

A METHOD OF DEPTH ROUTING AN ELECTRONIC LAYUP AND APPARATUS FOR EFFECTING SUCH A METHOD

FIELD OF THE INVENTION

5 The invention relates to a method of depth routing an electronic layup and apparatus for effecting such a method. The invention is particularly directed towards depth routing the electronic layup by way of sandblasting.

BACKGROUND TO THE INVENTION

10 The following discussion of the background to the invention is intended to facilitate an understanding of the present invention. However, it should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was published, known or part of the common general knowledge in any jurisdiction as at the priority date of the application.

15 Figure 1 shows a typical electronic layup. The electronic layup comprises a copper layer bonded to an FR4 laminate which is in turn bonded to a dielectric formed on a copper or aluminium substrate. Various techniques have been found to manufacture circuits from such layup. The most common technique at the date of filing of this patent application is depth routing.

20 The technique of depth routing to create a circuit involves eroding parts of each layer other than the copper or aluminium substrate. This can be achieved through chemical means, but more commonly this is performed by way of a Computer Numerical Control ("CNC") machine. This latter process is often referred to as mechanical depth routing or milling.

25 The problem with CNC-based mechanical depth routing is that the resulting eroded surface is uneven and may contain burrs. These burrs and/or irregularities in the surface reduce the geographical area of an electronic component that can make contact with the underlying copper or aluminium substrate. In some cases, the electronic component may not be able to make

any contact with the underlying copper or aluminium substrate – in which case heat is dissipated through the dielectric.

This is important as it is this contact with the underlying copper or aluminium substrate that allows an electronic component to dissipate heat (a heat sink connected to the underlying copper or aluminium substrate actually dissipating the heat). The greater the amount of contact between the electronic component and the underlying copper or aluminium substrate, the greater the amount of heat that can be dissipated. In addition, these burrs and/or irregularities in the surface make chemical plating less efficient and effective. Furthermore, the level of development in CNC-based mechanical depth routing has reached the point that any further refinement, in the inventor's opinion, will result in only marginal improvement in heat dissipation.

The current method of constructing a typical electronic layup as shown in Figure 1 is a complicated and expensive process. The steps undertaken using a mechanical depth routing or milling technique are briefly described as follows. A double sided FR4 laminate is provided and an indentation is created in the FR4 laminate by drilling and/or etching. This step of creating the FR4 laminate with indentation involves about 28 process steps in a conventional printed circuit board ("PCB") process. Next, a dielectric layer is provided. The dielectric layer is normally not die-cut. Die-cutting is carried out to conform to the fit and form of the FR4 laminate and the copper or aluminium substrate. After the dielectric layer has been suitably die-cut, the copper or aluminium substrate, the die-cut dielectric layer and the indented FR4 laminate are arranged sequentially and aligned accurately with the die-cut portion and the indented portion coinciding centrally of the electronic layup. The different layers are then mass laminated to form an integrated electronic layup as shown in Figure 1. The above-described process provides a schematic overview of manufacturing an electronic layup as shown in Figure 1. The pre-preparation steps, intermediate steps as well as finishing steps in preparing the electronic layup for shipment are typical PCB manufacturing steps commonly known to a person skilled in the

art and are therefore omitted in the present discussion. In summary, there are about 37 process steps involved in the manufacture of the electronic layup.

There are disadvantages associated with the current method of constructing a typical electronic layup as described above. Firstly, the step of creating the FR4 laminate with indentation involving about 28 process steps in a conventional PCB process incurs substantial time and costs. Die-cutting of the dielectric layer to conform to the fit and form of the FR4 laminate and the copper or aluminium substrate; and the subsequent arranging and aligning of the die-cut portion of the dielectric layer and the indented portion of the indented FR4 laminate involves a high degree of accuracy so as not to affect the quality, yield, reliability and engineering tolerance of the electronic layup.

Adding to this complication is that in the lamination of each layer of the electronic layup, each time the electronic layup is subjected to the lamination process, it is prone to warping or distortion. Where warping or distortion occurs, the problem of positioning an electronic component so as to obtain the greatest heat dissipation through the underlying copper or aluminium substrate arises. In addition, during the lamination process, care must be taken to ensure that the indentation is free of resin while ensuring that the resin is evenly distributed over the areas to be laminated so as not to affect the reliability and yield of the electronic layup.

