Fine Line Technology and Panel Plating – Opposing Directions, One Solution

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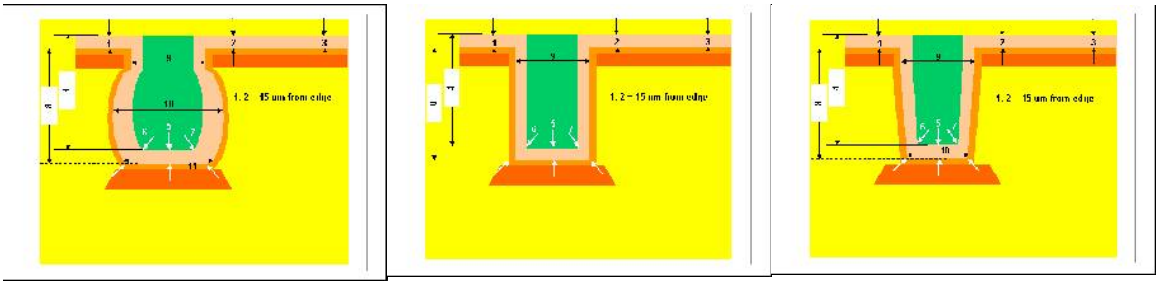
Abstract

The increasing requirements for high density interconnect can be summarised as a demand for ever finer line and spaces together with the need for improved high frequency operating characteristics. Both of these factors must be met under an ever increasing price pressure this now coming from significant increases in raw materials as well as the expectations from the OEM.
The standard method to achieve fine lines and spaces is by using a variation of pattern plate copper metallisation, however this technique suffers from the well known variation in surface distribution due to varying track density and width. The resulting track profile variation is difficult to reconcile with the increasing demands for high frequency application and in particular a narrow impedance control range.
In contrast the technique of panel plate copper metallisation offers the advantage of best possible surface distribution over the whole surface of a circuit together with uniformity of production giving obvious benefits for high frequency application. The critical disadvantage of the panel plating technique is that the required thickness of copper to achieve blind micro via filling, now a common requirement in HDI, cannot be etched to give the line and space tolerances which will be required.
This paper presents latest results with the Uniplate InPulse 2 horizontal copper plating system which combines excellent surface distribution together with a novel panel plate metallisation which ensures filled blind micro vias with minimum surface plated copper.
Blind micro vias typically seen in hand held devices with 70 µm depth and 100 µm diameter can be easily filled with only 15 µm copper deposited on the surface. This process offers the possibility to meet the requirement for 50 µm line and space. Also due to the low thickness of plated copper, savings in materials are very significant particularly in copper metal but also in solder mask and etching chemistry. The process has already reached a high acceptance in the mass production of HDI circuit boards.

Introduction

Production processes for blind micro via filling are currently in widespread use for both IC substrates and in the recent development for hand held applications. Reference [1] discusses the implementation of such processes in both vertical and horizontal systems. Standard processes for blind micro via filling for hand held devices can require plating of up to 30 µm to achieve a remaining dimple of less than 10 µm depending on the aspect ratio of the vias and the drilling quality. This copper thickness requirement is very dependant on the substrate material used for the micro vias. A significant quantity of production is now being made for mobile phone applications using FR4 glass fibre reinforced materials which are more demanding for the laser drilling process in comparison to RCF types of substrates. In this aspect the cost of drilling becomes critical and is very often the driving force which leads to poor final micro via shape after drill. Generally the more difficult the blind micro via for the filling process the more copper must be plated to reach the required quality of final dimple. The schematic shown in figure 1 illustrates the variation which may be seen in blind micro via shape after drilling, the easiest via for the copper plating processed is normally the most time consuming or the most expensive for mass laser drill production. Coupled to this is the inherent variation seen in the glass reinforced material due to the weave of the glass itself.

