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(54) Titre : PROCEDE DE DOPAGE SELECTIF DE SILICIUM ET SUBSTRAT DE SILICIUM AINSI TRAITE
(54) Title: METHOD FOR THE SELECTIVE DOPING OF SILICON AND SILICON SUBSTRATE TREATED THEREWITH

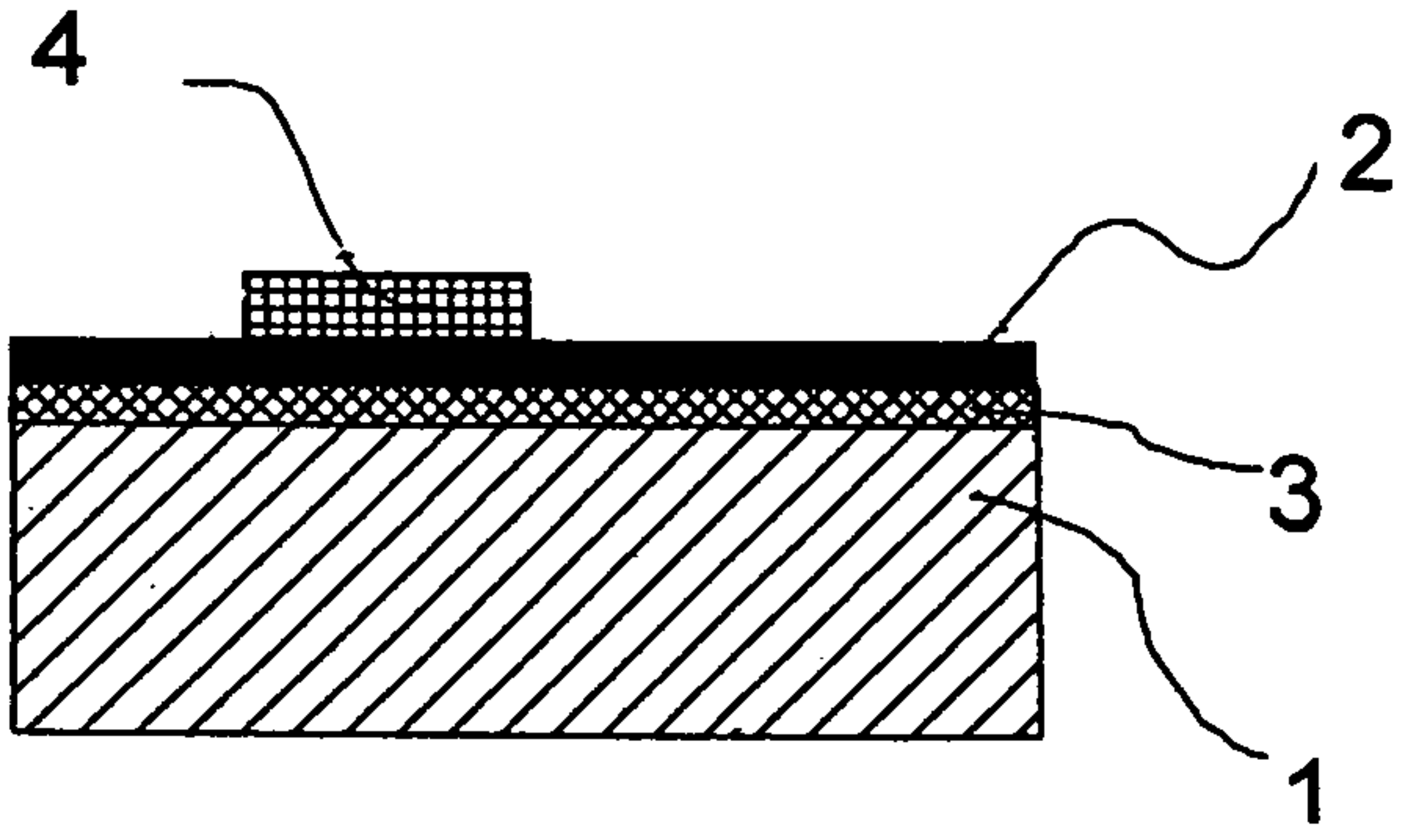

Fig.2

(57) Abrégé/Abstract:

A method for the selective doping of silicon of a silicon substrate (1) for producing a pn-junction in the silicon is characterized by the following steps: a) Providing the surface of the silicon substrate (1) with a doping agent (2) based on phosphorous, b) heating the silicon substrate (1) for creating a phosphorous silicate glass (2) on the surface of the silicon, wherein phosphorous diffuses into the silicon as a first doping (3), c) applying a mask (4) on the phosphorous silicate glass (2), covering the regions (5) that are later highly doped, d) removing the phosphorous silicate glass (2) in the non-masked regions, e) removing the mask (4) from the phosphorous silicate glass (2), f) again heating for the further diffusion of phosphorous from the phosphorous silicate glass (2) into the silicon as a second doping for creating the highly doped regions (5), g) complete removal of the phosphorous silicate glass (2) from the silicon.

