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(71) **Applicant** *(for all designated States except US)*: **OUTOKUMPU OYJ** [FI/FI]; Riihitontuntie 7, FIN-02200 Espoo (FI).

(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only)*: **HYVÄRINEN, Olli** [FI/FI]; Suoniityntie 18, FIN-28220 Pori (FI). **TASKINEN, Pekka** [FI/FI]; Pensastaskuntie 28, FIN-28220 Pori (FI). **SUORTTI, Tuija** [FI/FI]; Tammihäräntie 6, FIN-28200 Pori (FI).

(74) **Agent: PAPULA OY**; P.O.Box 981 (Fredrikinkatu 61 A), FIN-00101 Helsinki (FI).

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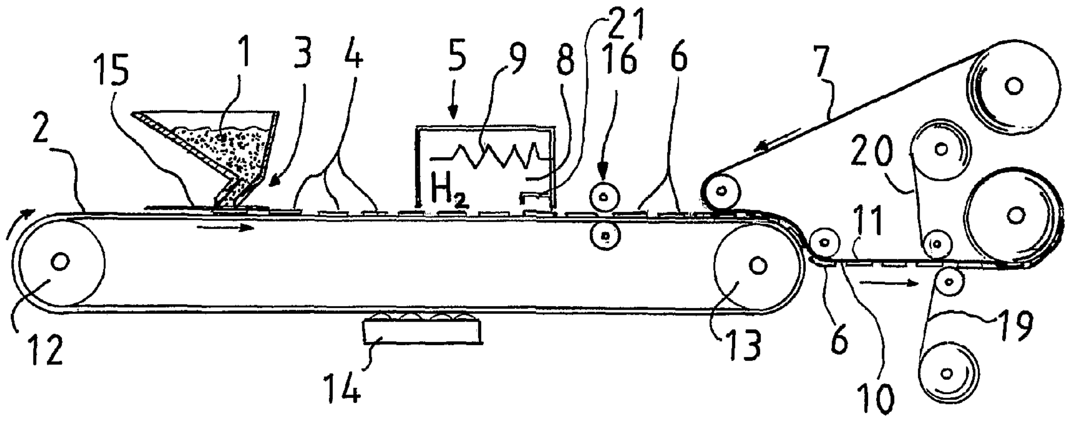

(57) **Abstract:** In the method and system for manufacturing an electrically conductive metal foil structure, a paste (1) containing fine-grained copper oxide powder with a grain size of the order of 10 mm or less, a binding agent and possible alloying elements and additives. Using a forming device (3), a conductor blank (4) of desired shape is formed from the paste (1) on the surface of a carrier substrate (2). The conductor blank (4) is metallized and sintered in a metallizing and sintering device (5) at an elevated temperature to form a continuous and electrically conductive copper foil (6). The carrier substrate (2) has a substantially non-adhesive surface, which is made of a material capable of withstanding the elevated temperature used for the metallization and/or sintering and non-reacting with the substances contained in the paste so that the copper foil (6) can be detached from the carrier substrate. After the metallization and sintering, the copper foil (6) can be detached and transferred further.

WO 2004/080137 A1

METHOD AND SYSTEM FOR MANUFACTURING AN ELECTRICALLY CONDUCTIVE METAL FOIL STRUCTURE

FIELD OF THE INVENTION

The present invention relates to a method as defined in the preamble of claim 1. In addition, the invention relates to a system as defined in the preamble of claim 29.

BACKGROUND OF THE INVENTION

In prior art relating to circuit board manufacture, e.g. in specification US 5,261,950, a method is disclosed wherein a fine-grained copper oxide powder having a granular size of the order of 10 µm or less is used for the formation of a paste. The paste is formed from copper oxide powder, a binding agent, alloying elements and additives. From the paste, a conductor blank of desired shape is formed on the surface of a substrate. The oxidic conductor blank on the surface of the substrate is reduced using e.g. hydrogen (i.e. metallized) and sintered using a high temperature to produce a continuous copper foil.

In prior-art methods of this type using copper oxide powder as a starting material which is reduced and sintered to form a metallic copper foil, the aim is always that the copper foil should remain permanently fixed to the surface of the underlying substrate. For this purpose, the prior-art paste contains a glass additive, among other things, which forms a strong bond to the underlying ceramic substrate. Since the metallization and sintering are performed at a very high temperature, which usually has to be at least of the order of over 500°C to ensure adequate sintering, the substrate must be made of a material having a good heat resistance, such as ceramic.

The prior-art method has the advantage that a copper foil, which has a good electric conductivity, can be formed electrically by a fast and low-cost procedure from copper oxide, which is cheap and has the characteristics of an insulator. Copper oxide powder as a starting material is chemically stable, unlike e.g. pure copper powder, which is so active that it tends to oxidize. In addition, copper oxide is cheap. In the copper foil manufacturing process, no copper oxide is wasted, so the efficiency and yield are good.

The problem with the prior-art method is that it is not suited for use in the formation of a conductor pattern in practical applications where a conductor pattern formed from copper foil having good electrical conductivity is to be laminated onto a plastic or paper substrate. Such applications include e.g. inductive sensors and antennas for various electrotechnical applications. It is obvious that a plastic or paper substrate would be destroyed if it were exposed to high temperatures as mentioned above.

