily be made 150μm or 200μm deep in which case the series resistance of the metal contact is also greatly reduced from that of a conventional contact without altering the shading losses. This gives an improvement in fill factor which translates to a further 1-2% boost in output power over the conventional solar cell.

(3) The large area of contact between the metal in the groove and the silicon reduces the contact resistance. This improvement however, is only small as contact resistance in conventional cells is rarely a significant factor.

(4) Another significant advantage of a solar cell having electrical contacts according to this invention is that it facilitates closely spaced fingers. In contrast, screen printed contacts typically have a minimum finger (metallisation) width of about 150μm. This consequently requires a minimum spacing between fingers to be in the vicinity of 3-4mm to prevent excessive shading of the solar cell surface. However, such widely spaced fingers require that the silicon surface be very heavily doped to increase its conductivity and hence reduce the lateral resistance for the generated charge carriers travelling in the diffused impurity layer. The unfortunate consequence of the heavy doping is a poor response of the solar cell to short wavelength light. This is because the high energy photons generate electron-hole pairs near the surface in the heavily doped region, which recombine without contributing to the generated current. These problems are overcome with a solar cell having contacts according to the present invention, as closely spaced fingers can be used without excessive shading, thereby facilitating a lightly doped silicon surface, thus providing a solar cell with good response to short wavelength light. The output power boost through this alone, over a conventional screen printed solar cell, is in the range of 5-10%. The nett electrical output current boost resulting from (1)-(4) is in the range 15-20%.

(5) The formation of buried contacts may be through the application of a metal paste via a squeegee, greatly simplifying the method for forming the metallisation. It removes the necessity for expensive vacuum evaporation equipment or equivalent and removes any alignment requirements when screen printing. The requirement, however, exists for forming the grooves which can be done in numerous ways, the sim-

plest probably being with a laser scriber which can simultaneously be done while carrying out an edge junction isolation step around the perimeter of the solar cell.

(6) A further electrical boost is obtained through having a buried contact, through its enhanced response to long wavelength light. Unlike high energy photons, many of the low energy photons are absorbed deep in the substrate thus generating electron hole pairs that are a long way from the rectifying P-N junction. However, the buried contact in the groove provides a P-N junction that is able to collect some of the generated charge carriers that would otherwise be lost by a cell with junction only at the cell surface.

(7) A particular area where a solar cell having buried contacts according to the present invention may have advantage is as a concentrator cell where the metallisation must be capable of carrying much greater currents but without excessive shading.

According to the present invention there is provided a p-n junction solar cell as featured in claim 1. Additionally, methods of forming this solar cell are provided.

The present invention will now be described by way of example with reference to the accompanying drawings, in which:-

Fig. 1 is a schematic cross-sectional view of a portion of a solar cell incorporating a buried contact in accordance with the invention; and

Figs. 2(a), (b) and (c) are profile shapes for three different grooves for receiving "buried" contacts in accordance with the present invention.

In Fig. 1 there is shown a section of a solar cell 1 having a top surface 10 formed of n-type material, a rear metal contact 11 and a cell body 12 of p-type material. A groove 13 formed in top surface 10 contains a metallised contact 14.

The solar cell 1 has a plurality of grooves 13 in the wafer surface to define the contact metallisation. The grooves 13 may be formed by laser scribing, chemically etching or mechanical abrasion. The metallisation can be applied in paste form by a sweeping stroke of a squeegee or equivalent, across the wafer surface forcing the metal paste into the grooves 13. The metal can also be filled into the grooves by various alternative means including solder dipping and electroplating. These latter techniques may first require the application of a thin layer of metal such as titanium, to the bottom of each groove 13 by such as vacuum evaporation or equivalent. Any of the above may be carried out in conjunction with appropriate photo lithographic work for defining grooves or for metal definition.

Formation of grooved contacts is particularly suited to polycrystalline substrates where the different grain orientations provide strength in the grooved regions. Grooves, however, can also be used in single crystal substrates but may require shallow grooves (i.e., only to 100μm depth) or else greater handling care during processing, and/or thicker substrates (i.e., 600μm thick). Typically the width of a groove relative to its depth is in the range 1:2 to 1:7.