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- *mit internationalem Recherchenbericht (Artikel 21 Absatz 3)*
- *vor Ablauf der für Änderungen der Ansprüche geltenden Frist; Veröffentlichung wird wiederholt, falls Änderungen eingehen (Regel 48 Absatz 2 Buchstabe h)*

(54) Title: METHOD FOR THE SELECTIVE DOPING OF SILICON AND SILICON SUBSTRATE TREATED THEREWITH

(54) Bezeichnung: VERFAHREN ZUR SELEKTIVEN DOTIERUNG VON SILIZIUM SOWIE DAMIT BEHANDELTES SILIZIUM-SUBSTRAT

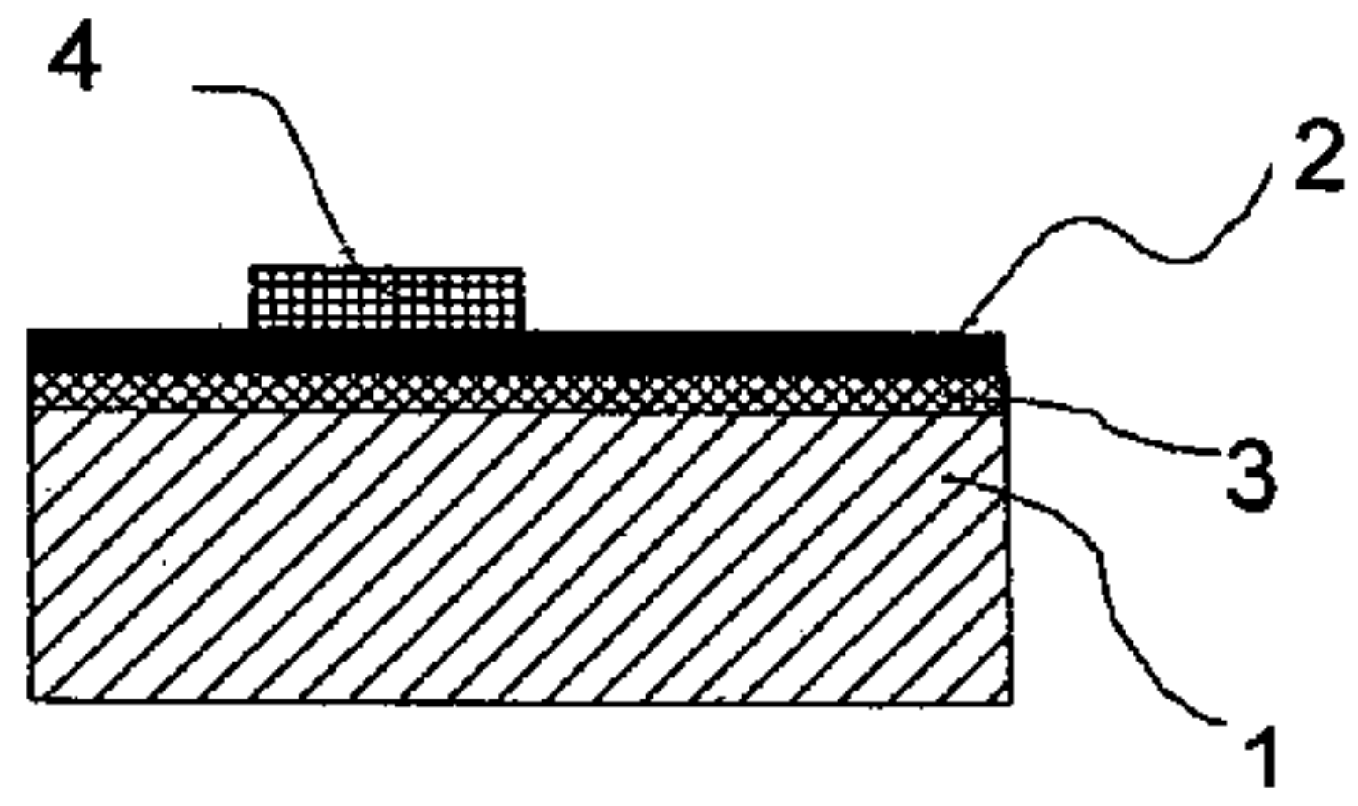

Fig.2

(57) Abstract: A method for the selective doping of silicon of a silicon substrate (1) for producing a pn-junction in the silicon is characterized by the following steps: a) Providing the surface of the silicon substrate (1) with a doping agent (2) based on phosphorous, b) heating the silicon substrate (1) for creating a phosphorous silicate glass (2) on the surface of the silicon, wherein phosphorous diffuses into the silicon as a first doping (3), c) applying a mask (4) on the phosphorous silicate glass (2), covering the regions (5) that are later highly doped, d) removing the phosphorous silicate glass (2) in the non-masked regions, e) removing the mask (4) from the phosphorous silicate glass (2), f) again heating for the further diffusion of phosphorous from the phosphorous silicate glass (2) into the silicon as a second doping for creating the highly doped regions (5), g) complete removal of the phosphorous silicate glass (2) from the silicon.

