(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 August 2012 (16.08.2012)

(10) International Publication Number
WO 2012/107524 A1

(51) International Patent Classification: *H01B 1/02* (2006.01)

(21) International Application Number: PCT/EP2012/052222

(22) International Filing Date: 9 February 2012 (09.02.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1150101-2 9 February 2011 (09.02.2011) SE
61/440,978 9 February 2011 (09.02.2011) US

(71) Applicant *(for all designated States except US)*: **IMPACT COATINGS AB** [SE/SE]; Westmansgatan 29, S-582 16 Linköping (SE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **LJUNGCRANTZ, Henrik** [SE/SE]; Kobergsgränd 4, S-587 21 Linköping (SE). **ULRICH, Christian** [SE/SE]; Skolgatan 7C, S-582 38 Linköping (SE). **FLINK, Axel** [SE/SE]; Drabantgatan 31, S-582 14 Linköping (SE). **JOELSSON, Torbjörn** [SE/SE]; Palmaers Gata 31, S-584 37 Linköping (SE).

(74) Agent: **SANDER-JAKOBSSON, Sofia**; Awapatent AB, Junkersgatan 1, S-582 35 Linköping (SE).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: MATERIAL FOR PROVIDING AN ELECTRICALLY CONDUCTING CONTACT LAYER, A CONTACT ELEMENT WITH SUCH LAYER, METHOD FOR PROVIDING THE CONTACT ELEMENT, AND USES OF THE MATERIAL

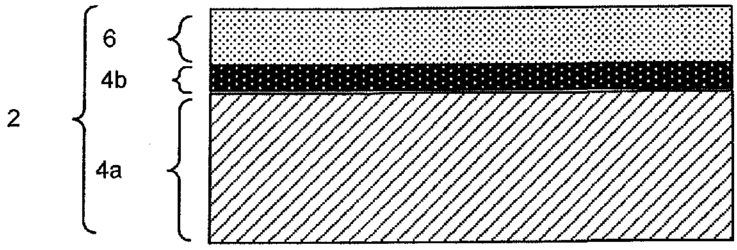

Fig. 1a

(57) **Abstract**: A material for providing an electrically conducting contact layer, the material comprising a base material being any one of Ag, Cu, Sn, Ni, a first metal salt of one thereof, or an alloy of one or more thereof. The material further comprises In within a range of 0.01 at.% to 10 at.%, Pd within a range of 0.01 at.% to 10 at.%, and, unless already the base material comprises Sn at a higher amount, Sn within a range of 0.01 at.% to 10 at.%. From such material, a contact layer (6) can be provided that, compared to a coating of only the base material, has improved corrosion resistance and low contact resistance. Also disclosed is: an electrically conducting contact element (2) that comprises a substrate (4) and coated thereon a contact layer (6) comprising the material, a method for providing the contact element (2), and uses of the material as contact layer and target material.

MATERIAL FOR PROVIDING AN ELECTRICALLY CONDUCTING CONTACT LAYER, A CONTACT ELEMENT WITH SUCH LAYER, METHOD FOR PROVIDING THE CONTACT ELEMENT, AND USES OF THE MATERIAL

Technical field

The present disclosure relates generally to electrically conducting contact layers and to materials for providing such layers.

Background

Electrically conducting contact elements, that is, elements adapted for electrically connecting a device, such as plug-in connectors and sliding- or stationary contacts, often comprise a conducting metallic body, and, to improve certain properties, e.g. electrical and/or protective properties, an electrically conducting contact layer covering at least a contact area of the contact element. Protection can be in regard to wear, corrosion or other detrimental chemical reactions that may take part with the environment where the contact element has its use.

Gold is one material that often is suitable as a contact layer, but is expensive. A potential gold replacement is silver. However, silver is not as inert as often would be desirable or needed, and some properties may therefore need to be further improved, such as resistance to corrosion, in particular in environments containing Cl^- and/or H_2S, that otherwise tend to react with silver and create a surface layer with deteriorated electrical properties.

In WO 2010/005382 A1 a conductive layer of a silver-indium alloy consisting of 1-10 % by weight of In and 90-99 % by weight of Ag, in particular 5 % by weight of In and 95 % by weight of Ag, is provided on the surface of a strip substrate. The electrical properties of the alloy were good and it did not easily react with sulfur in the ambient air.

EP1489193 discloses a sputter target of silver based alloy consisting of 0.01-5.0 % by weight of In and Sn, in particular 0.5 % by weight of In and 0.5 % by weight of Sn, and the rest consisting of silver.

US6565983 discloses an electrical contact element with a contact surface coated with a 0.001 µm to 1 mm thick friction reducing layer comprising a metal salt being a metal halogenide or metal sulfide.

US7670689 discloses a sulfidation-resistant silver base coating comprising a stack of one main layer made from silver-base material and one oxidized thin film between 10 nm and 1 µm.

T.R. Long, Platinum Metals Rev., 1976, 20, 46-47 discloses that a silver based alloy consisting of more than 20 wt.% Pd has improved resistance to corrosion.

Summary of the invention

In view of the above, an object of this disclosure is to present a solution overcoming or at least alleviating problems in the prior art, or to at least present an alternative solution. A more specific object is to present a solution enabling provision of an electrically conducting contact layer comprising an electrically conducting metallic base material, where the contact element has improved corrosion resistance compared to a contact element made of the electrically conducting metallic base material as such.

It has been found that corrosion resistance of an electrically conducting base material, in particular of silver, can be improved in regard of sulfidation (tarnishing) by addition of In and Sn (up to 10 at.%, that is, atomic percent), but that resistance to salt spray corrosion is not as good as would be desirable. Silver based materials with high Pd content (>20 wt.%) have previously been found to improve resistance to corrosion. However, the high price of Pd makes such material less commercially interesting. A material with less Pd content would therefore be preferable, but corrosion resistance to H_2S is then not sufficient. Investigations of silver based materials including both In+Sn and Pd revealed that the corrosion resistance effect from In+Sn and Pd could counteract each other, for example that Pd could adversely affect sulfidation resistance compared to when In+Sn was used without Pd. One challenge was thus to find a material with In+Sn and Pd, which enabled sufficiently improved corrosion resistance both to sulfidation and salt spray corrosion. Additionally, it was found that instead of basing the material on metal, e.g. pure silver, a metal salt, such as silver salt, could be used, either as the base material as such, or as an additive to the material, thereby enabling increase of corrosion resistance as well as lowering the friction coefficient of the material, while maintaining a low contact resistance. Although investigations has focused on silver as metal of the base material, the In+Sn and Pd additives could also be used with other base material metals, in general with silver, copper, tin, nickel or cobalt, a first metal salt of one thereof, or to alloys thereof.