Various parameters to be considered in designing a buried contact solar cell in accordance with the invention include:

(i) Sheet resistivity P_s is desirably >60Ω/□ as the response of the resultant cell to short wavelength light deteriorates rapidly below this value.

(ii) Groove width W_g is preferably >25μm to ensure spin-on diffusion source adequately coats the groove walls. Simultaneously, W_g must not be too wide (e.g. <100μm) as shading losses become excessive.

(iii) Groove depth t_g is preferably not greater than half the width of the wafer as too much weakening of the substrate results.

Preferably,

$t_g > 5000/W_g$ for t_g and W_g in μm for screen printed silver paste

or $t_g > 1700/W_g$ for t_g and W_g in μm for plated silver

as this provides adequate cross sectional area for the silver conductor.

(iv) Finger spacing should preferably be in the range of 1.5 - 2.5 mm depending upon the P_s and the shading losses created by W_g.

(v) Tapering of fingers and busbars is desirable so as to keep the current density within the silver below 1000A/cm² (for screen printed silver).

An embodiment of the present invention utilises a finger spacing of 1.8mm, a finger width of 45-50μm and a finger depth of 100-150μm. The resulting shading losses are 3.5-4.0% and the necessary sheet resistivity is about 80Ω/□.The corresponding power loss in the top diffused layer is of the order of 2%. Assuming the grooves are full of silver paste, the cross sectional area of the fingers is about 6000sq.μm thus allowing a 10cm length of finger to be utilised without exceeding the specified current density.

One example of a processing sequence suitable for producing a buried contact solar cell in accordance with the present invention is:

Sequence A

(i) Scribing of grooves,

(ii) Sodium hydroxide etch followed by HCl clean

(iii) Thorough D.I. rinse and dry
(iv) Spin-on phosphorus diffusion source
(v) Diffuse
(vi) Back contact application and fire
(vii) Hydrofluoric acid removal of oxidised spin-on source
(viii) Thorough D.I. rinse and dry
(ix) Application of silver paste and fire
(x) Edge isolation
(xi) Antireflection coating application
(xii) Electrically test

To be included in the processing sequence is plasma etching which will be done simultaneously with the antireflection coating. Its position in the processing sequence may be as in Sequence A or alternatively may be inserted either before the back contact application or else before the application of the silver paste.

Another sequence, which may yield a higher ficiency is that of Sequence B which includes an additional diffusion step and high quality oxide growth.

Sequence B

(i) Etch away saw damage as necessary
(ii) Spin-on and diffuse
(iii) Chemical clean with H.F.
(iv) High quality oxide growth
(v) Silicon nitride A.R. coating
(vi) Laser grooves
(vii) Sodium hydroxide etch out of grooves
(viii) Spin-on and diffusion of grooves
(ix) Back contact and fire
(x) Front contact and fire
(xi) Edge isolation
(xii) Electrically test

ROCESSING DETAILS FOR SEQUENCE A

(i) Scribing of Grooves

The shape of the cut made by the laser into the silicon is not very important as the groove is most effectively shaped through the subsequent sodium hydroxide etch. However, there are few preferred specifications the laser must meet: firstly, the width of the groove needs to be less than 35μm preferably only about 25μm; secondly the power of the laser needs to be consistent so as to provide reasonable uniformity to the groove depth; thirdly the laser power needs to be sufficient to scribe a cut of at least 100μm depth into silicon with preferably an option of being able to cut down to about 200μm; fourthly the speed of the laser needs to be adequate for production quantities; and finally the laser Q switch and shutter need to be software controllable. The latter of these is necessary because of the finite time taken for the mechanical shutter to open. To commence each scribe, the shutter needs to be already open with the beam turned off via the Q switch so that the beam can then be virtually instantly turned on when the X-Y table begins to move. If these are not synchronised in this manner then either the wafer will move before the beam commences or else even worse, the beam will commence while the wafer is stationary and hence drill a hole right through the wafer.

