

Laser-based Method and Machining Table for Metallizing the Rear Side of a
Semiconductor Component

Description

The invention relates to a method for metallizing the rear side of a semiconductor
5 component, which semiconductor component is a photovoltaic solar cell or a preliminary
stage in the production process of a photovoltaic solar cell, according to the preamble of
claim 1, and to a machining table for carrying out such a method.

In photovoltaic solar cells, charge carriers are typically conducted away by metal
structures. Metal structures are known in this connection that have all-over contact on
10 one side of a semiconductor component.

In the simplest form, the semiconductor component comprises a semiconductor layer
having a p-doped region and an n-doped region. The semiconductor layer can
additionally comprise insulating layers or other layers, most particularly semiconductor
layers.

15 Features that are essential to the efficiency of a solar cell include not only the electrical
properties such as, for example, the recombination properties of the surfaces and the
material quality of the semiconductor layers, but also the light yield. The light yield is the
ratio of the total generation of electrons in electron-hole pairs resulting from light
coupling into the solar cell to the electromagnetic radiation striking the front side. In
20 order to increase the light yield, it is also relevant, in particular, to extend the light path
within the solar cell: due to the low absorption properties, a portion of the longitudinal
wave light penetrates the solar cell and strikes the rear side of the solar cell. In order to
increase the light yield, it is therefore known to design the rear side to be reflective such
that a light beam striking the rear side is reflected back in the direction of the front side.

25 To this end, it is known to coat the rear side of the semiconductor component with all-

over, rear-side metallization, as rear-side reflectors. In this connection, it is also known that parasitic absorption occurs in structured or raw metal layers. For this reason, smooth (e.g., vapor-deposited) metal layers have much greater reflection than relatively raw layers (which are produced by means of screen printing, for example).

- 5 Another possibility for obtaining an internal light-path extension in solar cells is described in DE 10 2009 042 018 A1. Therein, a diffractive surface structure is formed on the rear side of the solar cell. This causes the photons that are reflected on the rear side to be reflected in discrete diffraction angles. In this manner it is possible to increase the absorption of longwave radiation by means of an internal extension of the light path.
- 10 The problem addressed by the present invention is that of providing a method for metallizing the rear side of a semiconductor component, the use of which improves the internal reflection properties of the rear side of the solar cell and which simultaneously makes it possible to obtain the most planar rear-side metallization possible, in order to minimize parasitic absorption. Another problem addressed by the invention is that of
- 15 creating a solar cell in which the rear-side metallization is improved in terms of the reflection properties and the planarity. The invention should also provide a machining table for producing such a solar cell and for carrying out such a method.

This problem is solved by a method according to claim 1, by a photovoltaic solar cell according to claim 12, and by a machining table for carrying out such a method

20 according to claim 13. Advantageous embodiments of the method are mentioned in claims 2 and 11. Advantageous embodiments of the machining table for carrying out the method are mentioned in claims 14 and 15. The wording of the claims is hereby incorporated into the description by express reference thereto.

The method according to the invention is used to metallize the rear side of a

25 semiconductor component. The semiconductor component is a photovoltaic solar cell or a preliminary stage of a photovoltaic solar cell in the production process and comprises at least one semiconductor layer. It lies within the scope of the invention that the

semiconductor layer is designed as a semiconductor substrate, more particularly as a silicon wafer.

The method comprises the following method steps:

5 In a method step A, at least one at least single-layer metal foil is applied onto the rear side of the semiconductor component.

In a method step B, the metal foil applied in method step A is locally heated. The metal foil, at the least, is thereby momentarily fused in local regions.

10 It is essential that a void is formed, at least in regions, between the metal foil and the rear side of the semiconductor component, which void is filled with a filler medium, which filler medium has an optical refractive index n of less than 1.4. In this connection and in the following, the parameter n represents the real component of the refractive index.

15 The invention is based on the applicant's knowledge that the formation of a void between the metal foil and the rear side of the semiconductor component results in an increase in the reflection of longwave electromagnetic radiation in the range of wavelengths > 1000 nm. Several-fold, additional reflection of the light increases the optical light path in the semiconductor component and, therefore, the likelihood of absorption and, therefore, the efficiency of the solar cell.

20 In terms of physics, this is based on the increased refractive index contrast between the semiconductor and the metal layer. According to the Fresnel equations, this results in increased internal reflection and a reduction in the critical angle at which internal total reflection occurs. The latter is important in combination with textured front sides, in particular, since, in this case, light strikes the rear side of the solar cell at slanted angles. If the angle of incidence on the rear side is greater than the total reflection
25 angle, virtually all radiation is reflected already at the transition between the semiconductor and the dielectric or semiconductor and an optically thinner filler medium

and does not even need to be reflected by the metallic mirror, which is prone to losses.