Figure 1: *Schematic to show blind micro via variation after drilling*

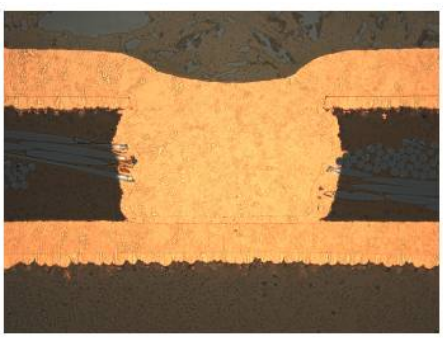


"Barrel" Shape "Straight" Shape "Tapered" Shape

The “tapered” shape is the preferred blind micro via for copper plating but it is seldom seen except possibly in IC substrate applications where homogenous base material and low volume blind micro vias make laser drilling less demanding.
Figure 2 shows a typical filled blind micro via from a vertical processing system, the blind micro via form is a “barrel” shape with a slight over hang of copper foil together with protruding glass fibres more on one side of the via than the other.

Figure 2 *Filled blind micro via produced in vertical processing equipment*.

Surface plate copper 30 µm
Diameter 110 µm
Depth 75 µm



The process used was panel plating in DC using insoluble anodes to give the best possible surface distribution. The applied current density was 1.5 A/dm² which means a plating time of approx 90 minutes was necessary to give a dimple of less than 10µm.
The demand for fine line and space is an ever present fact of life for high density interconnect. Currently 75 µm line and space is standard for mobile phone applications and requirements for 50 µm line and space are already in discussion. The panel plating process as illustrated in figure 2 above is limited in the capability for fine line imaging simply by the plated copper thickness. The problem may be overcome by use of thin copper foil but assuming a copper foil of 5 µm there will be a line and space limit of approx. 75 µm to 80 µm using the panel plating technology illustrated.
To overcome the limitations pattern plating may be considered or a combination of pattern and panel plating but then the difficulties of pattern plate surface distribution will be apparent. This aspect cannot be ignored when high frequency applications with defined impedance control range are required, pattern plating cannot meet the standard in surface distribution together with the productivity at high current densities of panel plating. The demands of blind micro via filling also pose problems for pattern plating, figure 3 illustrates this with the dimple variation depending on copper plated thickness.

Figure 3: *Variation in dimple with plating thickness for blind micro via filling.*

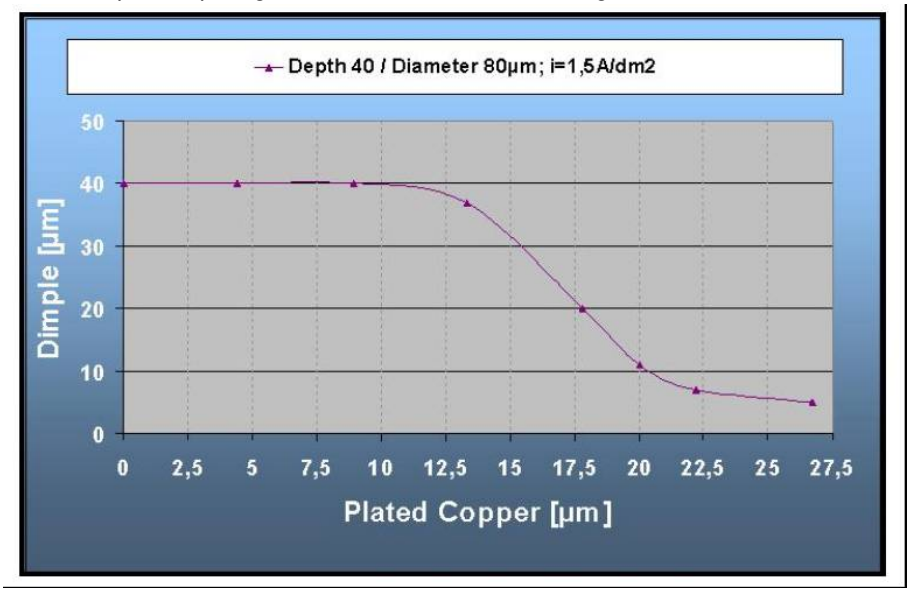


Figure 3 shows the dimple variation in a relatively simple blind micro via diameter 80 µm and depth 40 µm with varying copper thickness plated on the surface. With 10 µm plated copper the dimple is still 40µm, no filling has occurred and the dimple is equivalent to the original micro via depth. After plating of 20 µm on the surface the dimple has reached approx. 10µm, normally the minimum requirement for a blind micro via filling process. In the surface plating range between 15 µm to 20 µm there is a dimple reduction from 30 µm dimple to 10 µm dimple. This means that an absolute surface copper thickness variation of 5 µm can give a dimple variation of 20 µm.
Current and future applications in hand held devices require blind micro via filling with low dimple and thin copper plating together with a uniform plating quality over the entire panel surface. Together these factors can enable fine line production with possible 50 µm line and space tolerance.