(57) Zusammenfassung: Ein Verfahren zur selektiven Dotierung von Silizium eines Silizium-Substrats (1) zur Herstellung eines pn-Übergangs im Silizium ist durch folgende Schritte gekennzeichnet: a) Belegen der Oberfläche des Silizium-Substrats (1) mit einem auf Phosphor basierenden Dotiermittel (2), b) anschließendes Erhitzen des Silizium-Substrats (1) zur Erzeugung eines Phosphor-Silikatglases (2) auf der Oberfläche des Siliziums, wobei gleichzeitig Phosphor in das Silizium hinein diffundiert als erste Dotierung (3), c) Aufbringen einer Maskierung (4) auf das Phosphor-Silikatglas (2), die die später hochdotierten Bereiche (5) bedeckt, d) Entfernen des Phosphor-Silikatglases (2) in den nicht maskierten Bereichen, e) Entfernen der Maskierung (4) von dem Phosphor-Silikatglas (2), f) erneutes Erhitzen zum weiteren Eindiffundieren von Phosphor aus dem Phosphor-Silikatglas (2) in das Silizium als zweite Dotierung zur Erzeugung der hochdotierten Bereiche (5), g) vollständiges Entfernen des Phosphor-Silikatglases (2) von dem Silizium.

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

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 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 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 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 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 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 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 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 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 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 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 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 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 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 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 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 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 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 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.

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 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.

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 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.

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 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 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),

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),

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 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 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).

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 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.

