



Manufacturing printed circuit boards and semiconductors:

Improving plating quality, efficiency, and reliability

Meeting escalating demand
while delivering increasing complexity.

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Authored by Max Yung,
Senior Engineer in Power Electronics,
specialist in high-precision electroplating



Abstract

The quality of plating significantly affects the signal and data distribution, transmission speed, and heat dissipation of both PCBs and semiconductors.

This paper, looks at how manufacturers of PCBs and IC substrate can address challenges to optimize plating quality and costs using three different aspects of power conversion technology, (and the necessary process/application expertise), including:

- The application of pulse technology (PPR) to achieve uniform plating results.
- Improving data transmission and heat management through complex power conversion.
- The next generation of accurate current control for highest precision plating in semiconductors and advanced PCBs.

Introduction

The growth of the printed circuit board (PCB) and semiconductor market, fuelled by escalating demand across multiple sectors, looks set to continue.

The impact of 5G, digitalization, and the addition of 'smart' technology to an ever-increasing range of consumer products, business solutions, and healthcare applications, plus innovations in automotive, healthcare, industry, and communications, are all contributing to the need for more and better products. The PCBs are becoming more sophisticated, and the need for better heat dissipation and faster, more reliable data transmission continues to accelerate.

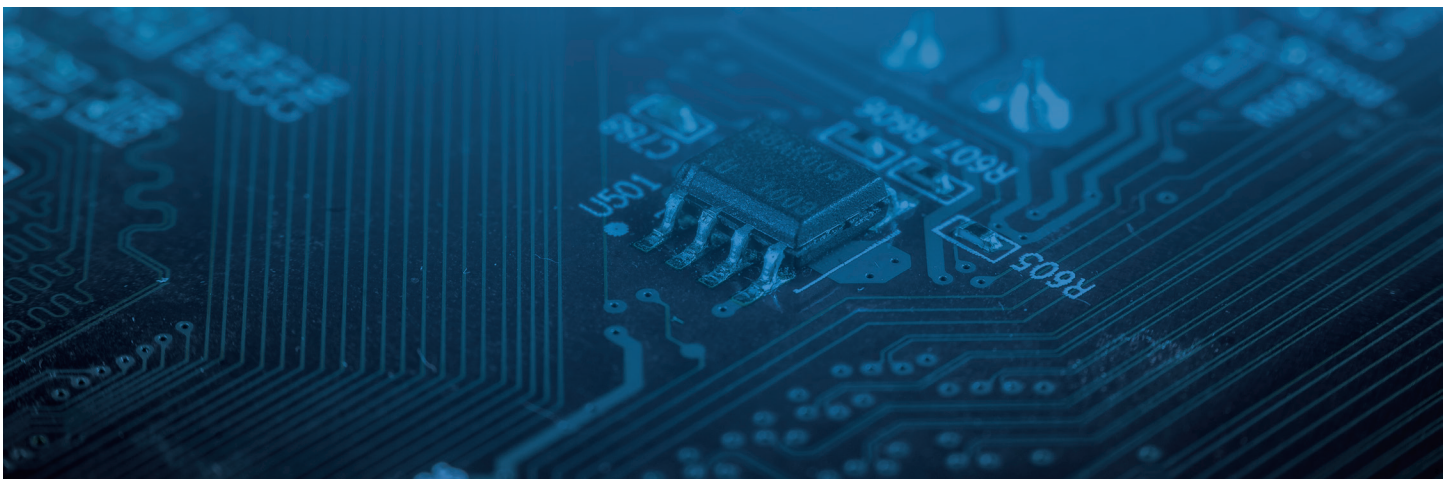
Skyrocketing energy and material prices are contributing to operational costs, driving the need for manufacturers to seek greater efficiency and reduction in waste, while delivering the quality, complexity, and scale needed for today's challenging specifications.

As demands for miniaturisation continue to grow, semiconductors and their accessories are getting smaller and smaller, including the platform package on which they are assembled. While integrated circuit (IC) substrates within semiconductors share the same requirements and challenges as the PCB, they require even more precision and refinement to deliver on a miniaturised scale.

Increasing circuit density means copper lines are becoming thinner and more delicate, while stacks are becoming thicker, with multi-layered boards requiring ever-deeper plated through-hole vias to connect them.

