CAP- A new plating sequence for advanced via filling and through hole plating

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Introduction

The constant pressure on further miniaturization has led in the last 5 years to new technologies for the production of PWBs. Especially, in Japan we have seen significant changes in production technologies to cope with that demand. One key element in production of smaller but still reliable structures is the realization of Blind Micro Vias (BMV) which are completely filled with copper. This technique allows for further miniaturization by using land free connections and stacking of such structures [Fig 1].

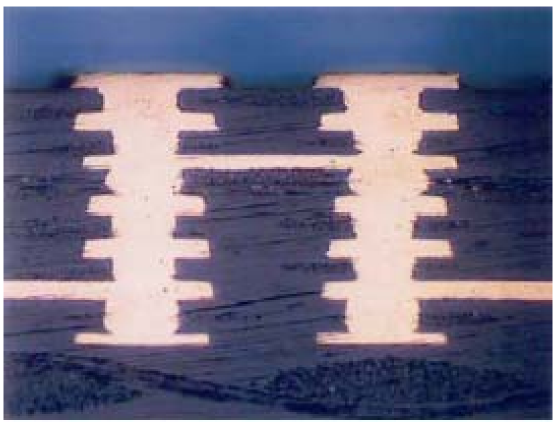

Fig1: A stacked via board with filled blind micro vias (IPC roadmap)

It is now very common in the so-called SAP process, the semi additive plating process. This process is often used to produce IC-substrates but for HDI application we have also seen a significant turn to such filled structures.
For these applications currently a wide range of via filling processes are being offered based mainly on 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. Another drawback of such electrolyte system is their limited life time. After a few weeks to month production the electrolytes tend to loose their ability to fill small structures (BMVs). It has been proposed that breakdown products of one additive (the so called brightener) might be responsible for the breakdown. Extensive efforts to resurrect the filling ability have been made such as H_20_2-UV cleaning [1] , full carbon treatment etc..
This publication describes a new process sequence for electrolytic Cu plating, the CAP process: Conditioning, Activation and Plating. In this sequence a new activation and conditioning step is introduced and combined with conventional plating technologies. Its purpose is to show that this process exhibits some significant improvements on through put, life time and filling performance!

General description of CAP process

The CAP process is a synergistic process combining pre-treatment and plating steps. It is absolutely necessary that all process steps are specially adapted and coordinated. Nevertheless, CAP does not need additional treatment tanks or specific plating machines. It can be adopted by standard plating lines with both soluble and insoluble anodes. Differences

in the CAP sequence are due to the different PTH process which are applied on the boards. SAP produced boards exhibit usually a sub micron thick layer of electroless plated Cu before electrolytic Cu is applied. On these boards a µ-etching step before plating cannot be applied. Thus, such boards will be produced in a different sequence than HDI boards which can be produced with a thin (several µ) Cu reinforced layer.
Table [1] shows a typical sequence for a SAP process in which no etching cleaner can be applied whereas table [2] shows a sequence

Table1: CAP-sequence for boards without reinforcement

Step	Sequence 1	Sequence 2
1	Acid Cleaner	Cupra Pro CAP 1
	Rinse	
2	Acid Dip+ CAP 1 Conditioner	Acid Dip
	Rinse	
3	Acid Cu	Acid Cu

Table2: CAP-sequence for boards with Cu reinforcement

Step	Sequence 3
1	Acid Cleaner
	Rinse
2	µ-Etch
	rinse
3	Acid Dip+ CAP 1 Conditioner
	Rinse
4	Acid Cu

Results

Parameters

We investigated physical properties and via filling ability for the new process. Parameters for the via filling ability were the remaining dimple the plated Cu surface thickness to achieve a proper filling Inclusions or voids.

