New Plating Technology for Blind Micro Via Filling and Through Hole Filling

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Abstract
Blind micro via filling technology is used in the chip carrier and packaging industry particularly for the production of stacked vias, as an example 3 or more filled blind micro vias can be produced on top of each other. The advantages of this technology particularly in enabling a greater degree of miniaturisation are now being used for hand held devices for example giving the possibility for direct bonding to the filled via in pad.

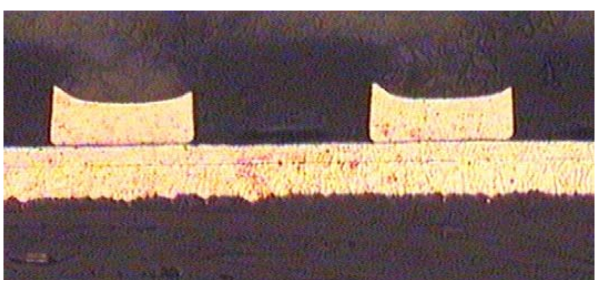
This paper discusses the limiting factors in the acid copper electrolyte lifetime currently in production for blind micro via filling and how this can be overcome in a system using insoluble anodes.

Examples of current production equipment and the via filling results achieved are shown from horizontal equipment as well as with conventional vertical and also vertical conveyorised equipment all using insoluble anode technology.

The extension of blind micro via filling to the filling of plated through holes is discussed and development results are shown using the insoluble anode system to fill through holes with electrolytic copper plating.

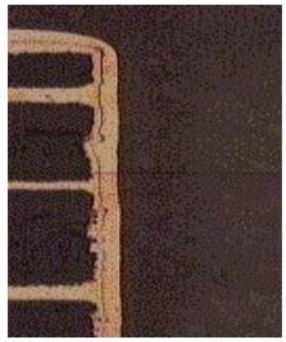
Introduction.
A wide range of via filling processes are currently being offered based on conventional electrolytic copper technology. This consists of a system in DC mode using soluble anodes, either bars or pellets and organic additives normally comprising a brightener or accelerator and a leveller or wetting agent / inhibitor. The target of the additives is to give a stable operating electrolyte with a smooth well levelled surface deposit which will preferentially fill the blind micro vias with the minimum of copper plated onto the surface. Typical additive systems which have been used have contained strong levelling agents based on dyes which give excellent levelling but have the draw back that corner flattening in through holes and irregular track profile with pattern plating are found. As one of the key driving forces for the development of filled vias the chip substrate industry uses pattern plating in the so called SAP process (semi-additive-process) the track shape after plating is a critical factor. Figure 1 shows a very irregular track profile caused by unsuitable leveller in the copper electrolyte.

Figure1: *Typical irregular track profile with strong leveller system*



An example of the typical corner flattening effect is seen in figure 2, this will have an obvious detrimental impact on the reliability of the plated copper layer.

Figure 2: *Corner flattening on plated through hole seen with the use of strong levellers*



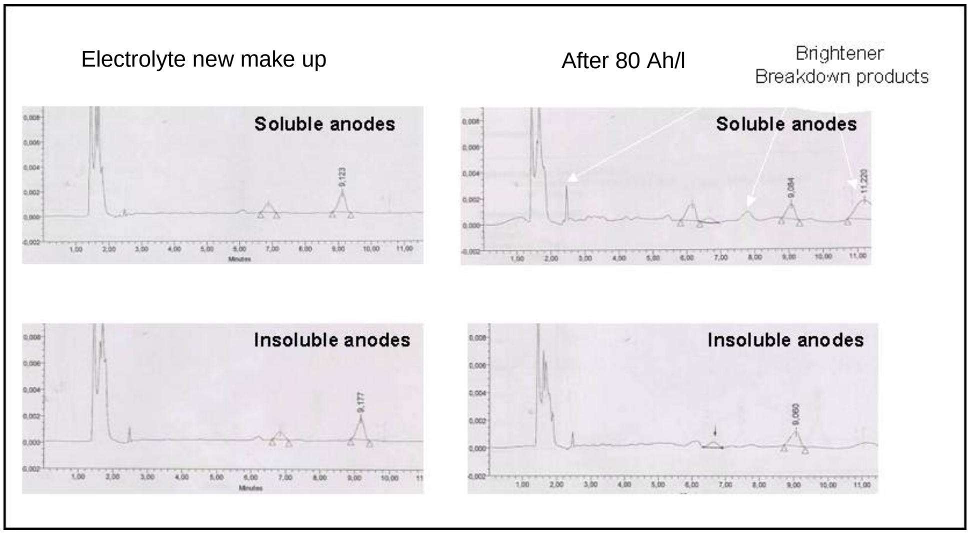
As a contrast use of copper plating systems with less strong non-dye based levellers exhibit a restriction in the electrolyte filling lifetime which is seen as a gradual reduction in the via filling quality depending on the throughput. Analysis of the plating electrolyte using HPLC techniques has shown that a build up of breakdown products is causing this deterioration in the quality. To overcome this problem and to ensure production quality, feed and bleed or simply new make up of the electrolyte is common.