Board aspect ratios are increasing

Only a few years ago, it was unusual to see any PCB with an aspect ratio as high as 20:1 - now ratios of 40:1 or more have become common, bringing plating challenges with them. The higher the aspect ratio (board thickness to through-hole via diameter), the more difficult it is to ensure even copper distribution.

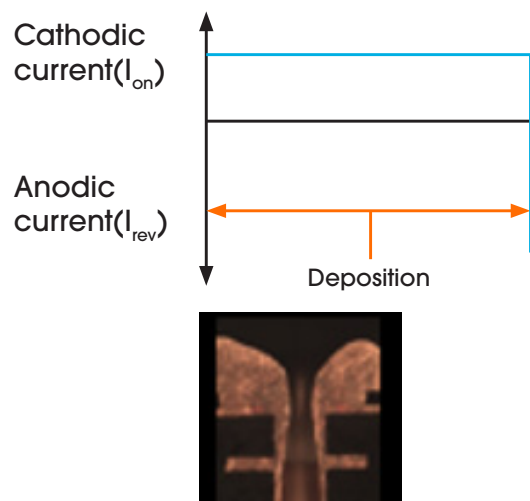


Achieving uniform plating using pulse technology (PPR)

The challenges in achieving even copper distribution within vias

The narrower or deeper a PCB's through-hole vias are, the more difficult it can be to achieve even and complete copper plating at the optimum thickness.

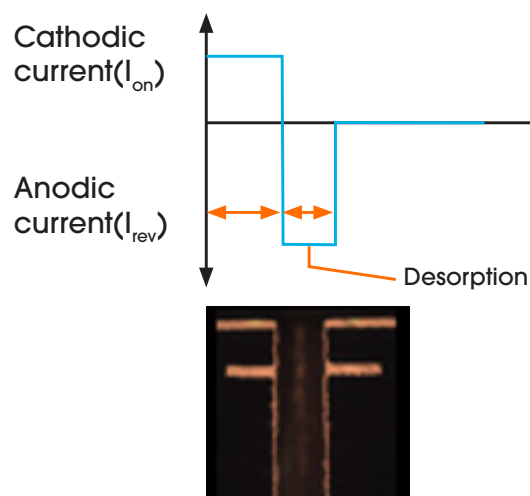
Correcting or reworking over-plated areas (high current density) waste time, materials, and energy, while low current density areas take an excessively long time to plate, putting a drain on resources.



Using DC current limits the throwing power, leading to uneven copper distribution.

This can be seen in the 'dog-bone' effect, when plating accumulates in the high current density areas, creating additional thickness around the edges at each end of the hole.

Plating using DC current (figure to the left)



An effective solution is to install a pulse rectifier that precisely controls the current – creates desorption which evens out the low and high current density area, and thus optimizes the electrolyte for even copper deposition. This in turn delivers a high-quality, uniformly-plated result while saving time, energy, and costs.

Plating using PPR current (figure to the left)

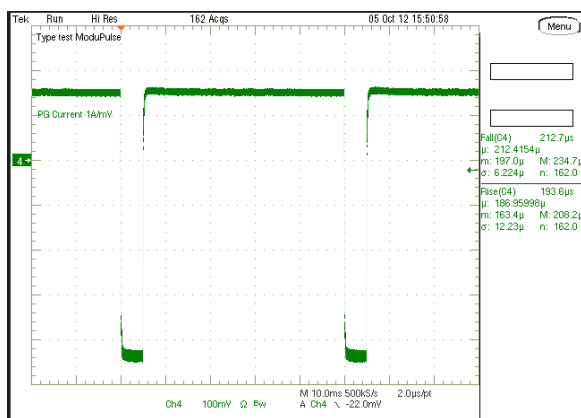
Increasing throwing power with pulse technology for reliable plating quality

'Throwing power' is the ratio between copper deposition inside the hole and copper deposition on the surface. Conventionally, it refers to the ability of an electroplating solution to deposit metal uniformly on a cathode of irregular shape. Thus, throwing power is a key measure of plating results for PCBs and IC substrates.

DC power technologies can achieve 70% throwing power, which is acceptable for lower aspect ratio boards.

However, DC power will not suffice for high aspect ratio plating. Pulse rectifiers can achieve closer to 100% throwing power (and even more), which is ideal for high aspect ratios.

A pulse rectifier that provides current as a periodic pulse reverse (PPR) waveform, is essential for even plating and uniform surface distribution on package substrates and printed circuit boards.



