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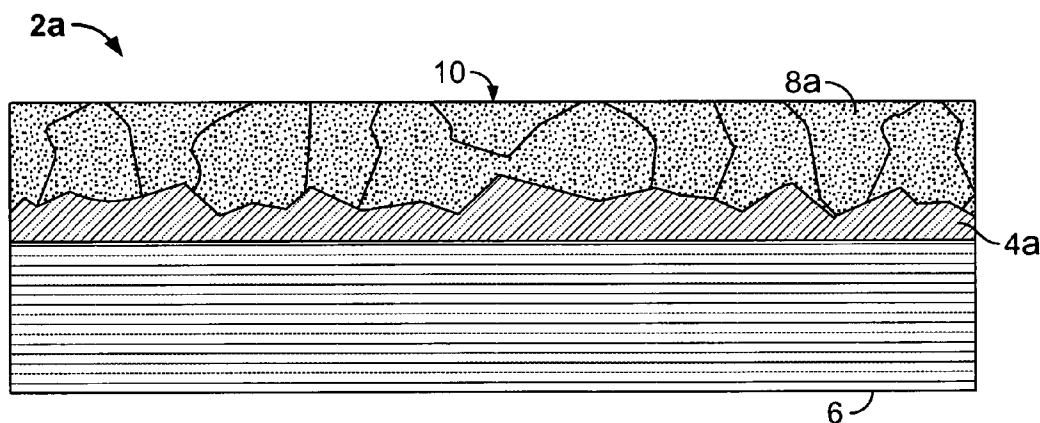


Fig. 1B

(57) Abstract: The present invention relates to a method of producing an electrical contact element, in which a multilayer structure is formed by applying a diffusion barrier layer to a base material and at least one metallic layer made of a metal to the diffusion barrier layer, at least one layer formed of tin being applied as the metallic layer. The present invention further relates to an electrical contact element with an electrically conductive base material and a coating which is formed on at least one portion of the electrically conductive base material, the coating having a diffusion barrier layer formed on the base material and the outer layer containing tin. To prevent whisker formation when using the electrical connector element, the present invention proposes, as a solution to the method-related problem, to subject the multilayer structure to a heat treatment such that at least one element of the layer located under the outer layer of the multilayer structure diffuses into said outer layer and the heat-treated outer layer comprises tin. To solve the device-related problem of the invention, it is proposed that the outer layer of the coating be a layer thoroughly alloyed by the diffusion of tin and at least one further metallic element.



WO 2009/043536 A1



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ELECTRICAL CONTACT ELEMENT AND A METHOD OF PRODUCING THE SAME

The present invention relates to a method of producing an electrical contact
5 element according to the preamble of claim 1. The invention further relates to an
electrical contact element according to the preamble of claim 9.

The requirements of electrical contact elements are many and varied. Thus,
contact elements may for example be used as plug-in contacts. In this case, electrical
contact elements need to be capable of being plugged in and unplugged repeatedly with
10 the lowest possible insertion forces, without the contact resistance changing
appreciably. Above all, electrical contact elements which are used in the production of
electrical systems, such as for example an anti-lock braking system (ABS), need to
reliably ensure electrical contacting and prevent misconnections.

A contact element is known from DE 103 49 584 A1. The contact element
15 disclosed therein comprises a press-fit contact and this document proposes to prevent
chip formation upon pressing a press-fit pin into a socket by providing an electrical
contact element with an outer layer which has a layer thickness of between 0.1 μm and
0.8 μm .

It is known that electrical contact elements with a contact surface formed for
20 example of pure tin have a tendency to form tin whiskers. Tin whiskers may lead to
malfunctioning in electronic assemblies.

However, reducing layer thickness does not always stop whisker formation. Just
slight abrasion and accumulation of abraded tin may lead to the occurrence of whiskers.

Taking the above, known problems as basis, it is an object of the present
25 invention to provide a method by which the formation of tin whiskers is avoided. A further
object of the present invention is to provide a contact element without any risk of tin
whisker formation.