A special application which uses thin conductive metal foil on a plastic and/or paper substrate is a radio-frequency identification device ("RF-ID tag"; also called as 'transponder'; see Figs. 2, 3). The RF-ID tag is an electrical circuit consisting of a microcircuit, a memory and an antenna, laminated in plastic or other surface material. RF-ID tags can be activated e.g. by an external HF or UHF field, so they need no power source. RF-ID tags can be used for the identification of objects (products, persons, animals, etc.) by using memory data stored in the microcircuit. Identification takes place from a distance, which varies depending on the used technology and the effective regulations. For the identification, the antenna produces an electric current for the microcircuit when in the field of a reader. The RF-ID device can be provided with a sticker surface to allow it to be attached to an object. RF-ID tags may be disposable, like those used on foodstuff and other consumer goods packages, being destroyed after use, or they may be designed for continuous use, such as those used in logistic applications, bank cards, personal identification cards or other ID applications.

A typical RF-ID antenna has a thickness of 5 - 50 μm and an area of 10 - 50 mm x 10 - 100 mm. The printed antenna is generally produced by the silk-screen printing technique. Electrical conductivity is provided by using conductive powder, which may be produced from e.g. silver, copper and graphite. Besides printed antennas, antennas are nowadays also made from e.g. thin copper wires by coiling and flattening the wires so as to form a thin foil. Other production methods include evaporating and electrolytic or chemical precipitation. From a continuous copper foil, which may be produced by different methods, the unnecessary parts are etched away to create an antenna pattern. The portion to be etched away may well exceed 50%. As the removal of the extra metal requires separate work stages, efforts are continuously being made in the field to create an antenna that is as near net shape as possible already at an early stage of the manufacturing process.

There are also prior-art methods wherein an RF-ID antenna is formed by die cutting from a thin metal foil. The problems are that in this manufacturing method the quality is poor and most of the metal foil is lost as waste.

Specification EP 0991014 discloses a photolithographic method of forming an RF-ID antenna from silver powder using various light-sensitive films, at least one intermediate agent facilitating the processing and two types of conductive metallic powder. Silver is expensive, so the antenna produced by this method is also expensive.

Especially in an RF-ID application, there is the problem that RF-ID tag antennas produced by prior-art manufacturing methods are expensive, which is an impediment to their more widespread use in disposable applications, such as e.g. foodstuff packages.

Generally known is also a method for producing a thin continuous foil e.g. by an electrolytic precipitation process. This method involves a cathode drum rotating in an electrolysis vessel and an arc-shaped anode consisting of one or more parts in the bottom part of the vessel. An electrolyte is supplied between the anode and the cathode, and the aim is to precipitate a copper foil as continuous and uniform as possible onto the surface of the cathode drum. When the deposited foil rises above the electrolyte, it is detached from the cathode and passed on to a further treatment process. The method has been under development since the 1930's, and it is described e.g. in US patent 2,044,415 and in published patent application US 2002/5363.

OBJECT OF THE INVENTION

The object of the present invention is to overcome the above-mentioned drawbacks.

A specific object of the invention is to disclose a method and system for producing an electrically conductive metal foil structure that provides all the known advantages of copper foil produced from copper oxide powder by metallizing and sintering while at the same time the finished copper foil is detachable from the carrier substrate and can be transferred onto another substrate, i.e. onto an application substrate, which need not be made of a material capable of withstanding the conditions required for metallizing and sintering treatments.

A further specific object of the invention is to disclose a method and system for producing a cheap RF-ID antenna having a good electrical conductivity.

BRIEF DESCRIPTION OF THE INVENTION

The method of the invention is characterized by what is disclosed in claim 1. The system of the invention is characterized by what is disclosed in claim 29.

In the method, fine-grained copper oxide powder having a grain size of the order of 10 µm or less is provided for the formation of a paste; a paste is formed from copper oxide powder, a binding agent and possible alloying elements and additives; using the paste, a conductor blank of desired shape is formed on the surface of a carrier substrate; the conductor blank on the surface of the carrier substrate is metallized and sintered at an elevated temperature to form a continuous and electrically conductive copper foil.

According to the invention, the carrier substrate, which has a substantially non-adhesive surface made of a material capable of withstanding the elevated temperature used for the metallization and/or sintering and non-reacting with the substances contained in the paste, is arranged to allow the copper foil to be detached from the carrier substrate. After the metallization and sintering, the copper foil is detached from the carrier substrate and can be transferred further. The copper foil can be transferred onto the surface of an application substrate.

Correspondingly, the system comprises a paste formed from fine-grained copper oxide powder having a grain size of the order of 10 µm or less, a binding agent and possible alloying elements and additives. Further, the system comprises a carrier substrate. Moreover, the system comprises a forming device for forming the paste into a conductor blank having the shape of a desired conductor pattern on the surface of the carrier substrate. In addition, the system comprises a metallizing and sintering device for metallizing and sintering the conductor blank on the surface of the carrier substrate at an elevated temperature to form a continuous and electrically conductive copper foil.