(ii) Sodium hydroxide etching of grooves

Hot sodium hydroxide will simultaneously clean out and shape the grooves and remove saw damage from the wafer surface. These etching conditions can however be fairly important if a particular groove shape is required. For instance, if a "V" shaped groove as indicated in figure 2(a) is required, then a low sodium hydroxide concentration (about 2%) should be used at moderately high temperatures (90-95°C) This allows depletion of the solution to take place deep in the groove and, in addition, the relatively high reaction rate caused by the high temperature creates much greater turbulence (and hence replenishment of the solution) near the surface thus resulting in greater etch rates towards the top surface. The nett result is very little etching at the bottom of the groove and progressively more etching towards the top of the groove thus giving gently sloping sides in a "V" formation. The other extreme is shown in figure 2(b) with the "U" shaped groove. The steep walls are obtained via a high concentration (about 30%) sodium hydroxide solution at fairly low temperatures (65-70°C).

The consequence of these conditions is that the solution no longer depletes in the bottom of the groove and so the etching proceeds at a fairly uniform rate independent of depth within the groove. Optimistically the latter is the desired shape from the viewpoint that for a given degree of top surface shading, the greatest cross-sectional area of groove is obtained. However, complications associated with coating such steep groove walls with the spin-on diffusion source may require a compromise as indicated by figure 2(c). By using a high concentration sodium hydroxide solution at a high temperature (95-110°C), considerable etching and hence widening of the groove takes place at the bottom, although still more so approaching the top surface. Time is of course another important variable with all etching conditions as it determines the overall groove width obtained.

Finally, regarding the etching of the grooves, the depth is solely determined by the laser as the sodium hydroxide tends not to etch away silicon in

the downwards direction from the top surface.

(iii) Cleaning and D.I. rinsing

All cleaning of grooved wafers in chemical solutions or D.I. water needs to be done a little more thoroughly than would be required for a flat suface wafer. This is the case because of the necessity for the solutions to thoroughly clean out the grooves. For instance, if 5 minutes rinsing in D.I. water was necessary for a flat surface wafer then probably 7 minutes would be required for a grooved wafer.

(iv) Spin-on phosphorus diffusion source

The coating of the grooved wafer with a phosphorus source can be effectively done on a spinner in a manner similar to non grooved wafers. One variation however, is that the grooves need to be filled before the spinning is actually commenced. This is achieved by delaying 2-3 seconds after application of a few drips of spin-on source prior to spinning. This allows the grooves to fill by capilliary action as the material literally shoots along them. Failure to incorporate this delay will result in the spin-on source being spun over the top of the grooves with very little finding its way into the grooves.

(v) Drying and diffusion of wafers

This is carried out in a manner identical to flat surface solar cells. However, it is important that all material in the grooves be dry prior to diffusion. If after inspection this is found not to be the case, then the drying temperature or time should be increased accordingly.

To roughly check the diffusion in the groove, repeated four point probe measurements could be made parallel to a groove at different distances from it. If the readings near the grooves are substantially higher than those further away then the groove diffusion is too light. At the other extreme if the readings closest to the groove substantially drop then it indicates heavier diffusion in the groove than elsewhere which should be quite acceptable and perhaps beneficial. Finally, if the values close to the grooves don't substantially change, then the diffusion in the grooves is probably comparable to that elsewhere on the surface which should also be acceptable.

(vi) Back contact application and firing

This technology is suited to almost any type of back metallic contact, whether screen printed, vacuum evaporated, plated, or other. There should be no adverse effects through the presence of the grooves.

(vii) Hydrofluoric acid removal of oxidised spin-on source

By dipping the wafers in 10% hydrofluoric acid, the oxidised spin-on source should be removed in under 30 seconds. If however after 30 seconds some material is still evident in the grooves, it is because that remaining material was not fully oxidised in the diffusion furnace. Initially this could well be the case since the diffusion source will probably be thicker in the grooves and hence more difficult to oxidise. The possible remedies include: raising the temperature that the wafers are exposed to in the oxidising region of the diffusion furnace (i.e. this should have little if any effect on the sheet resistivity); increasing the time that the wafers spend in the oxidising part of the diffusion furnace; increasing the spin speed of the spin coater to give a thinner layer everywhere; or else further diluting the spin-on source with iso propanol so less material will be left to require oxidation. Each possibility requires evaluation in terms of its success at solving the above problem (if it occurs) as well as with regard to any side effects the particular change causes.