The problems mentioned above can be minimized, if not eliminated, through using a standard insulated metal substrate commonly available and using a mechanical depth routing technique to create an indentation on the same.

SUMMARY OF THE INVENTION

Throughout this document, unless otherwise indicated to the contrary, the terms "comprising", "consisting of", and the like, are to be construed as non-exhaustive, or in other words, as meaning "including, but not limited to".

In accordance with a first aspect of the invention, there is provided a method of depth routing an electronic layup, the electronic layup comprising a dielectric

sandwiched between a metal layer and a metal substrate which is then laminated, the method comprising the steps of:

5 positioning a hardened mask so that the mask is interposed between the metal layer and at least one nozzle of a sandblasting machine, the mask having at least one aperture provided therein; and

sandblasting the electronic layup through the at least one aperture by way of the sandblasting machine

10 wherein the force, size and type of abrasive applied by the sandblasting machine are sufficient to erode the metal layer and the dielectric but not the metal substrate.

The method may also include the step of securing the electronic layup and hardened mask in a jig while maintaining the relative position of the hardened mask to the electronic layup. Ideally, the step of positioning the hardened mask includes the sub-step of positioning the hardened mask no more than 0.5 mm
15 away from the metal layer.

To facilitate automation of the method, the method may further include the steps of:

securing the jig to a feeder belt; and

20 controlling the movement of the jig relative to the sandblasting machine by way of the feeder belt.

Preferably, the step of sandblasting the electronic layup through the metal layer and the dielectric involves the sub-step of directing a fluid stream containing abrasive particles towards the electronic layup.

25 In accordance with a second aspect of the invention, there is provided a depth routed electronic layup formed in accordance with the method of the first aspect of the invention.

Preferably, the metal layer is copper. Similarly, it is preferable that the substrate is either copper or aluminium.

In accordance with a third aspect of the invention, there is provided a sandblasting machine for use in the method of the first aspect of the invention, the sandblasting machine configured to produce and direct a fluid stream containing abrasive particles towards the electronic layout.

- 5 The abrasive particles comprise at least one of the following types of abrasive particles: aluminium oxide; fused aluminium oxide with titanium; corundum. The size of the abrasive particles ranges from $5\ \mu\text{m}$ to $2800\ \mu\text{m}$. Although, in its preferred arrangement, the mean particle size of the abrasive particles is $10\ \mu\text{m} \pm 0.2\ \mu\text{m}$.
- 10 The pressure of the fluid stream may fall in the range of 0.3 MPa to 2 MPa. However, the preferred pressure range is $3.724 \times 10^5\ \text{Pa} \pm 0.098 \times 10^5\ \text{Pa}$. The exception is in the case of high temperature copper, where it is preferred that the fluid stream is a stream of air having a pressure range of 0 to $4.7 \times 10^5\ \text{Pa}$.

The at least one nozzle may be a ceramic nozzle, a tungsten carbide nozzle or
15 a boron carbide nozzle. Where ceramic nozzles are used, the size of the nozzle can be:

- 2.6 mm x conical outer x 50 mm length.
- 3 mm x conical outer x 50 mm length.

Where tungsten carbide nozzles are used, the size of the nozzle can be:

- 20
- 4 mm x 12.5 mm x 41mm length.
 - 6 mm x 20 mm x 41mm length.
 - 7.5 mm x 20 mm x 43 mm length.

Similarly, where a boron carbide nozzle is used, the size of the nozzle can be:

- 6.3 mm x 21 mm x 82 mm length.
- 25 • 8 mm x 21 mm x 82 mm length.
- 9 mm x 24 mm x 82 mm length.

- 10 mm x 24 mm x 82 mm length.
- 12 mm x 24 mm x 82 mm length.

The speed of the fluid stream produced can be between 5 m/min and 30 m/min. Preferably, the speed of the fluid stream produced is between 9 m/min and 11 m/min.