Periodic pulse reverse (PPR) for increased precision plating
Power is delivered as a single waveform current that can be controlled by current amplitude for set timing intervals. The reverse pulse enables desorption, which evens out the low current density and high current density areas.

Reducing raw materials, energy use, and waste



The overall process uses less copper in the electrolyte, reducing sludge and **the consumption of raw materials by around 10% to 20%.**



In addition, pulse rectifiers can **reduce plating time by up to 30%**, providing significant productivity and cost advantages.

Complex waveforms enable the development of multi-layer PCBs

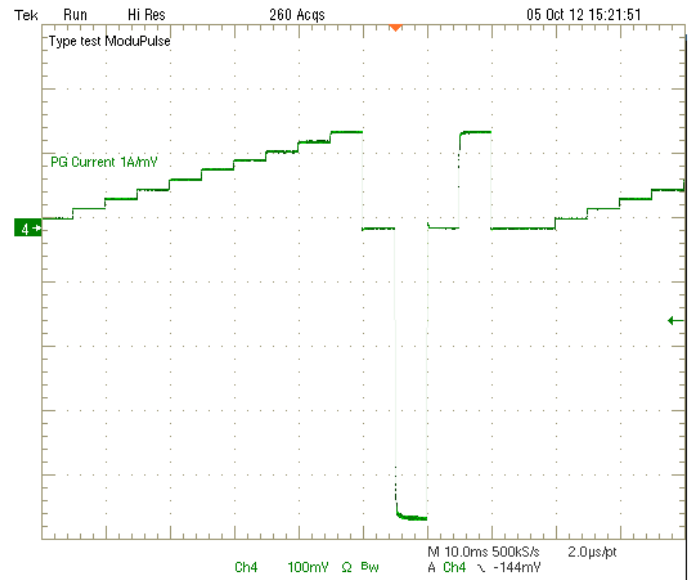
As PCB vias become smaller or deeper and aspect ratios increase, achieving uniform copper deposition becomes more of a challenge. This is where advanced rectifier technology is required.

Within the complex waveform, the ramp time between the different current steps needs to be less than $200\mu\text{s}$.

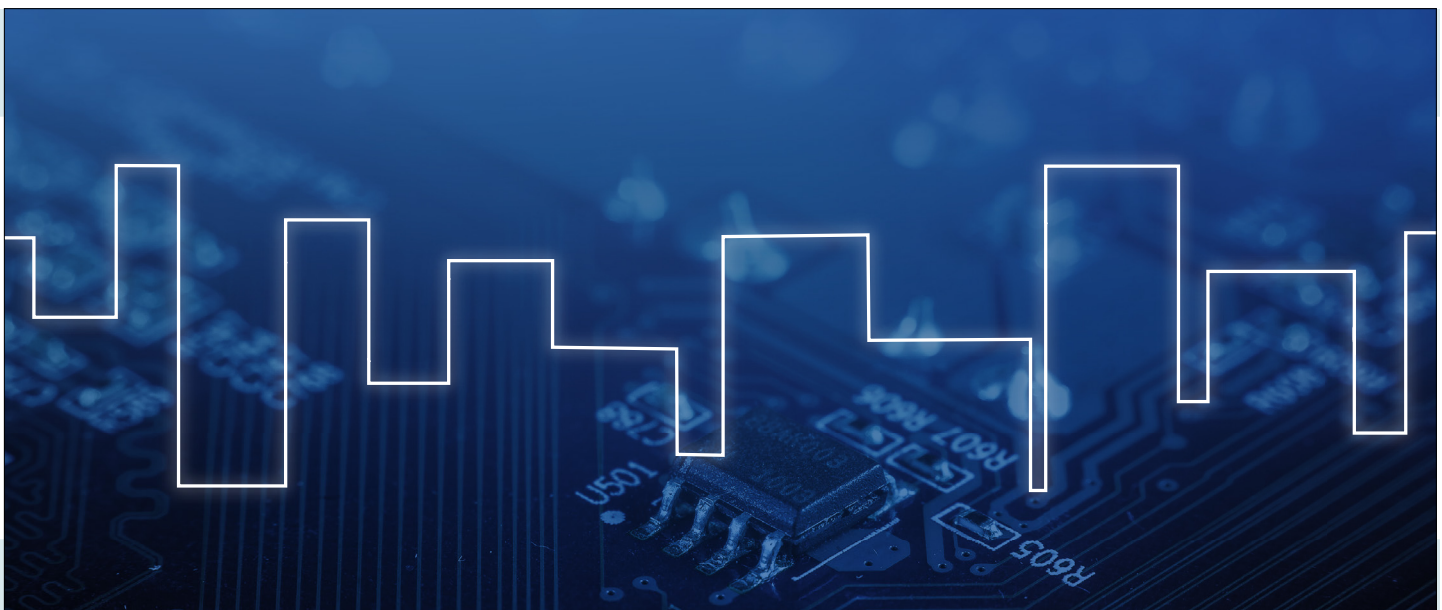
Each step needs to be precise with high accuracy and stable, with low ripple.