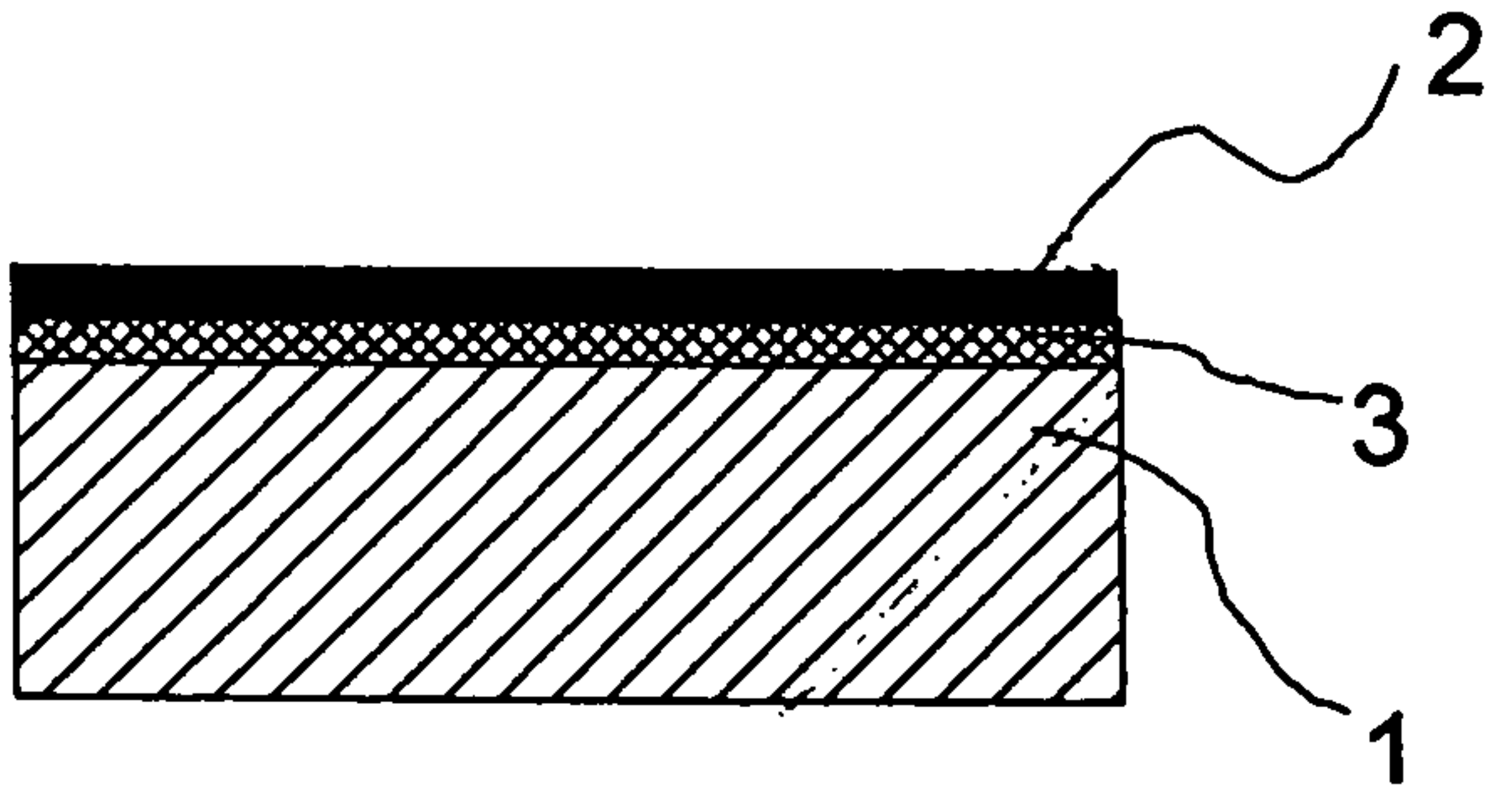

Fig.1