(viii) as per (iii)

(ix) Application of silver paste and subsequent firing

It is not a difficult task to adequately fill the grooves with silver paste by the stroke of a rubber squeegee directly across the wafer surface. However what could prove to be far more difficult is the task of preventing the remainder of the silver paste from making a mess on the base plate and the surrounds. It is probably necessary for the rubber squeegee to be in direct contact with the silicon surface and hence the problem remains to prevent the paste being pushed over the edge of the wafer.

For this step to be carried out most effectively, the rubber squeegee needs to always be in quite good condition and be mounted in a perfectly flat manner. If this is not the case, streaks of unwanted silver paste are likely to be left across the surface. Similarly if in step (ii) the wafers are over etched and it is polysilicon material, then vertical steps will result at the grain boundaries resulting in then being coated with silver paste in this current step. This latter case can be easily checked under the microscope.

Another potential problem in this step could be the "blowing out" of some regions of the paste during firing. There are two possible causes of this effect. Firstly, if the drying temperature is too high, the rapid evolution of evaporated solvents from the

pastes can lead to sufficient forces on the paste to force it out of the grooves. This being the case, the drying temperature should be reduced. It is anticipated that drying temperatures in the range of 150-300°C are quite suitable. Secondly, if the paste is not adequately dried when the wafer passes into the high temperature section similar results can occur for the same reasons. This time however, the drying temperature or time needs to be increased.

(x) Edge isolation

In the laboratory all edge isolations are carried out by scribing the rear of the solar cell and then cleaving off the edges. This gives superior results to a front surface laser scribed edge junction isolation and is essential for prototype small area cells which have been made. For larger cells however, leakage around the edge is not as important thus making a front surface scribe suitable.

Another alternative is to scribe a groove (200-300μm) right around the wafer edge at the same time as the grooves are put in for the metal. The edge bits will then require cleaving at the end and will need to be done with considerable care because they become somewhat more difficult to snap after the scribe has been cleaned out with the sodium hydroxide etch.

Finally, plasma etched edge isolation can be carried out by coin stacking the solar cells in the plasma system. This is the technique believed to be used very effectively by several commercial enterprises.

(xi) Antireflection coating

This can be done in the plasma system in the presence of ammonia gas and Silane. This will deposit silicon nitride which is an excellent material for antireflection coatings. The thickness needs to be in the vicinity of 70 nm which should give a deep blue, bordering on purple colour when deposited on polished silicon. Optimisation of this thickness cannot be carried out on textured wafers as from such a surface there will effectively be no reflection.

Silicon nitride is extremely resistant to chemical and mechanical attack thus giving it many beneficial characteristics. It does however pose a difficulty for subsequent soldering as the metal if not masked will also be coated. This problem may of course be alleviated if one of the alternative sequences is adopted.

(xii) Electrical testing

It is of benefit to test cells under a xenon arc lamp or equivalent that has a reasonable output at the blue end of the spectrum. Unfortunately ELH lamps lack this thus resulting in them failing to fully exploit the improved blue response of the buried contact solar cell. The resulting current measured will thus be relatively lower than it should be compared to that of a heavily diffused solar cell. (i.e. a conventional screen printed solar cell). This problem however is not of great importance when one buried contact solar cell is being measured relative to another. This means that calibration of buried contact solar cell standards should be done under a xenon arc lamp or equivalent but that ELH lamps would be suitable for routine monitoring of cells produced to the same specifications.

