# What's New in Vertical Acid Copper Plating for PCB Manufacturing

## Developments in the world of printed circuit boards.

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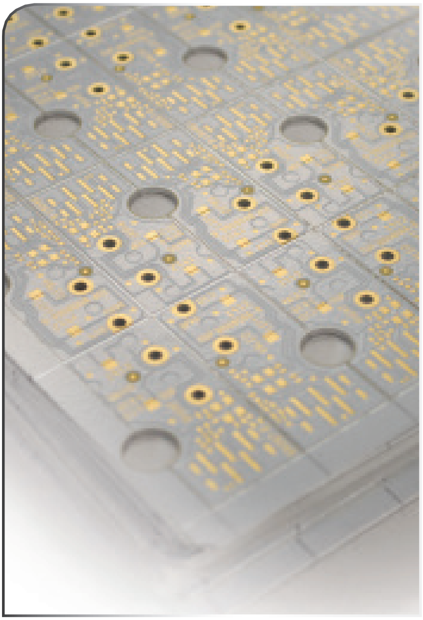
In the North American market there are some dramatic changes in the printed circuit board landscape, as we see the migration of manufacturing to the East, particularly to China. Most of the big runners are made overseas.

There are certain categories of products that remain in North America, however—those that are classified as high value added. These are primarily prototype boards, large backplane (>40 layers), and boards for military use.

Prototype boards require very elaborate front-end engineering to bring the part to its final configuration in a reasonable time frame. Prototype boards are never made in numbers, but they may go through a series of iterations before finalization. These boards cover a range of complexity with some being highly sophisticated with high layer count, small holes, and buried and blind laser drilled vias. Less than 3 mil lines and spaces and "Via Fill" are first encountered here.

Backplane type boards may reach a thickness of 400 mils, and although the holes are usually greater than 15 mils, it is the highest aspect ratio demand; 25:1 is actually being manufactured and plated today. This is one of the highest value added products in PCB manufacturing.

To meet these specification requirements the board shop is forced to seek new and advanced processes in every department in the manufacturing process. Acid copper plating comes under heavy scrutiny, as it is the process that forms the traces and the thru hole connectivity that convey the signal from end to end of the final device.



Surface uniformity is sometimes plagued with the occurrence of nodules, which come from a variety of sources. Gold wire bonding applications have no tolerance to any level of nodulation.

New developments are helping meet this challenge. A big part of the developments are focused on:

- New chemical additive packages for improved distribution.

- Mass transfer improvements to complement the additives
- Nodules elimination by use of insoluble anode
- "Via Filling," a specific application

### Acid Copper Organic Additives:

The additives fall into three main categories:

- Carriers
- Brighteners
- Levelers

**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 may produce a film that will suppress crystallographic differences. Alternatively brighteners may be adsorbed preferentially on particular active sites such as lattice kinks, growth steps, or tops of cones, or surface projections in general; growths at these locations are then blocked. 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. In case of a micro profile the diffusion layer does not follow the profile contour, but is maximum at the valleys and minimum at the peaks. Consequently, in absence of a leveling agent, depositing ions diffuse more rapidly to the peaks than to the valleys, and deposits grow more rapidly on the peaks, resulting in an exaggerated profile.

With good solution agitation, the leveler will accumulate more rapidly and readily at the peaks and it will inhibit growth or deposition. The valleys will allow faster deposit growth and allow the valleys to catch up to the peak, thus creating leveling.

### Pulse Plating

For the last few years the copper plating industry was focused on pulse plating and in particular periodic pulse reverse, as the solution for all. As time progressed and the level of difficulty continued to climb, the plating current density for pulse began to drop and the primary advantage of plating at higher current density began to disappear. Add to that the complexity of operating a pulse rectifier with added definition of ASF, forward to reverse ratio, duty cycle and waveform. In many instances pulse also required an elaborate and frequent scheme of organic regeneration to maintain the copper thickness distribution benefits.

Pulse plating is presently being utilized, it is a more complex process and requires additional controls, the deposit produced is usually not bright. The physical properties (tensile and elongation) of pulse plating, though meeting minimum requirements, are not as good as those produced by DC plating.

### High Throw DC Plating

A new generation of "High Throwing Power" acid copper systems have come to the market to fill the void. These baths are designed for today's plating currents, which are lower than the traditional 25 - 30 ASF, which was common in the days of double-sided, and simpler products.

