

**A system and a method for producing electrically conductive
interconnecting structures and a method for producing circuits and
equipped circuits**

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Specification

1 The present invention relates to a system for producing electrically conduc-
tive interconnecting structures, a method for producing electrically conduc-
tive interconnecting structures, a method for producing circuits and equip-
ped circuits as well as to the circuits and equipped circuits produced accor-
5 ding to these methods.

Generally, when electronic components or equipped circuits are produced,
it is necessary to mechanically-electrically connect metallic surfaces to me-
tallic connecting elements. To this end printed circuit boards usually are
10 produced by electroplating, the printed circuit board structure being ob-
tained by additive techniques or subtractive etching technologies. These
known methods, however, imply the risk of environmental pollution and the
necessity of recycling the galvanic liquids used therefor. The thus created
printed circuit boards serve as substrates for electronic components which
15 are connected to the printed circuit board. To a small extent, also electri-
cally conductive adhesives are employed for this purpose which in contrast
to softsoldering offer the advantage of low working temperatures. However,
these conventional conductive adhesives either are physical mixtures of
electrically conductive materials such as metal powders and polymer resins
20 being the matrix, or they consist of electrically conductive plastic materi-
als. The conductivity of such systems comes about by the quasi-metallic
contact of the conductive materials in the organic matrix.

In order to achieve good adhesion on the substrates, a high amount of poly-
25 mer resin is desired for such electrically conductive adhesives. On the other
hand, to achieve good electrical conductivity, conductive materials are re-
quired in large quantities. Adhesion to substrates and electrical conductivi-
ty thus are contrary demands on such adhesives. The connecting structures
obtained thereby e.g. have the drawback that they are not solderable. These
30 and other technical shortcomings have prevented heretofore the employ-
ment of conductive adhesives on a large scale.

Also electrically conductive adhesives have become known wherein the con-
ductivity is provided by a metallurgical reaction of different metals by for-
35 ming intermetallic connections. Also here it is necessary to admix an orga-
nic polymeric matrix so that the same problems arise as with adhesives fil-

1 led with electrically conductive materials.

It is, therefore, an object of the present invention to provide a system and a method for producing electrically conductive interconnecting structures as well as methods for producing circuits and equipped circuits by using this system, wherein the shortcomings of the prior art have been overcome and in particular excellent adhesion and good electrical conductivity and solderability of the created interconnecting structures and circuits are achieved.

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According to the invention, this object is accomplished by a system according to claim 1, a method for producing electrically conductive interconnecting structures according to claim 14, and methods for producing circuits and equipped circuits according to claims 15 and 19. Preferred or particularly useful designs of the subject-matter of the invention are defined in the subclaims.

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The subject-matter of the present invention, therefore, is a system for producing electrically conductive interconnecting structures comprising A) an adhesive material; and B) an electrically conductive metal paste containing at least two metal powders having different melting points, and a small amount of organic auxiliary agents, wherein the metal powders are selected so that during heating they produce an intermetallic phase, and wherein the organic auxiliary agents are volatilisable for the most part at the temperature used for producing the intermetallic phase.

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The subject-matter of the present invention further is a method for producing electrically conductive interconnecting structures with the use of the system under the present invention, comprising the steps of

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(1) applying the adhesive material onto a substrate; (2) applying the metal paste to the thus provided adhesive material; and (3) heating the metal paste at a temperature at which the metal powders produce an intermetallic phase.

The subject-matter of the present invention also is a method for producing a circuit using the system under the present invention, comprising the steps of

(1) applying the adhesive material in the form of a circuit pattern onto a

1 substrate); (2) applying the metal paste to the thus provided adhesive material; and (3) heating the metal paste at a temperature at which the metal powders produce an intermetallic phase.

5 The subject-matter of the present invention further is a method for producing equipped circuits using the system under the present invention, comprising the steps of

(1) applying the adhesive material in the form of a circuit pattern onto a substrate; (2) applying the metal paste to the thus provided adhesive material; (3) equipping the circuit pattern provided with the adhesive material and the metal paste with electrical or electronic components; and (4) heating the metal paste at a temperature at which the metal powders produce an intermetallic phase.