According to the invention, the carrier substrate has a substantially non-adhesive surface of a material capable of withstanding the elevated temperature used for the metallization and/or sintering and non-reacting with the substances contained in the paste so that the copper foil can be detached from the carrier substrate. Further, the system comprises an application substrate separate from the carrier substrate, and means for detaching the copper foil from the carrier substrate and transferring it onto the surface of the application substrate.

The invention has the advantage that, using the method and system, a good-quality metal foil structure having a good electrical conductivity is produced at a low cost, and that, by virtue of the carrier substrate used, the metal foil structure can be easily detached and transferred onto an actual application substrate.

In an embodiment of the method and/or system, the surface of the application substrate is arranged to form an adhesion surface having an adhesion to the copper foil that is greater than the adhesion of the substantially non-adhesive surface of the carrier substrate. The adhesion surface of the application substrate is brought into contact with the copper foil on the carrier substrate to detach the copper foil from the carrier substrate and transfer it onto the application substrate.

In an embodiment of the method and/or system, the carrier substrate is a polished smooth-surfaced sheet or band whose substantially non-adhesive surface is made of graphite. The graphite has preferably a surface roughness R_a of the order of 0.5 µm or less. Graphite is a cheap material having a good heat resistance. It is soft and can be easily polished by a simple technique to make it smooth enough to allow the copper foil to be readily detached from it, and it is regenerable for reuse so that it can be used multiple times. Graphite has excellent properties as a carrier substrate material.

In an embodiment of the method and/or system, the carrier substrate is a smooth-surfaced sheet or band whose substantially non-adhesive surface is made of a ceramic material.

In an embodiment of the method and/or system, the copper foil is rolled to a suitable thickness, rigidity and strength while it remains on the carrier substrate, a high production speed being thus achieved. The rolling can also be performed while the sintered/reduced copper foil is still hot, i.e. at a temperature of over 300°C, in which case the formation of the conductor blank on the carrier substrate and the sintering/reduction and rolling can all be carried out on the same production line.

In an embodiment of the method and/or system, the conductor blank is heated by infrared radiation for its metallization and sintering. For this purpose, the system may comprise an infrared radiation source.

In an embodiment of the method and/or system, the conductor blank is heated by microwave radiation for the metallization and sintering. For this purpose, the system may comprise a microwave radiation source.

In an embodiment of the method and/or system, the copper oxide powder consists of copper(I)oxide and/or copper(II)oxide, which is prepared from a water solution by precipitating at a controlled temperature, solution strength and other conditions controlling the properties and by drying to produce active, fine-grained, pure and homogeneous copper oxide powder. By precipitating from a water solution, sufficiently fine-grained and homogeneous powder is obtained.

In an embodiment of the method and/or system, the copper oxide powder is treated with an organic intermediate agent to form a reducing compound on the surfaces of the copper oxide particles of the powder. As an organic intermediate agent, e.g. acetic acid, oxalic acid and/or formic acid may be used. Metallization takes place by the aid and agency of these because they are reducing compounds. As it breaks down, such as an organic intermediate agent reduces the copper oxide next to it. The reducing intermediate agent added to the paste allows the metallization to be effected at a lower temperature. However, an organic intermediate agent alone is not sufficient without metallization performed at a high temperature, but it makes it possible to significantly reduce the temperature to be used, e.g. to 500°C.

In an embodiment of the method and/or system, an alloying element is mixed in the copper oxide powder to form a homogeneous alloy, said alloying element being selected from the following group: silver, gold, platinum, palladium, oxides of silver, gold, platinum and palladium, halogenides of silver, gold, platinum, palladium or mixtures of these. By using alloying elements, the properties of the alloy can be improved.

In an embodiment of the method and/or system, an organic binding agent serving as a binder, such as polyvinylbutyral (PVB) or dibutylphtalate (DBP), is mixed in the paste. In addition, alloying elements serving to control the rheology, creep and/or adhesion may be mixed in the paste. The printability of the paste can be adjusted by using intermediate agents like these, which may be resins, various dispersing agents, solvents, etc.

In an embodiment of the method and/or system, the conductor blank is formed as a paste layer having a thickness of about 5 - 100 µm.

In an embodiment of the method and/or system, the conductor blank is formed by an impression printing technique, such as silk-screen printing, tampo printing, in which case the conductor blank forming device in the system is a printing device, such as a silk-screen printing or tampo printing device. The conductor blank can also be formed by an output printing technique known from computer output technology, such as by using an ink jet output device or a laser output device, in which case individual conductor patterns of widely varying shapes can be easily created by a computer-aided method.

