

PRINTED CIRCUIT BOARDS WITH SOLID INTERCONNECT AND METHOD OF PRODUCING THE SAME

FIELD OF THE INVENTION

5 The present invention is related to printed circuit boards. In particular, the present invention is related to methods of producing interconnects in single or multiple layer printed circuit boards or substrates.

BACKGROUND OF THE INVENTION

10 Printed circuit boards (PCB's), including rigid, flexible, single, double and multilayer boards have found important uses in the semi-conductor and electronic industry. A PCB typically contain at least one dielectric layer with one or both sides metallized to form circuitry. Interconnections between the layers of metallic circuitry are often required such that the various metallic
15 layers may communicate with each other electrically.

 Conventional methods of fabricating a PCB board with interconnects involves the use of lasers or mechanical drills. The mechanical method is useful for drilling interconnecting holes which span the entire depth of the layers. For holes which only span one or more core or dielectric layers but
20 not all layers, controlled depth drilling would be needed. However, mechanically controlling the depth of drilling is extremely difficult to perform reliably, and therefore not widely used. Another widely used method for

fabrication of PCB with blind or blind via is to use sequential lamination where cladded cores are mechanically drilled and plated before laminating all the cores to form a multi-layer PCB. Where the via diameter is small, using mechanical drilling becomes difficult, and laser drilling is preferred.

5 In the laser method, a laser beam is used to form a via before plating is performed on the via such that electrical connection is formed. A CO₂ laser is typically used to drill the hole in the dielectric layer for the interconnection. This laser is effective in cutting through the polymeric resin, but cannot cut through metal. Therefore this technique is particularly useful in forming vias
10 of a controlled depth by providing a metallic layer below the dielectric layer wherethrough the via is to be formed. After the via or hole is drilled through the dielectric or core layer, electroless plating is performed to plate the metallic surface on the hole to provide electrical connection. However, an indentation is typically left in the plated via which is undesirable, since it can
15 easily trap contaminants, and also occupy previous space on that surface, as useful landscape cannot be made directly on the indentation. One prior art method to solve the indentation problem is to use solder paste or other electrically conductive paste to close the hole and also to serve as a composite interconnect. US patent 5,817,404 to kawakita et al. describes
20 the use of an electrically conductive paste containing electrically conductive particles and a thermosetting resin to fill the vias or holes after laser drilling. The paste, however, may sustain cracks during the multiple lamination process to form different layers of the board. This is because the paste is typically a composite of various materials, which have different coefficients of
25 expansion. Repeated cycles of heating and cooling may create internal

cracks in the composite material, or stresses along the plating of the via, affecting the effectiveness of the electrical interconnection.

OBJECT OF THE INVENTION

- 5 It is an object of the present invention to provide a PCB interconnect to overcome the shortcomings as stated above.

It is another object of the present invention to provide a PCB with an interconnect of solid metal.

- It is a further object to provide a method of making a printed circuit board with
10 a solid metallic interconnect.

SUMMARY OF THE INVENTION

The present invention provides an solid metallic interconnect which gives a stable and effective electrical interconnection between metallic layers separated by one or more dielectric layers. As solid metal is found in the interconnect, cracking caused by differences in a composite material may be eliminated. A solid metallic interconnect is defined as an interconnection made of solid metal, as opposed to interconnects made of composite material. Solid metal includes copper, copper with a thin layer of other metal such as gold, or metal alloy. composite material includes solder paste and other electrically conducting particles mixed with resin.

A method of producing the interconnect involves creating the solid metallic interconnect by metallic plating on the base copper at the interconnecting location, followed by the lamination of the appropriate dielectric layer. This dielectric layer may have a pre-cut hole corresponding to the solid metallic interconnect, which is registered with the interconnect before lamination. Alternatively, the solid interconnect may be used to pierce through the dielectric layer. Yet another alternative is to use a liquid or wet-type dielectric which can be applied to the base copper. A layer of dielectric polymer is then removed from the interconnect by traditional methods. This is followed by electroless plating and conventional metallization and circuitry formation. This process may also be applied to interconnect which spans more than one dielectric layer.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram to show a conventional method for producing interconnects.