Preferably, the abrasive particles have a hardness of between 7 and 9 Mohs.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

- 10 Figure 1 is a diagram showing an electronic layup according to the prior art;
- Figure 2 is a diagram showing an electronic layup as used by a first embodiment of the present invention;
- Figure 3 is a diagram showing the base plate of the sandblast jig;
- Figure 4 is a further diagram showing the protective stencil of the sandblast jig;
- 15 Figure 5 is a diagram showing the complete kit of the sandblast jig with base plate, protective stencil, tooling fixture plate and clampers;
- Figure 6 is a diagram showing cross-sectional illustration of a metal-clad printed circuit board being clamped in a complete kit of the sandblast jig with sandblasting nozzles; and
- 20 Figure 7 is a diagram showing the sanding-in process filter into the sandblasting nozzles to eject pressure and erode to achieve certain depth on the metal-clad printed circuit board through the protective stencil in a complete sandblast jig.

PREFERRED EMBODIMENTS OF THE INVENTION

- Specific embodiments of the present invention are now described in detail. The terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention.

In accordance with a first embodiment of the invention, there is provided a method of mechanical depth routing an electronic layup. The operation of the method requires the use of the following components:

- an electronic layup 12;
- 5 • a sandblasting machine 14;
- a jig 16; and
- a protective stencil 18; and
- a feeder belt 20.

10 The electronic layup 12 used in this embodiment is shown in Figure 2. The electronic layup 12 comprises a copper layer 22 bonded to a dielectric 24. The dielectric 24 is in turn bonded to a copper or aluminium substrate 26. The whole electronic layup 12 is then laminated. It is believed by the inventor that the lamination of the electronic layup 12 as a single flat sheet causes less warping or distortion to the process described in the prior art above.

15 The sandblasting machine 14 shown in Figure 6 is preferably (but is not limited to) the TM-CT conveyor-type automatic blasting machine from Shang Po Sandblasting which uses the PolyhedralKNOOP method of sandblasting. The sandblasting machine 14 is configured to the mode of blasting for plane work pieces. The conveyor speed of the sandblasting machine 14 is made adjustable
20 accordingly to requirements.

In this embodiment, the sandblasting machine 14 has eight conical ceramic nozzles 28. The size of the eight conical ceramic nozzles 28 is adjustable.

In Figure 6, the jig 16 has a base plate 30 (Figure 3) and a tooling fixture plate 32. The base plate 30 is adapted to securely receive the electronic layup 12.
25 The tooling fixture plate 32 is adapted to securely receive the protective stencil 18. The arrangement of the base plate 30 relative to the tooling fixture plate 32 is such that the protective stencil 18 is parallel to the electronic layup 12 and spaced therefrom by no more than 0.5 mm.

To ensure that there is no relative movement between the protective stencil 18 and the electronic layup 12 during the sandblasting operation, the jig 16 is clamped by clampers 34 (see Figure 5) prior to the sandblasting operation.

5 The protective stencil 18 is formed from hardened steel. In Figure 4, portions or apertures of the protective stencil 18 have been cut out representing those areas of the electronic layup 12 desired to be eroded by the sandblasting operation.

The feeder belt 20 has securing mechanisms for securing the jig 16 thereto. The speed of the feeder belt 20 is controllable within the range 5 to 30 m/min.

10 The embodiment will now be described in the context of its intended use.

The electronic layup 12 is securely received in the base plate 30 of the jig 16. Almost at the same time, the protective stencil 18 is securely received within the tooling fixture plate 32. The jig 16 is then clamped using the clampers 34.

15 With the jig 16 clamped, the jig 16 is attached to the feeder belt 20. Attachment is achieved by way of the securing mechanisms. Once so secured, the feeder belt 20 is operated so as to control the movement of the jig 16 relative to the sandblasting machine 14.