In an embodiment of the method and/or system, the metallization and sintering of the conductor blank to form a copper foil are performed in a hydrogen atmosphere in a chamber hermetically isolated from the environment. The chamber is provided with a heater, by means of which the conductor blank to be metallized and sintered is brought to a temperature exceeding 500 °C, preferably of the order of 1000 °C. When the copper oxide is reduced to copper, a porous spongy structure is formed, which has to be sintered to make it coherent. Since the spongy metal structure has a large area, even as large as hundreds of square meters in a gram of material, it would tend to oxidize unless a hydrogen atmosphere were provided in the chamber. At a temperature of the order of 1000 °C, thorough sintering takes place so that the spongy metal becomes sintered, i.e. solidified so as to form a continuous metal layer, which is simultaneously deactivated and will not oxidize again. When a temperature as mentioned above is used, the metallization and sintering take place quickly, in a few minutes, so the manufacturing process is fast and can be implemented on a continuous production line. After metallization the copper foil is cooled down to at least 170 °C under protective, i.e. non-oxidising, atmosphere in order to allow further processing. It is possible that the electrically conductive pattern is cooled down to even lower temperature such as 100 °C. The copper foil is cooled in order to prevent its reoxidation when it comes into room atmosphere. For example, hydrogen and/or nitrogen gas containing atmosphere can used as a non-oxidising atmosphere.

By this method, it is also possible to produce multi-layer conductor structures. In an embodiment, on top of a first layer formed by a conductor blank or copper foil, a second layer is formed from an electrically conductive material. To allow the superimposed conductor patterns to be at different potentials during use, an electrically insulating dielectric layer is formed on the first layer, and a second layer is only then formed on the dielectric layer. The second layer may be formed from the same material or a different material than the underlying first layer. The material of the second layer may be selected from the following group: copper, silver, gold, platinum, palladium, oxides of copper, silver, gold, platinum, palladium or mixtures of these. The second layer is formed before the metallization and sintering of the first layer, in other words, while the lower conductor blank remains in an oxidic form. Alternatively, the second layer may be formed after the metallization and sintering of the first layer. The second layer is preferably formed in the same way as the first layer. The metal foil structure may comprise several electrically conductive layers one upon the other, separated by a dielectric layer.

In an embodiment of the method and/or system, the copper foil forms a conductor pattern for a circuit board, and the application substrate onto which the copper foil is transferred is a circuit board blank.

In an embodiment of the method and/or system, the copper foil constitutes the conductor pattern of an integrated circuit, in which case the application substrate onto which the conductor pattern is transferred is the semiconductor base of the integrated circuit.

In an embodiment of the method and/or system, the copper foil is the antenna of an RF-ID device, in which case the application substrate, onto the first surface of which the conductor pattern is transferred, is made of paper, plastic or similar flexible material.

In an embodiment of the method and/or system, the copper foil is transferred from the carrier substrate onto a continuous web of application substrate in successive order.

In an embodiment of the method and/or system, the copper foil is the antenna of an RF-ID device, in which case the application substrate may be made of paper, plastic or a similar material. The application substrate has a first surface for receiving the copper foil and a second surface that is or that can be provided with a sticker glue layer.

LIST OF FIGURES

In the following, the invention will be described in detail by the aid of an embodiment example with reference to the attached drawing, wherein

Fig. 1 presents a diagram representing an embodiment of the system of the invention for implementing an embodiment of the method of the invention,

Fig. 2 presents an RF-ID device, i.e. transponder, and

Fig 3 shows another example of transponder.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 presents an example of a system for manufacturing an electrically conductive metal foil structure. Active, fine-grained copper(I)oxide powder having a grain size of the order of 10 µm or less (typically 0,5 - 10 µm) has been produced by precipitating from a water solution at a controlled temperature, solution strength and other conditions controlling the properties, by drying into powdery form and by treating so as to improve durability. An alloying element can be added to the copper(I)oxide powder, said alloying element being selected from the group: silver, gold, platinum, palladium, oxides of silver, gold, platinum and palladium, halogenides of silver, gold, platinum, palladium or mixtures of these. The powder may additionally be treated with organic reducing acids, such as acetic acid, oxalic acid or formic acid.

A paste 1 is produced by mixing copper(I)oxide powder prepared as described above, an organic binding agent, such as polyvinylbutyral (PVB) or dibutylphtalate (DBP), and other additives for controlling the rheology, creep, adhesion etc. of the paste, which is used as a printing ink for printing a conductor blank 4 having the shape of a desired conductor pattern as a layer of a thickness of 5- 100 µm on the surface of a carrier substrate 2. The paste 1 may be also applied onto the carrier substrate 2 by any other technique known to the person skilled in the art, such as other impression printing techniques or by methods like computer output techniques. To mention suitable printing techniques, silk, tampo, flexo, gravure, inkjet, laser and litho printing come in question.

In the example presented in Fig. 1, the carrier substrate 2 shown is an endless moving band, which is passed over a drive roll 12 and a diverting roll 13. Alternatively, the carrier substrate 2 used may consist of separate sheets carried successively (not shown) on the production line. The formation of the conductor blank 4 on the surface of the carrier substrate 2 as well as the other subsequent manufacturing steps are performed on the upper horizontal portion of the carrier band 2. At some point along the lower portion of the carrier band 2, a regenerating device 14 for restoring the characteristics of the band surface may be provided.