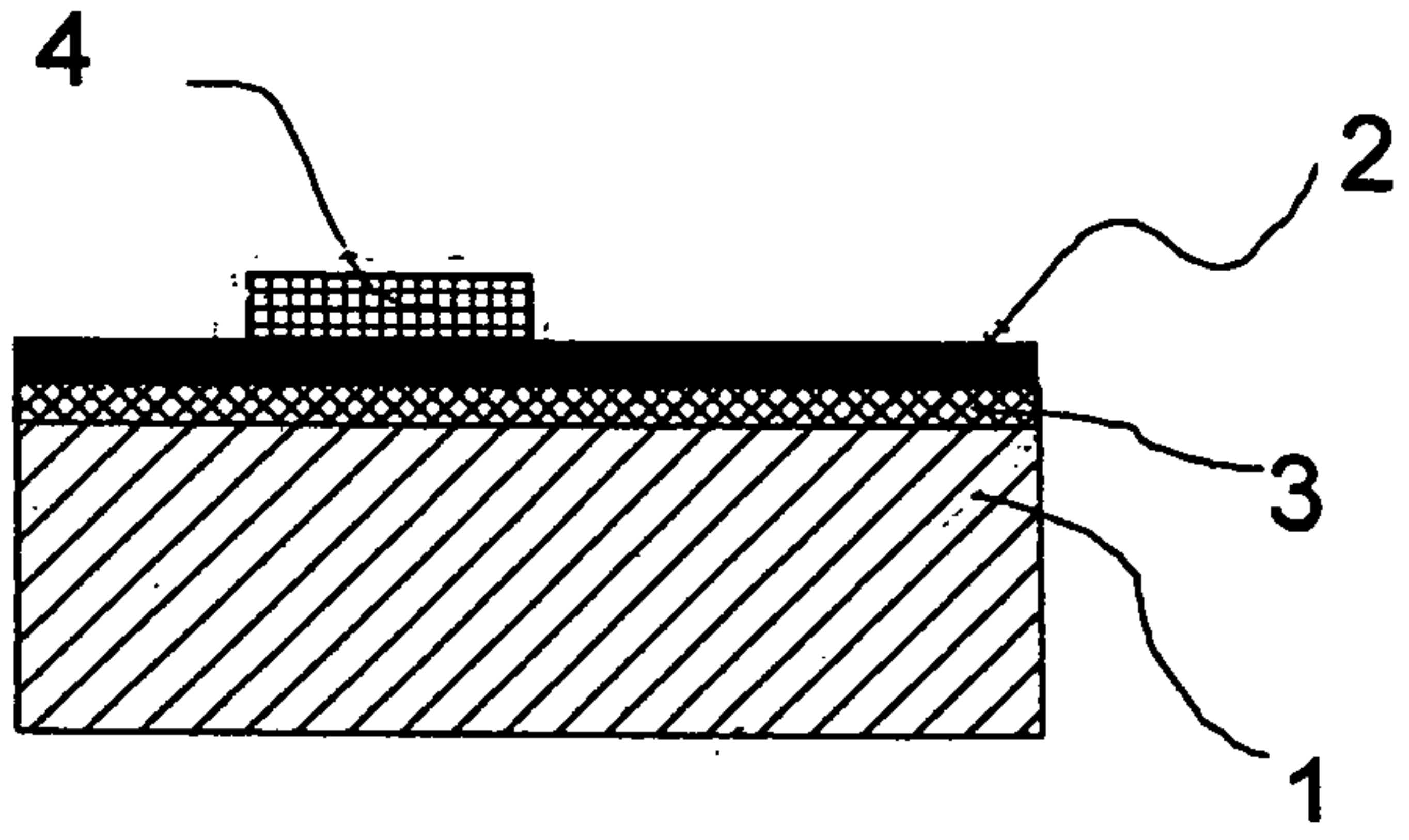

Fig.2

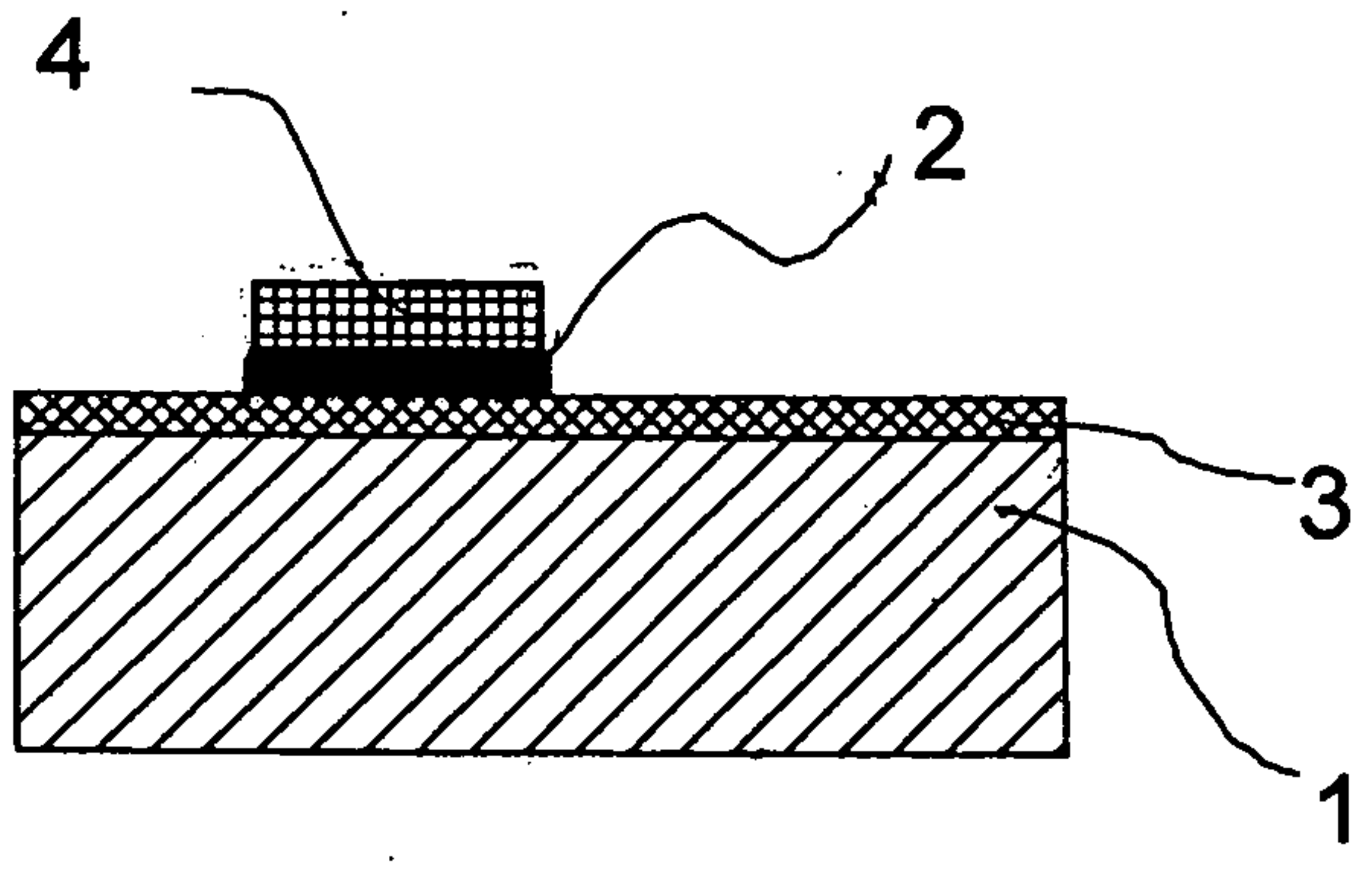