The method aspect of the present invention is achieved by a method according to
claim 1, which is characterised by heat treatment of a multilayer structure, said heat
30 treatment being such that at least one element of the layer located under the outer layer
of the multilayer structure diffuses into said outer layer and the heat-treated outer layer
comprises tin. According to the invention, a diffusion barrier layer is applied to a base
material, so preventing the base material from diffusing into the outer layer. The diffusion
barrier layer according to the invention serves accordingly as a diffusion barrier and
35 prevents the outer layer from being alloyed with the element(s) of the base material. At
least one metallic layer is applied to the diffusion barrier layer, at least one layer formed

of tin being applied as the metallic layer. Accordingly, for example, either just a pure tin layer is applied to the diffusion barrier layer or a pure tin layer and a further metallic layer is applied.

According to the invention, the multilayer structure comprising the diffusion barrier layer and the at least one metallic layer is heat-treated, i.e. is preferably subjected to a tempering method. This heat treatment of the multilayer structure causes at least one element to diffuse into the outer layer. As a result of the heat treatment according to the invention, the outer layer of the multilayer structure is virtually completely permeated by the at least one element of the layer thereunder and is thus formed of at least two metallic elements. The outer layer is preferably heat treated in such a way that it is formed solely or virtually solely of at least two metallic elements, i.e. as a result of diffusion the element from the layer located under the outer layer completely or virtually completely permeates the outer layer right up to the surface of the layer. As a result of the associated mixing of the at least two metallic elements, tin whisker formation is reliably prevented. Alloying on of the outer layer additionally offers the possibility of increasing the wear resistance of the surface of connector elements by a suitable alloy composition. The temperature and duration of the heat treatment are dependent on the metals used to form the metallic layers and on the layer thickness to be achieved.

The element diffused into the outer layer may come from the diffusion barrier layer, for example.

Preferably, thermally accelerated diffusion completely throughout the multilayer structure is obtained. In this way, a heat-treated outer layer is formed, which comprises a mixture of tin with at least one further metallic element. The heat-treated outer layer is accordingly not a pure tin layer, effectively preventing the risk of tin whisker formation.

According to a preferred exemplary embodiment of the method according to the invention, the outer layer is thoroughly alloyed with the at least one element right up to the surface. The heat treatment is preferably performed in such a way that the element present in the underlying layer is diffused right up to the surface of the outer layer, i.e. over the entire thickness of the outer layer. The resultant tin alloy layer may consist of a crystal mixture, mixed crystal or of an intermetallic compound.

One preferred further development of the method according to the invention has at least two metallic layers formed of different metals applied to the diffusion barrier layer and the elements of the layers are mixed together by diffusion. In addition to a tin layer, according to this preferred embodiment a further metallic layer is accordingly applied to the diffusion barrier layer. The tin layer does not have to be applied as the outer layer. The crucial factor is merely that the heat-treated outer layer comprises tin and at least

one further metallic element. The various metallic layers are applied individually to the diffusion barrier layer. This may take place, for example, as a result of physical vapour deposition (PVD), chemical vapour deposition (CVD), periodic reverse electroplating or the like. The various layers are preferably formed in a sandwich structure with mutually parallel flat layers. The number of alternately applied different metallic layers is determined by the desired intended application or by the desired layer thickness. Through the subsequent heat treatment, the metallic layers are preferably thoroughly alloyed, in order to provide an outer layer formed on the diffusion barrier layer by mixing tin with at least one further metallic element. Depending on the elements used, an intermediate layer may form for example between the outer layer obtained and the diffusion barrier layer, which intermediate layer is formed of a mixture of the elements of the metallic layers and of the element of the diffusion barrier layer.

According to a preferred embodiment, the outer layer is formed from tin. The applied outer layer of tin, in particular pure tin, is mixed by diffusion with at least one further element by the heat treatment effected. As a result of the heat treatment, the tin layer is thoroughly alloyed with at least one further element, whereby an outer layer not consisting of pure tin is obtained, which does not have a tendency to form whiskers.