20 In Figure 7, with the feeder belt 20 (not shown) operational, each conical nozzle 28 of the sandblasting machine 14 is supplied with an aluminium oxide abrasive. The aluminium oxide abrasive has a size of between $10\ \mu\text{m} \pm 0.2\ \mu\text{m}$. The abrasive is directed towards the jig 16 entrained in a fluid stream adjusted to a pressure of $3.724 \times 10^5\ \text{Pa} \pm 0.098 \times 10^5\ \text{Pa}$. The entrained particles are further controlled to move at a speed of $10\ \text{m/min} \pm 1\ \text{m/min}$. Further control of the nozzles 28 is effected to achieve the desired coverage of sandblasting.

25 In this manner, the entrained particles emitted by the sandblasting machine 14 are either stopped by the protective stencil 18 or allowed to pass through the apertures provided therein. Those particles that are allowed to pass through the apertures cause erosion on a layer 22, 24 (excepting the underlying copper or aluminium substrate layer 26) of the electronic layup 12. Over time and as the

nozzles 28 and the feeder belt 20 move in accordance with a predetermined pattern, the erosion of the various layers 22, 24 of the electronic layup 12 then form an identical pattern to that of the protective stencil 18.

The advantage of the above system is that the aluminium oxide abrasive chosen has sufficient strength to remove the copper layer 22 and the dielectric 24, but does not have the abrasive strength to remove the underlying copper or aluminium substrate 26 or cause damage to the protective stencil 18. This means that manufacturers only need focus on the x-y position of the sandblasting machine 14 as opposed to the x-y-z position of CNC-based mechanical depth routers (which are capable of removing the underlying copper or aluminium substrate 26, thereby rendering the electronic layup faulty). It also means that the surface of the underlying copper or aluminium substrate 26 near the eroded layers 22, 24 is significantly clear of burs and/or other irregularities.

In addition, with the use of the sandblasting technique, the total amount of material and the thickness of the electronic layup 12 can be reduced. For instance, in a conventional electronic layup shown in Figure 1, the materials include a copper layer (having negligible thickness), a FR4 laminate (1.6 mm), a dielectric layer (having negligible thickness) and an aluminium substrate (1 mm). With the present invention, the materials include a copper layer (having negligible thickness), a dielectric layer (0.1 mm) and an aluminium substrate (1.5 mm). This lesser materials leads to a reduction in material costs, and the leaner overall structure of the electronic layup allows more units of the electronic layups to be used in a given space, thereby making small form-factor electronic devices possible.

It should be appreciated by the person skilled in the art that the above invention is not limited to the embodiment described. In particular, the following modifications and improvements may be made without departing from the scope of the present invention

- The applicant has found that the abrasive used need not be aluminium oxide, but can be any similar particle such as fused aluminium oxide, fused aluminium oxide with titanium, or corundum.

- The applicant's experiments have shown that the particle size of the abrasive can range from 5 μm to 2800 μm . Ideally, the mean particle size is 10 μm .

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- Similarly, the pressure applied to the abrasive may range from 0.3 MPa to 2 MPa.

- The nozzles used by the sandblasting machine may be formed from ceramic, tungsten carbide or boron carbide.

- In the case of ceramic nozzles, the applicant has found that nozzles of the following specifications can be used:

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- 2.6 mm ID x conical outer x 50 mm length;
- 3 mm ID x conical outer x 50 mm length;

- In the case of tungsten carbide nozzles, the applicant has found that nozzles of the following specifications can be used:

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- 4 mm ID x 12.5 mm OD x 41 mm length;
- 6 mm ID x 20 mm OD x 41 mm length;
- 7.5 mm ID x 20 mm OD x 43 mm length.

- In the case of boron carbide nozzles, the applicant has found that nozzles of the following specifications can be used:

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- 6.3 mm ID x 21 mm OD x 82 mm length;
- 8 mm ID x 21 mm OD x 82 mm length;
- 9 mm ID x 24 mm OD x 82 mm length;
- 10 mm ID x 24 mm OD x 82 mm length;
- 12 mm ID x 24 mm OD x 82 mm length;

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- The particles may be entrained in a stream of air having a pressure range of between 0 to 4.7×10^5 Pa. The pressure range stated above is

of particular relevance to situations where high temperature copper is involved.

- Preferably, the speed range of the nozzle is between 5 m/min to approximately 30 m/min, with the preferred speed being approximately 10 m/min.