The conductor blank 4 is formed by printing the paste 1 onto the surface of the carrier substrate 2 by means of a forming device 3, which in the example in Fig. 1 is a silk-screen printing device shown in a diagrammatic form, which squeegees the paste 1 through a mask 15 comprising a part that has the shape of the conductor pattern and admits the paste 1 through it onto the surface of the carrier belt 2 to form successive/adjacent conductor blanks 4. The carrier belt 2 conveys the conductor blanks 4 to a metallizing and sintering device 5, where the conductor blanks 4 on the surface of the carrier belt are metallized and sintered in a hydrogen atmosphere and at a temperature of about 1000 °C, forming electrically conductive and continuous copper foils 6. The metallizing and sintering device 5 comprises a chamber 8 fitted to receive the carrier substrate 2 into the space inside it. The chamber 8 contains a hydrogen atmosphere as mentioned above. Also cooling means 21 are provided to the chamber 8 at the outlet side of the chamber for cooling down the copper foils 6 after metallization. The cooling takes place in the protective atmosphere provided by the hydrogen in the chamber 8.

The heating device 9 used to heat the conductor blank may be an IR or microwave radiation source or any other heating device known to the person skilled in the art.

After metallizing and sintering device 5, the copper foils 6 can be rolled on the carrier band 2 by the action of a roller pair 16 to a suitable thickness.

The carrier belt 2 or at least that surface of it on which the conductor pattern is formed is made of a substantially non-adhesive material that is capable of withstanding the metallizing and/or sintering temperature and that does not react with the substances contained in the paste 1. The carrier band 2 is preferably made of graphite, which has been polished to a surface roughness R_a of the order of 0.5 μm or less and from which the copper foil 6 can be easily detached and transferred onto the surface of an application substrate 7. The surface of the application substrate 7 has an adhesion to the copper foil 6 that is greater than the adhesion of the substantially non-adhesive surface of the carrier substrate 2.

Also referring to Figs. 2 and 3 the method and system are particularly advantageously applicable for the manufacture of a copper foil 6 designed for use as an antenna of a radio-frequency identification device (RF-ID, also called as 'transponder'), in which case the application substrate 7 receiving the copper foil 6 is made of plastic, paper or a similar flexible material. In the example in Fig. 1, the application substrate 7 is in the form of a windable, continuous web, onto which the copper foils 6 are transferred in successive order by transfer lamination. The application substrate web 7 has a first surface 10, whose adhesion to the copper foil 6 is greater than the adhesion of the graphite surface of the carrier band 2, so that when the carrier substrate web 7 is brought into surface contact with the carrier band 2, the copper foils 6 are transferred onto the application substrate 7 The adhesive layer touches the surface of the carrier belt 2 and the electrically conductive pattern 6 is released from the carrier belt 2 by adhesive forces, and thus the pattern is transferred to the application substrate 7, which in this case is a continuous flexible web. After the transfer lamination, suitable protective additional layers may be laminated on one side or both sides of the aforesaid web in a known manner, such layers being indicated in the figure by reference numbers 19 and 20.

Further referring to Figs 2 and 3, generally, an integrated circuit on a chip can be attached directly to the circuitry pattern 6, or the chip has been first attached to a separate module, which is attached to the application substrate. The techniques used for connecting the chip or the module are known as such. The transponders described in Figs. 2, 3a and 3b comprise on the application substrate 7 an integrated circuit on a chip 18 and a circuitry pattern 6 but instead of the bare chip 18, also the module can be used. When an electrical connection is formed between the circuitry pattern 6 and the module comprising the chip 18 it is possible that the connection is formed through at least one capacitor. In Fig. 2, an electrically insulating pattern 17 has been formed to separate electrically conductive leads from each other. The material of the module can be of the same material as the application substrate 7, or it can be of another material.

As seen in Figs. 2 and 3 the configuration of the circuitry pattern can vary enormously. The circuitry pattern shown in Fig. 2 is a coil-antenna intended for use in the HF region, the circuitry pattern shown in Fig. 3 is intended for use in the UHF region.

The price of an RF-ID antenna produced by the method of the invention is a fraction of the price of the antenna produced by prior-art methods.

Although the above presentation describes the manufacture of an RF-ID tag as a special application, the method and system of the invention may also be applicable in the manufacture of circuit boards and integrated circuits. When the copper foil forms a conductor pattern for a circuit board, the application substrate onto which the copper foil is transferred is a circuit board blank. If the copper foil is a conductor pattern for an integrated circuit, then the application substrate onto which the conductor pattern is transferred is the semiconductor base of the integrated circuit.

By following the principles described above, the system can be easily converted for the manufacture of multi-layer foil structures e.g. by providing in the production line a number of forming devices 3 and metallizing and sintering devices 5 corresponding to the number of successive layers to be formed. A multilayer foil structure comprises two or more superimposed conductor layers formed in the aforesaid manner and separated from each other by electrically insulating intermediate layers.

The invention is not limited to the embodiment examples described above; instead, many variations are possible within the scope of the inventive concept defined in the claims.