In the case of rough or textured rear-side semiconductor surfaces, a direct application of a metal layer by means of common methods (e.g., screen printing, sputtering, or vapor deposition) results in metal surfaces that are also structured. Typically, this is not

5 significantly changed by the application of dielectric passivation layers having common thicknesses of less than 100 nm. As mentioned above, absorption occurs in structured metals, which is considered to be parasitic in this case since this is absorption that is not usable for the solar cell. In the present invention, a method is described which minimizes these losses in the case of textured rear sides, since the internal reflection is
10 increased by means of a void and a well-defined, planar metal surface of the foil is dominant, thereby making it possible to minimize parasitic metal absorption.

Another field of application for the present invention is a combination with a use of diffractive structures on the rear side of the solar cell. In order to form such a diffractive structure, a photonic structure is formed on a passivated semiconductor surface, for
15 example. The formation of diffractive structures on a rear side of a solar cell is known *per se* and is described, for example, in DE 10 2009 042 018 A1. In a manner analogous to the previously described case, internal reflection is increased in this case as well by creating a void, which is filled with air, for example, between the structure and the metal foil. In addition, the metal foil disposed on the rear side functions as an optical
20 mirror and, advantageously, can further increase the internal reflection.

In contrast, when a metal layer or a dielectric layer is vapor-deposited directly onto a structure on the rear side of the solar cell, this metal layer adapts to the structure. A conformal modulation of the metal surface that is particularly disadvantageous to the photonic structure can therefore result: In this connection, in addition to the above-
25 described parasitic absorption, lattice effects induce an incoupling of the radiation into the metal, which enhances this negative effect. This problem can be substantially avoided by the use of a metal foil and the formation of voids for metallizing a rear side of a solar cell.

Another positive effect is that, when the described method is used on actual lattice structures, which are made of amorphous silicon, for example, a refractive index contrast of the lattice that is greater than with known methods can be achieved (for example, dielectric buffer layers of oxides between the photonic structure and the metal layer). This initially results in increased diffraction efficiencies, thereby increasing the internal extension of the light path. In addition, evanescent waves in the dielectric buffer layer that are not capable of propagating, which occur when photonic structures are used, are optimally dampened in a void, whereby, in turn, the parasitic absorption in the metal can be minimized.

By means of the method according to the invention, the rear side of a solar cell can be metallized such that a sufficiently large void remains between the passivation layer and the metal foil, which results in an increase in the retroreflection of the incoupled radiation. As a result, it is possible to decisively reduce the thickness of the passivation layer. Heretofore, attempts were made to achieve increased rear-side reflection by means of a passivation layer designed having a suitable thickness. A thicker passivation layer results in higher process costs and a longer process duration, however. Another advantage of a thinner passivation layer is that this is a smaller barrier for the contacting process: In order to form the contacting structure, the passivation layer must be plated-through in order to establish direct contact with the semiconductor material. This is simpler when the thickness of the passivation layer is reduced.

The method according to the invention therefore offers, for the first time, a low-cost possibility for metallizing the rear side of semiconductor components using a thin passivation layer without this resulting in substantial losses in efficiency. In comparison to previously known methods for rear-side metallization, it is possible to produce solar cells in which the thickness of the passivation layer can be reduced to approximately 5 nm.

Within the scope of this description, the void that is formed on the rear side of the semiconductor component is filled with the filler medium.

In a preferred embodiment, a gas, preferably air and/or an inert gas, more particularly preferably a noble gas is used as the filler medium. This results in the advantage that, in a simple and low-cost manner, the void filled with the filler medium has a refractive index n of less than 1.4.

- 5 In another preferably embodiment, an adhesive is used as the filler medium. This results in the advantage that the void is stabilized and the metal foil is additionally fixed. In this connection, commercially available adhesives having a refractive index n of less than 1.4 can be used, for example adhesives of the MY series from Polytec PT GmbH, Waldbronn, e.g., MY-132 or MY-133.
- 10 It lies within the scope of the invention to apply additional interlayers before method steps A and/or B.

Preferably, at least one interlayer is applied onto one side of the semiconductor component in an additional method step A-1 before the method step A. This interlayer is preferably a dielectric layer. This results in the advantage that the interlayer can be

15 designed to increase the efficiency of the solar cell, most particularly by designing the interlayer as a passivation layer in order to reduce the charge carrier recombination on the surface of the semiconductor layer and/or by designing the interlayer as an optical layer in order to improve the reflectance properties of the solar cell and, therefore, the light absorption. Particularly preferably, a design of the interlayer as a dielectric layer,

20 most particularly preferably as a silicon dioxide layer, silicon nitride layer, or an aluminum oxide layer is advantageous.

Preferably, in method step B, the metal layer is locally heated by means of a layer, most particularly preferably by means of a pulsed laser. Preferably, a laser having a wavelength in a range of 190 nm to 11 μm , most particularly preferably having a

25 wavelength of 1064 nm is used. Preferably, a laser having a pulse length in the range of one picosecond (ps) to 20 microseconds (μs), particularly preferably of 10-300 nanoseconds (ns) is used. Investigations carried out by the inventors have shown that

the aforementioned parameters make a smooth and error-free process sequence possible. The use of a laser for local heating and, therefore, fusing the metal foil is advantageous in that the local fusion can take place at any point and with high accuracy.

