

**Method for the selective doping of silicon and silicon  
substrate treated therewith**

5

**Fields of application and Prior Art**

The invention relates to a method for the selective doping of silicon of a silicon substrate in order to produce a pn junction in the silicon. This method is  
10 required for example in the production of solar cells.

The selective doping of the emitter of silicon for the production of a pn junction in silicon is used to improve the contact-making and conduction properties in  
15 solar technology. The efficiency of solar cells can be increased by means of this process. Laser technologies wherein the doping medium diffuses into the silicon by means of a high-energy laser beam have previously been used for the production of selective emitters. Other  
20 methods are based on the plasma etching of highly doped emitters. The regions in which the high doping is intended to be retained are masked beforehand.

One example of further methods is US 5,871,591, wherein  
25 in principle the regions in which the initially high doping is intended to be retained after etching are usually masked lithographically. These methods therefore remove a thin layer, usually 100-200 nm thick, having a high doping near the surface, in order  
30 to obtain a selective emitter distribution. One disadvantage of these methods, however, is that the etching of the surface has to be effected very precisely in order not to bring about a significant loss in the efficiency of the solar cells. In the case  
35 of laser-aided technologies, there is likewise the risk of severe damage to the solar cell surface, which is why this technology is also used only very occasionally in solar technology.

### Object and way of achieving it

The invention is based on the object of providing an  
5 initially mentioned method as well as a silicon  
substrate treated therewith whereby problems in the  
prior art can be eliminated and, in particular, an  
efficient and readily practicable method for the  
selective doping of a silicon substrate can be  
10 achieved.

This object is achieved by means of a method comprising  
the features of Claim 1 as well as a silicon substrate  
comprising the features of Claim 7. Advantageous and  
15 preferred configurations of the invention are specified  
in the further claims and are explained in more detail  
below. In this case, some of the features are mentioned  
only for the method or the silicon substrate, but are  
intended to be applicable independently thereof to all  
20 aspects of the invention. The wording of the claims is  
incorporated by express reference in the content of the  
description. Furthermore, the wording of the priority  
application DE 102008019402.6 of 14 April 2008 in the  
name of the present applicant is incorporated by  
25 express reference in the content of the present  
description.

The method has the following steps according to the  
invention. In a step a), the surface of the silicon or  
30 of the silicon substrate is coated with a dopant which  
is based on phosphorus or contains phosphorus. By way  
of example, this is a solution composed of phosphoric  
acid. In a step b) afterwards, the silicon substrate is  
heated, as is the dopant, in order to produce  
35 phosphosilicate glass from the dopant on the surface.  
In this case, phosphorus is simultaneously diffused  
into the silicon as first doping of the silicon

substrate. The intensity of this doping can be set by the duration and temperature of the heating.

In a subsequent step c), a masking is applied to the phosphosilicate glass on the surface of the silicon substrate. In this case, the masking is applied in such a way that it covers the subsequently highly doped regions of the silicon substrate. In a subsequent step d), the phosphosilicate glass is removed in the non-masked regions. Afterwards in turn, in a step e), the masking is removed from the surface or the phosphosilicate glass. In a subsequent step f), the silicon substrate is heated anew in order to bring about a further indiffusion of phosphorus from the residual phosphosilicate glass into the silicon. This is the second doping of the silicon substrate in order to produce the highly doped regions. In the regions that are free of phosphosilicate glass, only the comparatively low phosphorus doping near the surface serves as a secondary doping source for the deeper diffusion of phosphorus into the base material. In a further step g), the remaining phosphosilicate glass and the oxide on the weakly doped regions are also completely removed from the silicon substrate. This procedure not only generally provides a selective doping of a silicon substrate with highly doped regions that can form emitters of a solar cell. It is primarily also possible to provide a method which provides suitable production or processing of silicon substrates on a large scale. The method can primarily be carried out in a continuous-throughput apparatus. Complicated technology such as lasers or plasma etching sources can be obviated.

In a further configuration of the method according to the invention, the phosphorus-based dopant can be a solution containing phosphoric acid.

A printing technology can be used to apply the masking to the silicon substrate and the phosphosilicate glass formed thereon. This can be effected either by means of screen printing or  
5 alternatively by means of so-called inkjet printing technology. In this case, the masking, which comprises a wax or resist, for example, is applied in liquid or pasty form by means of a method corresponding to that used in so-called inkjet printers. A desired masking  
10 can thereby be produced both very accurately and rapidly and over a large area. By means of this method, a contact grid can be produced for example as a highly doped or conductive emitter, wherein the solar cell is formed by the silicon substrate. The highly doped  
15 regions arise as a result of the double doping of the silicon. The doping can be effected even more intensely primarily in step f) of the second doping by means of a longer duration of action or longer heating. Consequently, the doping can be many times higher in  
20 the highly doped region than in the other, more lightly doped regions.

In order to remove the phosphosilicate glass in the non-masked regions in accordance with step c), an  
25 etching process can be used. By way of example, HF-based etching solutions are appropriate here, but other etching media are also possible. This can be effected either in one process step or in a plurality of steps with different chemicals.

30

A continuous-throughput apparatus for carrying out the method can comprise a plurality of modules. In this case, a plurality of the steps can possibly also be carried out in one module. A horizontal  
35 continuous-throughput apparatus on which the silicon substrates are conveyed and treated in a horizontal position is particularly preferred.