Figure 2 is a schematic diagram to show one method according to the present invention for producing solid metallic interconnects.

Figure 3 is a schematic diagram to show another method according to the present invention for producing solid metallic interconnects.

Figure 4 is a schematic diagram to show a further method according to the present invention for producing solid metallic interconnects.

Figure 5 shows a multi-layered printed circuit board according to the present invention.

DESCRIPTION OF THE INVENTION

The solid metallic interconnect according to the present invention may be produced from a solid metal such as copper such that not only is the indentation eliminated, but the solid material also provides a stable and effective electrical interconnection between the metallic layer.

Figures 1A to 1E show a prior art process of producing an interconnect, and a product produced thereof. In this example, a PCB of two dielectric layers and three metallic layers is shown. For multilayer boards, the layers are typically produced from the innermost to the outermost layers. Figure 1A shows dielectric layer 22 cladged by lamination with metallic layers 24 and 26 on the two opposing surfaces. This may be produced by any

conventional method such as photolithography and plating. Figure 1B shows dielectric layer **28** and metallic layer **30** laid onto metallic layer **24**. For laser drilling, layers **28** and **30** are typically a single product such as a copper coated resin film, in which layer **30** is a copper foil coated onto polymeric resin layer **28**. CO₂ laser is typically used to drill the hole in the dielectric layer for the interconnection. This laser is effective in cutting through the polymeric resin but cannot cut through metal. Therefore, to allow CO₂ laser drilling to occur, a mask is first used to protect metallic layer **30** and to expose the site on which the interconnection is to be made. Then conventional etching is performed such that the metallic coating at position **32** is removed, as shown in Figure 1C. Laser drilling is then used to form hole **34**, as shown in Figure 1D. This is followed by the removal of a thin layer of resin using conventional methods such as plasma ablation or desmearing. These resin removal techniques are needed to ensure that metallic surface **24** is completely free of residual non-conducting resin. Then masking and electroless plating is performed such that a metallic layer **36** is deposited on the wall of hole **34**. Further photolithography, metal plating and etching may be performed as known in art to produce the desired PCB.

It is clear from the description above and from Figure 1E that hole **34** is not completely filled using the conventional electroless plating method to produce the interconnection, and indentation **38** is found. This can lead to problems such as rupturing or bubbling due to entrapment of air during lamination of the next layer. As mention in the previous section, the solution in the art is to fill indentation **38** with electrically conductive epoxy or paste as a filler after electroless plating. However, the difference in material

between the composite filler and the metallic wall **36** may give cracks when subjected to temperature cycling in the environment in the subsequent assembly processes.

Figures 2A-F show one method of producing a solid metallic interconnect according to the present invention, and a product produced using this method. Figure 2A shows a dielectric layer **40** with two metallized surfaces **39** and **41**. Conventional photolithography and plating are then performed to create circuitry **42** and **44** as shown in Fig. 2B. Before etching is performed on the base copper, layers **39** and circuitry **42** are covered with mask **46**, exposing only position **43** where the solid metallic interconnection is to be made, as shown in Figure 2C. Then electrolytic plating is performed such that a metallic post **48** is formed. Metals such as copper and/or nickel may be used for plating. An additional layer of etch-resistant metal such as gold may also be plated on the surface of the post to protect the post during the subsequent etching step. The mask is then removed and base copper **38** etched by conventional methods as shown in Figure 2D. As a further example, to produce the next layer of the board, a copper coated resin layer containing a layer of dielectric **50** and a layer of copper foil **51**, with a pre-cut hole corresponding to the position of the metallic post (i.e. the interconnection) is registered on layer **42** as shown in Fig. 2E. This is followed by conventional curing, for example by heat pressing. During the lamination process, the resin flows into the space around post **48**, and encloses it as it cures to form dielectric layer **50**, as shown in Figure 2F. Mechanical brushing is then applied to remove the thin film of resin covering the connective end of post **48**. The tip of the metal post may also be shaped

into a flat surface by brushing at this stage. Conventional lithography, plating, and etching are then performed to create the desired circuitry on metallic layer 52.