Fig. [2] illustrates the above mentioned parameters

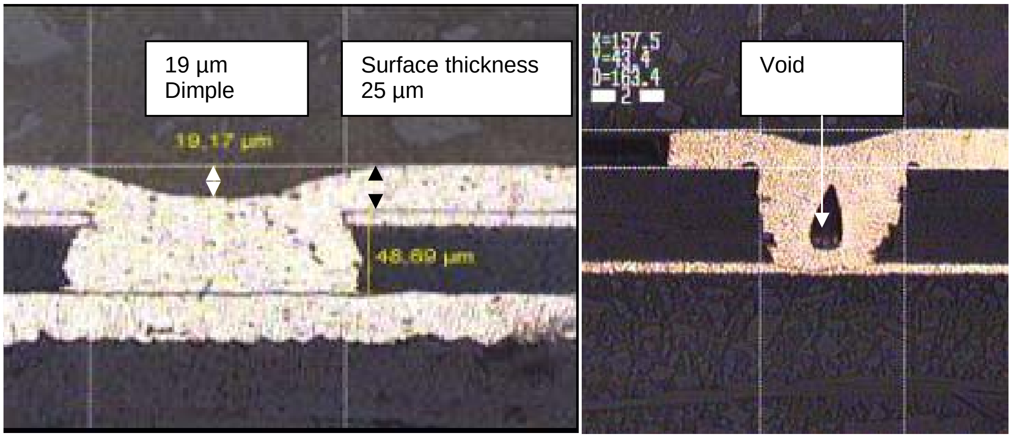

Fig. [2] Illustration of dimple, surface thickness and voids

Physical properties

A test panel has been plated according to sequence 1 and crystal structure as well as physical properties have been investigated. Table 3 summarizes the findings and it can be concluded that physical properties of the Cu layer plated with CAP process are comparable to standard Cu qualities.

Table 3: Physical properties of a Cu layer plated according to sequence 2

	Hardness Vickers [N/mm^2]	Elastic modulus [GPa]	Ductility %	Tensile strength [KN/cm^2]	Solder Shock 280°C
Cupracid VF1 with CAP	142	99	18-21	49	6 times passed
Cupracid BLCT	120-140	-	17-25	27-40	6 times passed
Cuprapulse	78-111	-	21-24	31-36	6 times passed

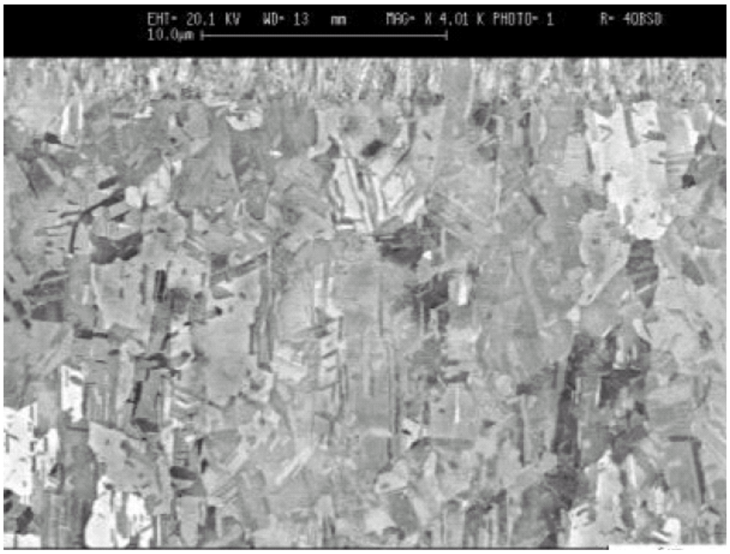

Fig [3] Crystal structure of an electrolytic Cu layer plated according to sequence 1. Typical polygonal structure can be observed

Influence of surfactants in CAP process on BMV filling

The conditioning activation step prior to plating is an essential step to achieve a proper via filling capability. The activation/conditioning electrolyte Cupra Pro Cap 1 consists of special activator molecules combined with surfactants and ions. Each of these additives have very specific tasks. The surfactant has to wet the surface and guarantee that the activator additive can reach the surface. Ions serve as anchor systems to enhance the adsorption of activator molecules.

How important it is to choose a right combination of these ingredients illustrates Fig.[4]. In this graph results of a series of experiments in lab scale according to sequence 2 have been performed in which everything apart from the surfactant in Cupra Pro Cap 1 step 1 was kept constant. All test boards were reinforced with a 5 µm thick Cu starting layer. The Cu via filling bath was a Cupracid VF1 bath, driven with 3 ASD to achieve a surface thickness of 25 µm Cu.