5 In a preferred embodiment, the fusion of the metal foil is carried out in method step B such that the void is delimited by the metal foil, the rear side of the semiconductor component, and the fused regions. As a result, the void is sealed with respect to the surroundings. The fused region is designed to at least partially enclose the void. Advantageously, the fused region extends at least partially constantly along the outer
10 edge of the semiconductor component. The connection between the metal foil and the semiconductor component produced by the fusion of the metal foil therefore fulfills the purpose of sealing the void between the metal foil and the semiconductor component with respect to the surroundings. The metal foil can also be fixed on the semiconductor component in local regions, which are distributed over the rear side of the
15 semiconductor component.

Electrical contacting of the semiconductor layer preferably takes place at the points at which the metal foil is locally fused in that the metal foil and the semiconductor layer are connected in an electrically conductive manner. This can take place in a manner known
20 *per se* during the fusion process, in particular one or more interlayers between the metal foil and the semiconductor layer can be easily penetrated by the metal foil during the fusion process.

In another preferable embodiment, the metal foil is structured simultaneously with the fusion of the metal foil in method step B. In this case, structuring means that a separation forms between the regions in which fusion takes place in the metal foil and
25 the regions in which the metal foil was not fused. In another preferable embodiment, at least predetermined breaking points are additionally formed in the metal foil in method step C. The predetermined breaking points are produced in the regions that are located on the side of the sealing of the metal foil facing away from the void. This makes it

possible to easily remove the metal foil at the edges of the semiconductor component.

It is advantageous, in particular, when the metal foil on the fusion regions of method step C are completely severed during the laser processing process itself. This makes it possible to easily remove the metal foil at the edges of the semiconductor component. Preferably, a laser having a pulse length in the range of a few picoseconds to a few femtoseconds is used in method step C. As a result, the metal foil is thinned in the regions acted upon with laser radiation, i.e., metal is removed. In this case, it is advantageous that no fusion takes place on the rear side of the semiconductor component. Therefore, no connections are formed between the metal foil and the semiconductor component.

In another preferable embodiment, the metal foil is fixed at points on the semiconductor component by means of local heating in a method step A-a after the method step A. In an additional, subsequent method step A-b before the method step B, a filler medium is actively introduced between the semiconductor component and the affixed metal foil. Next, in method step B, as described above, the metal foil is fixed on the semiconductor component by local heating and, therefore, the void is sealed with respect to the surroundings. Due to this sealing, the filler medium cannot emerge from the void and enter the surroundings. In this preferred embodiment, the filler medium is preferably a gas, in particular air, because a gas can be actively introduced between the semiconductor component and the metal foil in a particularly simple manner, for example being blown therein.

The active introduction of the filler medium into the void between the metal foil and the semiconductor component results in the advantage that the thickness of the void can be controlled. In addition, when a sufficient filling amount is introduced, only a few contact points, and preferably no contact points, form in the region within the seal between the metal foil and the semiconductor component. As a result, the rear-side reflection is additionally increased by the larger surface expansion of the void region.

In another preferable embodiment, before the filler medium is actively introduced, the metal foil is fixed on the semiconductor component in a gas-tight manner, preferably by means of local heating. In this connection, at least one filling opening, preferably exactly one filling opening, is formed such that, after the above-described fixation, the filler
5 medium can be introduced into the space delimited by the semiconductor component, the metal foil, and the gas-tight fixation via the at least one filling opening. As a result, a defined filling amount and a defined filling pressure are made possible. Preferably, the filling opening is then also closed in a gas-tight manner, in particular by means of local heating.

- 10 In another preferable embodiment, the rear side of the semiconductor component is structured in a method step A0 before the method step A. The structure on the rear side comprises a plurality of protrusions and depressions such that, when the foil is placed thereon, voids form in the recesses due to the presence of structures in the semiconductor surface. The structuring is preferably carried out with a nanoimprint
15 method and/or a dry- and/or wet-chemical etching method and/or with a printing or lithography process (H. Hauser et al., "Diffractive Backside Structures via Nanoimprint Lithography", 2012, Proceedings of the Silicon PV Conference).

It is advantageous, in particular, to carry out the structuring exclusively using the nanoimprint method: The structures obtained by means of nanoimprint can be further
20 used as a preliminary stage for further structuring processes (for example, etching or lift-off processes), and directly as an optical active layer in the solar cell. In this connection, it is possible to use polymeric materials such as sol-gel materials orOrmocer® materials.

The structure sizes of the rear side structuring can be selected in the range between
25 200 nm to 10 μm . Preferably, structure sizes between 400 nm and 2 μm are used. In this case, it is advantageous, in particular, that the thickness of the void can be controlled depending on the structure size. The thickness of the void in this case refers to the dimension of the void perpendicularly to the plane of the rear side of the

semiconductor component.