Although copper coated resin (which is a combination of layers 50 and 51) is used as an example in Fig. 2F, it is clear that dielectric layer 50 alone may be use. For example, electroless plating may be employed later to create metallic layer 51 on the exposed surface of dielectric layer 50 which can then be used to create circuitry 51.

Figure 3 shows another method of producing another PCB with a solid metallic interconnect according to the present invention. In this example, dielectric layer 56 is cladded with copper foil 58 as shown in Fig. 3A. Two vias or holes 60 are then created by conventional laser technology. Electrolytic plating is then performed such that two solid metallic interconnects 62 are created from metallic layer 58 and inside vias 60, as shown in Fig. 3C. Then brushing is performed to flattened the solid metallic interconnects 62, followed by electroless plating to create a layer of base copper 64 on the upper surface of dielectric layer 56. Then standard photolithography and etching may be performed on metallized surfaces 64 and 58 to create circuitry 66 and 68 respectively. Additional dielectric and metallic layers can then be added and additional solid vias created at various layers according to the teachings disclosed herein.

Figure 4 shows yet another method of producing solid vias according to the present invention. In this example, a layer of copper foil 70 is taped onto a carrier and used as the starting material as shown in Fig. 4A. A photoresist

is placed on foil 70 having holes at the locations corresponding to the solid metallic interconnects to be created (not shown). The solid metallic interconnects 72 are then created by conventional electrolytic plating, as shown in Fig. 4B. A layer of dielectric 74 is then layered above copper foil 70, as shown in Fig. 4C. In this example, no holes corresponding to the solid interconnect is precut. Instead, the solid metallic interconnect is allowed to pierce through the film of dielectric, e.g. a B-stage bond film with or without reinforcement. During heat pressing, the resin will flow around the interconnect and form a good seal around it, as shown in Fig. 4C. This is followed by brushing to flatten the upper surface of solid metallic interconnect and to remove any dielectric material from it. Electroless plating can then be performed on dielectric layer 74, to create an additional metallic layer 76 on the upper surface of dielectric layer 74. Conventional photolithography and etching can then be performed on the metallic layers.

15 Instead of using a film-type of dielectric as described above for Fig. 4C, the wet type of dielectric may also be used. This is achieved by spraying a layer of resin onto copper base 70. During the curing process, the resin will form around the solid interconnect in the same manner as the film-type resin. Brushing, shaping and polishing can then be performed on the solid interconnect as described above. It is clear that the dielectric layers may be produced from wet or dry material, and that solid metallic interconnects may be produced on the same board connecting various metallic layers

From the embodiments given above, it is clear that all types of PCB boards having solid interconnect may be produced. For example, additional dielectric and metallic layers may be added to create a PCB with three core

layers (80, 82 and 84) and four circuitrized metallic layers (86, 88, 90, and 92), and a solid metallic interconnect which connects metallic layers 88, 90 and 92 as shown in Figure 5. It should be understood that other PCB's with solid interconnects spanning one or more dielectric core layer and
5 connecting one or more metallic layers may be produced based on the teachings provided herewith. It is contemplated that many changes and modifications may be made by one of ordinary skill in the art without departing from the spirit and the scope of the invention described.