Fine Line Production In InPulse 2

The InPulse 2 system gives an inherently good copper plated surface distribution due to the use of insoluble segmented anodes as shown in figure 4.

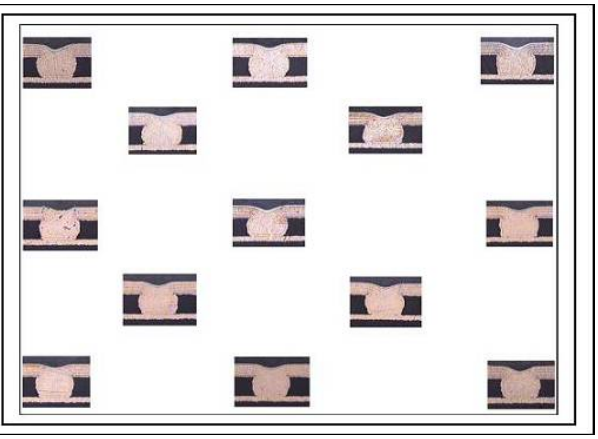
Figure 4: *Segmented anode unit to ensure optimum surface distribution.*

Segmented insoluble anode showing the four individually controlled segments

Production panels with thin copper foil even down to 1 µm can be successfully plated using the specially designed equipment. Also standard blind micro via filling can be made as shown in figure 5.

Figure 5: *Uniformity in blind micro via filling over standard panel.*

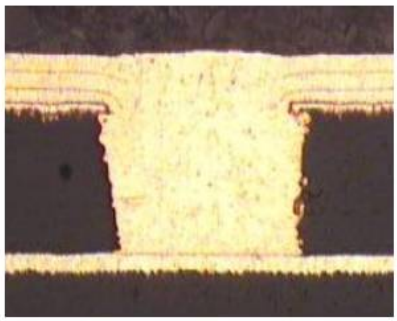
Micro-section results of filled blind micro vias over entire panel



Standard blind micro via filling uses standard pulsed plating parameters and will achieve results as shown in detail in figure 6.

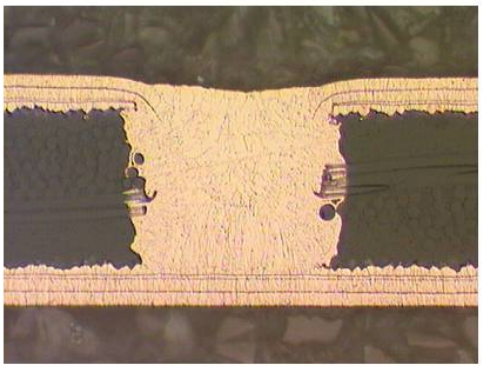
Figure 6: *Standard blind micro via filling result in horizontal process equipment.*

Diameter 110 µm
Depth 80 µm
Plating thickness 27 µm
Dimple 0 µm



The filling quality is good in this example, there is no dimple seen in micro-section and the filling result is uniform over the panel but the plated copper thickness is in the range as seen in vertical DC plating systems and cannot reach the target of 50 µm line and space. In contrast however to vertical systems with 60 to 90 minutes plating time the higher applied current density means that the plating time will be in the region of 30 to 40 minutes. Even standard blind micro via filling in horizontal systems has production time advantages over vertical systems.
The key to fine line production in panel plate with the InPulse 2 is the use of modified pulse parameters as described in [2]. Generally use of strong reverse pulse plating current density gives a significant reduction in the plating time needed to achieve the required dimple. The inorganic parameters are modified to promote blind micro via filling, this means higher copper concentration in relation to sulphuric acid and the organic additives must be monitored in the correct range. Using the "Super Filling" process the surface plated copper required is reduced whilst maintaining dimple after filling at less than 10 µm. Figure 7 shows an example of "Super Filling" with non-ideal blind micro via.
Figure 7: *"Super BMV Filling" with protruding glass fibres in FR4 material.*