In addition to the use of the cavities of the structuring as voids, in another advantageous embodiment, contiguous inclusions of the filler medium are formed on the rear side between the metal foil and the rear side of the semiconductor component, which
5 inclusions have a larger surface area laterally than the cavities in order to obtain a void that covers a plurality of cavities over a large area. This void therefore forms an additional filler medium layer, which extends on the rear side horizontally over the plurality of cavities, preferably substantially over the rear side. The thickness of this filler medium layer is preferably in the range of 20 nm to 500 nm, preferably 100 nm to 300
10 nm. A further improvement of the optical properties of the rear side of the solar cell is achieved by means of the aforementioned filler medium layer in combination with the above-described diffractive structure.

In another preferable embodiment, in method step A, a structured metal foil is used, which comprises a plurality of protrusions and depressions at least on the side facing
15 the semiconductor component. In this case, the structure of the surface of the metal foil on the side facing the semiconductor component results in the formation of voids when the foil is placed onto the rear side of the semiconductor component. It is thereby made possible to enclose a freely selectable filler medium by sealing the voids with respect to the surroundings by fusing the metal foil by means of laser radiation.

20 In another preferable embodiment, a metal foil having stochastic textures is used in method step A.

In another embodiment, a metal foil having periodic textures, in particular a texture having a combination of periodic and stochastic structures, is used in method step A.

Advantageously, there is no need to structure the semiconductor component in the
25 aforementioned embodiments of the method according to the invention. The structuring process is transferred to a second parallel process for structuring the metal foil. This makes a faster and lower-cost process sequence of the overall process possible.

In another preferable embodiment, a metal foil coated with a dielectric layer is used in method step A. In this connection, the dielectric layer is applied on the side of the metal foil facing the semiconductor component.

It is advantageous that, in the case of a rear side of a solar cell or a metal foil that is planar, but also, in particular, that is structured, a dielectric buffer layer that is well defined in terms of material quality and layer thickness can be additionally deposited on the metal foil in advance in order to positively influence the reflection properties. Such a well-defined buffer layer can also be deposited on the metal foil and on wafers in a lower-cost and faster process, since roll-to-roll processes can be used here. Potential depositing methods are, for example, PVD or dip coating processes. The dielectric layer is preferably formed with a thickness in the range of 5 nm to 500 nm, preferably 20 nm to 200 nm.

In another preferable embodiment, the metal foil is fastened on the semiconductor component at least during method step B. Investigations carried out by the inventors have shown that the metal foil preferably rests against the semiconductor component in a planar manner during fusion, since, for example, an air inclusion between the foil and the semiconductor component in the region to be fused can result in the situation, due to the absence of thermal contact of the metal foil with the semiconductor component, that the metal foil is entirely or partially vaporized during local heating and, therefore, a connection either does not form or is insufficient.

The metal foil is therefore tensioned onto the semiconductor component and/or is suctioned thereon and/or is blown thereon during the method step B. Suctioning or blowing the metal foil thereon, in particular, is a possibility that is simple in terms of process engineering and, in particular, is contactless, for ensuring the contact between the metal foil and the semiconductor component in method step B.

The above-described problem is also solved by a solar cell according to claim 12.

The photovoltaic solar cell according to the invention comprises a semiconductor layer,

an insulating layer, contacts on the front side of the solar cell, a passivation layer on the rear side of the solar cell, and a metal foil, which is applied onto the rear side of the solar cell. A plurality of voids is formed between the metal foil and the passivation layer. The voids are sealed with respect to the surroundings and are filled with a filler medium, 5 which filler medium has a refractive index of less than 1.4. The enclosed filler medium contributes to an increase in the reflection of the longwave electromagnetic radiation and thereby makes it possible to substantially reduce the passivation layer thickness, as described above.

In a preferred embodiment, the voids on the rear side of the solar cell according to the 10 invention are filled with air and/or an inert gas, in particular a noble gas.

The solar cell according to the invention is advantageously produced by carrying out the method according to the invention or a preferable modification thereof.

The above-described problem is also solved by a machining table according to claim 13. The machining table according to the invention is used to carry out the above- 15 described method according to the invention or, preferably, a preferable modification of the method according to the invention.

The machining table according to the invention comprises a support region for a semiconductor component, a fixing region for the semiconductor component, a fixing region for the metal foil, and at least one blow-off opening. It is essential that the blow- 20 off opening is disposed between the fixing region for the metal foil and the support region for the semiconductor component. To this end, the blow-off opening is preferably connected to a blow-off channel. The support region is preferably disposed in the center.

The machining table according to the invention offers considerable advantages in the 25 formation of a rear-side metallization for increasing the retroreflection on the rear side of a semiconductor component:

When the machining table according to the invention is used, the semiconductor component is fixed in the support region. The affixed semiconductor component is covered with a metal foil. The fixing region for the metal foil is disposed in the central support region for the semiconductor component in an enclosing manner, i.e., enclosing
5 the support region on the machining table, at least in a top view, and is designed such that the metal foil is fixed on the semiconductor component at the edge of the semiconductor component, enclosing the semiconductor component, without air inclusions. Any air inclusions at the edge of the semiconductor component enclosing the semiconductor component would result in the situation during execution of the method
10 according to the invention in which the metal foil is entirely or partially vaporized due to the absence of thermal contact with the semiconductor component during local heating and, therefore either no seal or an insufficient seal is formed. The voids that are formed and the filler medium enclosed therein would not be sufficiently sealed in this case. This is avoided by means of the fixing region, which encloses the support region.

