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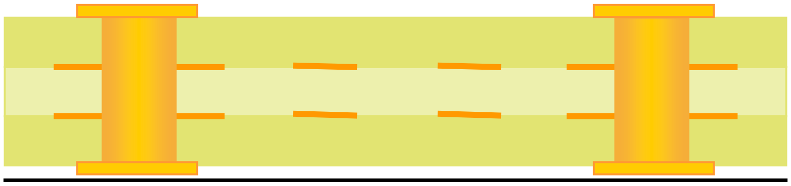
Cost Effective Electroplating

April 2009

This Article is currently published at PCB 007 website



Cost Effective Electroplating

While the physics of electroplating has not changed since Faraday’s time, both the bath chemistries and application equipment used within the PWB industry have undergone a continuous evolution. During the early years of printed circuit manufacturing, plating shops always had a definite ammonia aroma, due in part to the use of alkaline copper pyrophosphate chemistries. This technology was replaced by “acid copper”, initially using dyed additive systems, which in turn were replaced by the non-dyed additives most commonly used today.

Electroplating is a capital intensive process and very often represents a bottleneck within a manufacturing facility. It is therefore particularly important to optimize this process for the highest possible productivity. During the 70’s and 80’s, vertical rack equipment coupled with a single additive system was capable of handling all board designs. The only adjustments needed were to plating times and current densities, depending on board complexity. Today, optimization of the copper electroplating process for a given board design requires us to consider many more process conditions variables.

Segmentation of copper electroplating objectives allows for the most appropriate process solutions for given groups of board designs. Effective alignment between board design and electroplating process brings efficiency, performance and cost gains.

If processing only one type of PWB design, the electroplating operations can be optimized for those specific parameters. As the number and type of PWB designs increases, a wider variety of plating options have to be considered.

Table 1: Physical Characteristics of Different Categories of PWB Products

Design	Typical Thicknesses	Aspect Ratio of Vias
Double Sided / Plated Innerlayer	0.1 – 2.0mm	Low
Multilayer	0.8 – 12mm	Low to High
HDI	0.8 – 2.0mm	Low to Medium
Flex	0.05 – 0.1mm	Low

Specific end market requirements will also influence the choice of process, since these requirements will influence minimum copper thickness and copper thickness distribution, as well as thermal, mechanical and electrical property requirements.

Table 2: Reliability Requirements for End-Use Segments

Market	Relative Reliability Requirements
Consumer	Low
Industrial	Medium
Automotive (in car)	Medium
Automotive (inside engine compartment)	High
Medical	Medium / High
Military / Aerospace	Very high

Process suppliers offer a wider range of choices for electroplating process system choices than ever before. Selecting the system best aligned to your market, designs and customer requirements will determine how effectively manufacturing cost and product performance will be aligned to those needs.

Table 3: Copper Electroplating Equipment and Additive System Alternatives

Equipment	Rectification	Anode Type	Additive System Capability
Horizontal	Direct Current	Soluble	Low Current Density
Vertical	Periodic Pulse Reverse	Insoluble	High Current Density
Conveyorized Vertical			Viafilling
			Bright, Matt, Satin

Conveyorized (vertical or horizontal) systems, where anodes and cathodes are in close proximity, provide improved copper surface distribution, compared to vertical rack equipment. Additionally, panel to panel consistency can be improved, as each panel experiences essentially the same plating conditions. However, to minimize equipment footprint and cost, higher current density is often required. In order to provide the required throwing power at these elevated current densities, pulse plating rectifiers and additives are often required, adding further to cost and complexity.

On the other hand, vertical rack systems offer a higher degree of flexibility in processing multiple board design formats and plating parameter requirements. It is feasible, and often desirable, to have several different plating solutions within one vertical process line. If your product designs include, for example, 10% high aspect ratio, 80% conventional multilayers and 10% HDI product requiring viafilling, then three separate electrolytes should be operated, each one tuned to a specific segment.

Another decision that has to be made is whether to panel plate or pattern plate, or to balance the “benefits” by using semi-panel plate. In general, panel plating will provide improved surface distribution of copper compared to pattern plating, but will reduce fine line etching throughput and capability.

Consideration must be given to end-customer requirements for the printed circuit board. Investments in new or expanded plating capability must consider what is likely to be required in future years and to take this into account. Factors such as demand for filled microvias, changes in minimum line and space, increases in thermal reliability requirements and impedance control / signal integrity must also be considered. Since automotive, military and aerospace requirements are quite different to consumer electronics, changes in target customers must also be included in the analysis.

