Ultra High Density Interconnect Printed Circuit Boards

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Abstract

Further miniaturisation of electronic devices of many kinds and the higher level of integration require a different approach on the manufacturing of printed circuit boards. Electronic components and packages are still getting smaller almost every year. According to Moore's law, a doubling of the number of components per integrated circuit is happening every 24 months. To make best use of this development, more densely packed printed circuit boards are needed. This need is rapidly increasing in many business segments. Miniaturisation is a need in all dimensions, not just pattern density in x and y, but also thickness of circuits is of high importance. Currently used techniques have reached their limits or it will be reached within the next few years. New manufacturing processes or new combination of processes will be required to fulfill the needs, as well as keeping costs under control. Potential approaches to produce these type of ultra high density circuits will be discussed in this paper.

1 Introduction

PCB manufacturers have been using different technologies for the production of printed circuits. Historically, the two methods panel plating and pattern plating have been used for many decades. Both of the methods have their pro's and con's and their clear limitations. For circuits with line widths and spacings of less than 35 microns, several concessions have to be made to achieve acceptable results and output. The currently used production process is typically not enabling the use of the whole set of possibilities of modern PCB technology, e.g. for example via stacking, via in pad structures or integrated antennas.

2 Limitations of standard production technologies

2.1 Pattern Plating

The standard process for pattern plating is to use of metallic etch resists for pattern formation. The copper plating is typically done in a 2 step process, where as a first step the conductive layer, as well as an optional strike plating copper layer is deposited on the manufacturing panels. After doing the photolithographic step, copper is selectively plated, followed by the plating of metallic etch resist (electroplated tin) on top of the selectively plated copper. After forming the image by alkaline etching, the metallic resist has to be stripped off the remaining copper image. Although, strippers used for this purpose are selective and only attack copper to a certain extent, there is still an influence on the etched pattern noticeable. The smaller the image features get, the more important this influence gets.

2.2 Panel Plating/Tenting Technology

In panel plating or tenting technology, copper plating is done in a one-step mode and all the required copper is plated on the manufacturing panels before starting the pattern formation. The downside of this process is a limitation in smallest achievable line width and spacing and/or maximum possible copper thickness.

Following the rule by the thumb, that:
Smallest Spacing >/= (Cu thickness + photoresist thickness) x 1.3

a resolution of 25 micron and spacing (1mil) can only be reached with very low copper thickness of appr. 8 microns, if 10 micron photoresist is used. If liquid photoresist is the chosen process and if there are through holes on the circuits, a combination of liquid and dry film photoresist has to be used due to the limited tenting capabilities of liquid photoresist. The overall maximum copper thickness of 8 microns is preventing the use of state of the art layer to layer interconnection using stacked via

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technology or via in pad structures. Even if base materials with ultrathin copper claddings are used, the thickness of plated copper is not sufficient to properly fill blind holes. The low overall copper thickness also can have a negative influence on the performance of frequency sensitive parts of circuits like antennas.

2.3 Using Thinfilm Technology on a Larger Scale

Thinfilm technology has been used more and more over the past years for circuits on organic carrier materials like foils or liquid dielectrics. Thinfilm manufacturers are using a classical semi additive process involving vacuum deposition of adhesion layers, metal seed layers, photolithography, electroplating and chemical or dry etching. Other processes used in thinfilm technology will not be covered in this paper as there is no direct influence on the pattern formation of ultrafine line circuits.

Structures with line width and spacing of less than 15 microns have been successfully produced and are supplied in low to medium volumes. The downside of this technology is the production unit size that is typically maximum 8 inch square. Especially for price sensitive circuits this is a concern, as the price for single components is significantly higher than for PCB's. Upscaling this technology is technically feasible, a new set of processes has to be implemented to complement the existing process environment:

- Large area vacuum deposition
- Adhesion layer etching
- Handling of flex foils without copper claddings
- Improved cleanroom environment

There are significant investments involved to retrofit PCB manufacturing and make it suitable for semi additive technology using flexible base materials.

In addition to new processes, different materials will be needed. Currently used high grade polyimide materials are not available without copper claddings, copper would have to be removed prior to the start of semi additive processing. Photoresists suitable for semi additive technology have to be used.

Even if manufacturing of circuits on panel sizes that are standard for PCB industry, cost will be higher due to the higher overall process cost. From a technical standpoint, the adhesion of the metal layers on the base substrate material is a concern.

2.4 DenciTec®

Cicor's DenciTec® is enabling us to produce ultrahigh density circuits, without the mentioned downsides of the methods mentioned above. A unique set of state of the art equipment and the best use of its capabilities are opening new possibilities in PCB manufacturing. Highly reliable circuits without any limitation of freedom in design are the outcome of this latest development.

Another key enabler is a new set of base materials.

DenciTec® is driving our capabilities for further miniaturisation in a direction that will be of great benefit for our customers.