Fig.3

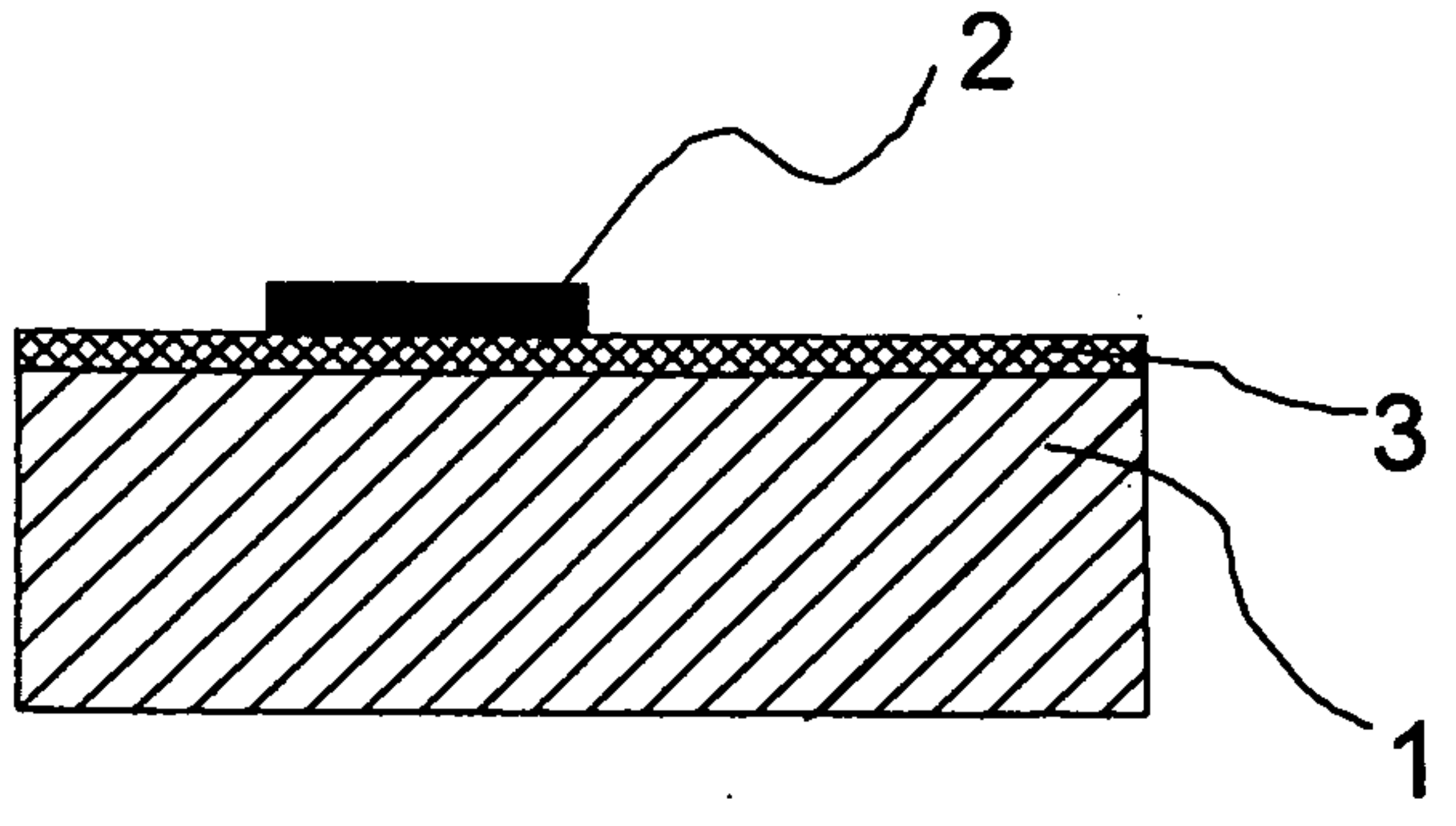

Fig.4