The invention is defined by the appended independent claims. Embodiments are set forth in the dependent claims and in the following description and drawings.

Hence, the above-mentioned and other objects and advantages, which will be evident from the following description, are:

According to a first aspect achieved by a material for providing an electrically conducting contact layer, the material comprising a base material being any one of Ag, Cu, Sn, Ni, Co, a first metal salt of any one thereof, or an alloy of any one or more thereof, wherein the material further comprises In within a range of 0.01 at.% to 10 at.%, Sn within a range of 0.01 at.% to 10 at.%, unless already the base material comprises Sn at a higher amount, and at least one element selected from the group including Au, Ag, Pd, Pt, Rh, Ir, Ru, Os, Re, or any combination thereof, within a range of 0.01 at.% to 10 at.%, unless the at least one element already is present in the base material.

For example, if the base material is Sn, the material may further comprise In within the range of 0.01 at.% to 10 at.% and for example Pt within a range of 0.01 at.% to 10 at.%.

From such material, a contact layer can be provided that, compared to a coating of only the base material, has improved corrosion resistance and low contact resistance. By base material is here meant a material constituting at least 50 at.% of the material and being the target for the improved corrosion resistance.

The base material may be Ag. In one embodiment the material may comprise less than or about 5 at.% In, less than or about 10 at.% Sn, and less than or about 5 at.% of the at least one element or combinations of elements. The material may comprise the base material within a range of 70 at.% to 99.7 at.%, such that the sum of all constituents in the material is 100 at.%. This means that for a contact layer composition comprising for example 10 at.% In, 10 at. % Sn and 10 at.% Pt, the rest, 70 at.%, would consist of the base material chosen.

According to a second aspect achieved by a material for providing an electrically conducting contact layer, the material comprising a base material being any one of Ag, Cu, Sn, Ni, a first metal salt of one thereof, or an alloy of one or more thereof, wherein the material further comprises In within a range of 0.01 at.% to 10 at.%, Pd within a range of 0.01 at.% to 10 at.%, and, unless already the base material comprises Sn at a higher amount, Sn within a range of 0.01 at.% to 10 at.%. For example, if the base material is Sn, the material may further comprise In within a range of 0.01 at.% to 10 at.% and Pd within a range of 0.01 at.% to 10 at.%.

The base material may be Ag. In one embodiment the material may comprise less than or about 1.5 at.% In, less than or about 1.5 at.% Sn, and less than or about 3 at.% Pd.

The material may further comprise at least about 0.01 at.% of a second metal salt, preferably a metal halogenide or metal sulfide. By addition of the second metal salt, resistance to corrosion can be further improved. The second metal salt may comprise one or more of the following metals: Ag, Sn and Cu. The second metal salt may be a metal halogenide comprising one or more of the following halogenides: iodide, chloride and bromide.

In one embodiment the first metal salt of one of Ag, Cu, Sn, Ni, is the base material and the first metal salt is one or more of iodide and bromide. The first metal salt may be AgI or AgBr.

In one embodiment the material may further comprise at least one element selected from the group including Au, Ag, Pt, Rh, Ir, Ru, Os, Re, or any combination thereof, within the range of 0.01 at. % to 10 at. %, unless the at least one element already is present in the base material.

Such a material may comprise less than or about 10 at.% of the at least one element or combinations of elements, such that the sum of Pd and the at least one element or combinations of elements is less than or about 10 at.%.

In one embodiment the material may comprise the base material within a range of 70 at.% to 99.7 at.%, such that the sum of all constituents in the material is 100 at.%.

According to a third aspect achieved by a material providing an electrically conducting contact layer, the material comprising a base material being any one of Ag, Cu, Sn, Ni, Co, a first metal salt of any one thereof, or an alloy of any one or more thereof, wherein the material further comprises In within a range of 0.01 at.% to 10 at.%, Pd within a range of 0.01 at.% to 10 at.%, and, unless already the base material comprises Sn at a higher amount, Sn within a range of 0.01 at.% to 10 at.%.

The base material may be Ag.

In one embodiment the material may further comprise at least one element selected from the group including Au, Ag, Pt, Rh, Ir, Ru, Os, Re, or any combination thereof, within the range of 0.01 at. % to 10 at. %, unless the at least one element already is present in the base material.

Such a material may comprise less than or about 10 at.% of the at least one element or combinations of elements, such that the sum of Pd and the at least one element or combinations of elements is less than or about 10 at.%.

In one embodiment the material may comprise the base material within a range of 70 at.% to 99.7 at.%, such that the sum of all constituents in the material is 100 at.%.

According to a fourth aspect achieved by a material for providing an electrically conducting contact layer, the material comprising a base material being any one of Ag, Cu, Sn, Ni, Co, a first metal salt of any one thereof, or an alloy of any one or more thereof, wherein the material further comprises In within a range of 0.01 at.% to 10 at.%, and at least one element selected from the group including Au, Ag, Pd, Pt, Rh, Ir, Ru, Os, Re, or any combination thereof, within a range of 0.01 at.% to 10 at.%, unless the at least one element already is present in the base material.

The base material may be Ag. In one embodiment the material may comprise less than or about 5 at.% In and less than or about 5 at.% of the at least one element or combinations of elements.

In one embodiment the material may comprise the base material within a range of 80 at.% to 99.8 at.%, such that the sum of all constituents in the material is 100 at.%.

According to a fifth aspect achieved by a material for providing an electrically conducting contact layer, the material comprising a base material being any one of Ag, Cu, Sn, Ni, Co, a first metal salt of any one thereof, or an alloy of any one or more thereof, wherein the material further comprises Sn within a range of 0.01 at.% to 10 at.%, unless already the base material comprises Sn at a higher amount, and at least one element selected from the group including Au, Ag, Pd, Pt, Rh, Ir, Ru, Os, or any combination thereof, within a range of 0.01 at.% to 10 at.%, unless the at least one element already is present in the base material.

The base material may be Ag. The material may comprise less than or about 10 at.% Sn and less than or about 5 at.% of the at least one element or combinations of elements.

In one embodiment the material comprises the base material within a range of 80 at.% to 99.8 at.%, such that the sum of all constituents in the material is 100 at.%.