- The operation time of the sand blasting machine may range from 5 to 25 min. The operation time of the sand blasting machine may be manually or automatically controlled.

- The electronic layup may take the form of a metal-core printed circuit board, a copper-clad laminate or any other type of laminated board for printed circuit manufacture.

- Ideally, the hardness of the particles ranges from 7 to 9 on the Mohs hardness scale.

- An X-Y table may be used to facilitate erosion of the electronic layup by way of the protective stencil.

- The operation of the whole system may be manually controlled or automatically controlled. Ideally, the system is automatically controlled and implemented by replacing the mechanical routing components of a CNC machine with the sand-blasting apparatus of the sand blasting machine.

Furthermore, the features described in the above embodiments and the additional features mentioned above may be combined to form yet additional embodiments that fall within the scope of the present invention.

We Claim:

1. A method of depth routing an electronic layup, the electronic layup comprising a dielectric sandwiched between a metal layer and a metal substrate which is then laminated, the method comprising the steps of:
 - 5 a. positioning a hardened mask so that the mask is interposed between the metal layer and at least one nozzle of a sandblasting machine, the mask having at least one aperture provided therein; and
 - b. sandblasting the electronic layup through the at least one aperture
10 by way of the sandblasting machinewherein the force, size and type of abrasive applied by the sandblasting machine are sufficient to erode the metal layer and the dielectric but not the metal substrate; and the surface of the resulting depth routed metal substrate is substantially even and free from burrs and/or irregularities to
15 increase geographical contact between the metal substrate and at least one electronic component.
2. A method of depth routing an electronic layup according to claim 1, wherein the increased geographical contact increases heat dissipation from the at least one electronic component to the metal substrate.
- 20 3. A method of depth routing an electronic layup according to claim 1 or 2, wherein the surface of the metal substrate is co-planar.
4. A method of depth routing an electronic layup according to any of claim 1 to 3, further including the step of securing the electronic layup and hardened mask in a jig while maintaining the relative position of the
25 hardened mask to the electronic layup.
5. A method of depth routing an electronic layup according to any preceding claim, wherein the step of positioning the hardened mask includes the

sub-step of positioning the hardened mask no more than 0.5 mm away from the metal layer.

6. A method of depth routing an electronic layup according to claim 5, further including the steps of:
 - 5 a. securing the jig to a feeder belt; and
 - b. controlling the movement of the jig relative to the sandblasting machine by way of the feeder belt.
7. A method of depth routing an electronic layup according to any preceding claim, wherein the step of sandblasting the metal layer and the dielectric
10 involves the sub-step of directing a fluid stream containing abrasive particles towards the electronic layup.
8. A method of depth routing an electronic layup according to claim 7 wherein the abrasive particles comprise at least one of the following types of abrasive particles: aluminium oxide; fused aluminium oxide with
15 titanium; corundum.
9. A method of depth routing an electronic layup according to claim 7 or claim 8 wherein the size of the abrasive particles ranges from 5 μm to 2800 μm .
10. A method of depth routing an electronic layup according to claim 9,
20 wherein the mean particle size of the abrasive particles is 10 $\mu\text{m} \pm 0.2 \mu\text{m}$.
11. A method of depth routing an electronic layup according to any one of claims 7 to 10, wherein the pressure of the fluid stream is in the range 0.3 MPa to 2 MPa.
- 25 12. A method of depth routing an electronic layup according to claim 11, wherein the pressure of the fluid stream is in the range $3.724 \times 10^5 \text{ Pa} \pm 0.098 \times 10^5 \text{ Pa}$.

