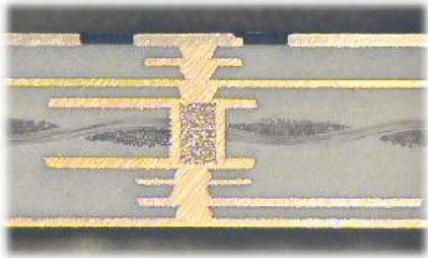


## HOW TO SET UP A SUCCESSFUL BLIND VIA HOLE FILL DC PLATING PROCESS

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### ABSTRACT

Blind vias that connect layer 1 to layer 2 or to layer 3 are an enabling technology for HDI (high density Interconnect) type boards. Via fill makes for a robust connection see fig 1 with no chance of any voids during assembly. Vias with 1 : 1 aspect ratio are common.



**Figure 1:** Stacked vias as an enabling HDI technology

Successful via fill plating requires a specific electrolyte; the copper concentration is as high 50 – 60 g/L copper with low sulfuric acid at 30 – 60 g/L. This is combined with a unique organic additive combination with a prominent leveling component. The leveling component acts predominantly on the surface and suppresses the surface plating allowing the brightener and carrier combination to plate up from the bottom of the via. Ideally the solution movement must be vigorous and parallel to the surface (laminar flow); this ensures adequate leveler replenishment.

### INTRODUCTION

The mechanism of via filling is different from thru hole plating. A good understanding of the following influencing factors is paramount to the success of the process:

### THE ELECTROLYTE

The electrolyte is composed of inorganic and organic components. The inorganic component for via fill is primarily a high copper low acid system. This ensures that there is no shortage or depletion of copper ions anywhere on the plating surface. The organic additives are composed of three components, namely the carrier or suppressor, the brightener or accelerator and the leveler which is a selective suppressor.

Carriers increase the polarization resistance and are current suppressors. The suppression is a result of the carrier being adsorbed to the surface of the cathode; this results in increasing the effective thickness of the diffusion layer. The

result is better organization. This gives rise to a deposit with a tighter grain structure. The carrier modified diffusion layer also improves plating distribution without burning the deposit.

The brightener is a grain refiner. Its random adsorption produces a film that will suppress crystallographic differences. The brightener produces a fine grained non directional (equiaxed) grain structure. It is the additive that directly affects the tensile strength and elongation properties of the deposit.

Levelers are small molecules that carry a partial charge that are attracted preferentially to the higher current density areas on the plating surface. Levelers, or leveling agents, are selective inhibitors present at low concentrations in the electrolyte as compared to the depositing metal. Vigorous solution movement is required to replenish the leveler at the surface of the panel. Fig 2 shows an example of a misplaced air sparging pipe resulting in vigorous solution movement on the filled side with hardly any movement on the voided side.

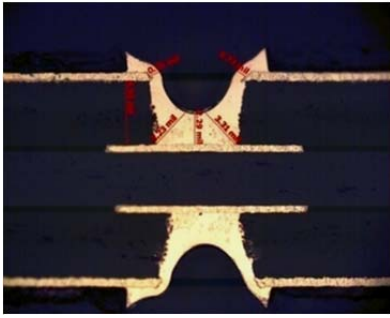


**Figure 2:** Misplaced air sparger; solution movement only on one side (filled vias)

### FILLING MECHANISM

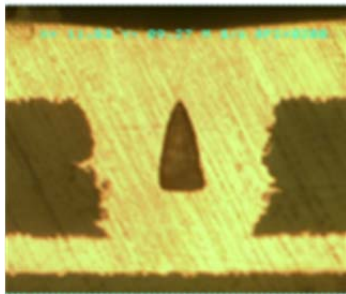
There are multiple concurrent mechanisms that take place for the via filling process to occur. The brightener and the carrier are evenly distributed throughout the via and their combined effect is to promote plating. The leveler component is only active at the knee of the hole (high current density area). It inhibits the plating at the via entrance; kind of keeps the via open allowing the

brightener/carrier combination to bring the bottom up, Refer to the progress of plating Fig 3.



**Figure 3:** Preferential bottom plating in progress

The replenishment of the leveling component at the surface is a function of solution movement. Vigorous laminar flow across the surface must be designed in the original setup. In the absence of the leveler effect the knee of the via would plate at an accelerated rate closing the via before the filling is complete. See Fig. 4. This same mechanism can fill a small diameter, low aspect ratio thru hole like a 6.0 mil diameter hole in a 10 mil thick laminate.