According to a preferred further development, the at least one metallic layer formed under the outer layer is made of silver, gold, bismuth, iron, indium, zinc, cadmium, palladium and/or tin. For example, a combination of tin/silver layers is applied to the diffusion barrier layer, wherein a plurality of tin and a plurality of silver layers may be applied alternately one over the other, in order to achieve a uniform outer layer of relatively large thickness after heat treatment for a reasonable treatment time. In this way, an outer layer with relatively large layer thicknesses of greater than 2 μm may be produced. This brings with it, in particular, the advantage that contact surfaces may be provided for connector contacts which have advantageous tribological characteristics.

Depending on the requirements to be met, a phosphorus layer may also be applied in combination with, for example, tin or silver layers, such that the phosphorus diffuses into the adjoining layer as a result of the heat treatment.

The device-related problem on which the invention is based is solved by an electrical contact element according to claim 9, which is characterised in that the outer layer of the coating is a layer mixed by diffusion of tin and at least one further metallic element. The outer layer is particularly preferably a virtually complete mixture of the at least two different elements. A contact element, for the purposes of describing the invention, may be for example a press-fit pin terminal or a connector contact. The outer, thoroughly alloyed layer according to the invention is provided at least in the area of a contact element which comes into contact with a further contact element. For example,

the outer, thoroughly alloyed layer forms a contact surface of a connector contact, of a press-fit pin or the like.

According to a particularly preferred embodiment, the outer layer is a thoroughly alloyed layer, i.e. a layer completely permeated by tin and at least one further element.

5 The elements are in particular mixed together right up to the surface of the outer layer.

Further details, advantages and features of the present invention will become apparent from the following description of exemplary embodiments together with the drawings, in which:

10 Figs. 1a and 1b are a first schematic sectional representation of one exemplary embodiment of a multilayer structure of an electrical connector element according to the invention before and after heat treatment;

Fig. 2 shows a comparative example, which shows a multilayer structure not according to the invention of a connector element; and

15 Figs. 3a-3d show further exemplary embodiments of a connector element according to the invention.

Figure 1a shows a multilayer structure 2 of a press-fit pin, in which a diffusion barrier layer 4 formed of nickel has been applied to a base material 6. A 2 µm thick outer layer 8 formed of tin is formed on the nickel diffusion barrier layer 4.

20 After applying the nickel diffusion barrier layer 4 and the outer layer 8, which is a pure tin layer, the multilayer structure 2 is heat treated at 90°C for 4 hours.

The duration and temperature of the heat treatment are dependent on the materials used and the desired layer thickness. Since the outer layer 8 is formed of tin, however, the heat treatment temperature should not exceed the melting point of tin, i.e. 232°C.

25 Once the heat treatment is complete, the resultant heat-treated multilayer structure 2a comprises a heat-treated recrystallised outer layer 8a (cf. Fig. 1b). This layer 8a consists of a mixture of tin and nickel elements. Due to the heat treatment performed, nickel elements have diffused out of the diffusion barrier layer 4 into the outer layer 8 located thereabove. As is clear from Figure 1b, the heat treatment
30 performed has brought about complete, thorough mixing of the outer layer 8. The heat-treated outer layer 8a comprises both tin and nickel elements. The heat treatment has the effect, in particular, that the nickel elements diffuse right up to the surface 10 of the outer layer 8, so ensuring that the heat-treated outer layer 8a does not contain any pure tin even close to the surface 10. In this way, a press-fit pin with a contact surface is
35 provided which does not carry any risk of tin whisker formation.

In contrast to the above exemplary embodiment according to the invention, Figure 2 shows a comparative example, in which the heat-treated outer layer 8b is a pure tin layer.

5 Due to incomplete heat treatment, the outer layer 8b according to the comparative example shown in Figure 2 is not a thoroughly alloyed layer comprising a mixture of tin and nickel elements. In particular, because of the incomplete heat treatment no diffusion of the nickel elements up to the surface 10 of the outer layer 8b has been brought about. Although mixing of tin and nickel elements has been achieved (as illustrated by the intermediate layer 12), this comparative example carries a risk of
10 whisker formation, since the outer layer 8b is a pure tin layer.