Parallel to development work in vertical via filling, experiments in the use of horizontal equipment using pulse plating and insoluble anodes with iron redox copper replenishment have been carried out. It has been seen that the electrolyte used did not show the typical lifetime restriction as in vertical soluble anode systems, also generally the electrolyte configuration used in such systems is inherently suited for blind via plating and subsequent filling.

- Uniform constant surface distribution due to the insoluble anodes.
- Pulse or DC plating allowing variation in all plating parameters.
- Generally higher copper concentration than comparable vertical systems giving improved copper mass transport in blind micro vias.
- Spray impingement onto the cathode using frequency controlled pumps enabling optimal electrolyte exchange in blind micro vias.

Comparison to vertical systems also using insoluble anodes has been made and in particular the analysis of the working electrolyte after bath loading. Figure 3 shows the HPLC analysis of the via filling electrolyte from a standard soluble anode system in comparison to an insoluble anode system.

Figure 3: *HPLC analysis of working electrolyte from soluble and insoluble anode system.*

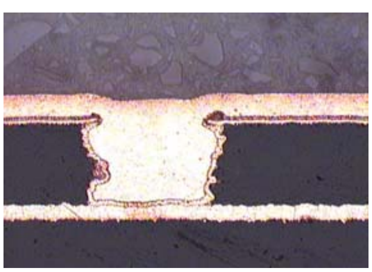


The HPLC analysis was made after make up of the electrolyte and after a bath loading of only 80 Ah per litre, it is common to find via filling lifetime issues after such a short lifetime with standard electrolytes. As can be seen in the analysis, breakdown products seen in the HPLC spectrum are much more frequent and intense in the soluble anode system, the additives are generating by products which are causing deteriorating via filling. The findings of this analysis have been confirmed in laboratory plating tests and have shown that insoluble anode systems also in DC mode do not exhibit lifetime issues.

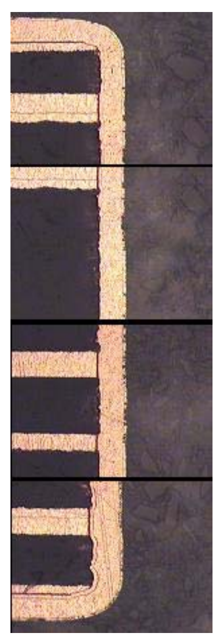
The insoluble anode system used incorporates the iron redox copper replenishment system as has been presented [1] and as such the electrolyte is maintained in very constant working conditions which are essential for full production.

Blind micro via plating results and through hole plating results achieved with the system are shown in figure 4. The laboratory scale set up has been adapted and installed in customer production equipment.

Figure 4: *Filled blind micro via and through hole plating in vertical test equipment*.



Blind micro via
Diameter 100 µm
Depth 80 µm
Surface plated 20 µm
Through hole
Diameter 0.6 mm
Panel thickness 1.8 mm



Vertical application.

The insoluble anode system for via filling has been installed in customer production equipment in conventional mode and in vertical conveyorised mode. Modification of the equipment is relatively simple, insoluble anodes must be installed and a circulation system must be available to pump the electrolyte over the copper replenishment system. In one case as a sump system was already present in the equipment simply putting the existing titanium anode baskets with copper pellets into the sump was found to be adequate for this purpose. An alternative is the installation of a specially designed filter pump and copper pellet unit as shown in figure 5. The electrolyte is directed to the copper replenishment unit by the use of diaphragms and suitably positioned flow and return from the working tank, it is essential that the electrolyte return from the copper replenishment unit is preferentially directed into the cathode area of the working cell.