13. A method of depth routing an electronic layup according to any one of claims 7 to 12, wherein the fluid stream is a stream of air having a pressure range of 0 to 4.7×10^5 Pa.
- 5 14. A method of depth routing an electronic layup according to any one of claims 7 to 13, wherein the speed of the fluid stream produced is between 5 m/min and 30 m/min.
15. A method of depth routing an electronic layup according to claim 14, wherein the speed of the fluid stream produced is between 9 m/min and 11 m/min.
- 10 16. A method of depth routing an electronic layup according to any one of claims 7 to 15, wherein the abrasive particles have a hardness of between 7 and 9 Mohs.
17. A depth routed electronic layup formed in accordance with the method of any of claim 1 to 3.
- 15 18. A depth routed electronic layup according to claim 17, wherein the metal layer is copper.
19. A depth routed electronic layup according to claim 17 or claim 18, wherein the metal substrate is either copper or aluminium.
- 20 20. A sandblasting machine configured to be used in the method of any of claim 1 to 3, the sandblasting machine configured to produce and direct a fluid stream containing abrasive particles towards the electronic layup.
21. A sandblasting machine as claimed in claim 20, wherein the abrasive particles comprise at least one of the following types of abrasive particles: aluminium oxide; fused aluminium oxide with titanium; corundum.
- 25 22. A sandblasting machine as claimed in claim 20 or claim 21, wherein the size of the abrasive particles ranges from $5 \mu\text{m}$ to $2800 \mu\text{m}$.

- 23.A sandblasting machine as claimed in claim 22, wherein the mean particle size of the abrasive particles is $10\ \mu\text{m} \pm 0.2\ \mu\text{m}$.
- 24.A sandblasting machine as claimed in any one of claims 20 to 23, wherein the pressure of the fluid stream is in the range 0.3 MPa to 2 MPa.
- 25.A sandblasting machine as claimed in claim 24, wherein the pressure of the fluid stream is in the range $3.724 \times 10^5\ \text{Pa} \pm 0.098 \times 10^5\ \text{Pa}$.
- 26.A sandblasting machine as claimed in any one of claims 20 to 25, wherein the fluid stream is a stream of air having a pressure range of 0 to $4.7 \times 10^5\ \text{Pa}$.
- 27.A sandblasting machine as claimed in any one of claims 20 to 26, wherein the at least one nozzle is a ceramic nozzle.
- 28.A sandblasting machine as claimed in claim 27, wherein the at least one nozzle is a 2.6 mm x conical outer x 50 mm length nozzle.
- 29.A sandblasting machine as claimed in claim 27, wherein the at least one nozzle is a 3 mm x conical outer x 50 mm length nozzle.
- 30.A sandblasting machine as claimed in any one of claims 20 to 26, wherein the at least one nozzle is a tungsten carbide nozzle.
- 31.A sandblasting machine as claimed in claim 30, wherein the at least one nozzle is a 4 mm x 12.5 mm x 41 mm length nozzle.
- 32.A sandblasting machine as claimed in claim 30, wherein the at least one nozzle is a 6 mm x 20 mm x 41 mm length nozzle.
- 33.A sandblasting machine as claimed in claim 30, wherein the at least one nozzle is a 7.5 mm x 20 mm x 43 mm length nozzle.
- 34.A sandblasting machine as claimed in any one of claims 20 to 26, where the at least one nozzle is a boron carbide nozzle.

35. A sandblasting machine as claimed in claim 34, wherein the at least one nozzle is a 6.3 mm x 21 mm x 82 mm length nozzle.
36. A sandblasting machine as claimed in claim 34, wherein the at least one nozzle is a 8 mm x 21 mm x 82 mm length nozzle.
- 5 37. A sandblasting machine as claimed in claim 34, wherein the at least one nozzle is a 9 mm x 24 mm x 82 mm length nozzle.
38. A sandblasting machine as claimed in claim 34, wherein the at least one nozzle is a 10 mm x 24 mm x 82 mm length nozzle.
- 10 39. A sandblasting machine as claimed in claim 34, wherein the at least one nozzle is a 12 mm x 24 mm x 82 mm length nozzle.
40. A sandblasting machine as claimed in any one of claims 20 to 39, wherein the speed of the fluid stream produced is between 5 m/min and 30 m/min.
- 15 41. A sandblasting machine as claimed in claim 40, wherein the speed of the fluid stream produced is between 9 m/min and 11 m/min.
42. A sandblasting machine as claimed in any one of claims 20 to 41, wherein the abrasive particles have a hardness of between 7 and 9 Mohs.