Figures 3a-3d show a further exemplary embodiment according to the invention, in which a plurality of layers have been applied to the nickel diffusion barrier layer 4.

Figure 3a shows a layer 14a formed of silver, which has been formed on the diffusion barrier layer 4. Depending on the desired layer thickness, a plurality of silver
15 layers 14a may also be applied, as shown in Figure 3b. There, the silver layer 14a has been applied to the diffusion barrier layer 4 alternately with a tin layer 14b. The alternate application of silver and tin layers 14a, 14b forms a sandwich structure, in which the outer layer 8 is a tin layer 14b.

The resultant multilayer structure 2b is then subjected to a heat treatment method
20 according to the invention, whereby the various layers 14a, 14b are thoroughly alloyed in order to form a heat-treated outer layer 8a consisting of tin and silver elements. A pure tin layer is thus avoided as a constituent of the outer layer 8a (cf. Fig. 3c).

Depending on the metallurgical characteristics of the layers formed, it is possible,
25 as shown in Figure 3d, to form an intermediate layer 12a between the heat-treated outer layer 8a and the diffusion barrier layer 4a. Unlike in the comparative example according to Figure 2, the multilayer structure 2c according to Figure 3d does not carry any risk of whisker formation, since the outer layer 8a is a thoroughly alloyed outer layer 8a.

As shown in Fig. 4, a multilayer structure 2d may be formed which is produced
30 from three different elements. Figure 4 shows a multilayer structure 2d in which a silver layer 16a, a phosphorus layer 16b and a tin layer 16c are formed alternately on the diffusion barrier layer 4 in such a way that the outer layer 8 is formed of a tin layer 16c.

This multilayer structure 2d is heat-treated according to the invention in such a way that the plurality of layers 16a, 16b, 16c are thoroughly alloyed, as described above in relation to Figure 3c.

35

CLAIMS

1. A method of producing an electrical contact element, in which a multilayer structure (2) is formed by applying a diffusion barrier layer (4) to a base material (6) and at least one metallic layer (14) made of metal to the diffusion barrier layer (4), at least
5 one layer formed of tin being applied as the metallic layer, characterised by heat-treating the multilayer structure (2) in such a way that at least one element of the layer (14) located under the outer layer (8) of the multilayer structure (2) diffuses into said outer layer (8) and the heat-treated outer layer (8a) comprises tin.
2. A method according to claim 1, characterised in that thermally accelerated
10 diffusion completely throughout the multilayer structure (2) is performed.
3. A method according to claim 1 or 2, characterised in that the outer layer (8) is thoroughly alloyed with the at least one element up to a surface (10) thereof.
4. A method according to claim 1, 2 or 3, characterised in that at least two metallic
15 layers (14) made of different metals are applied to the diffusion barrier layer (4) and the elements of the layers (14a) are mixed together by diffusion.
5. A method according to any one of the preceding claims, characterised in that the outer layer (8) is formed of tin.
6. A method according to any one of the preceding claims, characterised in that at
20 least one layer (14) is selected from the group of: silver, gold, bismuth, iron, indium, zinc, cadmium, tin and/or palladium is formed under the outer layer (8).
7. A method according to any one of the preceding claims, characterised in that a layer (16b) of phosphorus is additionally formed under the outer layer, said layer (16b) diffusing into the outer layer.
8. A method according to any one of the preceding claims, characterised in that the
25 diffusion barrier layer (4) is formed of nickel.
9. An electrical contact element having:
an electrically conductive base material (6); and
a coating (2), which is formed on at least a portion of the electrically conductive
base material (6), the coating (2) comprising a diffusion barrier layer (4) formed on the
30 base material (6) and the outer layer (8a) containing tin,
characterised in that the outer layer (8a) of the coating is a layer (8a) mixed by
diffusion of tin and at least one further metallic element.
10. A contact element according to claim 9, characterised in that the outer layer (8a)
is a thoroughly alloyed layer.