High throw baths are designed to give the desired physical properties at current densities as low as 5 ASF and as high as 20 ASF. They produce bright ductile deposits.

These bath types are characterized by a specific combination of organic additive package that includes a unique leveling agent. The leveler plays a key role in improving throwing power particularly if it is coupled with eductor (airless) agitation.

Some of these baths can give a throwing power greater than 65 percent for a 28:1 aspect ratio drilled hole plating 1.0 mil in the hole, in a vertical dip tank mode.

## Mass Transfer

Mass transfer becomes a key parameter that must be understood and managed for high aspect ratio plating. An example is plating a 330-mil-thick board with a 22-mil hole diameter, a 15:1 aspect ratio, an 8-mil-hole in a 93- or 125-mil-thick board, or a blind via with an aspect ratio greater than1.0. Mass transfer is influenced first and foremost by diffusion, also affected by solution agitation, and part or rack agitation. Of course, a reduction in plating rate will always improve distribution by maximizing the role of diffusion for mass transfer.


**Diffusion** refers to the movement of ions through the solution in response to a concentration gradient. It is a consequence of random molecular motion that operates to produce more uniform distribution throughout the solution. As soon as plating begins to deplete the copper ions in the immediate vicinity of the cathode (in the diffusion layer) diffusion drives more ions in to equalize the concentration. If the plating rate is higher than the rate of diffusion alternate sources of "mixing" are required.

**Eductors** are used today in many of acid copper plating tanks. They create turbulent solution flow without the use of air sparging. The design and layout of the eductor sparging system is important to maximize the solution shearing action at the surface for the board to be plated. If properly designed eductors can preclude the need for part agitation. The increased solution flow at the surface as compared to the middle of the hole could be effective in improving the throwing power, provided the chemical additives used are designed to respond preferentially to solution movement. Eductors eliminate the need for compressed air or air blowers, and also provides a safer environment where acid is not constantly been blown into the air, or the exhaust system.

**Air sparging** is used in acid copper plating as a means of solution agitation to replenish the metal ions at the depositing site. Air spargers should be properly designed to give sufficient turbulence

## Nodule Elimination Insoluble Anode

The use of insoluble anodes is well established in the acid copper conveyorized equipment. It offers a series of advantages over the conventional copper slugs/balls in titanium baskets. The most prominent advantage is the

*This automated line enables plating of about 1,500 PCB panels each week.*

absence of copper anodes, which need to be filmed and bagged to contain naturally occurring sludge from getting on the work.

Anodes, even in their purest form, are prolific sources of suspended matter that leads to nodules. Insoluble anodes eliminate the need for dummy plating to film the anode. The need for standard anode maintenance is also eliminated. The anode shape and dimensions are not altered throughout the life of the insoluble anode.

The insoluble anode requires a continuous supply of copper ions brought into the system from an external source. Some of the methods used to generate copper are the dissolution of copper oxide into the electrolyte, the electrolytic dissolution in an external rectified cell and the use of ozone to oxidize copper metal.

Adapting this to vertical plating lines is beginning to make inroads in the industry.

The elimination of anode maintenance, the consistency of the anode area and the elimination of the soluble anode as a source of nodulation have proven to be major assets.

## Via Fill Plating

To meet the demands of high density interconnect, "via filling" is quickly becoming a clear choice for connecting the different layers in buildup technology (stacked vias and vias in pad) manufacturing. They result in an overall improvement in long-term reliability of the PCB and the package.

Suppliers have developed new electrolytes for plugging vias shut. Both pulse plating and DC plating proprietary "Via Filling" chemistries are available in the market place. DC plating offers a series of advantages as it does not require pulse rectification and avoids the complexity of managing a pulse wave. In addition DC plating systems are stable and do not require the constant regeneration of pulsed electrolytes.

Via filling is based on high depositing ion concentration coupled with a low concentration of a leveling agent, in addition to the carrier and the brightener additives. Most of these systems require optimized solution flow. The flow allows the leveler to accumulate on the surface, thus inhibiting plating while the bottom of the via continues to plate. The plating dynamics in the bottom of the hole are very different than those on the board surface. Eventually as the hole fills, the plating dynamics even out.

Acid copper plating has come a long way since the early days of double and single sided printed wiring boards. Plating challenges will continue to increase as new product demands (lighter smaller and more reliable) come to market. As one leading edge milestone is conquered, a new one is set. Stay tuned.