According to a sixth aspect the above-mentioned and other objects and advantages are achieved by an electrically conducting contact element comprising a substrate and coated thereon a contact layer comprising the material. With “material” is here and henceforth meant any of the above described materials.

The electrically conducting contact element may further comprise an outer protective layer deposited on the contact layer, wherein said outer protective layer substantially consisting of Si, O, and C.

By “substantially consisting” is meant that the layer consists of (only) the constituents to a degree achievable under practical circumstances as will be recognized by the skilled person.

The electrically conducting contact element may further comprise an outer protective layer deposited on the contact layer, wherein said outer protective layer substantially consists of indium oxide and tin oxide.

Such outer protective layers protect the contact layer from e.g. discoloration during storage of the contact element without any significant reduction of contact resistance.

According to a seventh aspect the above-mentioned and other objects and advantages are achieved by a method for providing an electrically conducting contact element, comprising the steps of providing a substrate and providing the substrate with a contact layer, wherein the contact layer comprises the material.

The contact layer may be coated on the substrate by means of evaporation, preferably by physical vapor deposition, and preferably from a target material comprising the material. The physical vapor deposition techniques used may be for example dc magnetron sputtering and High Power Impulse Magnetron Sputtering (HIPIMS). Other possible coating methods are plating, chemical plating, plasma spraying, rolling, etc.

The method further comprises the step of coating the surface of the contact layer with an outer protective layer resulting from PVD or CVD of either a polymeric coating substantially consisting of Si, O, and C, or a metal oxide substantially consisting of indium oxide and tin oxide.

According to a eighth aspect the above-mentioned and other objects and advantages are achieved by use of the material as a contact layer of an electrically conducting contact element.

According to a ninth aspect the above-mentioned and other objects and advantages are achieved by a use of the material as a target material for deposition by evaporation, preferably by physical vapor deposition.

Brief description of the drawings

The above, as well as other aspects, objects and advantages of the present invention, will be better understood through the following illustrative and non-limited detailed description, with reference to the appended schematic drawings.

Figs. 1a-b show schematic partial cross section views of embodiments of an electrically conducting contact element

Fig. 2 is a block diagram schematically showing steps in method for providing an electrically conducting contact element.

Fig. 3 shows experimental results from evaluation of an embodiment of an electrically conducting contact element before and after subjecting the element to salt spray corrosion testing and before and after exposing the element to a tarnishing environment.

In the drawings the same reference numerals are used for same, similar or corresponding features, even when the reference numerals refer to features in different embodiments.

Detailed description

Fig. 1a shows a schematic partial cross section view of an electrically conducting contact element 2 comprising a substrate 4a, 4b and coated thereon a contact layer 6 comprising a material that will be discussed in detail below. The substrate 4a may be a copper alloy having a nickel alloy 4b plated thereon, or a stainless steel having a nickel alloy 4b coated thereon by PVD. Also other types of substrates are possible, of other materials, and/or comprising only one layer, or a stack of more than two layers. In general any conventional electrically conducting contact element substrate may be used. It is well recognized that electrical contact elements in general are used in all kinds of different applications where it is desirable to in a repeatable manner be able to create and/or break an electrical connection. Applications where the present solution may be used include i.e. connectors, switches and breakers in general, power connectors, smart card connectors, battery contact applications, charge contacts of mobile phones, contacts in consumer electronics, electrical contact elements in industry applications, car applications, defense and airspace applications, and electrical contact elements for signal applications, and including low voltage, mid-voltage and high-voltage applications. The electrically conducting contact element 2 may be used to replace any conventional electrical contact element. The material is comprising a base material that is any one of Ag, Cu, Sn, Ni, Co, a first metal salt of one thereof, or an alloy of one or more thereof, the material further comprising from 0.01 up to 10 at.% of In, from 0.01 up to 10 at.% of Sn (unless Sn is part of the base material at higher amount), and from 0.01 up to 10 at.% of Pd. Hence, the amount of each one of In, Sn and Pd is at least above 0, here at least 0.01 at.%, although in practice an effective amount would typically be at least 0.1 at.%. The base material typically constitutes substantially the rest of the material, or at least to the extent possible in practical circumstances. However, it may be possible that some amount of additional additive not being part of any of the base material, In, Sn and Pd, is present in the material as well, but should then not have any substantial detrimental effect on the effects provided by the base material in combination with the In, Sn and Pd, that is, not having any substantial detrimental effect on contact resistance and corrosion resistance compared to a situation where the material would substantially consists of the base material, In, Sn and Pd. In any case the base material should constitute at least 50 at.% of the material. More detailed embodiments of the material will follow below.

Typically the contact layer 6 is formed from the material, and may thus substantially consist of the material, but it may in some embodiments be parts, for example sub areas or sub layers of the contact layer 6, that consists of or comprises the material. The contact layer 6 may also contain additional specimen, not being part of the material as such, which for example may be partly present in the contact layer to provide some additional property or function. One more detailed example of such contact layer 6 will be given below.

The thickness of the contact layer 6 is typically above 10 µm, but also smaller thicknesses are possible. However, preferably the thickness is less than 1 µm, or about 0.3 µm.

In some embodiments, the material may comprise less than or about 5 at.% In and/or 5 at.% Sn and/or 5 at.% Pd, or even less than or about 1.5 at.% In, and/or less than or about 1.5 at.% Sn, and/or less than about 3 at.% Pd. Embodiments are e.g. possible where the amount of Sn, In and Pd compared to the total material is within ranges marked A-M in Table 1 below.

	Sn	In	Pd
A	≤ 10 at.%	≤ 10 at.%	≤ 10 at.%
B	≤ 10 at.%	≤ 5 at.%	≤ 10 at.%
C	≤ 5 at.%	≤ 10 at.%	≤ 10 at.%
D	≤ 5 at.%	≤ 5 at.%	≤ 5 at.%
E	≤ 5 at.%	≤ 5 at.%	≤ 3 at.%
F	≤ 5 at.%	≤ 5 at.%	≤ 10 at.%
G	≤ 5 at.%	≤ 5 at.%	≤ 3 at.%
H	≤ 5 at.%	≤ 1.5 at.%	≤ 10 at.%
I	≤ 5 at.%	≤ 1.5 at.%	≤ 3 at.%
J	≤ 1.5 at.%	≤ 5 at.%	≤ 10 at.%
K	≤ 1.5 at.%	≤ 5 at.%	≤ 3 at.%
L	≤ 1.5 at.%	≤ 1.5 at.%	≤ 10 at.%
M	≤ 1.5 at.%	≤ 1.5 at.%	≤ 3 at.%

Table 1 – Examples of possible ranges

The amounts according to A-M in table 1 is each one possible to use with any base material that is any one of Ag, Cu, Sn, Ni, Co, a first metal salt of one thereof, but may be of particular interest when the base material is Ag.