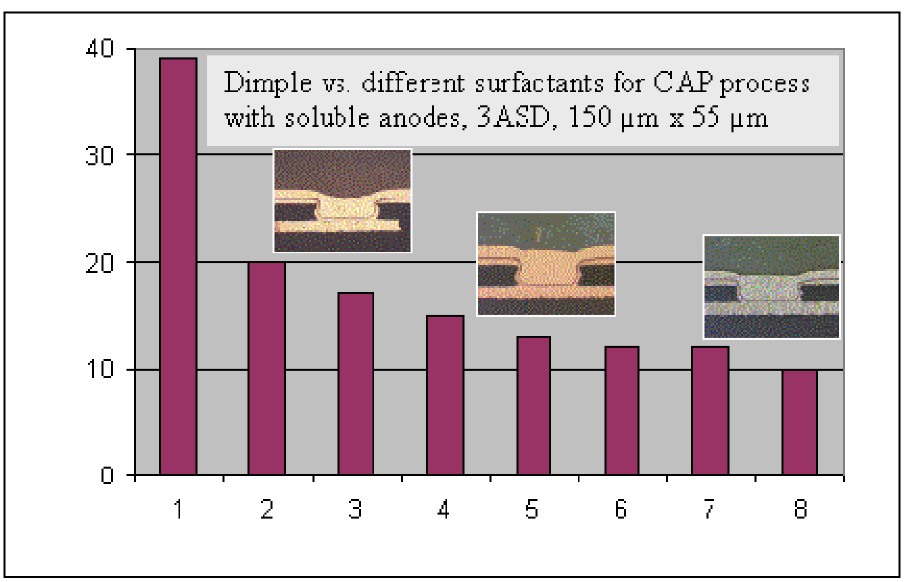

Fig [4] Influence of 8 different wetting agents in the CAP solution on the via filling performance. Wetting agent 8 gave the best result and has been adopted to the standard process

This graphs stresses the importance of a well balanced and compatible process, in which pre-treatment and plating are acting in a synergistic way. From this experience we chose No 8 as the standard surfactant for this process.

Defect rate:
We also investigated the effect of the CAP pre-treatment on the defect rate of blind micro vias. Therefore, we applied comparably high current densities on test boards and used different amounts of the CAP pre-treatment solution (Cupra Pro CAP 1) in sequence 2 and used a standard Cupracid VF1 electrolyte. The use of high CD s generates usually a lot of voids in BMV. We investigated at least 20 BMVs per run and counted the defect rate
Table 4 summarizes our findings. It is clear from the results that the void rate is indeed decreasing with the CAP process but over about 100 ml/l no improvement is visible anymore.

Table 4: Defect rate (voids) as a function of additive concentration of Cupra Pro CAP 1 in

Concentration of Cupra Pro CAP 1 in sequence 2	Defect rate (voids in %)
0 ml/l	30
25 ml/l	15
50 ml/l	14
75 ml/l	11
100 ml/l	7
125	9
150	8

Life time of electrolyte

The CAP plating electrolyte is running with reduced but measurable brightener system. This generates less critical breakdown products and therefore increases the life time of the electrolyte. In our laboratory we made a series of tests which investigated this process. In identical set ups we performed experiments and the result is shown in table [5]

Table [5]: Life time comparison of a CAP Cu electrolyte with standard via filling bath

Process	Cupracid VF1 with CAP*	Cupracid HLF Standard *
Life time in Ah/l	Ca 175	40-80

*No cleaning procedure in by pass or any treatment to resurrect via filling has been made

The life time of the standard electrolyte is comparably short since we did not take any measures to keep the electrolyte clean e.g. by pass filtering etc. which is usually applied in production units.
Application of the CAP process results in a significantly longer life time but not to an infinite bath life.

Plating results with inert anodes system

A practical test in a 400 l scale on a 18” x 24” reinforced PWB has been done to demonstrate the superior via filling behaviour of the CAP process also with an inert anode system. The Cu plating system Inplate VF1 exhibits a Fe-redox system similar to well known Inpulse system described elsewhere [2]. Results from tests with and without CAP pre-treatment are compared and shown in fig [5] Obviously, the CAP plated boards give better results.