CLAIMS

- 1 1. A printed circuit board comprising :

2 a first metallic layer and a second metallic layer insulated by at least
3 one dielectric layer, said first metallic layer and said second metallic
4 layer electrically interconnected by at least one solid metallic
5 interconnect.
- 1 2. A printed circuit board according to claim 1 wherein said solid metallic
2 interconnect is made of plated gold, copper, nickel, alloy or a
3 combination thereof.
- 1 3. A printed circuit board according to claim 1 wherein at least one
2 additional dielectric layer is laminated next to said first metallic layer
3 or said second metallic layer.
- 1 4. A printed circuit board according to claim 1 wherein said first metallic
2 layer and second metallic layer is insulated by at least two dielectric
3 layers, said dielectric layers insulating at least one additional metallic
4 layer.
- 1 5. A printed circuit board according to claim 1 wherein said first metallic
2 layer and second metallic layer are insulated by at least two dielectric
3 layers with at least one additional metallic layer therebetween, said
4 additional metallic layer further electrically connected to said first
5 metallic layer.



- 1 6. A printed circuit board according to claim 1 wherein said first metallic
2 layer and second metallic layer are insulated by at least two dielectric
3 layers with at least one additional metallic layer therebetween, said
4 additional metallic layer electrically connected to said first metallic
5 layer via at least one solid metallic interconnect.
- 1 7. A printed circuit board according to claim 1 wherein said first metallic
2 layer and second metallic layer are insulated by at least two dielectric
3 layers with at least one additional metallic layer therebetween, said
4 additional metallic layer electrically connected to said first metallic
5 layer and said second metallic layer.
- 1 8. A printed circuit board according to claim 1 wherein said first metallic
2 layer and second metallic layer are insulated by at least two dielectric
3 layers with at least one additional metallic layer therebetween, said
4 additional metallic layer electrically connected to said first metallic
5 layer and said second metallic layer via at least one solid metallic
6 interconnect.
- 1 9. A method for producing a solid metallic interconnect in a printed circuit
2 board comprising :
- 3 a) protecting a first surface of a metallic layer with a protective
4 layer such that the metallic surface corresponding to at least
5 one interconnect is exposed; and
- 6 b) electroplating on said exposed metallic surface of said metallic
7 layer to form a solid post.



- 1 10. A method according to claim 9 wherein the height of said post is
2 higher than the height of said interconnect.
- 1 11. A method according to claim 9 wherein said protective layer is a
2 photoresist layer, and etching is performed after said plating step to
3 remove said photoresist layer.
- 1 12. A method according to claim 9 wherein said protective layer is a
2 photoresist layer, and said method further comprises the steps of:
- 3 (c) etching to remove said photoresist layer;
- 4 (d) laminating a dielectric layer on said first surface;
- 5 (e) cleaning said top surface of said post to remove non-electrically
6 conducting material;
- 7 (f) shaping said post to the desired shape and height;
- 8 (g) producing a second metallic layer on said dielectric layer
9 opposite said metallic layer; and
- 10 (h) producing electric circuitry on said metallic layer and said first
11 metallic layer whereby an electrical connection is created
12 therebetween via said post.
- 1 13. A method according to claim 9 wherein said protective layer is a
2 dielectric layer, and said method further comprises :
- 3 (c) cleaning said top surface of said post to remove non-electrically
4 conducting material;



- 5 (d) shaping said post to the desired shape and height;
- 6 (e) producing a second metallic layer on said dielectric layer opposite
7 said metallic layer; and
- 8 (f) producing electric circuitry on said metallic layer and said first
9 metallic layer whereby an electrical connection is created
10 therebetween via said post.
- 1 14. A method according to claim 12 wherein said cleaning step comprises
2 a plasma ablation process or a desmearing process; and said
3 shaping step comprises is a mechanical brushing process.
- 1 15. A method according to claim 13 wherein said cleaning step comprises
2 a plasma ablation process or a desmearing process; and said
3 shaping step comprises is a brushing process.
- 1 16. A method according to claim 12 wherein said laminating step is
2 performed by spraying a resin layer onto said first metal surface such
3 that the post pierces through said film.
- 1 17. A method according to claim 12 wherein said laminating step is
2 performed by laying a dielectric film onto said first surface.