It may be advantageous to keep a relation between In+Sn and Pd so that the at.% of Pd is less than at least about the double amount of In+Sn in at.%, or even less than about 1.5 times the amount of In+Sn in at.%.

In one more specific embodiment the substrate 4a is a Grade 304 stainless steel which has been PVD coated with a Ni-alloy, containing at least 72 at.% Ni, forming substrate layer 4b, upon which a contact layer 6 has been coated using PVD. The contact layer is formed from an Ag-alloy comprising 95.5 at.% Ag, 1 at.% In, 1 at.% Sn, and 2.5 at.% Pd.

Note that the substrate need not be electrically conductive and thus in some embodiments may be non-conductive.

In embodiments where the base material comprises a first metal salt of any one of Ag, Cu, Sn, Ni, the first metal salt is preferably one or more of iodide and bromide, such as AgI or AgBr.

In one embodiment the base material is Ag and AgI (proportion about 1:1) at 95.5 at. % and the material may further comprise about 1 at. % In, about 1 at. % Sn and about 2.5 at. % Pd.

When the base material comprises other material than Ag, that is, Cu and/or Sn and/or Ni and/or Co, the amount of In, Sn and Pd may be selected in an upper part of the respective range A-M, that is at comparatively higher amounts, in order to better compensate for that these materials are less inert than Ag.

In some embodiments the material may further comprise at least about 0.01 at.%, or in practice typically at least about 0.1 at.%, of a second metal salt, preferably a metal halogenide or metal sulfide. Preferably the metal is one or more of silver, tin and copper, and preferably the halogenide is any one of iodide, chloride and bromide.

In one embodiment the base material is Ag, the material comprises about 1 at. % In, about 1 at. % Sn and about 2.5 at. % Pd, and further comprises 45% AgI (silver iodide), the rest substantially consisting of the base material Ag .

Electrically conducting contact elements 2 provided with contact layers 6 of different compositions were evaluated in environmental corrosion tests involving salt mist exposure (the test used corresponds well to the IEC 60068-2-11 Test Ka) and hydrogen sulfide exposure (the test used corresponds well to the IEC 60068-2-60 Test Ke). The electrically conducting contact elements 2 used in the environmental corrosion tests corresponds to the one shown in Fig. 1a, wherein the substrate 4a was a Grade 304 stainless steel coated with 0.3 μm Ni-alloy, containing at least 72 at.% Ni, forming substrate 4b, upon which a 0.3 μm contact layer 6 was coated.

The salt mist exposure test involved subjecting the electrically conducting contact element 2, placed in a closed container at room temperature, to a salt mist spray (NaCl 5% (w/w) in water) 5-10 times per day during 48 hours. Thereafter, the electrically conducting contact element 2 was rinsed in de-ionized water. In the hydrogen sulfide exposure test the electrically conducting contact element 2 was fixated in a beaker 10-100 mm above the surface of a 50 ml Na_2S (22.8 g/l) solution for 24 hours. The beaker was located in a closed container at room temperature.

After salt mist exposure the electrical properties of the electrically conducting contact element 2 and the corrosion resistance of the contact layer 6 of said element 2 were examined.

After exposure to hydrogen sulfide the tarnish resistance of the contact layer 6 was examined, i.e. its resistance against sulfidation. Tarnishing results in increased contact resistance of the electrically conducting contact element 2. Some contact layer 6 compositions exhibited a faint yellowish discoloration after exposure to hydrogen sulfide, which did not, however, affect the electrical properties of the electrically conducting contact element 2 negatively.

An electrically conducting contact element 2 provided with a contact layer 6 of pure Ag (100 at.%) was subject to corrosion after exposure to both salt spray and hydrogen sulfide. By addition of Pd to the contact layer 6, Ag-Pd (90-10 at.%), a considerably better corrosion resistance against salt mist and a slightly improved resistance against sulfidation was achieved than for a pure Ag contact layer 6. An even higher level of Pd in the Ag composition would, as is generally known, result in improved resistance also to sulfidation.

The corrosion resistance of an electrically conducting contact element 2 provided with a contact layer 6 comprising Ag as base material was increased with regard to tarnishing by addition of In and Sn to the base material, up to 10 at.% for Sn and below 5 at.% for In. However, resistance to salt mist corrosion was not improved for such contact layer 6 compositions.

An electrically conducting contact element 2 provided with a contact layer 6 composition of Ag-Pd-In exhibited even for very low concentrations of Pd and In (0.5 at.% Pd and 1 at.% In) no detectable corrosion after exposure to salt mist and a faint yellowish discoloration after exposure to hydrogen sulfide, which did not, however, affect the electrical properties of the electrically conducting contact element 2 negatively. The same results were achieved also for a contact layer 6 composition of Ag-Pd-Sn down to very low concentrations of Pd and Sn (0.5 at.% Pd, 1 at.% Sn).

For a contact layer 6 composition comprising Ag, Pd, In and Sn, corrosion resistance effects from In+Sn and Pd could counteract each other. Pd may adversely affect tarnishing resistance compared to if only In+Sn is used. A contact layer 6 composition of Ag-Pd-In-Sn having a Pd content of 0.01 at.% and In/Sn levels within the intervals specified above, resulted in an improved resistance against tarnishing compared to contact layers 6 of pure Ag, but no significantly improved corrosion resistance against salt mist. With an increased Pd level in the Ag-Pd-In-Sn composition of 0.5 at.%, there were no signs of corrosion after salt mist or hydrogen sulfide exposure. Such a contact layer 6 exhibited therefore considerably better corrosion resistance against salt mist and hydrogen sulfide than pure Ag and an improved corrosion resistance against salt mist compared to Ag-In-Sn. Within the range of 0.01 at.% and 5 at.% of Pd an Ag-Pd-In-Sn composition resulted in better corrosion resistance against hydrogen sulfide and salt mist than pure Ag. A Pd content in the range of 0.1 at.% to 5 at.% resulted in improved corrosion resistance against hydrogen sulfide and salt mist compared to contact layer 6 compositions of pure Ag, and to salt mist corrosion compared to Ag-In-Sn compositions. By varying the content of Sn and In the Ag-Pd-In-Sn composition it was found that an Sn level within the range of 0.01 to 10 at.%, and an In level within the range of 0.01 to 5 at.% resulted in improved corrosion resistance compared to pure Ag.