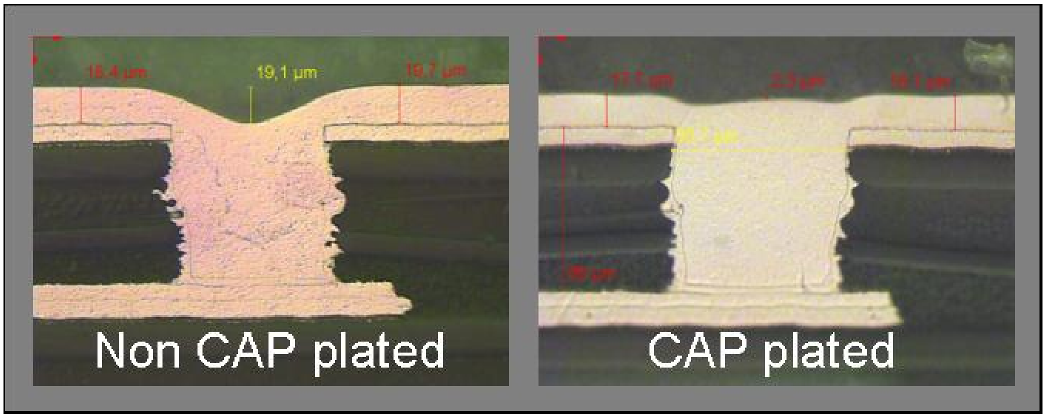

Fig. [5] Example for the capability of CAP process: left non CAP plated, right CAP plated according to sequence 2 , both plated at 1,2 ASD with inert anode system. BMV dimensions: 85 µm x 95 µm, plating thickness 17-19 µm

Further investigation showed a general improvement on via filling with CAP process both in panel and in pattern mode.

With the CAP process it can be observed that for some BMV types even a “negative” dimple can appear, Fig [6]. This phenomenon can easily be controlled by applicable current density, time, additive concentration etc.

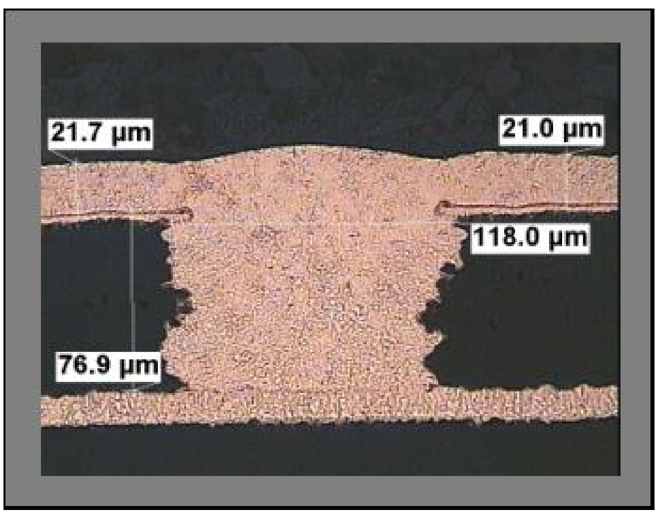

Fig. [6] Example for the capability of CAP process: CAP plated according to sequence 2, at 2 ASD with inert anode system (Inplate VF1). BMV dimensions: 118 µm x 77 µm, plating thickness 21 µm on fresh eless PTH

To achieve best performance with the CAP process one should consider the following aspects the PTH should be as fresh as possible (best wet in wet production) fresh electroless Cu performs even better than reinforced material.
Pre-treatment and plating electrolyte are one system working in a synergistic way.

Summary

We have presented a new process sequence for BMV filling. This process can be adopted by standard plating lines both operating with inert and soluble anodes.
The CAP process is a synergistic procession combining pre-treatment and plating. The performance of the novel process is superior to standard process in terms of filling ability,

applicable current density and life time. It can also be performed with inert anode system for both pattern and panel plating systems.

Literature

[1] Özkök et al. EP 0405874 and DE 103 25 101 A1,
[2] Barthelmes, J. „Acid Cu Plating with Insoluble Anodes- A novel Technology in PCB Manufacturing , Proceedings of the Electronics Circuit World Convention 8 (1999)