Plating sequence

A modification to "Sequence B" above could be used to allow the metal contacts to the cell to be applied by electrolytic or electroless plating. Steps (i) to (viii) would be as described. After diffusion and removal of diffusion oxide, nickel would be electrolessly plated to the cell in regions not covered by the silicon nitride antireflection coating. Sensitizing prior to nickel plating by a suitable electroless solution may give best results. After sintering of the nickel layer, a conducting layer probably copper could be plated to the nickel to a thickness consistent with producing low resistance. Without the grooves, this would cause considerable broadening out of the top metallisation lines. The grooves, however, would confine the plated metal to the volume within the groove until it was completely filled with plated material. The copper layer could be covered by a thin electrolessly plated layer of another metal if its reactivity with cell encapsulating material was a concern. Edge junction isolation could be achieved with any of the standard methods. Alternatively, after nickel plating the cell may be solder dipped. The solder would attach itself preferentially to the plated regions. The grooves then determine the lateral geometry of the solder layer.

Claims

1. A p-n junction solar cell comprising a semiconducting substrate of one conductivity type and a plurality of grooves formed in the top surface of said substrate, wherein a semiconducting layer of the opposite conductivity type is formed on said surface of said solar cell substrate and in said grooves, wherein the front electrical contact is formed by conducting material confined to and substantially filling said grooves such that the conducting material is in intimate contact with said semiconducting layer of the opposite conductivity type formed within

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said grooves, and wherein said grooves extend a distance into said substrate greater than their width.

2. A solar cell as claimed in claim 1 wherein the ratio of the width to the depth of each respective groove lies in the range of 1:2 to 1:7.

3. A solar cell as claimed in claim 1 wherein the transverse cross-section of said groove is U-shaped.

4. A solar cell as claimed in claim 1 wherein the transverse cross-section of said groove is V-shaped.

5. A method of forming a p-n junction solar cell according to claim 1 having a semiconducting substrate of one conductivity type, said method comprising forming grooves in the top surface of the cell, so that each groove extends a distance into said substrate greater than the width of each groove, introducing impurities of the opposite conductivity type into the walls of said grooves and into the said substrate and applying an electrically conducting material as a conductive paste material to the said surface of the cell by a sweeping stroke of a squeegee or scraper, forcing the paste material into said grooves, whereby said paste material is confined to and substantially fills said grooves.

6. A method of forming a p-n junction solar cell according to claim 1 having a semiconductor substrate of one conductivity type, said method comprising the steps of forming a semiconducting layer of the opposite conductivity type over the top surface of the semiconducting substrate, forming an insulating layer over the said layer of the opposite conductivity type, forming grooves through said insulating layer and said layer of the opposite conductivity type into said substrate, each groove extending distance into substrate greater than the width of each groove, introducing impurities of the opposite conductivity type into the walls of said grooves and subsequently selectively depositing metal in said grooves, whereby said metal is confined to and substantially fills said grooves.

7. A method as claimed in claim 6 in which the metal is subsequently selectively deposited in said grooves by electrolytic or electroless plating, such plating being continued so as to substantially fill said grooves.

8. A method as claimed in claim 6 including selectively depositing the metal in said grooves by electrolytic or electroless plating, followed by dipping the cell in solder, said solder selectively adhering to the previously plated grooves.

9. A method as claimed in any one of claims 5 to 8 wherein the grooves are formed by laser scribing.

10. A method as claimed in any one fo claims 5 to 8 wherein the grooves are formed by mechanical abrasion.

11. A method as claimed in claim 5 wherein the conductive paste comprises silver.

12. A method as claimed in claims 7 wherein the plated metal is nickel.

13. A method as claimed in claim 7 wherein the plated metal is a nickel layer followed by a copper layer.

14. A method as claimed in claim 7 wherein the plated metal is a nickel layer followed by a copper layer and a subsequent layer of another metal.

Revendications

1. Cellule solaire à jonction p-n comprenant un substrat semi-conducteur d'un type de conductivité et plusieurs rainures ménagées sur la surface supérieure dudit substrat, caractérisée en ce que ladite surface dudit substrat de ladite cellule solaire ainsi que lesdites rainures sont recouvertes d'une couche semiconductrice du type de conductivité opposé, en ce que le contact électrique frontal est formé par un matériau conducteur confiné dans et remplissant complètement lesdites rainures de telle manière que le matériau conducteur soit en contact intime avec ladite couche semi-conductrice du type de conductivité opposé, formée à l'intérieur desdites rainures, et en ce que lesdites rainures ménagées dans ledit substrat sont plus longues que larges.