**Figure 4:** Conformal plating

### THE PLATING CELL

The plating cell design is not that different from standard acid copper plating. Attention must be made to ensure adequate anode cathode spacing (7-12 ins) in the initial design. The plating cell must be equipped with temperature control capabilities, mostly cooling. An overflow weir is recommended to maintain solution level and to facilitate filtration of suspended particles. Filtration thru 5 – 10 micron filter cartridges should be continuous and designed at a flow rate to ensure a minimum of two solution turn overs per hour (>2 STO). The filtration system draws from the bottom of the weir and returns below the cathode.

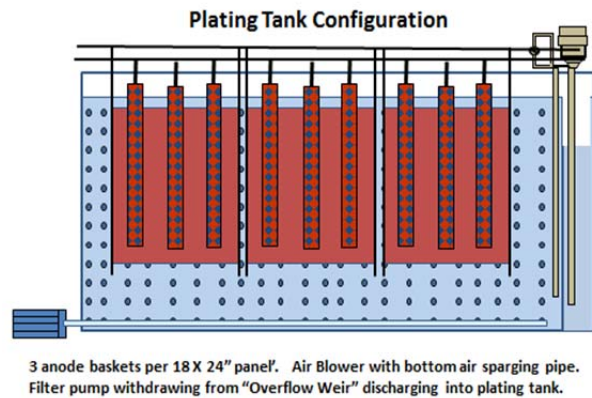
The number of anodes (usually titanium baskets full of copper balls) should be optimized for the platable area of the cathode; maximum for panel plate and minimum for dot pattern (pads only). Anode placement should be such that the active length of the anode is 3 – 4 inches shorter than the cathode, and should be tucked in 3 – 4 inches inside the cathode window on the outside vertical edges..

The panels ideally should have a common vertical dimension and should be racked with minimum gaps. If the

cathode bar is not fully racked, dummy panels or thieving strips must be used to prevent imbalance in thickness distribution; alternatively the anode baskets opposing the gap may be isolated.

Solution agitation is initiated at the bottom of the tank, it may be air sparging or e-ductor agitation. There should be 2 manifolds one in front of the panel and one in the back. The spacing between the top of the sparging system and the bottom of the panel should be at least 6 inch. It is intended to produce a uniform laminar flow across the surface of the panel. The flow should be vigorous to ensure sufficient leveler replenishment at the entrance of the via. Via filling will not occur if solution agitation is inadequate as demonstrated in Fig 2.

Part agitation is not necessary in this setup.



### RECTIFICATION

The rectifier should be sized to supply the desired output, example if the platable area is limited a smaller rectifier would be the right choice, it is not advised to use a 200 Ampere rectifier to plate at 10 -20 amperes. Ripple (% AC; alternating current) should be less than 5% to ensure the deposit is fine grained adherent and equiaxed. High ripple would have an adverse effect on the physical properties of the deposit. The rectifier control accuracy or resolution should be 1 – 2% to ensure consistency of output.

The ASF to be used in plating the blind via should be optimized, for the via dimensions. More demanding vias (higher aspect ratio) will require lower ASF for a longer time. Traditionally there are 2 approaches to the plating CD (current density). The first approach is a single CD for the duration of plating. The second approach is to step up the CD with time, example 10 ASF for 45 minute followed by 20 ASF for 30 minutes and then 25 ASF for 15 minutes. Both methods work and the choice should be made at the initial installation thru experimentation. Once established this becomes the method. The method may be optimized again as the next level of difficulty (higher aspect ratio) is encountered.

## PANEL VS PATTERN PLATING

Both methods of plating are being utilized in the industry. Panel plate creates greater uniformity across the board, however, it is more demanding on the planarizer to reduce the plated surface copper. Flash plating the electroless copper is not recommended as it tends to increase the aspect ratio of the hole.

Pattern plate in most cases is a pads only pattern, referred to as a “dot” pattern. The panel after electroless metallization is imaged using photo-imagable dry film resist. A half inch of non-imaged laminate copper is left exposed on all four sides. This edge is used for rack connectivity during plating. This copper edge has a thieving effect on the distribution of the copper thickness above the via. Vias or pads in the center of the panel will plate much higher than their counterparts closer to the edge. See fig 5. The figure shows that the CD at the different locations varies more than 2X between the vias along the edge vs the vias in the center of the panel; note that all the vias are filled in spite of the large variation in CD from via to via. All the variability in thickness of copper above the via is removed during planarization.