CLAIMS

1. Method for manufacturing an electrically conductive metal foil structure, in which method

- fine-grained copper oxide powder having a grain size of the order of 10 µm or less is provided for the formation of a paste,

- a paste is formed from the copper oxide powder, a binding agent and possible alloying elements and additives,

- using the paste, a conductor blank of desired shape is formed on the surface of a carrier substrate,

- the conductor blank on the surface of the carrier substrate is metallized and sintered at an elevated temperature to form a continuous and electrically conductive copper foil, characterized in that

- the carrier substrate, which has a substantially non-adhesive surface made of a material capable of withstanding the elevated temperature used for the metallization and/or sintering and non-reacting with the substances contained in the paste, is arranged to allow the copper foil to be detached from the carrier substrate, and

- after the metallization and sintering, the copper foil is to be detached from the carrier substrate.

2. Method according to claim 1, characterized in that the carrier substrate used consists of a polished smooth-surfaced sheet or band whose substantially non-adhesive surface is made of graphite.

3. Method according to claim 2, characterized in that the graphite has a surface roughness R_a of the order of 0.5 µm or less.

4. Method according to claim 1, characterized in that the carrier substrate used consists of a smooth-surfaced sheet or band whose substantially non-adhesive surface is made of a ceramic material.

5. Method according to any one of claims 1 - 4, characterized in that the copper foil is rolled on the carrier substrate.

6. Method according to any one of claims 1 - 5, characterized in that the conductor blank is heated by infrared radiation for the metallization and sintering.

7. Method according to any one of claims 1 - 6, characterized in that the conductor blank is heated by microwave radiation for the metallization and sintering.

8. Method according to any one of claims 1 - 7, characterized in that the formation of the conductor blank on the carrier substrate, the metallization and possible sintering are performed on the same production line.

9. Method according to any one of claims 1 - 8, characterized in that the copper oxide powder consists of copper(I)oxide and/or copper(II)oxide prepared from a water solution by precipitating at a controlled temperature, solution strength and other conditions controlling the properties and by drying to produce an active, fine-grained, pure and homogeneous copper oxide powder.

10. Method according to any one of claims 1 - 9, characterized in that the copper oxide powder is treated with an organic intermediate agent to form a reducing compound on the surfaces of the copper oxide particles of the powder.

11. Method according to claim 10, characterized in that the organic intermediate agent se-

lected for use is one of the group: acetic acid, oxalic acid, formic acid.

12. Method according to any one of claims 1 - 11, characterized in that an alloying element is mixed in the copper oxide powder to form a homogeneous alloy, said alloying element being selected from the following group: silver, gold, platinum, palladium, oxides of silver, gold, platinum and palladium, halogenides of silver, gold, platinum, palladium or mixtures of these.

13. Method according to any one of claims 1 - 12, characterized in that an organic binding agent serving as a binder is mixed in the paste.

14. Method according to claim 13, characterized in that the binding agent mixed in the paste is polyvinylbutyral (PVB) and/or dibutylphtalate (DBP).

15. Method according to any one of claims 1 - 14, characterized in that alloying elements controlling the rheology, creep and/or adhesion are mixed in the paste.

16. Method according to any one of claims 1 - 15, characterized in that the conductor blank is formed as a paste layer having a thickness of about 5 - 100 µm.

17. Method according to any one of claims 1 - 16, characterized in that the conductor blank is formed by an impression printing technique, such as silk-screen printing, tampo, flexo, gravure, litho printing, or by an output printing technique, such as an inkjet or laser output technique.

18. Method according to any one of claims 1 - 17, characterized in that the metallization and sintering of the conductor blank to form a copper foil are performed in a hydrogen atmosphere and at a temperature exceeding 500 °C, preferably of the order of 1000 °C.

19. Method according to any one of claims 1 - 18, characterized in that after metallization and sintering the copper foil is cooled down.

20. Method according to claim 19, characterized in that the copper foil is cooled down in a protective non-oxidising atmosphere.

21. Method according to claim 20, characterized in that the protective non-oxidising atmosphere is a hydrogen and/or nitrogen gas containing atmosphere.

22. Method according to any one of claims 1 - 21, characterized in that, on top of the first layer formed by the conductor blank or copper foil, a second layer is formed from an electrically conductive material.

23. Method according to claim 22, characterized in that an electrically insulating dielectric layer is formed on the first layer and the second layer is formed on the dielectric layer.

24. Method according to claim 22 or 23, characterized in that the second layer is formed from the same material or a different material than the first layer.

25. Method according to claim 24, characterized in that the material of the second layer is selected from the group: copper, silver, gold, platinum, palladium, oxides of copper, silver, gold, platinum, palladium or mixtures of these.

26. Method according to any one of claims 22 - 25, characterized in that the second layer is formed before the metallization and sintering of the first layer or alternatively after the metallization and sintering of the first layer.

27. Method according to any one of claims 22 - 26, characterized in that the second layer is formed in the same way as the first layer.

28. Method according to any one of claims 22 - 27, characterized in that several electrically conductive layers are formed one upon the other, separated by a dielectric layer.