11. A contact element according to claim 9 or 10, characterised in that the outer layer (8a) comprises an alloy containing tin and at least one element selected from the group of: silver, gold, bismuth, iron, indium, zinc, cadmium and palladium.

5 12. A contact element according to claim 11, characterised in that the alloy additionally comprises phosphorus.

13. A contact element according to any one of claims 9 to 12, characterised in that the diffusion barrier layer (4) is made of nickel.

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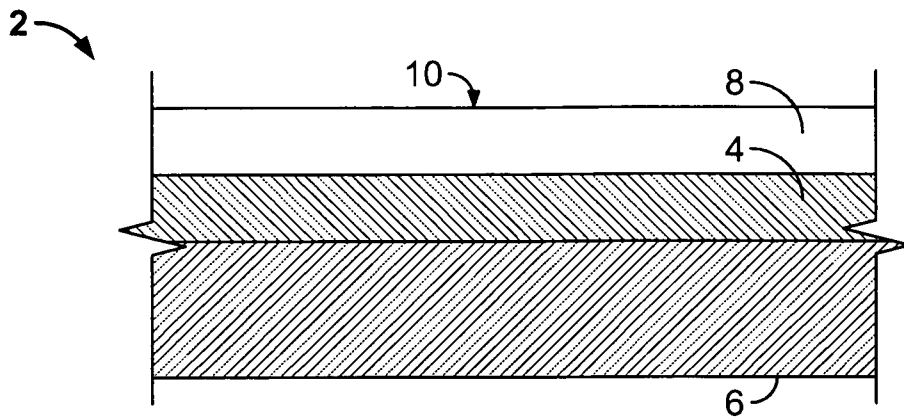