15 In another preferable embodiment, the support region for the semiconductor component is designed as a depression such that, when a semiconductor component is placed into the depression, the semiconductor component and the surface of the machining table laterally adjacent thereto form a planar surface. It is thereby ensured that the fixed metal foil forms a planar surface and, therefore, leakage caused by any waves that may be
20 present in the metal foil are avoided when the metal foil is connected to the semiconductor component.

In a preferred embodiment, the fixing region for the semiconductor component is designed as at least one suction opening, which is connected to a first suction line. The semiconductor component can be acted upon with vacuum/underpressure via the first
25 suction line and the suction opening and thereby be fixed on the support region.

In another preferable embodiment, the fixing region for the metal foil is designed as a suction duct enclosing the support region for the semiconductor component. The suction duct is connected to a second suction line. The metal foil can be acted upon

with vacuum/underpressure via the second suction line and the suction duct and thereby be fixed on the semiconductor component.

Given that the blow-off opening is disposed between the fixing region for the metal foil and the support region for the semiconductor component, it is possible after the local
5 fusion to feed a filler medium through the blow-off opening, preferably a gas, in the manner described above such that the gas is blown onto the metal foil and, therefore, the metal foil is at least partially spaced apart from the semiconductor component in the non-fused regions. The removal of excess metal foil is simplified as a result.

The machining table according to the invention is particularly suited for carrying out an
10 exemplary embodiment of the method according to the invention, as described in the following:

The machining table comprises a support region for the semiconductor component. In a first method step, the semiconductor component is suctioned onto the machining table via the fixing region and the suction line.

15 The metal foil is applied onto the semiconductor component, which metal foil is fixed on the semiconductor component via the suction lines and the suction openings at the fixing regions.

In a further method step, the metal foil is locally fastened on the semiconductor component by means of local heating, preferably by means of laser radiation. Due to
20 the local heating by means of laser radiation, the metal foil melts at the irradiated points and forms a local, fluid-tight connection, preferably an electrically conductive contact, with the semiconductor component disposed thereunder.

In a further method step, a filler medium, preferably a gas, is introduced via the blow-off channel through the blow-off openings, as described above, between the locally fixed
25 metal foil and the semiconductor component. As a result, the metal foil rises up off of the rear side of the semiconductor component and inclusions are formed.

In a further method step, the metal foil is connected to the rear side of the semiconductor component around the edge of the semiconductor component by means of laser radiation and is sealed with respect to the surroundings. As a result, the introduced filler medium is enclosed in the voids between the metal foil and the rear
5 side of the semiconductor component.

Preferably, in a further method step, the metal foil is trimmed at the edges along the semiconductor component by means of laser radiation. The trimming takes place along the connecting line of the metal foil and the rear side of the semiconductor component on the side of the metal foil facing away from the void. The overhanging foil can
10 therefore be easily removed.

In an alternative preferable embodiment, the metal foil is structured simultaneously with the fusion of the metal foil at the edge of the semiconductor component, i.e., while the void is being sealed with respect to the surroundings. In this case, structuring means that a separation forms between the regions in which fusion takes place in the metal foil
15 and the regions in which the metal foil was not fused. As a result, predetermined breaking points, at the least, and preferably a severance in the metal foil are formed. The structuring is produced in the regions that are located on the side of the sealing of the metal foil facing away from the void. This makes it possible to easily remove the metal foil at the edges of the semiconductor component.

20 The method according to the invention is preferably designed for forming a solar cell according to the invention or a preferred embodiment thereof and/or for carrying out said method by means of the machining table according to the invention and/or a preferable embodiment thereof. The solar cell according to the invention or a preferred embodiment of the solar cell according to the invention is preferably produced by
25 carrying out the method according to the invention or a preferable embodiment thereof and/or by means of the machining table according to the invention or a preferable embodiment thereof.

Further advantageous features and embodiments of the present invention are described in the following with reference to exemplary embodiments and the figures. Therein:

- Figure 1a to Figure 1h show method steps of a first exemplary embodiment of the method according to the invention;
- 5 Figure 2a to Figure 2d show method steps of a second exemplary embodiment of the method according to the invention;
- Figure 3a to Figure 3c show method steps of a third exemplary embodiment of the method according to the invention;
- 10 Figure 4a to Figure 4g show a schematic illustration of the use of an exemplary embodiment of the machining table according to the invention.

Figures 1 to 3 are schematic views of a semiconductor component, which is a photovoltaic solar cell or a preliminary stage of such a solar cell, during the production process. A partial section is schematically depicted in each case; the solar cell continues in an analogous manner on both sides. Reference signs that are the same in the figures designate elements that are identical or that function in an identical manner.

Figures 1a to 1h schematically show a first exemplary embodiment of the method according to the invention.