Within the intervals stated above similar results were obtained in the environmental tests for Ag-In-Sn alloys with other noble metals than Pd, or in combination with Pd. For contact layer 6 compositions comprising Ag-Ru-Pd-In-Sn (97.5-0.25-0.25-1-1 at.%), Ag-Pt-In-Sn (97.5-0.5-1-1 at.%) and Ag-Au-In-Sn (97.5-0.5-1-1) there were no signs of corrosion in either of the environmental tests. All three contact layer 6 compositions exhibited considerably higher resistance against corrosion than contact layers 6 of Ag-

In-Sn or pure Ag. These results indicate that addition of any noble metal, including Au, Ag, Pd, Pt, Rh, Ir, Ru, Os, Re, or combinations of noble metals, in an Ag-In-Sn composition, would increase the corrosion resistance of the contact layer 6 compared to if pure Ag or Ag-In-Sn compositions are used.

Contact layer 6 compositions comprising Ag-Pd-In, as discussed above, resulted in improved corrosion resistance compared to pure Ag. The positive indication above for the use of any noble metal, including Au, Ag, Pd, Pt, Rh, Ir, Ru, Os, Re, or combinations of noble metals, in an Ag-In-Sn composition should therefore be applicable also for Ag-In compositions. The same reasoning applies for contact layer compositions of Ag-Sn.

It is considered likely that a contact layer 6 composition comprising another base material than Ag, e.g. Cu, Sn, Ni, Co, or combinations of base materials, also would result in an electrically conducting contact element 2 with improved corrosion resistance compared to an electrically conducting contact element 2 having a contact layer 6 of only the base material as such. By forming an alloy of two or more metals, it is possible to drastically improve the corrosion resistance of the base material with a sustained or improved contact resistance. It is for example known in the art that an alloy of Cu and Ni has found extensive use in marine applications due to increased corrosion resistance as compared to Cu and Ni alone.

Fig. 1b shows a schematic partial cross section view of an electrically conducting contact element 2 comprising a substrate 4a, 4b and coated thereon a contact layer 6. These parts of the shown structure corresponds to the structure of Fig. 1a and the respective part may be the same or similar as was discussed above in relation to Fig. 1a. Additionally, Fig. 1b comprises an outer protective layer 8 deposited on the contact layer 6. The outer protective layer 8 may be resulting from a PVD or CVD of either a polymeric coating consisting of mainly Si, O, and C or a metal oxide consisting of mainly indium oxide and tin oxide, see e.g. *M. Grischke, A. Hieke, F. Morgenweck, H. Dimigen, Diamonds and Related Materials, 1998, 7, 454-458*. The polymeric coating thickness may be less than 20 nm. The metal oxide layer coating thickness may be less than 100 nm.

By the deposition of the polymeric layer, the protective layer 8 may be formed so that it comprises an outer (top) portion comprising Si, O, C, F resulting from the deposition and/or there may be a reaction during the deposition with the underlying contact layer 6 forming at least part of the protective layer 8.

Conventionally, contact layers, e.g. Au layers, are deposited using plating. The material according to the present disclosure may be plated as well, but is advantageously deposited using evaporation techniques, in particular physical vapor deposition (PVD). Advantages form this include possibility to coat materials that are difficult to plate, e.g. stainless steel and aluminum, it allows for better controllability of layer composition and thickness, and deposition can be made more environmentally friendly. In case of a protective coating 8 resulting from the deposition of the polymeric layer, it is advantageous to use a PVD coating equipment having separate chambers, where a contact element 4 having a contact layer 6 coated in one chamber is moved to a subsequent chamber for coating of the protective layer 8. The present applicant's PVD equipment REELCOATER® and INLINECOATER® may advantageously be used and are adaptable to volume production which previously has been a drawback for evaporation techniques compared to plating.

In addition to coating techniques as mentioned above, the contact layer can be formed separately and then attached, e.g. by soldering, to the contact element. Other conventional techniques that could be used e.g. rolling down a piece of the material, e.g. a wire made of the material, into the surface of the substrate 4 or into an already existing contact layer of a starting material that in a previous step has been provided on top of the substrate.

Fig. 2 is a block diagram schematically showing steps in a method for manufacturing the electrically conducting contact element 2. In step 102 a substrate is provided, which may be one of the substrates discussed in the foregoing. Step 102 may include a coating, e.g. by PVD, of the substrate, such as layer 4b as discussed in the foregoing on a pre-produced substrate 4a, but may also include providing a fully pre-produced substrate, which e.g. may be a contact element made from a base metal or metal alloy. Following this, in step 104, the substrate 4a, 4b is coated with contact layer 6, wherein the contact layer comprises the material as discussed in the foregoing. As already mentioned, step 104 is preferably performed by means of evaporation, preferably by physical vapor deposition (PVD) and preferably from a target material comprising the material. However, also multiple targets, such as one for each constituent of the material, may be used. How target material comprising the material can be provided is discussed in some further detail below. In a last optional step 106, the contact layer 6 is coated, also preferably by means of PVD, with the Si-O-C layer, so that the result is an outer protective layer 8 typically having a thickness below about 20 nm. Such protective layer was discussed above.

The material of the present disclosure can be pre-produced in different ways for further use as a coating material for deposition of a contact layer using PVD, that is, can be provided in the form of, and used as, a target material. In one embodiment the constituent materials are alloyed, that is, melted and mixed in a liquid state and then cooled down. In another embodiment one or more of the constituents are being provided in the form of powders which are sintered, including cold or hot isostatic pressing of the powders (CIPing or HIPing). The pressed powders are then heat treated at about 200-400°C for 1-4 hours. In yet another embodiment, a target material comprising the material is made from a starting material being a pure metal, or an alloy of parts of the material, for example using the base material as starting material, then the remaining constituents are being provided by means of diffusion in an oven, vacuum chamber or chemical bath where the starting material is located.