Fig. 1A

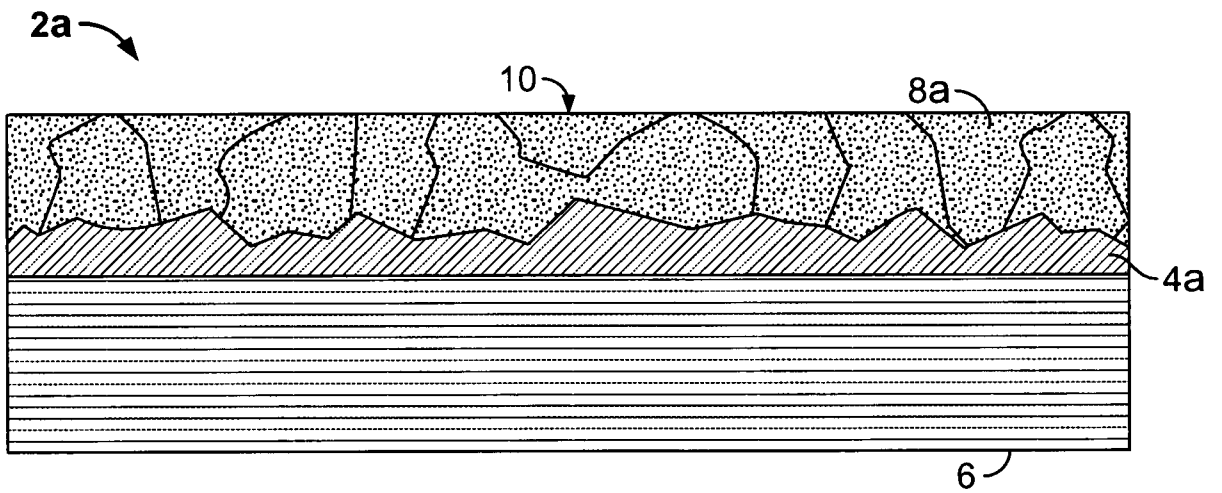


Fig. 1B

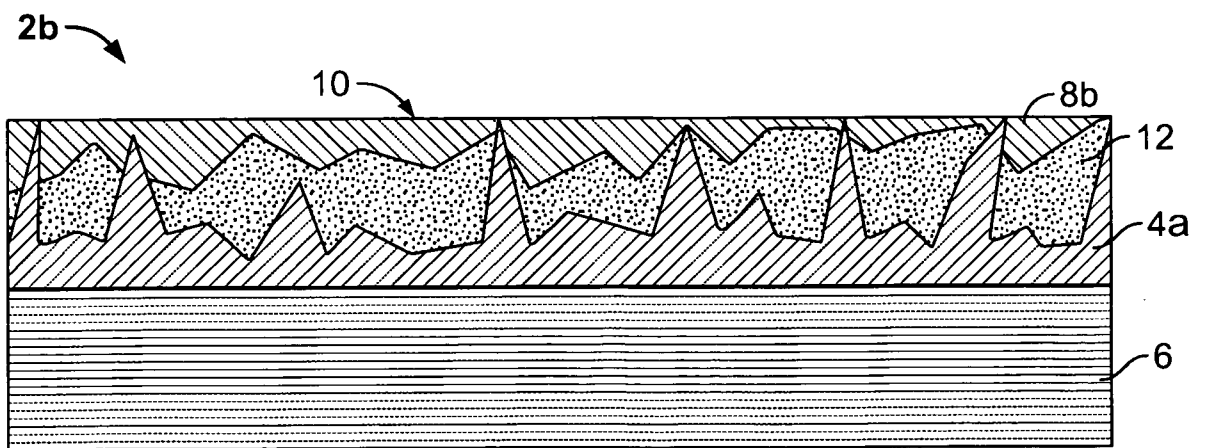


Fig. 2

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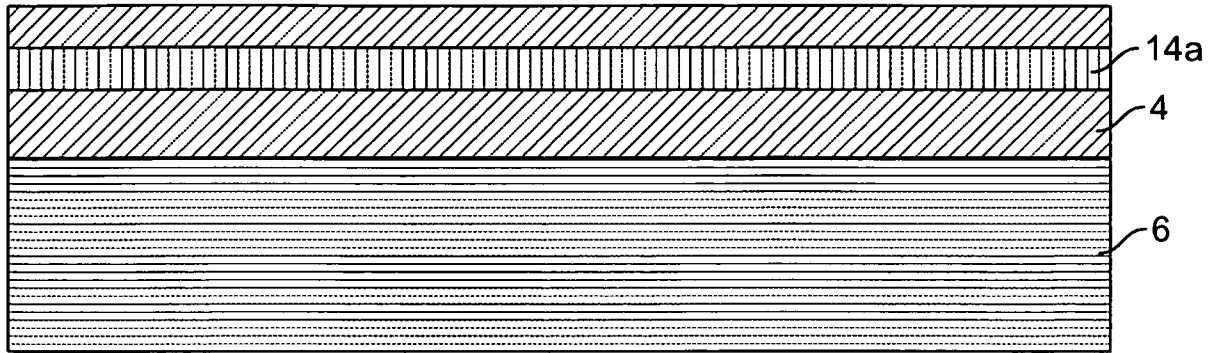