15 Furthermore the circuits and equipped circuits produced according to the above methods are subject-matters of the present invention.

In contrast to the techniques heretofore used it has been found in the scope of the present invention that electrically conductive metal pastes which contain only a small amount of organic auxiliary agents and in which the metal powders are selected so that during heating they produce an intermetallic phase can be employed for producing electrically conductive interconnecting structures. The generally insufficient adhesion of such metal pastes to substrates or bases is achieved by an adhesive material which

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1 has been previously applied to the substrate or base.

The adhesive material can be an anorganic or an organic material. Anorganic and organic adhesives are known to the skilled man and can be selected
5 by him depending on the purpose of use, e.g. depending on the materials used for the substrates. Anorganic adhesives are e.g. those made predominantly on a mineral basis such as a silicate basis. Hydraulically curable anorganic materials can also be suited. Suitable adhesives on an organic
10 basis are e.g. thermoplastic resins, in particular those having higher softening or melting points. In particular, curable organic resins proved to be useful, curing being made either thermally or by radiation.

The adhesive material usually contains no metallic components and exhibits no electrical conductivity. Its purpose is to provide an adherent thermoplastic connection with the base and to permit adhesion of the second
15 component, namely of the electrically conductive metal paste. Especially one-component and two-component adhesives on an epoxy resin basis, polyurethane resins, melamine formaldehyde resins, vinylidene chloride-vinyl acetate copolymer resins or materials known as solder stop lacquers can be
20 used as adhesive materials. Particularly preferable are two-component adhesives on an epoxy resin basis. The selection of the respective adhesives depends on the adhesion properties of the used substrates such as circuit bases and the flexibility that may be required.

25 The metal paste used under the present invention suitably contains at least one metal powder of a metal of good electrical conductivity, preferably selected from the group consisting of gold, silver, copper and alloys thereof, and at least one metal powder of a metal having a lower melting point than that of the metal of good electrical conductivity, preferably selected from
30 the group consisting of tin, indium and the alloys thereof, preferably its alloys including e.g. lead and/or antimony and/or zinc, such as tin lead, tin antimony or tin antimony lead. According to the invention it is necessary that the metal powders having different melting points undergo a metallurgical reaction during heating by forming an intermetallic phase. Additive
35 metal powders from the group consisting of nickel, germanium, titanium, iron, but also other alloy components which are known as so-called grain refiners can be employed here for achieving special properties. Particularly preferable is a metal paste which contains a mixture of copper powder and

- 1 a powder of the solder alloy 62Sn36Pb2Ag in a weight ratio of from about 4:1 to about 1:1.

5 The metal powders of the metal paste suitably have a mean particle size of from about 1 to 100 μm , preferably of from about 10 to 50 μm , more preferably of from about 20 to 30 μm .

10 The content of metal powder in the metal paste should be as high as possible and under the present invention preferably is at least about 85 % by weight, more preferably at least about 90 % by weight. With a metal powder of approximately above 95 % by weight, however, the handling of the metal paste may involve difficulties.

15 The organic auxiliary agents contained in the metal paste under the present invention e.g. can be volatile organic compounds such as solvents, e.g. diol, glycol, glycol ether and dicarboxylic acid ester, deoxidating auxiliary agents containing metal powder activating substances such as carboxylic acid and amines, and additives controlling the viscosity such as long-chain acid amides or paraffins. Preferably, amine compositions are used which are volatile
20 at the selected metallurgical reaction temperatures. Furthermore, coactivators selected from the group consisting of the nonvolatile carboxylic acids and amines and compounds which are dehalogenating at the temperature used for producing the intermetallic phase can be contained therein. The selection of these organic auxiliary agents depends e.g. on the selected

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1 application method of the metal paste. Further small amounts of thik-
keners, binders, natural resins such as colophonium and colophonium deri-
vates can be added to the metal pastes. A metal paste which is suitable un-
der the present invention contains e.g. about 90 % by weight metal powder
5 and about 10% by weight organic auxiliary agents.