Fig. 3 shows experimental results from evaluation of one embodiment of an electrically conducting contact element 2 before and after environmental test. In each group, the left column indicates result as deposited, the middle column indicates results after salt spray exposure (IEC 60068-2-11 Test Ka) and the right column indicates results after mixed gas exposure (IEC 60068-2-60 Test Ke). The evaluated electrically conducting contact element is in accordance with Fig. 1a, where the substrate 4a is a Grade 304 stainless steel which has been PVD coated with a 0.3 µm Ni-alloy, containing at least

72 at.% Ni, forming substrate layer 4b, upon which a 0.3 µm contact layer 6 has been coated using PVD. The contact layer is formed from an Ag-alloy comprising 95.5 at.% Ag, 1 at.% In, 1 at.% Sn, and 2.5 at.% Pd. The salt spray exposure involves subjecting the electrical conducing contact element 2 to a salt mist during 48 hours, at 35°C and 90-95 % relative humidity (RH). The mixed gas exposure involves subjecting the electrical conducting contact element to the mixed gas (H_2S 0,1 ppm + SO_2 0,5 ppm at 25°C, 75 % RH.) for 2 to 96 hours.

The material in the present disclosure, which may be seen as a compound material, is meant to i.a. include mixture of the constituting elements, that is, a metal based material or metallic mixture, for example but not necessary as in an alloy, and not requiring a fully homogenous distribution of the mixed constituents. For example, when the material is provided in the form of the contact layer 6 discussed in the foregoing, some of the constituting elements, for example Sn and In, may be in higher concentration in a surface portion of the layer. It is also possible with other variations of composition throughout a contact layer made from the material, e.g. other variations in concentration, such as gradients, and the layer may include a multilayered structure, e.g. including atomic thin layers of some constituent material laminated with layers of another constituent material.

The abbreviations used for the chemical elements in this disclosure are all well know, each unambiguously corresponding to a chemical element: Ag (silver), Au (gold), Ni (nickel), Sn (tin), In (indium), Pd (palladium), Cu (copper), Si (silicon), C (carbon), O (oxygen), F (flourine), Na (sodium), Cl (chlorine), Br (bromine), I (iodine), S (sulfur), H (hydrogen), Cobalt (Co).

Any illustration and description in the drawings and in the foregoing text is to be considered exemplary and not restrictive. The invention is not limited to the disclosed embodiments.

The present invention is defined by the claims and variations to the disclosed embodiments can be understood and effected by the person skilled in the art in practicing the claimed invention, for example by studying the drawings, the disclosure, and the claims. Use of the word "comprising" in the claims does not exclude other elements or steps, and use of the article "a" or "an" does not exclude a plurality. Occurrence of features in different dependent claims does not per se exclude a combination of these features. Any reference signs in the claims are for increasing intelligibility and shall not be construed as limiting the scope of the claims.

CLAIMS

1. A material for providing an electrically conducting contact layer, the material comprising a base material being any one of Ag, Cu, Sn, Ni, Co, a first metal salt of any one thereof, or an alloy of any one or more thereof, wherein the material further comprises In within a range of 0.01 at.% to 10 at.%, Sn within a range of 0.01 at.% to 10 at.%, unless already the base material comprises Sn at a higher amount, and at least one element selected from the group including Au, Ag, Pd, Pt, Rh, Ir, Ru, Os, Re, or any combination thereof, within a range of 0.01 at.% to 10 at.%, unless said at least one element already is present in said base material.

2. The material as claimed in claim 1, wherein the base material is Ag.

3. The material as claimed in claim 1 or 2, wherein the material comprises less than or about 5 at.% In, less than or about 10 at.% Sn, and less than or about 5 at.% of said at least one element or combinations of elements.

4. The material as claimed in any one of claims 1-3, wherein the material comprises the base material within a range of 70 at.% to 99.7 at.%, such that the sum of all constituents in the material is 100 at.%.

5. A material for providing an electrically conducting contact layer, the material comprising a base material being any one of Ag, Cu, Sn, Ni, a first metal salt of any one thereof, or an alloy of any one or more thereof, wherein the material further comprises In within a range of 0.01 at.% to 10 at.%, Pd within a range of 0.01 at.% to 10 at.%, and, unless already the base material comprises Sn at a higher amount, Sn within a range of 0.01 at.% to 10 at.%.

6. The material as claimed in claim 5, wherein the base material is Ag.

7. The material as claimed in any one of claims 5-6, wherein the material comprises less than or about 1.5 at.% In, less than or about 1.5 at.% Sn, and less than or about 3 at.% Pd.

8. The material as claimed in any one of claims 5-7, wherein the material further comprises at least about 0.01 at.% of a second metal salt, preferably a metal halogenide or metal sulfide.

9. The material as claimed in claim 8, wherein the second metal salt comprises one or more of the following metals: Ag, Sn and Cu.

10. The material as claimed in any one of claims 8-9, wherein the second metal salt is a metal halogenide comprising one or more of the following halogenides: iodide, chloride and bromide.

11. The material as claimed in any one of claims 5-10, wherein the base material is the first metal salt of one of Ag, Cu, Sn, Ni, and is one or more of iodide and bromide.

12. The material as claimed in any one of claims 5-11, wherein the first metal salt is AgI or AgBr.

13. The material as claimed in any one of claims 5-12, further comprising at least one element selected from the group including Au, Ag, Pt, Rh, Ir, Ru, Os, Re, or any combination thereof, within the range of 0.01 at. % to 10 at. %, unless said at least one element already is present in said base material.

14. The material as claimed in claim 13, wherein the material comprises less than or about 10 at.% of said at least one element or combination of elements, such that the sum of Pd and said at least one element or combinations of elements is less than or about 10 at.%.

15. The material as claimed in any of claims 5-14, wherein the material comprises the base material within a range of 70 at.% to 99.7 at.%, such that the sum of all constituents in the material is 100 at.%.

16. A material for providing an electrically conducting contact layer, the material comprising a base material being any one of Ag, Cu, Sn, Ni, Co, a first metal salt of any one thereof, or an alloy of any one or more thereof, wherein the material further comprises In within a range of 0.01 at.% to 10 at.%, Pd within a range of 0.01 at.% to 10 at.%, and, unless already the base material comprises Sn at a higher amount, Sn within a range of 0.01 at.% to 10 at.%.

17. The material as claimed in claim 16, wherein the base material is Ag.

18. The material as claimed in any one of claims 16-17, further comprising at least one element selected from the group including Au, Ag, Pt, Rh, Ir, Ru, Os, Re, or any combination thereof, within the range of 0.01 at. % to 10 at. %, unless said at least one element already is present in said base material.

19. The material as claimed in claim 18, wherein the material comprises less than or about 10 at.% of said element or combination of elements, such that the sum of Pd and said at least one element or combinations of elements is less than or about 10 at.%.

20. The material as claimed in one any of claims 16-19, wherein the material comprises the base material within a range of 70 at.% to 99.7 at.%, such that the sum of all constituents in the material is 100 at.%.