- 20 Figure 1a shows a semiconductor component 1 comprising a semiconductor layer 2 having a p-doped region 2a and an n-doped region 2b and the contacts 3. The n-doped region 2b is coated with an insulating layer 4. Figure 1a therefore shows the initial state of the semiconductor component.

- 25 Figure 1b shows a schematic depiction of the semiconductor component after method step A0 has been carried out. The rear side 5 of the semiconductor component is roughened by means of a wet-chemical etching method.

The roughening can take place by using a mixture of HF (hydrofluoric acid) and

hydrogen peroxide as the etching solution. As an alternative, texturing can be carried out in the manner used in the prior art to produce texturing on the front side of a solar cell. In particular, methods that are known *per se* for producing pyramid structures, in particular pyramids having a height of approximately 5 μm can be used. Such a texture
5 can be formed, for example, by means of an HF-HNO₃ solution. It is also possible to use a solution with 2% KOH and 4% IPA. In order to produce roughness, it is also feasible to use a "standard damage etch", which is known *per se*, in particular with a 10-20% KOH solution.

By means of the targeted production of depressions in the rear side of the
10 semiconductor component, rear-side textures having structure sizes in the range of 20 nm to 10 μm are formed.

In this manner it is ensured that voids form between the rear side 5 of the semiconductor component and the metal foil 7 when the metal foil is applied in the subsequent method step.

15 In Figure 1b, a passivation layer 6 is placed onto the rear side 5 of the semiconductor component, which has been roughened using a wet-chemical method. The passivation layer 6 has a passivation effect with respect to the adjacent surface of the semiconductor layer 2 such that the charge carrier recombination velocity and, therefore, recombination losses are reduced at this surface.

20 As shown in Figure 1c, a metal foil 7 is applied onto the passivated rear side 6 of the solar cell in method step A. A plurality of voids 8 form, in regions, between the metal foil 7 and the rear side of the solar cell 5. These voids 8 are filled with air as the filler medium and therefore have a different refractive index as compared to the passivation layer and as compared to the metal foil. The difference in the refractive index between
25 the air-filled voids and the passivation layer, in particular, makes a substantial contribution to the desired increase in optical reflection on the rear side. A different gas or an adhesive can also be used as the filler medium.

In method step B, which is depicted in Figure 1d, local regions of the metal foil are fused by means of laser radiation 9. As a result, the metal foil is locally fixed on the rear side of the solar cell. A melt mixture of the metal foil 7, the passivation layer 6, and the semiconductor layer 2 forms at the heated regions 10. After the melt mixture hardens, there is an electrical contact 10 to the semiconductor layer 2 thereunder. In addition to the fixation of the metal foil on the solar cell, local contacting structures form, which connect the metal foil 7 to the semiconductor layer 2 in a fluid-tight manner.

Figure 1e shows a depiction of the connection of the metal foil 7 to the rear side of the semiconductor component 5. The fused region delimits the air-filled void 8 and seals the void 8 with respect to the surroundings. The fused region extends along the edge of the semiconductor component. The air is therefore enclosed, relative to the surroundings, in the voids 8 between the metal foil 7 and the passivated rear side 6 of the semiconductor component. Figure 1d therefore shows the state after method step B has been carried out.

In a final method step C, which is depicted in Figure 1f, the metal foil 7 is trimmed at the edge of the semiconductor component 11 by means of laser radiation 9. The metal foil 7 is severed here by means of laser radiation 9 by locally fusing the metal foil. Figure 1f therefore shows the state after method step C has been carried out.

Figure 1g shows the solar cell after the method according to the invention has been carried out. The photovoltaic solar cell according to the invention comprises a semiconductor layer 2, an insulating layer 4, contacts on the front side of the solar cell 3a, 3b, a passivation layer 6 on the rear side 5 of the solar cell, and a metal foil 7, which is applied onto the rear side of the solar cell. A plurality of voids 8, which are filled with air, are enclosed between the metal foil 7 and the passivation layer 6. The enclosed air contributes to an increase in the reflection of the longwave electromagnetic radiation and thereby makes it possible to substantially reduce the thickness of the passivation layer.

Figure 2a shows a semiconductor component 1, as an equivalent to Figure 1a. In order to avoid repetitions, only the differences between the individual exemplary embodiments of the method according to the invention will be discussed in the following.

In Figure 2a, the semiconductor layer 2 is additionally provided with a passivation layer 6 on the planar rear side 5 of the solar cell. An additional structuring layer 12 is applied
5 onto the passivation layer 6. This structuring layer 12 can be subsequently structured. In the exemplary embodiment shown, the structuring layer 12 is an amorphous silicon layer.

In a nanoimprint method, a layer is structured by means of a punch, which said layer
10 can be subsequently used directly as an optically active layer, or the pattern of which can be used as a template for the following structuring processes (for example, for etching processes in the amorphous silicon layer 12). Such a method is described, for example, in H. Hauser et al., "Diffractive Backside Structures via Nanoimprint
Lithography", 2012, Proceedings of the Silicon PV Conference. The structure sizes in
15 this case can be selected in the range between 200 nm and 10 μm , preferably between 400 nm and 2 μm . Figure 2b shows the state of the semiconductor component 1 after the nanoimprint method has been carried out in method step A0.