Designing a Copper Electroplating Process

The first stage of optimizing copper electroplating processes is to gather information about the production and performance requirements for the products being made (or planned). Factors to consider include the following:

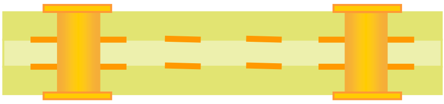
Board Quantity
Batch sizes
Minimum and maximum board thickness
Panel construction process sequences
Minimum hole diameter and minimum centre hole copper thickness
Filled Microvia dimensions
Filled holes and dimensions
Minimum surface feature size
Pad flatness
Thermal and mechanical performance
Impedance control requirements

The answers to the above questions, for both current and future customer requirements, will help you to work with your chemistry and equipment suppliers to select an optimum combination of processes to meet those needs.

If the board designs and customer requirements from the above analysis vary substantially, then the use of two or more different plating systems should be considered to optimize operating efficiency, cost control and alignment with customer requirements.

Taking a more detailed look at some general categories of board designs reveals some of the possibilities.

Figure 1: Conventional Multilayer Boards

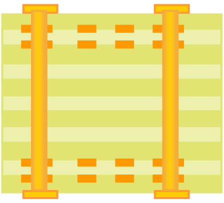


While multilayer boards can be manufactured using a wide variety of plating processes, for almost all end-use applications, the physical performance of the copper deposit is critical to the reliability of the end-use system. Stresses accumulated during the assembly and lifetime of the system can result in early failure, if the plating process has not been optimized to meet such requirements. Areas with abnormally thin plated copper are most likely to fail first. Although defects of this type are most often caused by factors such as poor drilling, they can be worsened by inadequate plating performance, for example

Poor throwing power
Poor deposit levelling
Additive imbalance causing thin corners
Non-optimized pulse rectification
Over-aged or contaminated plating solution

The performance of an electrolyte, which may have been excellent initially, may have declined to unacceptable levels due to contamination and by-product buildup. Since even a relatively small loss of throwing power, surface distribution or tensile performance can be costly, the proper use of carbon filtration, carbon treatment or bath replacement is essential to maintain performance.

Figure 2: Thick Boards

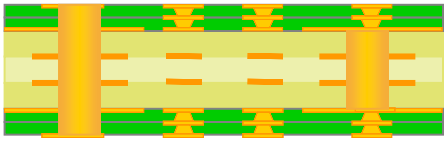


“Thick boards” is always a relative term. For customers whose current process is optimized for 0.8mm – 1.6mm thick panels, 2.4mm would be considered thick. For other customers, “thick boards” can mean telecommunications system back panels up to 12mm thick, that look more like doors than printed circuit boards. This type of ultra-thick panel has unique requirements in terms of handling equipment, plating equipment and electrolytes.

The lower end of the “thick board” range, from 2.4mm to 4.8mm, can be plated with excellent throwing power and surface distribution using the latest pulse plating additive systems in pattern plate mode, typically with vertical rack equipment. These systems provide equiaxed copper deposits that are capable of meeting demanding end user reliability requirements.

Thick backpanels, typically intended for use with press fit connectors, have very tight through hole plating thickness and uniformity tolerances. These targets demand the use of low current densities and long plating times to achieve optimal copper throw. These heavy boards also require specialized handling and clamping systems, since a lot of damage can be done if a panel of this size and weight accidentally falls from a rack !

Figure 3: High Density Interconnect (HDI) Boards



HDI construction has migrated from consumer electronics into almost all segments of the market. Demand for plated and filled microvias will continue to grow substantially over the coming years, offering both opportunities and challenges to board producers. Production of HDI boards almost always requires the use of multiple metallization processes within a single board. This complexity can cause real bottlenecks in the manufacturing area, with copper electroplating often being the most significant of these bottlenecks. Viafilling demands a combination of relatively low current density and electrolytes with relatively high copper concentrations. While dedicated viafilling electrolytes are necessary, they can be accommodated within conventional plating equipment. The best available viafill processes now offer the flexibility to manufacture using either panel plate or pattern plate processes, and excellent viafilling with good through hole throwing power.

As microvia densities increase and via diameters decrease, equipment design and solution flow play an increasingly important role in ensuring consistent filling performance.