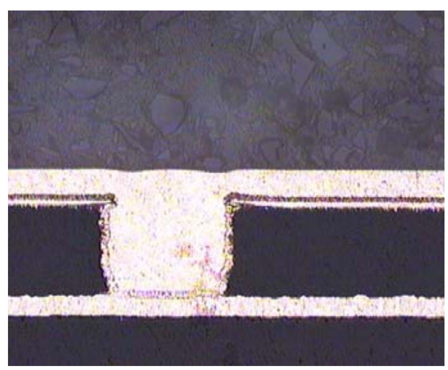
Figure 5: *Copper replenishment unit including filtration.*

This unit is suitable for the use of 500Kg
Copper pellets

Blind micro via filling results achieved with a modified conventional plating line are shown in figure 6.

Figure 6: *Qualification results from a conventional vertical plating line*.

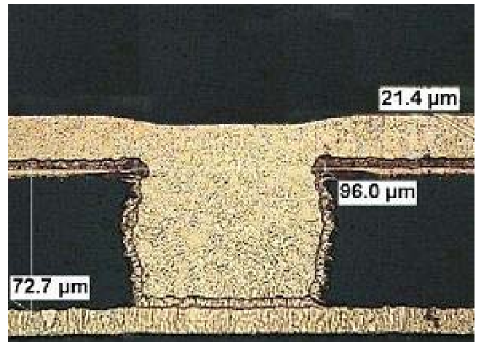
Blind micro via	
Current density	1.0 A/dm²
Diameter	100 µm
Depth	70 µm
Plating Thickness	20 µm
Dimple	0 µm



A vertical conveyorised line has also been modified to incorporate the insoluble anode system with iron redox copper replenishment, qualification results are shown in figure 7.

Figure 7: *Qualification results from vertical conveyorised line.*

Blind micro via	
Current density	2.0 A/dm²
Diameter	96 µm
Depth	73 µm
Plating Thickness	22 µm
Dimple	< 5 µm

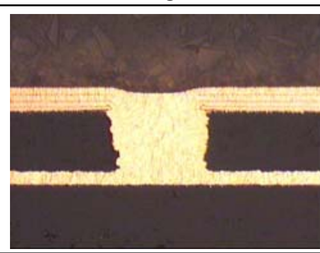
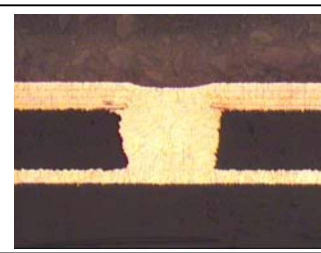
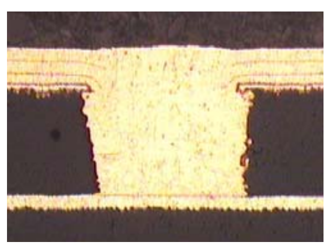
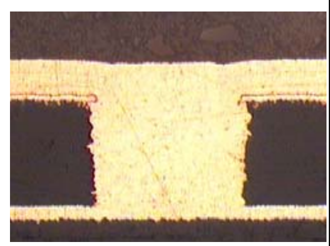


Via filling results achieved are equally good in both vertical conventional and vertical conveyorised equipment.

Horizontal Application.

Existing horizontal equipment has been used to investigate the pulse parameters and electrolyte settings necessary to achieve optimal via filling. Two examples of the plating results achieved are shown in figure 8.

Figure 8: *Blind micro via filling in horizontal production equipment.*

		Panel edge	**Centre**
Current density Diameter Depth Plating Thickness Dimple	3.5 A/dm² 100 µm 70 µm 22 µm < 11 µm		
Current density Diameter Depth Plating Thickness Dimple	3.5 A/dm² 110 µm 80 µm 27 µm 0 µm		

As can be seen due to the uniform plating distribution the corresponding via filling distribution is also good.