After the rear-side structuring is carried out, the metal foil 7 is applied onto the rear side of the semiconductor component. Voids having air inclusions 13 therefore form, due to
20 the structuring carried out previously, between the metal foil and the nanostructures on the rear side of the semiconductor component, as shown in Figure 2d.

Analogous to Figures 1d to 1f, the metal foil 7 is locally fixed on the rear side of the semiconductor component. In a further method step, the metal foil is connected to the semiconductor component in an air-tight manner peripherally along the edge of the
25 semiconductor component and, in a final method step, is trimmed on the edge. The result thereof is an exemplary embodiment of a solar cell 23 according to the invention having an air gap 13, which is enclosed on the rear side, as depicted in Figure 2d.

Figure 3a shows a semiconductor component, which is analogous to Figure 1a. The rear side of the semiconductor component 5 is coated with a planar passivation layer 6.

In contrast to the above-described exemplary embodiments, in this exemplary embodiment, a structured metal foil 22 is placed onto the planar passivated rear side 6 of the semiconductor component. This step is shown in Figure 3b. Due to the structuring of the metal foil, air inclusions 13 are formed here as well between the metal foil 22 and the rear side 5 of the semiconductor component 1 and therefore result in increased reflection on the rear side of the solar cell.

In a manner analogous to Figures 1d to 1f, the structured metal foil 22 is locally connected to the rear side of the semiconductor component. The edges are connected around the periphery of the semiconductor component and are sealed with respect to the surroundings. The metal foil is trimmed at the edges in a final method step.

Figure 3c shows a solar cell 23 after this exemplary embodiment of the method according to the invention has been carried out. The solar cell is coated on the rear side with a structured metal foil 22, wherein air inclusions 13 are present between the rear side 5 of the solar cell and the metal foil 22.

Figure 4a shows a schematic depiction of an exemplary embodiment of a machining table according to the invention.

The machining table 14 has a central support region 15 for a semiconductor component 1, a fixing region 16 for the semiconductor component, a fixing region 17 for the metal foil 7, and a blow-off opening 18. In the present exemplary embodiment, the fixing regions 16 and 17 are suction openings, which are connected to suction lines 19. The blow-off opening 18 is connected to a blow-off channel 20 and is disposed between the fixing region for the metal foil 17 and the support region 15.

The execution of an exemplary embodiment of the method according to the invention using an exemplary embodiment of the machining table according to the invention,

which is depicted in Figures 4b to 4g, is described in the following.

Figure 4b shows the machining table 14 with the semiconductor component 1 inserted. The semiconductor component 1 is suctioned on the machining table via the fixing region 16 and the suction line 19. The metal foil 7 is placed onto the semiconductor component 1, which said metal foil is fixed on the semiconductor component 1 via the suction openings at the fixing regions 17.

Figure 4c shows the method step B. The metal foil 7 is locally fastened on the semiconductor component 1. Due to the local heating by means of laser radiation 21, the metal foil 7 fuses at the radiated points and forms a local contact 10 with the semiconductor component disposed thereunder.

In a further method step, air is blown between the locally fixed metal foil 7 and the semiconductor component 1, through the blow-off openings 18, via the blow-off channel 20. This is shown in Figure 4d. As a result, the metal foil 7 rises up off of the rear side 5 of the semiconductor component 1 and voids 8 are formed.

Figure 4e shows the air-tight connection of the metal foil 7 to the semiconductor component 1. The metal foil 7 is fixed to the rear side 5 of the semiconductor component around the edge of the semiconductor component by means of laser radiation 21. As a result, the blown-in air is enclosed in the voids 8 between the metal foil 7 and the rear side 5 of the semiconductor component.

In a further method step, the metal foil 7 is trimmed along the edges of the semiconductor component 1 by means of laser radiation 21. The overhanging foil 7 can therefore be easily removed.

Figure 4g shows the finished semiconductor component 1 with an air gap 13 enclosed between the metal foil 7 and the rear side 5 of the semiconductor component. Figure 4g therefore shows the state after the exemplary embodiment of the method according to the invention has been carried out.

The support region 15 is designed as a depression such that, when a semiconductor component 1 is placed into the depression, the semiconductor component 1 and the surface of the machining table 14 laterally adjacent thereto form a planar surface. It is thereby ensured that the suctioned-on metal foil 7 rests on the semiconductor

5 component 1 around the edges of the semiconductor component without any unwanted air inclusions. If there are any unwanted air inclusions, when the method according to the invention is carried out, the metal foil 7 is vaporized in entirety or in part due to the absence of thermal contact with the semiconductor component 1 during local heating and, therefore, either no seal or an insufficient seal is formed along the edge of the
10 semiconductor component. In this case, the seal of the air inclusions would no longer be ensured. Due to the formation of the semiconductor component 15 as a depression such that, when the semiconductor component 1 is placed into the depression, the semiconductor component 1 and the surface of the machining table 14 laterally adjacent thereto form a planar surface, the advantage results that the likelihood of air inclusions
15 forming between the metal foil 7 and the semiconductor component 1 along the edge around the semiconductor component is reduced and, as a result, the quality of the seal of the air inclusions 13 increases.