Benefits of Insoluble Anodes for Horizontal and Vertical Applications

The traditional use of soluble anodes in an electroplating cell makes the plating bath management relatively easy, since the metal ions consumed during electroplating are directly replaced by the dissolution of metal from the anode. In recent years, there has been a growing trend towards the use of insoluble anodes in copper electroplating, which requires that the copper in the electrolyte be maintained using an external copper source, such as copper oxide.

Given that the use of insoluble anodes requires more complex bath management, why are more and more companies investing in this technology?

The first type of plating systems to move to insoluble anodes were horizontal copper plating modules. This move greatly reduced the time that the lines had to be shut down for anode maintenance and increased production throughput. It avoided potential problems of particles from copper anodes causing surface roughness and maintained a constant anode profile for optimal copper distribution, as well as allowing higher plating current densities.

With these benefits demonstrated for horizontal processing, should vertical equipment also consider use of insoluble anodes ?

Increasing numbers of vertical process lines have been successfully converted to insoluble anodes, demonstrating that the technical and commercial benefits outweigh the installation and running cost.

Benefits for vertical installations include many of those shown previously in horizontal equipment

Stable anode area providing improved copper surface distribution
Elimination of copper anode maintenance
Increased equipment uptime / capacity
Reduced potential for surface roughness caused by anode particles

Additional benefits have also been seen in improved plating bath life and performance, based on reduced additive by-product formation.

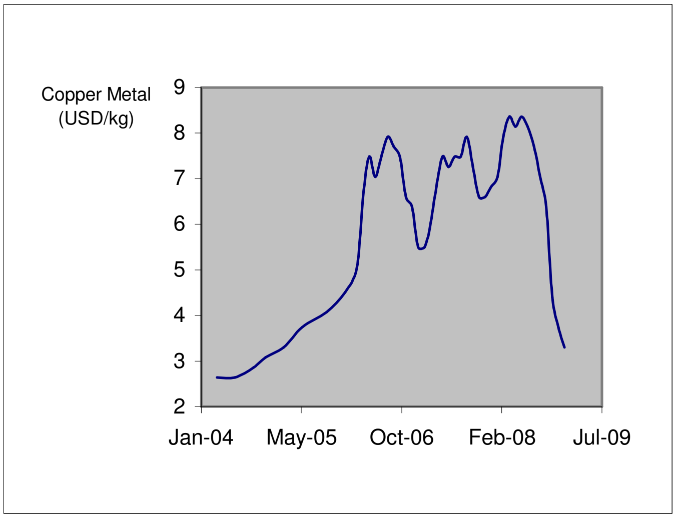
Impacts of Excessive Copper Thicknesses

No matter what copper electroplating process or processes are selected, use of electroplated copper thicknesses that are greater than necessary adversely affects process cost and capability in the following areas.

Plant capacity costs
Plant operating costs
Materials costs for copper metal and additives
Reduced fine line etching and resist stripping process capability
Dry film thickness increases for over plated features
Increased soldermask usage to provide coverage of isolated features

These processing impacts have been amplified in recent years by the unpredictable (and recently very high) price of copper metal. Copper price has varied between $2/kg to $9/ kg over the past few years, dramatically affecting the cost of making printed circuit boards. This provides still another motivation to seek manufacturing efficiencies and demands the optimal use of copper and associated processes.

Figure 4: Price of Copper Metal (2004 – 2009)



Every effort should therefore be made to eliminate copper plating that is not required by the end customer, in order to reduce costs and to optimize plant utilization.

Summary

To employ the most cost-efficient electroplating process, capable of meeting end-customer performance specifications, requires many factors to be taken into consideration. Time and effort invested in carefully analyzing the requirements for present and planned product, and then selecting and optimizing the correct combination of electroplating processes and equipment, is always repaid in the form of lower process costs, higher throughput, improved capability, improved reliability or a combination of these benefits.

Dow Electronic Materials continues to invest in the development of electroplating process solutions offering the broadest range of capabilities matched to end user requirements, to ensure our customers can provide the most cost effective electroplating of copper for printed circuit manufacture.

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The Interconnect Technologies group of Dow Electronic Materials is a global supplier of a comprehensive range of electroplating products, including cleaners, microetches and electrolytic copper and tin products and a full range of via filling processes for HDI and packaging substrate applications.