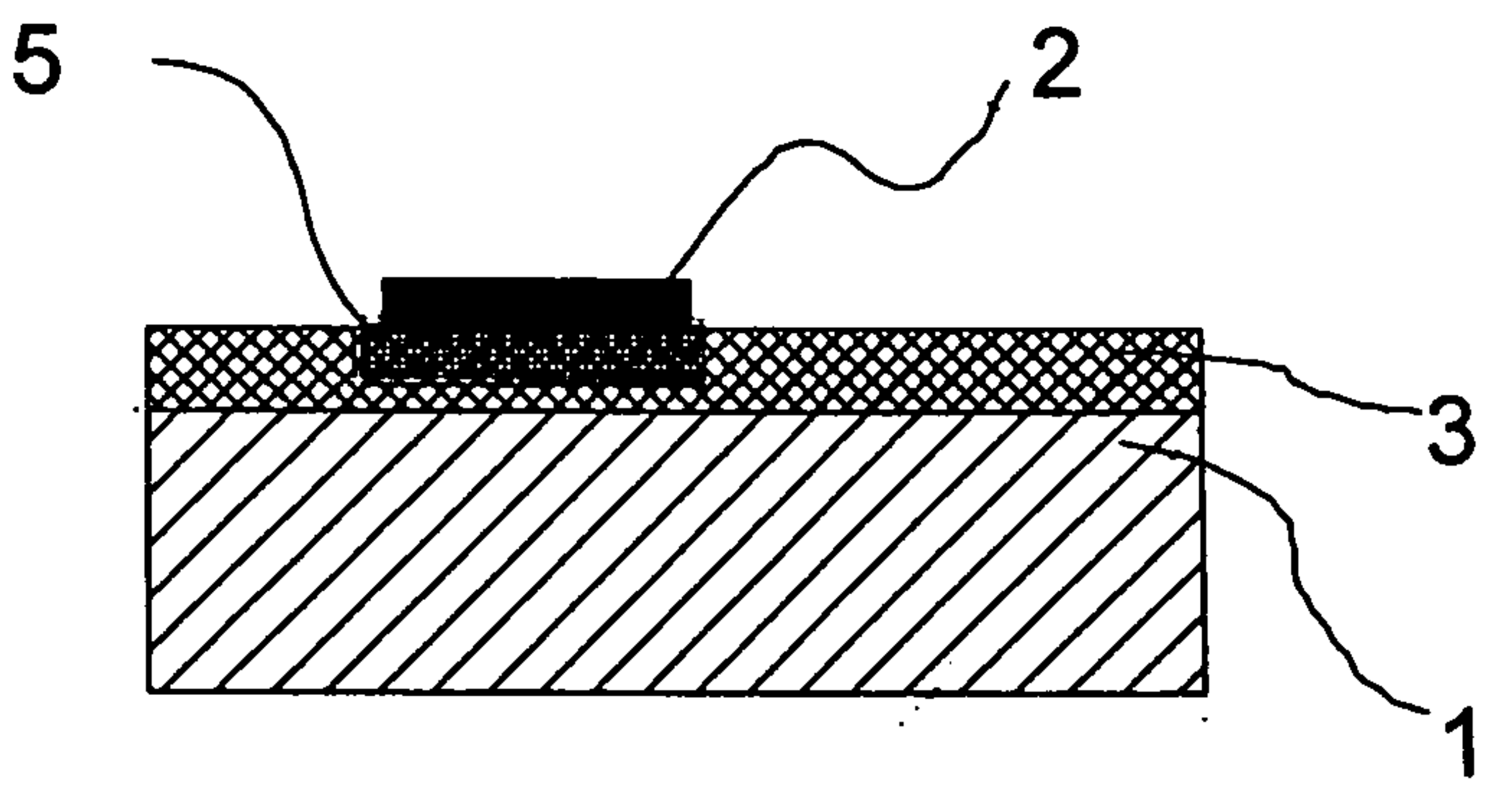

Fig.5

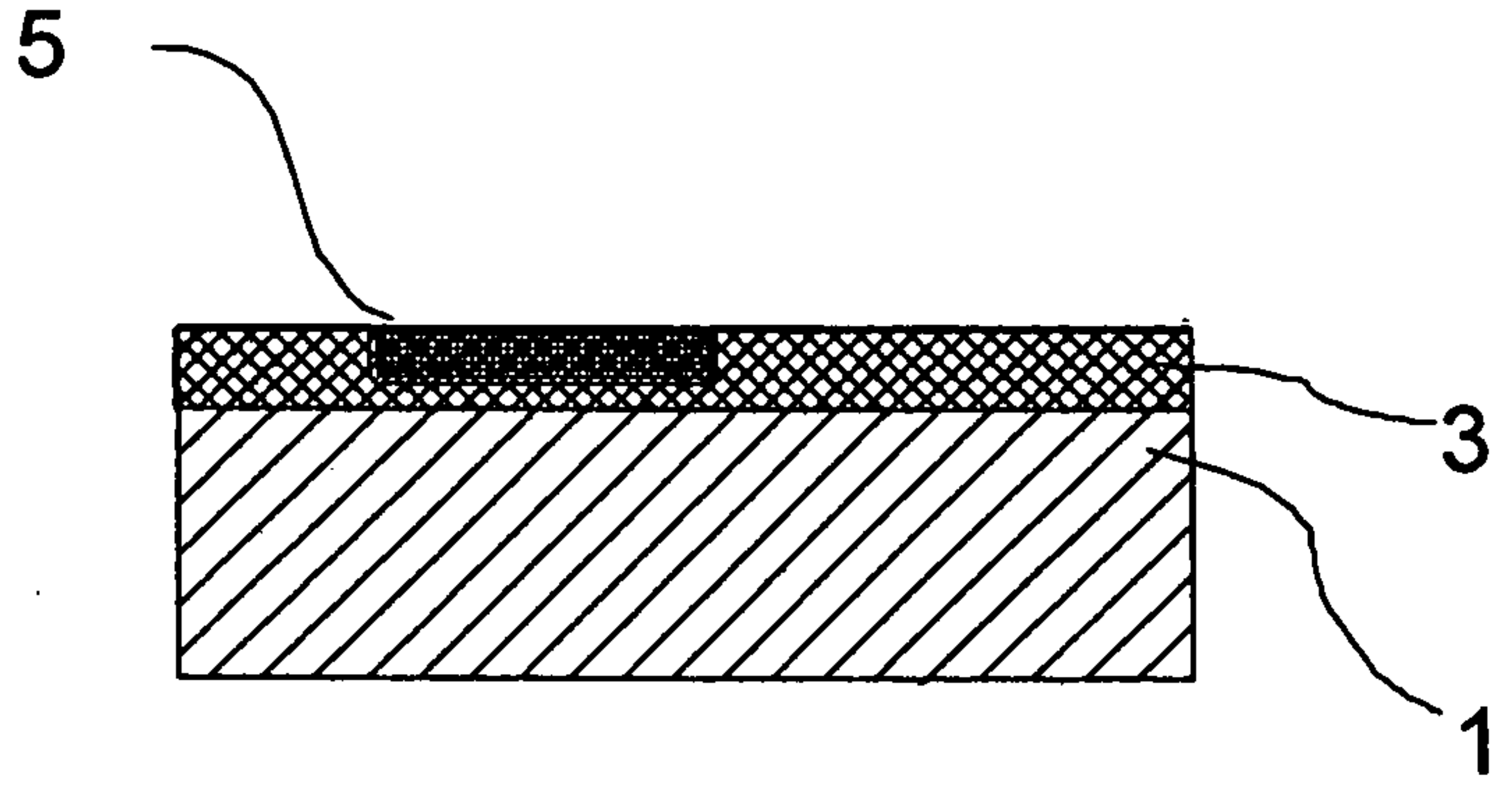