29. System for manufacturing an electrically conductive metal foil structure, said system comprising

- paste (1) formed from fine-grained copper oxide powder having a grain size of the order of 10 µm or less, a binding agent and possible alloying elements and additives,
- a carrier substrate (2),
- a forming device (3) for forming the paste so as to form a conductor blank (4) having the shape of a desired conductor pattern on the surface of a carrier substrate,
- a metallizing and sintering device (5) for metallizing and sintering the conductor blank on the surface of the carrier substrate at an elevated temperature to form a continuous and electrically conductive copper foil (6), characterized in that the carrier substrate (2) has a substantially non-adhesive surface of a material capable of withstanding the elevated temperature used for the metallization and/or sintering and non-reacting with the substances contained in the paste so that the copper foil (6) can be detached from the carrier substrate.

30. System according to claim 29, characterized in that the carrier substrate (2) is a sheet or band whose substantially non-adhesive surface is a graphite surface polished smooth.

31. System according to claim 30, characterized in that the graphite has a surface roughness R_a of the order of 0.5 µm or less.

32. System according to claim 29, characterized in that the carrier substrate (2) is a

smooth-surfaced sheet or band whose substantially non-adhesive surface is made of a ceramic material.

33. System according to any one of claims 29 - 32, characterized in that the copper oxide powder of the paste (1) is a powder of copper(I)oxide and/or copper(II)oxide precipitated from a water solution at a controlled temperature, solution strength and other conditions controlling the properties and dried to form an active, fine-grained, pure and homogeneous copper oxide powder.

34. System according to any one of claims 29 - 33 , characterized in that the copper oxide powder (1) has been treated with an organic intermediate agent to form a reducing compound on the surfaces of the copper oxide particles of the powder.

35. System according to claim 34, characterized in that the organic intermediate agent has been selected from the group: acetic acid, oxalic acid, formic acid.

36. System according to any one of claims 29 - 35 , characterized in that the copper oxide powder of the paste (1) contains an alloying element selected from the group: silver, gold, platinum, palladium, oxides of silver, gold, platinum and palladium, halogenides of silver, gold, platinum, palladium or mixtures of these.

37. System according to any one of claims 29 - 36, characterized in that the paste (1) contains an organic binder.

38. System according to claim 37, characterized in that the organic binder consists of polyvinylbutyral (PVB) and/or dibutylphtalate (DBP).

39. System according to any one of claims 29 - 38, characterized in that the paste (1) contains alloying elements controlling the rheology, creep and/or adhesion.

40. System according to any one of claims 29 - 39, characterized in that the conductor blank (4) is a paste layer having a thickness of 5 - 100 μm.

41. System according to any one of claims 29 - 40, characterized in that the metallizing and sintering device (5) comprises

- a chamber (8) fitted to receive the carrier substrate (2) and having a hydrogen atmosphere inside, and

- a heating device (9) for heating the conductor blank in the chamber (8) to an elevated temperature exceeding 500 °C, preferably of the order of 1000 °C for the metallization and sintering of the conductor blank.

42. System according to claim 41, characterized in that the heating device (9) is an infrared radiation source.

43. System according to claim 41, characterized in that the heating device (9) is a microwave radiation source.

44. System according to any one of claims 29 - 43, characterized in that the system comprises cooling means (21) for cooling down the copper foil under protective non-oxidising atmosphere.

45. System according to claim 44, characterized in that the cooling means (21) are disposed in a near proximity to the metallizing and sintering device (5), or integrated thereto.

46. System according to any one of claims 29 - 45, characterized in that the forming device (3) is an impression printing device, such as a silkscreen, flexo, gravure, or tampo printing device.

47. System according to any one of claims 29 - 46, characterized in that the forming device (3) is an output printing device, such as an ink-jet or laser printing device.