The method for producing electrically conductive interconnecting structures
according to the present invention comprises the steps of applying the ad-
hesive material onto a substrate, applying the metal paste to the thus pro-
10 vided adhesive material and heating the metal paste at a temperature at
which the metal powder forms an intermetallic phase.

Preferably, the adhesive material applied to the substrate is subjected to
thermal treatment prior to application of the metal paste, this thermal
15 treatment, however, being dimensioned so that no or no complete curing of
the adhesive material takes place. To this end it is expedient to first flash
off the adhesive material at ambient temperature for an adequate time peri-
od for evaporating solvents, if any. Subsequently the thermal treatment is
made, e.g. at 80°C for about 20 minutes under laboratory conditions.
20 Thereby, a dry, well processable surface of the adhesive material is ob-
tained.

In a next step the previously described metal paste is applied to the dried
surface of the adhesive material. The application of the adhesive material
25 and of the metal paste can be suitably made by means of a dispenser, a
silk-screen process or any other printing method according to techniques
which are known to the skilled man.

For finally producing a conductive interconnecting structure such as a cir-
30 cuit, the metal paste is heated so that the organic auxiliary agents evapora-
te for the most part and the metal particles are interconnected by soft sol-
der, thereby producing intermetallic

1 phases. As the organic auxiliary agents are volatile at the respective working temperature, no disturbing residues remain. The adhesion to non-metallic substrates of the metal pastes is ensured by the previously applied adhesive material which has a composition suited for the respective application and the used heating temperature, respectively. In the case of thermal treatment it must be observed that the metal powders form no melt as otherwise discrete metal beads would form caused by the surface tension.

10 The thermal treatment for producing electrically conductive interconnecting structures and for producing circuits and equipped circuits can be made in apparatus known in connection with the soldering technique. For example, a so-called reflow oven is suitable, the thermal treatment preferably being made in nitrogen atmosphere. It is also possible to introduce activators for the metal powder into the gas atmosphere, preferably formic acid. On the other hand such activators may also be contained in the metal paste, as mentioned above.

20 As a result of the method under the present invention, a layer structure is obtained which is comprised of the now completely cured adhesive material and a metal layer thereon which is substantially free from organic additives. The special advantage of such a layer structure resides in the solderability of the metallic layer. In contrast thereto, interconnecting structures obtained by means of known conductive adhesives usually are not solderable due to the intimate mixture of the metal and the polymeric matrix in the form described and put on the market today.

30 By the production of intermetallic phases according to the present invention, the remelting temperature of the metals is higher so that a high remelting temperature permits subsequent soldering processes. According to the invention the production of electrically conductive interconnecting structures such as circuits on insulating carrier materials is possible, the substrates used being all kinds of bases e.g. printed circuit boards, flexible printed circuit boards, alumina ceramics or anodized aluminum printed circuit boards. The skilled man can adapt the suitable adhesive materials and adhesive systems, respectively, to the individual substrate materials. By appropriate selection of the metallurgical components, plane or three-dimensional electrically conductive structures can be produced which can be further processed by subsequent bonding steps which are standard in the

1 production of electronic components, e.g. by soldering.

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CLAIMS

1. A system for producing electrically conductive interconnecting structures comprising
 - A) an adhesive material; and
 - B) an electrically conductive metal paste containing at least two metal powders having different melting points, and a small amount of organic auxiliary agents, wherein said metal powders are selected so that during heating they produce an intermetallic phase, and wherein said organic auxiliary agents are volatilizable for the most part at the temperature used for producing the intermetallic phase.
2. The system as set forth in claim 1, wherein said adhesive material is an anorganic material.
3. The system as set forth in claim 1, wherein said adhesive material is an organic material.
4. The system as set forth in claim 3, wherein the organic material is a thermoplastic resin.
5. The system as set forth in claim 3, wherein the organic material is an organic curable resin.
6. The system as set forth in claim 5, wherein the curable resin is a one-component or two-component adhesive on the basis of epoxy resin.
7. The system as set forth in at least one of the preceding claims, wherein the metal paste contains at least one metallic powder of a metal of good electrical conductivity and at least one metallic powder of a metal having a lower melting point than that of the metal of good electrical conductivity.
8. The system as set forth in claim 7, wherein the metal of good electrical conductivity is selected from the group



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consisting of gold, silver, copper and alloys thereof.