These and further features emerge not only from the claims but also from the description and the drawings, wherein the individual features can be realized in each case by themselves or as a plurality in the form of subcombinations in an embodiment of the invention and in other fields and can constitute advantageous and inherently protectable embodiments for which protection is claimed here. The subdivision of the application into sub-headings and individual sections does not restrict the general validity of statements made hereunder.

### **Brief description of the drawings**

An exemplary embodiment of the invention is schematically illustrated in the drawings and is explained in more detail below. In the drawings, figures 1 to 6 show method steps a) to g) on a silicon substrate for the production of a solar cell.

### **Detailed description of the exemplary embodiment**

Figure 1 illustrates a silicon substrate 1, to which a dopant has been applied over a large area in accordance with step a) and step b). This dopant 2 contains phosphorus or is based on phosphorus and is for example a solution composed of phosphoric acid. Furthermore, phosphorus is indiffused from the dopant 2 into the silicon substrate 1 or the top side thereof by heating in a manner not illustrated in greater detail, for example by radiant heaters or the like. A lightly doped region 3 has arisen as a result, which is illustrated by the cross hatching.

Figure 2 illustrates how a masking 4 is applied to the top side of the dopant 2 in accordance with step c). This masking 4 is applied by means of an inkjet printing technology in the manner described above and

advantageously runs largely in the narrow tracks illustrated, though other masking patterns are also possible. These tracks of the masking 4 correspond to the desired highly doped regions, which will be discussed in even more detail below.

Figure 3 illustrates how, in accordance with step d), the dopant 2, which has been converted into phosphosilicate glass after the heating in accordance with figure 1 and step b), has been removed wherever it is not covered by the masking 4. Consequently, essentially the surface of the lightly doped region 3 of the silicon substrate 1 is uncovered. Correspondingly formed regions of the phosphosilicate glass 2 are still present beneath the masking 4.

As is illustrated in Figure 4, the masking 4 is subsequently removed in accordance with step e). While the phosphosilicate glass can be removed by HF etching in step d) in accordance with figure 3, a much less aggressive solution suffices for removing the masking 4.

Figure 5 illustrates how, in accordance with step f), phosphorus indiffuses anew into the silicon substrate 1 by renewed heating from the now uncovered phosphosilicate glass 2 with a form corresponding to the masking 4 that was applied and removed again. The phosphorus from the phosphosilicate glass 2 forms a narrow region with a form corresponding to the phosphosilicate glass 2 in accordance with figure 4 or the masking 4 in accordance with figure 2. It is also the case moreover that in the lightly doped region 3 of the silicon substrate 1, that is to say essentially over the whole area, phosphorus is diffused from the region near the surface into the silicon substrate 1 somewhat more deeply than is the case after the first diffusion step. In the lightly doped region 3 and in

the highly doped region 5, the phosphorus concentration decreases from the surface into the base material, wherein the doping depth can indeed differ.

5 In accordance with step g), as is illustrated in figure 6, the remaining phosphosilicate glass 2 is also removed, advantageously again by HF etching. A thin layer with an oxide in the weakly doped region is likewise removed during this step. The silicon  
10 substrate 1 in accordance with figure 6 is then present with a region 3 lightly doped over the whole area. The highly doped regions 5 run in this lightly doped region 3 and form the low-impedance emitter or a so-called contact grid in a solar cell.

15

The invention enables a selective doping of a silicon substrate to be effected by means of methods which are readily controllable technologically and which can all be carried out in continuous fashion. It is thus  
20 possible by way of example, as described, to produce a contact grid for a solar cell.

Claims

1. Method for the selective doping of silicon of a  
5 silicon substrate (1) for the production of a pn  
junction in the silicon, comprising the following  
steps:
- a) Coating of the surface of the silicon substrate  
(1) with a phosphorus-based dopant (2),
  - 10 b) subsequent heating of the silicon substrate (1) in  
order to produce a phosphosilicate glass (2) on  
the surface of the silicon, wherein phosphorus  
simultaneously diffuses into the silicon as a  
first doping (3),
  - 15 c) application of a masking (4) to the  
phosphosilicate glass (2) in such a way that the  
masking (4) covers the subsequently highly doped  
regions (5),
  - d) removal of the phosphosilicate glass (2) in the  
20 non-masked regions,
  - e) removal of the masking (4) from the  
phosphosilicate glass (2),
  - f) renewed heating for the further indiffusion of  
phosphorus from the phosphosilicate glass (2) into  
25 the silicon as second doping for the production of  
the highly doped regions (5),
  - g) complete removal of the phosphosilicate glass (2)  
and the oxide from the silicon substrate (1).
- 30 2. Method according to Claim 1, characterized in that  
the phosphorus-based dopant (2) is a solution  
comprising phosphoric acid.
3. Method according to Claim 1 or 2, characterized in  
35 that the masking (4) is applied by means of a printing  
technology, preferably by means of a so-called inkjet  
printing technology.

4. Method according to any of the preceding claims, characterized in that a contact grid of a solar cell is produced thereby, wherein the silicon substrate (1) forms the solar cell, wherein the twice doped regions (5) of the silicon are highly doped and therefore have low impedance and constitute a contact region of the solar cell.
5. Method according to any of the preceding claims, characterized in that the removal of the phosphosilicate glass (2) in the non-masked regions in accordance with step d) is effected by etching, preferably HF etching.
6. Method according to any of the preceding claims, characterized in that it is carried out in a continuous-throughput apparatus, preferably in a horizontal continuous-throughput apparatus.
7. Silicon substrate (1) for a solar cell, characterized in that it has been treated with a method according to any of the preceding claims.