21. A material for providing an electrically conducting contact layer, the material comprising a base material being any one of Ag, Cu, Sn, Ni, Co, a first metal salt of any one thereof, or an alloy of any one or more thereof, wherein the material further comprises In within a range of 0.01 at.% to 10 at.%, and at least one element selected from the group including Au, Ag, Pd,

Pt, Rh, Ir, Ru, Os, Re, or any combination thereof, within a range of 0.01 at.% to 10 at.%, unless said at least on element already is present in said base material.

22. The material as claimed in claim 21, wherein the base material is Ag.

23. The material as claimed in claims 21 or 22, wherein the material comprises less than or about 5 at.% In and less than or about 5 at.% of said at least one element or combinations of elements.

24. The material as claimed in any one of claims 21-23, wherein the material comprises the base material within a range of 80 at.% to 99.8 at.%, such that the sum of all constituents in the material is 100 at.%.

25. A material for providing an electrically conducting contact layer, the material comprising a base material being any one of Ag, Cu, Sn, Ni, Co, a first metal salt of any one thereof, or an alloy of any one or more thereof, wherein the material further comprises Sn within a range of 0.01 at.% to 10 at.%, unless already the base material comprises Sn at a higher amount, and at least one element selected from the group including Au, Ag, Pd, Pt, Rh, Ir, Ru, Os, or any combination thereof, within a range of 0.01 at.% to 10 at.%, unless said at least one element already is present in said base material.

26. The material as claimed in claim 25, wherein the base material is Ag.

27. The material as claimed in any one of claims 25 or 26, wherein the material comprises less than or about 10 at.% Sn and less than or about 5 at.% of said at least one element or combinations of elements.

28. The material as claimed in any one of claims 25-27, wherein the material comprises the base material within a range of 80 at.% to 99.8 at.%, such that the sum of all constituents in the material is 100 at.%.

29. An electrically conducting contact element (2) comprising a substrate (4) and coated thereon a contact layer (6) comprising the material as claimed in any one of the preceding claims 1-4, 5-15, 16-20, 21-24 or 25-28.

30. The electrically conducting contact element (2) as claimed in claim 29, further comprising an outer protective layer (8) deposited on the contact layer (6), said outer protective layer (8) comprising, preferably substantially consisting of, Si, O, and C.

31. The electrically conducting contact element (2) as claimed in claim 29, further comprising an outer protective layer (8) deposited on the contact layer, said outer protective layer (8) comprising, preferably substantially consisting of, indium oxide and tin oxide.

32. A method for providing an electrically conducting contact element (2), comprising the steps of:

providing (102) a substrate (4); and

providing (104) the substrate with a contact layer (6), wherein the contact layer comprises the material as claimed in any one of claims 1-4, 5-15, 16-20, 21-24 or 25-28.

33. The method as claimed in claim 32, wherein the contact layer is being coated on the substrate by means of evaporation, preferably by physical vapor deposition, and preferably from a target material comprising the material as claimed in any one of claims 1-4, 5-15, 16-20, 21-24 or 25-28.

34. The method as claimed in any one of claims 32-33, wherein the method further comprises the step of:

coating (106) the surface of the contact layer (6) with an outer protective layer (8) resulting from PVD or CVD of either a polymeric coating substantially consisting of Si, O, and C, or a metal oxide substantially consisting of indium oxide and tin oxide.

35. Use of the material as claimed in any one of claims 1-4, 5-15, 16-20, 21-24 or 25-28 as a contact layer (6) of an electrically conducting contact element (2).

36. Use of the material as claimed in any one of claims 1-4, 5-15, 16-20, 21-24 or 25-28 as a target material for deposition by evaporation, preferably by physical vapor deposition.