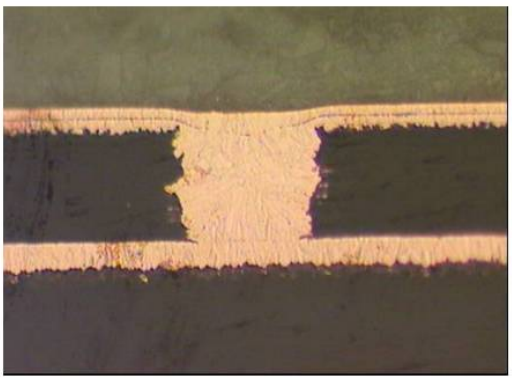
Diameter 130 µm
Depth 110 µm
Plating Thickness 20 µm
Dimple < 10 µm
Plating time 29 minutes



The result in figure 7 is an excellent filled blind micro via with strongly protruding glass fibres but dimple less than 10 µm.
The production result in figure 8 shows a filled blind micro via with a plating thickness less than 15 µm. Assuming a copper foil of 5 µm and metallisation of 2 – 3 µm the total copper thickness to be etched is 20 – 25 µm, this can meet the requirements for fine line production.

Figure 8: *"Super BMV Filling" with minimum surface thickness.*

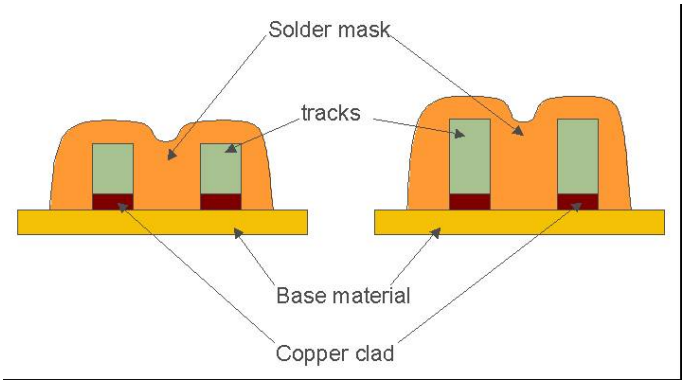
Diameter 90 µm
Depth 65 µm
Plating Thickness 12 µm
Dimple < 5 µm
Plating time 25 minutes



Summary

Horizontal plating systems equipped with insoluble anodes have offered advantages for production quality and cost savings for some years. The elimination of anode maintenance and constant surface distribution are key factors in uniform production quality together with the potential to have wet to wet production of metallisation and copper plating. Higher applied current densities can be used in particular for blind micro via filling which gives advantages in processing time over conventional vertical and also vertical conveyorised equipment.
True “Super Filling” now gives further advantages for blind micro via filling from the technical side as well as offering large cost savings for the highest technology production. The low thickness of plated copper is an enabling technology which allows fine line and space to be realised with panel plate. The obvious cost savings when less copper is plated can mean in the region of US$1.5 saving per plated m² panel depending on market copper price. The excellent surface distribution is necessary for good blind micro via filling distribution but this also gives potential for savings in solder mask as illustrated in the schematic in figure 9.

Figure 9: *Schematic of savings possible in solder mask with reduced copper thickness.*



The uniform plated copper over the panel and the entire production run means that less solder mask is consumed, also equipment set up is simplified due to the uniformity. Further cost savings are possible due to lower thickness of copper to be etched and also the necessary effluent treatment can be reduced.
The “Super Filling” process is already in mass production for mobile phone applications for the latest production models.

References

[1] S. Kenny and B. Reents “*Production processes in horizontal and vertical technology for blind micro via filling*” EIPC 2004 Proceedings of the European PCB Convention.
[2] B. Chao, S. Chien and B. Reents “*Horizontal plating process for blind microvia and through hole filling*” TPCA 2006 Proceedings of the TPCA Forum.