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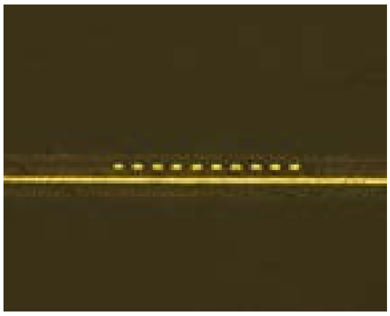
These capabilities are:

- Line width and spacing as small as 25microns
- Copper thickness of 20 +/- 5 microns on all layers
- Laser via diameters of 35 microns
- Annular rings of 30 microns on inner layers and 20 microns on outer layers
- Copper filled blind vias enabling via stacking and vias in pad
- Ultrathin circuits using 12.5 micron polyimide core material
  (4 layer flex circuits with less than 120 micron thickness)
- Highest level of reliability

Pic.1:
Stacked blind vias with diameter 40microns and 100micron capture pads



Pic 2:
Innerlayer structures with 25micron linewidth spacing and 16micron copper thickness

2.5 Comparison of different options/technologies

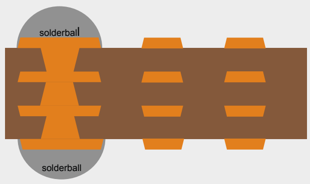
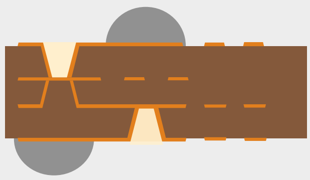
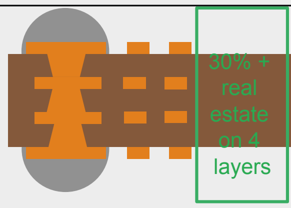
Option	Technology	Cross Section	Real Estate gain compared to option 1 (remarks)
1	Panel Plating/ Tenting Technology		n.a.
	Line Width/ Spacing 50 microns		
	150 micron BGA pad size (200 micron pitch)		
	Cu thickness 20 microns		
2	Panel Plating/ Tenting technology		OL: none
	Line Width/ Spacing 25 microns		IL: appr. 30%
	150 micron BGA pad size (200 micron pitch)		
	Cu thickness 6-8 microns		
3	DenciTec®		OL: 30%
	Line Width/Spacing 25 microns		IL: 37%
	150 micron BGA pad size (200 micron pitch)		(not utilizing the whole range of capabilities)
	Cu thickness 20 microns		

Table: Application example fine line circuit with 200 micron pitch BGA

If the whole range of capabilities of DenciTec is used, even further miniaturization is possible and more real estate can be gained, to either increase the level of integration or relax certain design values. Using stacked via technology, up to 70% per layer of additional real estate can be gained compared to technologies currently considered to be standard.

An additional benefit can be seen in the cross section of the traces and/or conductive elements. As shown on picture 3, the trace cross section of patterns created using DenciTec is superior to other technologies due to the rectangular shape.

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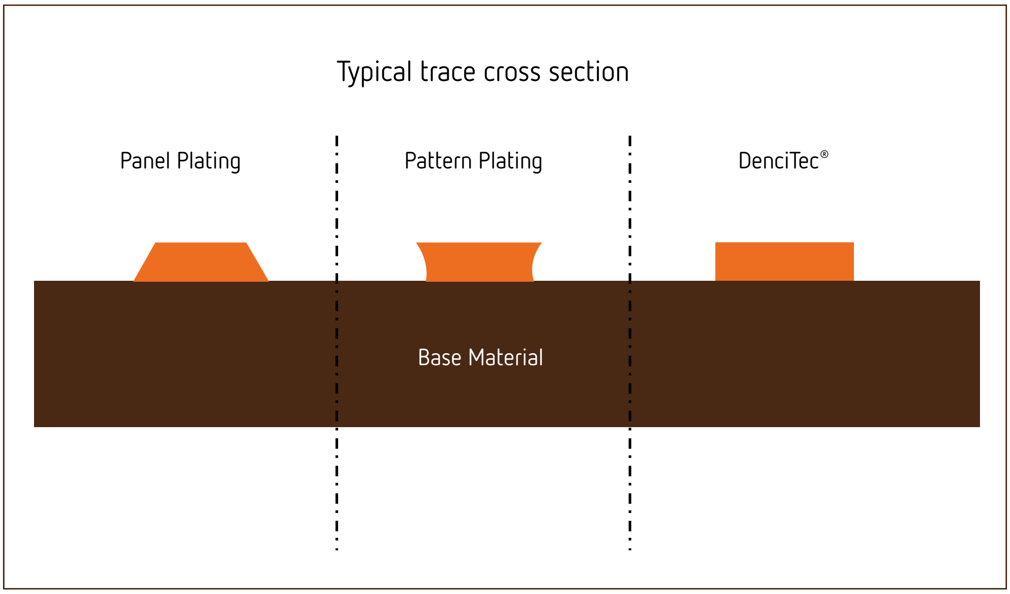

Pic 3

3 Conclusion

For many applications, standard PCB technology has reached its limits. As shown in this paper, concessions have to be made if circuits with delicate design features are produced using the standard fabrication process. Especially in the medical field, reliability is a must. Though semi additive technology, which would be a technology merger of thin film technology and PCB technology, would be a viable solution, cost together with high investment cost would be a blocking point. With Cicor's DenciTec®, a solution is available, that has no implication on reliability and is offering a very flexible solution to customers. It is clearly superior to the currently existing technologies. Production output and yields are at levels typical for PCB manufacturers.

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