Fig. 3A

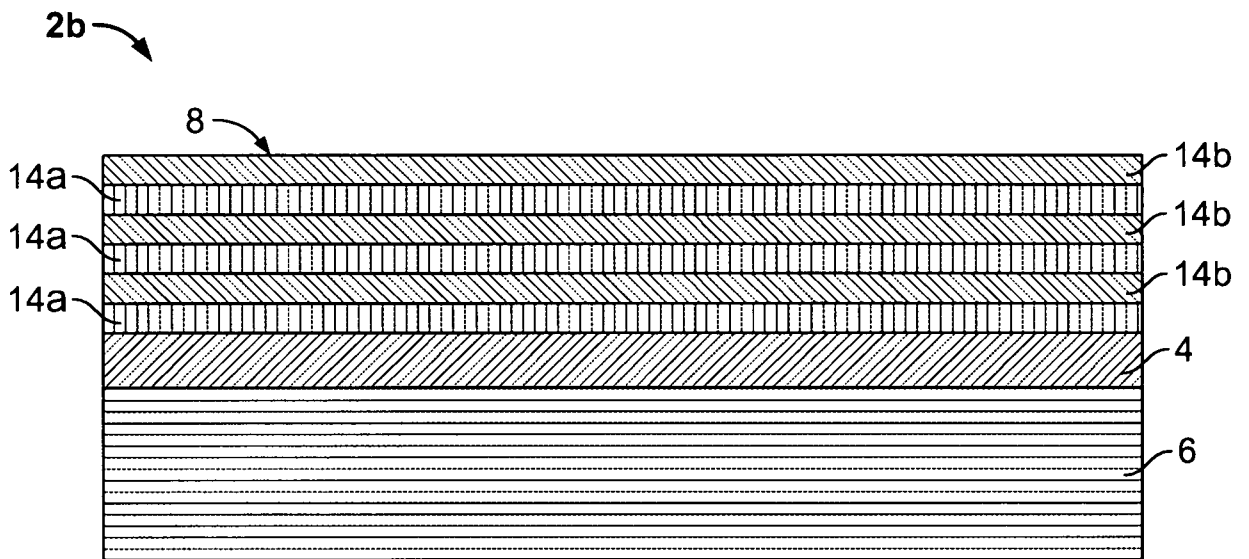


Fig. 3B

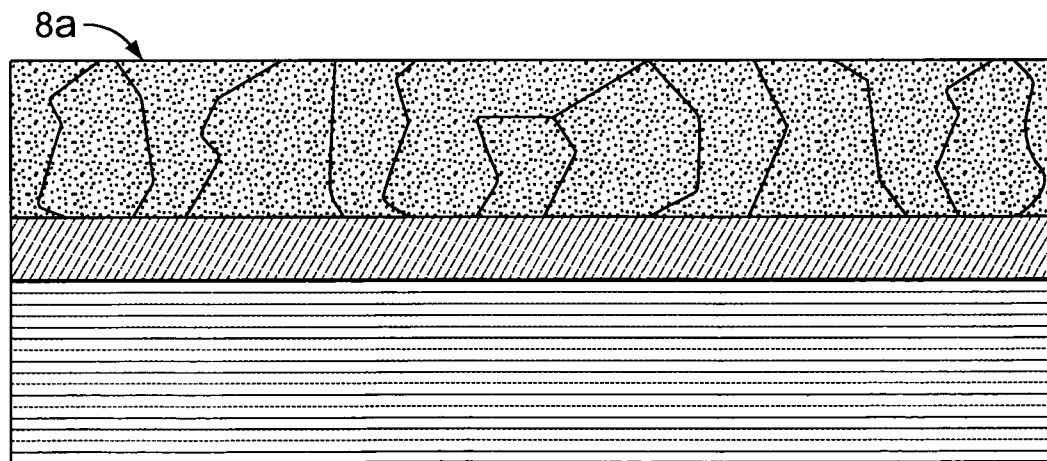


Fig. 3C

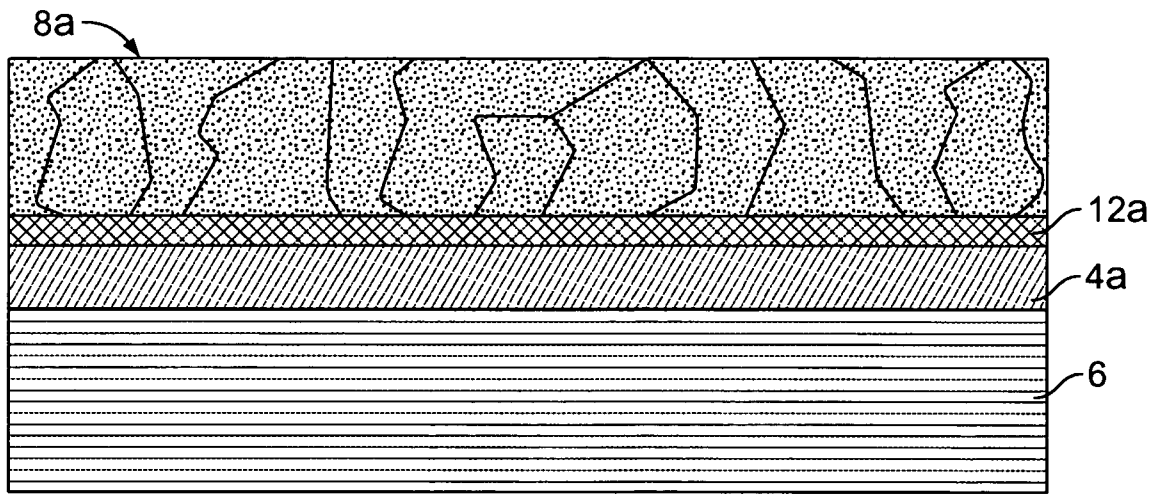


Fig. 3D

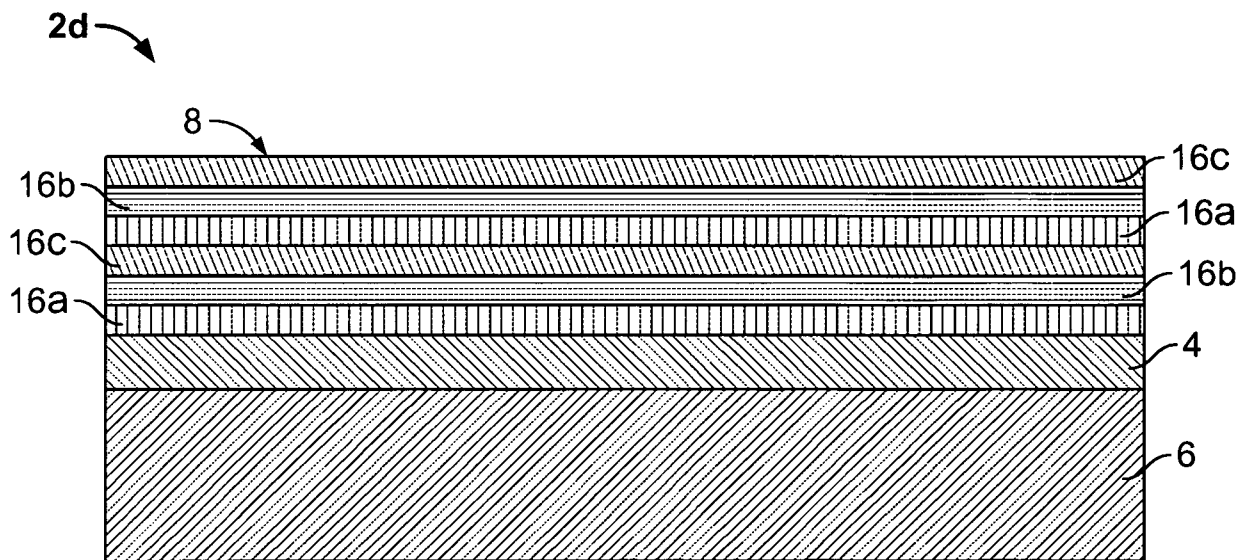


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/008161A. CLASSIFICATION OF SUBJECT MATTER
INV. H01R13/03 C25D5/50

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01R C25D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006/134665 A (FUJITSU LTD [JP]; SAKUYAMA SEIKI [JP]) 21 December 2006 (2006-12-21) paragraph [0007] - paragraph [0008] paragraph [0014] - paragraph [0020] paragraph [0029] - paragraph [0032] figures 1A-1C	1-13
X	US 2005/106408 A1 (CHEN SZUCHAIN F [US] ET AL) 19 May 2005 (2005-05-19) paragraph [0016] - paragraph [0019] paragraph [0046] - paragraph [0048]	1-13
X	US 5 916 695 A (FISTER JULIUS C [US] ET AL) 29 June 1999 (1999-06-29) column 1, line 64 - column 2, line 24 column 2, line 60 - column 3, line 59 claim 1; figures 1,3	1-13
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 Further documents are listed in the continuation of Box C. See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/008161

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/EP2008/008161

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