Fig.6

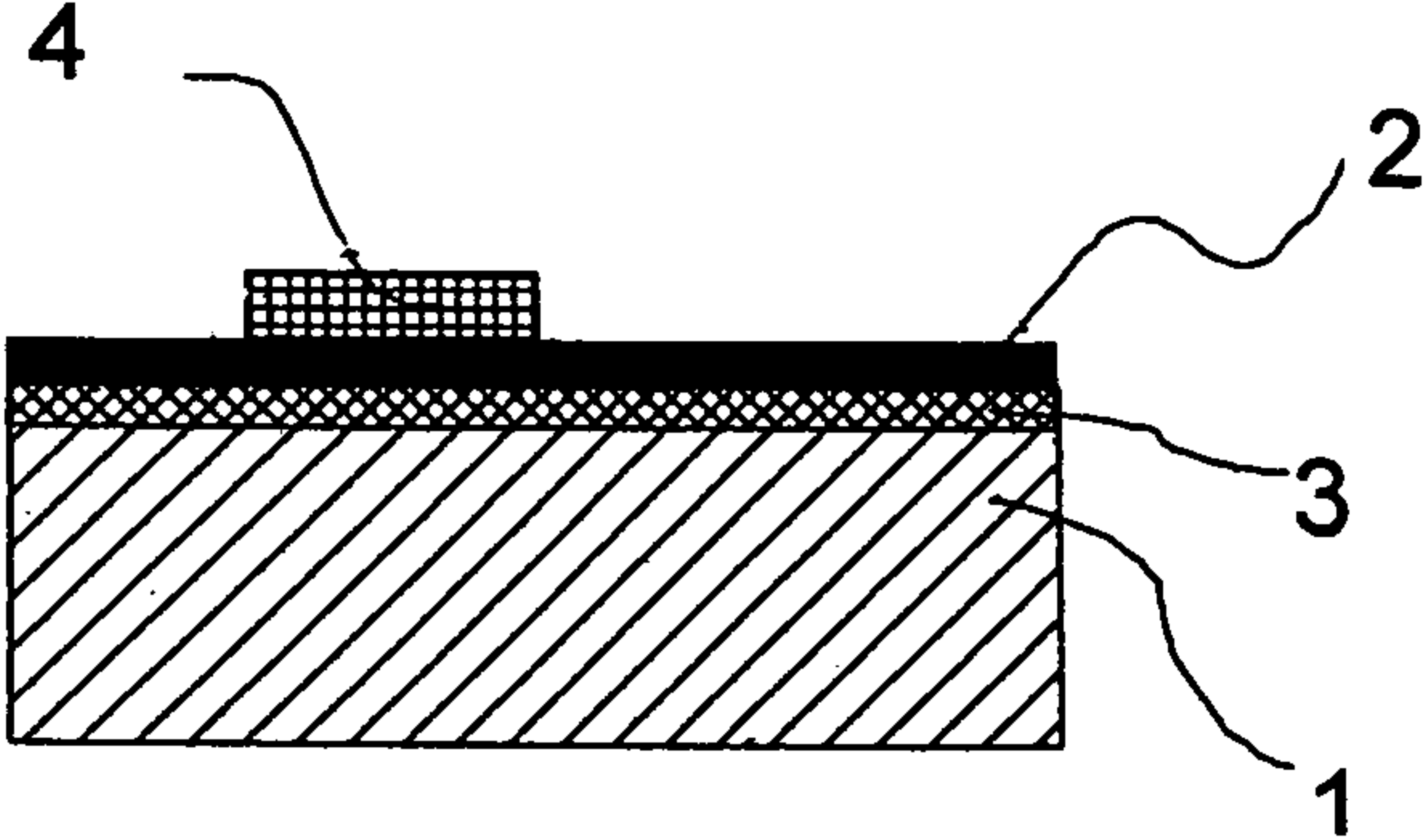

Fig.2