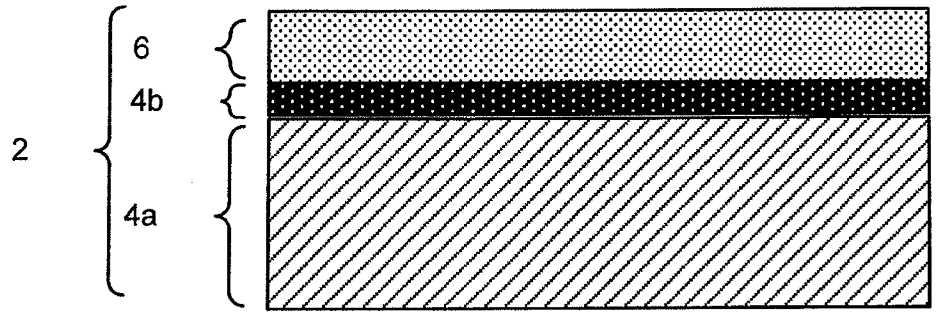

Fig. 1a

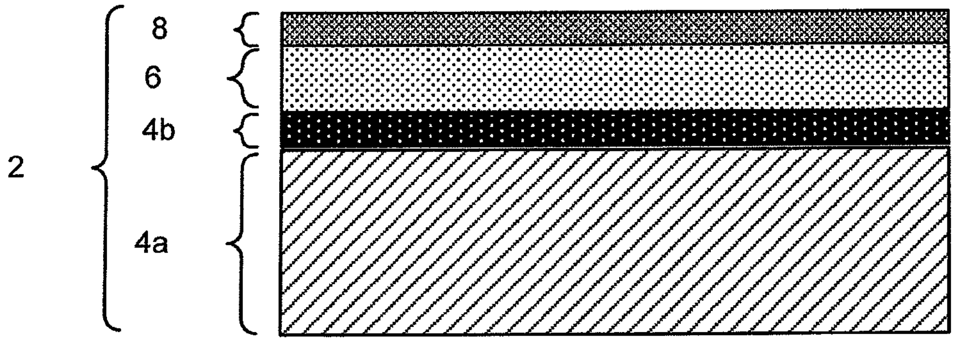

Fig. 1b

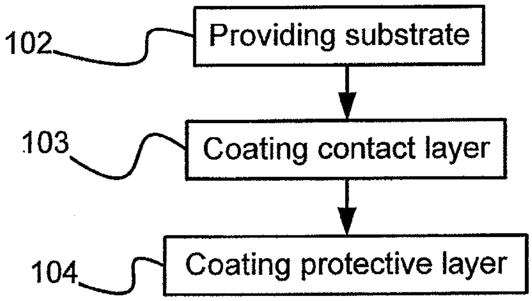

Fig. 2

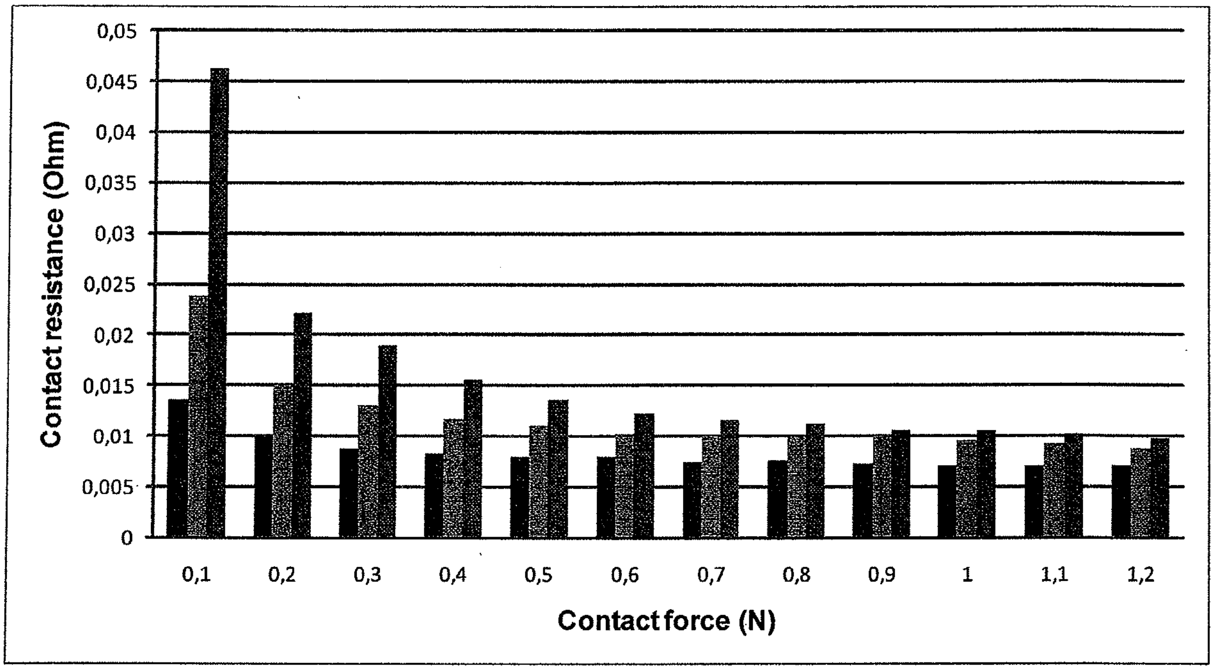
0,05
0,045
0,04
0,035
0,03
0,025
0,02
0,015
0,01
0,005
0
Contact resistance (Ohm)
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1
1,1
1,2
Contact force (N)

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/052222

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01B1/02
ADD.

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)
H01B H01H

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002/096662 A1 (SCHLEICHER KLAUSE [DE] ET AL SCHLEICHER KLAUS [DE] ET AL) 25 July 2002 (2002-07-25) claims 1-19	1-4, 21-36
X	EP 1 475 814 A1 (SUMITOMO ELECTRIC INDUSTRIES [JP]) 10 November 2004 (2004-11-10) claims 1-7	1-4, 21-36
X	US 2005/089439 A1 (KEDUKA HIROYUKI [JP] ET AL) 28 April 2005 (2005-04-28) examples 1-4; tables 1-9	1-4, 21-36
X	EP 1 489 193 A1 (HERAEUS GMBH W C [DE]) 22 December 2004 (2004-12-22) the whole document	1-4, 21-36
	-/--	

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 11 July 2012	Date of mailing of the international search report 20/07/2012
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Kövecs, Monika

3

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 26 37 490 B1 (HERAEUS GMBH W C) 5 January 1978 (1978-01-05) the whole document -----	1-36
A	WO 2008/123259 A1 (FURUKAWA ELECTRIC CO LTD [JP]; YAMAGUCHI SUGURU [JP]; KOBAYASHI YOSHIA) 16 October 2008 (2008-10-16) abstract -----	1-36
X	DE 39 32 535 C1 (W.C.HERAEUS GMBH) 26 July 1990 (1990-07-26) the whole document -----	25-36
X	US 2 157 933 A (HENSEL FRANS R ET AL) 9 May 1939 (1939-05-09) the whole document -----	21-24, 29-36

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/052222

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002096662 A1	25-07-2002	AT 277754 T	15-10-2004
		CN 1325155 A	05-12-2001
		DE 10025107 A1	22-11-2001
		EP 1157820 A1	28-11-2001
		ES 2225349 T3	16-03-2005
		HK 1040838 A1	24-08-2007
		JP 2002020825 A	23-01-2002
		PT 1157820 E	31-12-2004
		TR 200402789 T4	22-11-2004
		TW 495769 B	21-07-2002
		US 2002096662 A1	25-07-2002
EP 1475814 A1	10-11-2004	CN 1620706 A	25-05-2005
		EP 1475814 A1	10-11-2004
		JP 2003217375 A	31-07-2003
		US 2005115812 A1	02-06-2005
		WO 03063191 A1	31-07-2003
US 2005089439 A1	28-04-2005	AU 2003289251 A1	30-06-2004
		CN 1703746 A	30-11-2005
		EP 1569215 A1	31-08-2005
		JP 2004192702 A	08-07-2004
		KR 20050086366 A	30-08-2005
		US 2005089439 A1	28-04-2005
		WO 2004053861 A1	24-06-2004
EP 1489193 A1	22-12-2004	DE 10327336 A1	27-01-2005
		EP 1489193 A1	22-12-2004
		JP 2005008983 A	13-01-2005
		KR 20040108585 A	24-12-2004
		TW I316092 B	21-10-2009
		US 2004253137 A1	16-12-2004
		US 2007062810 A1	22-03-2007
DE 2637490 B1	05-01-1978	DE 2637490 B1	05-01-1978
		JP 1095550 C	27-04-1982
		JP 53037130 A	06-04-1978
		JP 56039373 B	12-09-1981
		US 4149883 A	17-04-1979
WO 2008123259 A1	16-10-2008	NONE	
DE 3932535 C1	26-07-1990	NONE	
US 2157933 A	09-05-1939	NONE	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2012/052222

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☒ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-4, 21-28(completely); 29-36(partially)

   A material for a contact layer according claims 1, 21 and 25.

   ---

2. claims: 5-20(completely); 29-36(partially)

   A material for a contact layer according claims 5 and 16.