Periodic carbon treatment, to remove organic contaminants leaching from the dry film, must be set up on a regular basis to ensure consistent performance from the electrolyte.



It is clear from the thickness on the surface that the current density is very different in the three locations. The “Center” carries the most current the “Off Edge” and the “Edge” are much closer to the thieving edge and are robbed of current. The ratio of the surface copper plating thickness is 1.0 for the Edge to 1.6 for Off Edge and 2.2 for the Center.

**Figure 5:** Variation in Current Density distribution in a “Dot” pattern

## PRE-TREATMENT

Prior to introducing the panel to the plating line, make sure that there is no debris in the vias. One source of debris is developer residues nor rinsed out after develop. If debris is encountered, special measures to remove it have to be added to the regular processing. High pressure wash, excessive vibration in the cleaner and increased dwell in the microetch may be necessary to dislodge any debris that would interfere with the plating/filling of the via.

The pre-treatment is composed of the following steps; Cleaner, Micro-etch and Pre-dip.

## The Cleaner Step

The cleaner is composed of a solvent, an acid and a surfactant. The solvent removes organic surface residues by dissolution. The acid removes oxidation and the surfactant wets the surface. The wetting is very important when plating small high aspect ratio holes or blind vias; a well wetted surface will not trap air. Intermittent vibration in this step is helpful to ensure that all air is dislodged from tight spaces. Follow vendor’s recommendations of concentration, temperature, dwell time and dump and remake schedule to ensure the cleaner functions as intended. Good 2 step rinsing is important after the cleaner as its components in trace amounts, if dragged down the line may adversely affect the plating.

## The Micro-etch Step

The Micro-etch is made up with a strong oxidant like sodium persulfate or hydrogen peroxide in a sulfuric acid medium. The micro-etch oxidizes the surface copper and literally etches it away exposing a fresh copper surface for plating. If the metallization used is electroless copper; the concentration and dwell time should be controlled to ensure that the electroless copper is not etched away. In addition the micro-etch can undercut minute stubborn residues that the cleaner did not remove. Concentration, temperature, dwell time and dump and remake schedule must be adhered to. The panels are double rinsed after the micro-etch.

## The Pre-dip Step

The Pre-dip is made up with sulfuric acid at 5 – 10%. This step ensures that the surface is oxidation free and is acidic to match the acidity of the electrolyte. There is no rinse between the pre-dip and the acid copper bath.

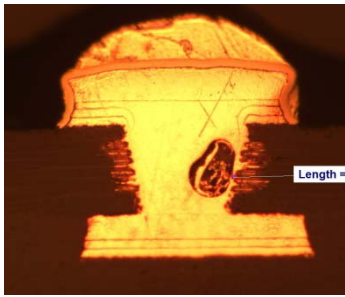
## VOIDS

Ideally there should be no voiding in the copper filled via. Refer to the IPC latest version of 6012 D, where the acceptability criteria is clearly delineated.

Three different causes of voiding have been identified.

## Entrapped Air

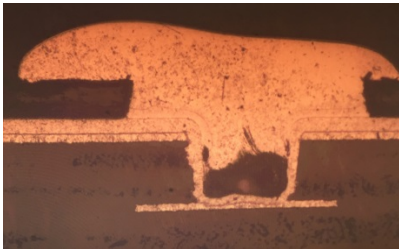
The primary reason for voids is poor wetting of the via by “Entrapped Air”. All air must be removed from the via in the initial cleaner step. Cleaners with low surface tension are better suited for this task. Intermittent vibration in the cleaner ensures that all air is dislodged and that the surface of the via is fully wetted. Figure 7 demonstrates air entrapped voiding.



**Figure 6:** Void due to air entrapment in the via.

#### **Debris in the via**

Debris in the hole is usually associated with pattern plate, where the board is imaged, exposed and developed. If the developer equipment is not properly setup or if the rinsing after develop is inadequate. Residues from the developing solution may get trapped in the via.



**Figure 7:** Void due to debris in the hole

#### **Conformal plating**

Another form of voiding occurs when the plating at the knee of the via proceeds at a faster rate than the bottom; refer back to figures 2 & 4. Here the hole is closed at the entrance before the bottom plating comes up. This is the result of imbalance in the leveling component, poor solution agitation or both.

#### **CONCLUSION**

Understanding the principal of plating , the role of the additives, cell design and the critical role of “Pre-Treatment” are key for the successful running of the Via fill process day in and day out.