9. The system as set forth in claim 7 and/or claim 8, wherein the metal having the lower melting point is selected from the group consisting of tin, indium and the alloys thereof, preferably its alloys with lead and/or antimony and/or zinc.

10. The system as set forth in at least one of the preceding claims, wherein the metal paste contains a mixture of copper powder and a powder of the alloy 62Sn36Pb2Ag in a weight ratio of from about 4:1 to about 1:1.

11. The system as set forth in at least one of the preceding claims, wherein the metal powders have a mean particle size of from about 1 to 100 μm , preferably of about 10 to 50 μm , more preferably of about 20 to 30 μm .

12. The system as set forth in at least one of the preceding claims, wherein the content of the metal powders in the metal paste is at least about 85% by weight, preferably at least about 90 % by weight.

13. The system as set forth in at least one of the preceding claims, wherein the organic auxiliary agents of the metal paste are selected from volatile organic compounds, deoxidizing auxiliary agents, metal powder activating substances and the additives controlling the viscosity.

14. A method for producing electrically conductive interconnecting structures by using a system of at least one of the preceding claims, comprising the steps of

- (1) applying the adhesive material onto a substrate;
- (2) applying the metal paste to the thus provided adhesive material; and
- (3) heating the metal paste at a temperature at which the metal powders produce an intermetallic phase.

15. A method for producing a circuit by using a system of at least one of claims 1 to 13, comprising the steps of:



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- (1) applying the adhesive material in the form of a circuit pattern onto a substrate;
- (2) applying the metal paste to the thus provided adhesive material; and
- (3) heating the metal paste at a temperature at which the metal powders produce an intermetallic phase.

16. A circuit produced by the method according to claim 15.

17. A method for producing an equipped circuit by using a system set forth in at least one of claims 1 to 13, comprising the steps of:

- (1) applying the adhesive material in the form of a circuit pattern onto a substrate;
- (2) applying the metal paste to the thus provided adhesive material;
- (3) equipping the circuit pattern provided with the adhesive material and the metal paste with electric or electronic components; and
- (4) heating the metal paste at a temperature at which the metal powders produce an intermetallic phase.

18. An equipped circuit produced according to the method set forth in claim 17.

19. The method as set forth in any of claims 14, 15, and 17, wherein the applied adhesive material prior to the application of the metal paste is exposed to thermal treatment subject to the condition that the adhesive material is not or not completely cured during this process.

20. The method as set forth in at least one of claims 14, 15, 17, and 19, wherein the adhesive material and the metal paste are applied by means of a dispenser, a screening method or any other printing method.

21. The method as set forth in any of claims 14, 15, 17, 19, and 20, wherein the substrate is a plane circuit base.

SUMMARY

A system and a method for producing electrically conductive interconnecting structures and a method for producing circuits and equipped circuits

The invention describes a system for producing electrically conductive interconnecting structures comprising

A) an adhesive material; and
B) an electrically conductive metal paste containing at least two metal powders having different melting points, and a small amount of organic auxiliary agents, wherein said metal powders are selected so that during heating they produce an intermetallic phase, and wherein said organic auxiliary agents are volatilizable for the most part at the temperature used for producing the intermetallic phase;

as well as a method for producing electrically conductive interconnecting structures with the use of this system, comprising the steps of:

(1) applying the adhesive material onto a substrate;
(2) applying the metal paste to the thus provided adhesive material; and
(3) heating the metal paste at a temperature at which the metal powders produce an intermetallic phase.

The invention also describes a method for producing circuits and equipped circuits by using the above-mentioned system.

According to the present invention, electrically conductive interconnecting structures such as circuits are obtained providing excellent adhesion, good electrical conductivity and solderability.