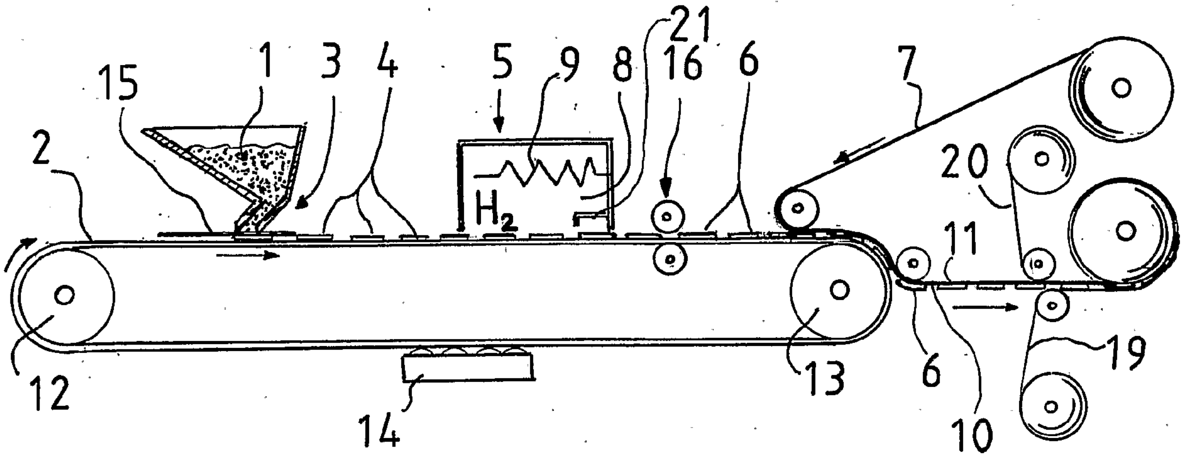

Fig 1

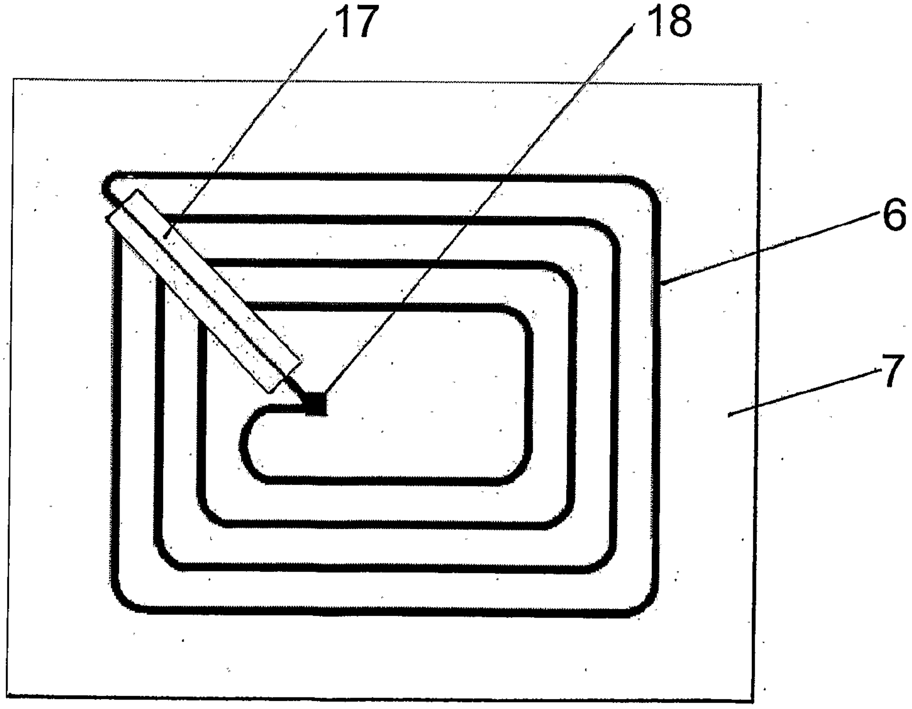

Fig 2

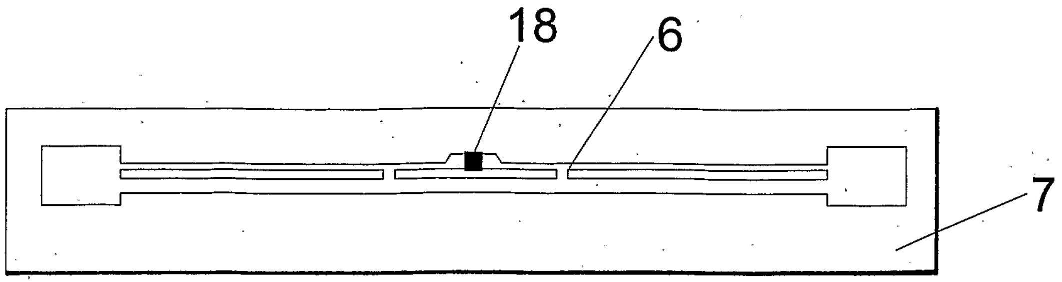

Fig 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 03/00632

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H05K 3/04, H05K 3/12
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)

IPC7: H05K

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 29905472 U1 (VOGT ANDREAS), 27 July 1999 (27.07.99), see whole document --	1-47
A	EP 0991014 A2 (TOPPAN FORMS CO., LTD), 5 April 2000 (05.04.00), see whole document --	1-47
A	DE 19853018 C1 (PROMETRON GMBH), 20 April 2000 (20.04.00), see whole document -- --------	1-47

☐ 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
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"P" document published prior to the international filing date but later than the priority date claimed
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"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
18 December 2003

Date of mailing of the international search report
29-12-2003

Name and mailing address of the ISA/
Swedish Patent Office
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer
Stefan Hultquist/MN
Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

31/10/03

International application No.

PCT/FI 03/00632

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 29905472 U1	27/07/99	NONE	
EP 0991014 A2	05/04/00	CN 1262492 A	09/08/00
		JP 2000113138 A	21/04/00
		KR 2000023478 A	25/04/00
		SG 74754 A	22/08/00
		TW 460560 B	00/00/00
		US 6165386 A	26/12/00
		JP 2000219829 A	08/08/00
		JP 2000219824 A	08/08/00
		JP 2000286550 A	13/10/00
		JP 2000315705 A	14/11/00
		JP 2000319583 A	21/11/00
		JP 2000319592 A	21/11/00
		JP 2000319593 A	21/11/00
		JP 2000339428 A	08/12/00
		JP 2000172813 A	23/06/00
DE 19853018 C1	20/04/00	DE 19914032 A	28/09/00