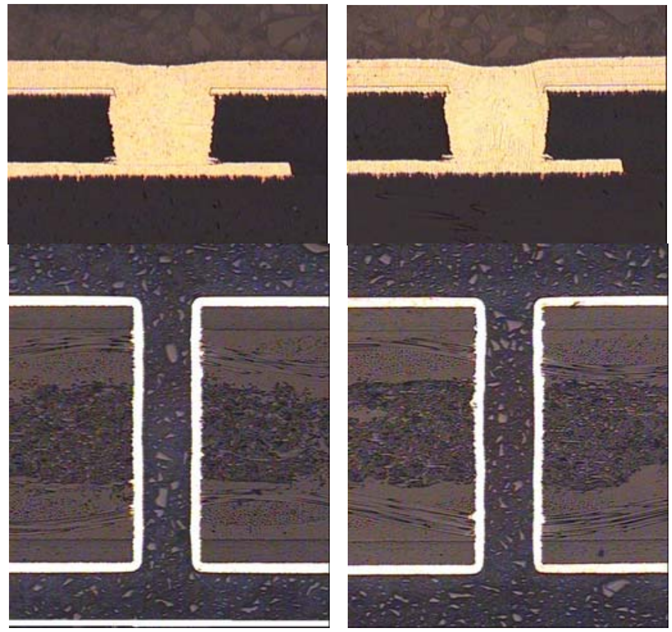
A BMV filling result with the corresponding through hole plating result is shown in figure 9.

Figure 9: *Through hole plating result in equipment set up for blind micro via filling*

Blind micro via	
Current density	3.5 A/dm²
Diameter	100 µm
Depth	80 µm
Plating Thickness	29 µm
Dimple	< 10 µm

Through hole	
Current density	3.5 A/dm²
Thickness	1.0 mm
Diameter	0.2 µm
Plating Thickness	29 µm
Minimum in hole	25 µm
Minimum throw	85 %

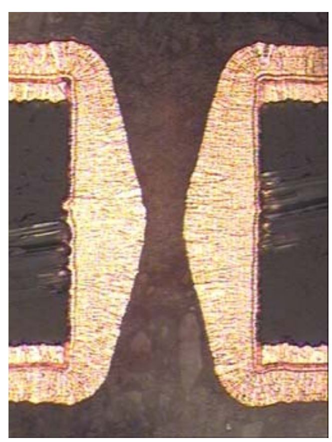
Panel edge **Centre**



The throwing power is good in the region of 80 - 90% and there is no significant corner flattening effect. Often it has been seen that the copper plating thickness is larger in the centre of the hole. This effect can be enhanced and is dependant on the electrolyte and pulse plating parameters. A more extreme example of this effect is seen in the through hole as shown in figure 10. This effect has been used to enable through hole filling and will be described below. Horizontal equipment is currently in full production for blind micro via filling applications.

Figure 10: *Exaggerated through hole plating*

Through hole	
Current density	3.5 A/dm²
Thickness	0.2 mm
Diameter	0.15µm
Throw in the centre	250 %



Through hole filling.

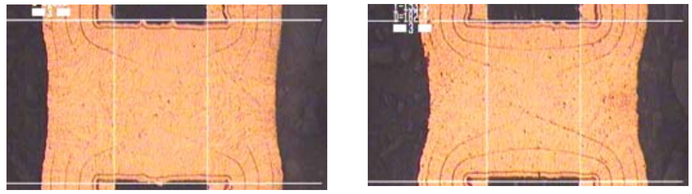
The through hole plated results from figure 6 show the initial stages in the through hole filling process. With further modification of the electrolyte and use of pulse plating results as in figure 11 can be achieved.

Figure 11: *Through hole filling results achieved with horizontal plating system*

Panel thickness 0.1 mm

Hole diameter 0.15 mm

Plating thickness 50 µm



Clamp side of panel Centre of panel

The through hole filling results achieved are inclusion free and the plated surface is smooth with a low dimple. The panel aspect ratio is not very high at this time but further electrolyte modifications are being made to extend the filling capability.

Summary and outlook.

Vertical and horizontal equipment with insoluble anodes is in full production producing filled blind micro vias both with and without plated through holes.

First experimental steps have been made to achieve the filling of through holes with electrolytic copper plating. This is possible with limitations in the aspect ratio of the panel and the plated thickness of copper on the surface. The target is to enable this technology to replace conventional resin plugging of through holes.

References.

[1] S. Kenny and K. Matejat "*HDI production using pulse plating with insoluble anodes*" EPC 2000 Proceedings of the European PCB Convention.