The use of the machining table according to the invention, in accordance with the exemplary embodiments depicted in Figures 4a to g, has an advantageous application,
20 in particular, when the objective of the method according to the invention is that of connecting a semiconductor component 1 having a planar rear side 5 to a metal foil 7. In this case, when the machining table according to the invention is used, air can be actively blown between the metal foil 7 and the rear side 5 of the semiconductor component given that the metal foil 7 is locally spaced apart from the rear side 5 of the
25 semiconductor component. It is thereby ensured that, by connecting the metal foil 7 and the semiconductor component 1 in an air-tight manner around the edge of the semiconductor component while air is simultaneously blown between the metal foil and the rear side of the semiconductor component, air inclusions 13 form between the metal foil and the rear side of the semiconductor component.

Claims

1. A method for metallizing the rear side (5) of a semiconductor component (1), which semiconductor component (1) is part of a photovoltaic solar cell or a preliminary stage in the production process of a photovoltaic solar cell, comprising the following method steps:
 - A applying at least one at least single-layer metal foil (7) onto the rear side (5) of the semiconductor component (1);
 - B locally heating at least the metal foil (7) such that the metal foil (7) fuses momentarily in local areas,characterized in that a void (8) is formed, at least in regions, between the metal foil (7) and the rear side (5) of the semiconductor component (1), which void (8) is filled with a filler medium, which filler medium has an optical refractive index n of less than 1.4.
2. The method according to claim 1, characterized in that a gas, preferably air or an inert gas, more particularly preferably a noble gas is used as the filler medium or that an adhesive is used as the filler medium.
3. The method according to any one of the preceding claims, characterized in that, in method step B, the void (8) is delimited by the metal foil (7), the rear side (5) of the semiconductor component (1), and the fused regions, more particularly in that at least one fused region is formed so as to enclose the void (8), preferably that this fused region extends constantly along an outer edge, preferably all outer edges of the semiconductor component (1).

4. The method according to any one of the preceding claims,
characterized in that
a laser is used for the fusing in method step B.
5. The method according to any one of the preceding claims,
characterized in that
in method step B, at least predetermined breaking points are simultaneously
formed in the metal foil (7) during the fusing.
6. The method according to any one of the preceding claims
characterized in that
in an additional method step C, at least predetermined breaking points are formed
in the metal foil (7), preferably the metal foil (7) is severed at the fusion regions of
method step C.
7. The method according to any one of the preceding claims,
characterized in that
in a method step A-a, the metal foil (7) is fixed at points on the semiconductor
component by local heating and, in an additional method step A-b before method
step B, the filler medium, most particularly gas, preferably air, is actively
introduced between the semiconductor component (1) and the metal foil (7).
8. The method according to any one of the preceding claims,
characterized in that
the rear side (5) of the semiconductor component (1) is structured in a method
step A0 before the method step A, preferably using a nanoimprint method and/or
dry- and/or wet-chemical methods and/or printing and/or lithography processes.
9. The method according to any one of the preceding claims,
characterized in that
the void (8) is formed with an average thickness in the range of 10 nm to 1 μ m,
preferably 10 nm to 100 nm.

10. The method according to any one of the preceding claims,
characterized in that
the metal foil (22) in method step A is a structured metal foil.
11. The method according to any one of the preceding claims,
5 characterized in that
the metal foil (7) in method step A is a dielectrically coated film, preferably the
dielectric layer is formed with a thickness in the range of 5 nm to 500 nm,
preferably 20 nm to 200 nm.
12. A photovoltaic solar cell,
10 comprising at least one semiconductor layer (2), at least one interlayer (4) on one
side of the semiconductor layer, and at least one metal foil (7),
characterized in that
the photovoltaic solar cell comprises, at least in regions, a void (8), which is filled
with a filler medium, between the metal foil (7) and the rear side (5) of the
15 semiconductor component (1), which filler medium has an optical refractive index
of less than 1.4.
13. A machining table, in particular for carrying out a method according to any one of
the preceding claims 1 to 11,
which machining table (14) comprises a support region (15) for a semiconductor
20 component (1), at least one fixing region (15) for a metal foil, and at least one
blow-off opening (18), which blow-off opening (18) is connected to a blow-off
channel (20) and is disposed between the fixing region (15) and the support region
(15).
14. The machining table according to claim 13,
25 characterized in that
the fixing region (15) is designed to enclose the support region (15), preferably as
a suction duct, which suction duct is connected to a suction channel (19).

15. The machining table according to claim 13 or 14,
characterized in that
the support region (15) is designed as a depression such that, when a
semiconductor component (1) is placed into the depression, the semiconductor
5 component (1) and the surface of the machining table (14) laterally adjacent
thereto form a planar surface.