2. Cellule solaire selon la revendication 1, caractérisée en ce que le rapport de la largeur sur la profondeur de chaque rainure est compris entre 1:2 et 1:7.

3. Cellule solaire selon la revendication 1, caractérisée en ce que la section transversale de ladite rainure présente une forme de U.

* C L M S *

4. Cellule solaire selon la revendication 1, caractérisée en ce que la section transversale de ladite rainure présente une forme de V.

5. Méthode de réalisation d'une cellule solaire à jonction p-n selon la revendication 1, présentant un substrat semi-conducteur d'un type de conductivité, caractérisée en ce qu'elle comprend la formation de rainures dans la surface supérieure de la cellule, de manière à ce que chaque rainure ménagée dans ledit substrat soit plus longue que large, l'introduction d'impuretés du type de conductivité opposé à l'intérieur des parois desdites rainures et à l'intérieur dudit substrat et l'application d'un matériau électriquement conducteur sous forme de pâte conductrice sur ladite surface de la cellule par un mouvement de va et vient au moyen d'un rouleau ou d'un racloir, afin de faire pénétrer la pâte dans lesdites rainures, et de remplir complètement lesdites rainures.

6. Méthode de réalisation d'une cellule solaire à jonction p-n selon la revendication 1, présentant un substrat semi-conducteur d'un type de conductivité, ladite méthode comprenant les étapes suivantes : formation d'une couche semi-conductrice de type de conductivité opposé sur la surface supérieure du substrat semi-conducteur, formation d'une couche isolante sur ladite couche de type de conductivité opposé, formation, dans ledit substrat, de rainures à travers ladite couche isolante et ladite couche de type de conductivité opposé, chaque rainure ménagée dans ledit substrat étant plus longue que large, introduction d'impuretés du type de conductivité opposé à l'intérieur des parois desdites rainures, puis dépôt sélectif de métal dans lesdites rainures, caractérisée en ce que ledit métal est confiné à et remplit complètement lesdites rainures.

7. Méthode selon la revendication 6, caractérisée en ce que le métal est déposé ultérieurement de façon sélective dans lesdites rainures par dépôt électrolytique ou autocatalytique, et ce jusqu'à ce que lesdites rainures soient complètement remplies.

8. Méthode selon la revendication 6, comprenant le dépôt sélectif du métal dans lesdites rainures par dépôt électrolytique ou autocatalytique, suivi de l'immersion de la cellule dans de la soudure, ladite soudure adhérant sélectivement aux rainures préalablement recouvertes.

9. Méthode selon l'une quelconque des revendications 5 à 8, caractérisée en ce que les rainures sont tracées au laser.

10. Méthode selon l'une quelconque des revendications 5 à 8, caractérisée en ce que les rainures sont formées par abrasion mécanique.

11. Méthode selon la revendication 5, caractérisée en ce que la pâte conductrice contient de l'argent.

12. Méthode selon la revendication 7, caractérisée en ce que le métal déposé est du nickel.

13. Méthode selon la revendication 7, caractérisée en ce que le métal déposé consiste en une couche de nickel suivie d'une couche de cuivre.

14. Méthode selon la revendication 7, caractérisée en ce que le métal déposé consiste en une couche de nickel suivie d'une couche de cuivre et d'une couche supplémentaire d'un autre métal.

Patentansprüche

1. Solarzelle mit p-n-Verbindung, die ein Halbleitersubstrat eines Leitfähigkeitstyps und eine Vielzahl von Vertiefungen umfaßt, die in der oberen Oberfläche des Substrates ausgebildet sind, wobei auf dieser Oberfläche des Solarzellensubstrates und in den Vertiefungen eine Halbleiterschicht des entgegengesetzten Leitfähigkeitstyps ausgebildet ist, wobei der vordere elektrische Kontakt durch leitendes Material gebildet wird, das auf diese Vertiefungen begrenzt ist und diese im wesentlichen füllt, so daß das leitende Material im engen Kontakt mit der Halbleiterschicht des entgegengesetzten Leitfähigkeitstyps steht, die in den Vertiefungen ausgebildet ist, und wobei sich diese Vertiefungen in einem Abstand in das Substrat erstrecken, der größer als ihre Breite ist.

2. Solarzelle nach Anspruch 1, worin das Verhältnis der Breite zur Tiefe jeder entsprechenden Vertiefung im Bereich von 1:2 bis 1:7 liegt.

3. Solarzelle nach Anspruch 1, worin der Querschnitt der Vertiefung U-förmig ist.

4. Solarzelle nach Anspruch 1, worin der Querschnitt der Vertiefung V-förmig ist.

5. Verfahren zur Bildung einer Solarzelle mit p-n-Verbindung nach Anspruch 1, die ein Halbleitersubstrat eines Leitfähigkeitstyps aufweist, wobei dieses Verfahren die Bildung von Vertie-

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fungen in der oberen Oberfläche der Zelle, so daß sich jede Vertiefung in einem Abstand in das Substrat erstreckt, der größer als die Breite jeder Vertiefung ist, die Einführung von Verunreinigungen des entgegengesetzten Leitfähigkeitstyps in die Wände der Vertiefungen und in das Substrat und das Auftragen eines elektrisch leitenden Materials als leitendes Pastenmaterial auf die Oberfläche der Zelle durch schwingendes Streichen mit einem Wischgummi oder Abstreicher umfaßt, der das Pastenmaterial in die Vertiefungen drückt, wodurch das Pastenmaterial auf diese Vertiefungen begrenzt ist und diese im wesentlichen füllt.

6. Verfahren zur Bildung einer Solarzelle mit p-n-Verbindung nach Anspruch 1, die ein Halbleitersubstrat eines Leitfähigkeitstyps umfaßt, wobei das Verfahren die Schritte der Bildung einer Halbleiterschicht des entgegengesetzten Leitfähigkeitstyps auf der oberen Oberfläche des Halbleitersubstrates, die Bildung einer isolierenden Schicht über dieser Schicht des entgegengesetzten Leitfähigkeitstyps, die Bildung von Vertiefungen durch die isolierende Schicht und die Schicht des entgegengesetzten Leitfähigkeitstyps in das Substrat, wobei sich jede Vertiefung in einem Abstand in das Stubstrat erstreckt, der größer als die Breite jeder Vertiefung ist, die Einführung von Verunreinigungen des entgegengesetzten Leitfähigkeitstyps in die Wände der Vertiefungen und das anschließende selektive Auftragen von Metall in die Vertiefungen umfaßt, wodurch das Metall auf die Vertiefungen begrenzt ist und diese im wesentlichen füllt.

7. Verfahren nach Anspruch 6, worin das Metall durch elektrolytisches oder stromloses Plattieren anschließend selektiv in den Vertiefungen aufgetragen wird, wobei dieses Plattieren fortgeführt wird, um die Vertiefungen im wesentlichen zu füllen.

8. Verfahren nach Anspruch 6, das das selektive Auftragen des Metalls in den Vertiefungen durch elektrolytisches oder stromloses Plattieren, gefolgt vom Tauchen der Zelle in ein Lötmittel umfaßt, wobei dieses Lötmittel selektiv an den vorher plattierten Vertiefungen haftet.

9. Verfahren nach einem der Ansprüche 5 bis 8, worin die Vertiefungen durch Lasermarkierung gebildet werden.

10. Verfahren nach einem der Ansprüche 5 bis 8, worin die Vertiefungen durch mechanischen Abrieb gebildet werden.

11. Verfahren nach Anspruch 5, worin die leitfähige Paste Silber umfaßt.

12. Verfahren nach Anspruch 7, worin das plattierte Metall Nickel ist.

13. Verfahren nach Anspruch 7, worin das plattierte Metall eine Nickelschicht, gefolgt von einer Kupferschicht ist.

14. Verfahren nach Anspruch 7, worin das plattierte Metall eine Nickelschicht, gefolgt von einer Kupferschicht und einer anschließenden Schicht eines weiteren Metalls ist.