The diagram to the right shows an example of what a multi-pulse waveform looks like. This complex waveform will enable precise deposition of copper in sophisticated circuits and vias of PCBs.

While advanced rectifier technologies can provide features for complex waveforms, it's really the expertise in how to apply, interpret, and refine the output results that makes the difference. It's about creating custom made electroplating recipes with waveform shifts as the 'bonding ingredient'.



Example of periodic pulse reverse with complex waveforms

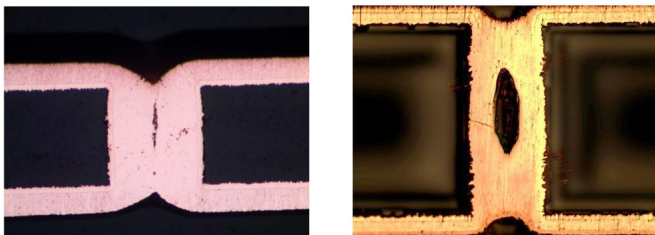


Reducing process complexity using advanced pulse power

Precision-plated, 5G printed circuit boards, can now be produced without requiring major investment or adding complex processes. This is especially true when cross-disciplinary teams – chemical specialist, power supplier, machine builder, and process planners – work together to streamline the manufacturing process, and improve plating quality and reliability.

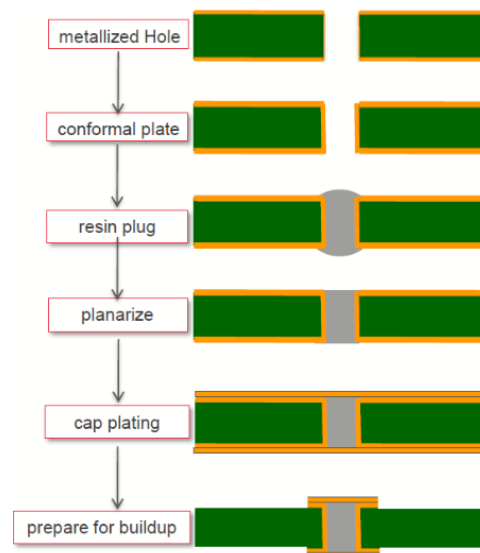
Improving thermal management while eliminating plating voids and dimples

The presence of voids and dimples in copper-filled through holes (as shown below) has long been recognized as a common quality issue. These gaps can lead to excessive heat build-up and reduce conductivity. Addressing such issues is a must, and there are complex and lengthy manufacturing processes to deal with the situation.



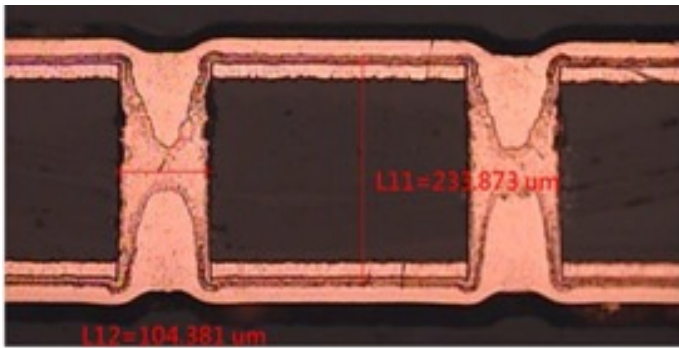
Voids and dimples in copper-filled through holes – a quality issue

Some manufacturers choose to plug vias using a proxy (resin or silver paste), which is then planarized and capped with copper to eliminate the risk of voids. However, this approach brings its own challenges. Its complex process, involving increased labour, time, and materials, results in a less-than-optimum product. The conductivity of the materials used as a proxy can create inconsistency, affecting product quality and reliability.



*Traditional process using proxy to plug vias
Image courtesy of MacDermid*

Via hole plugging with copper, should be undertaken using a pulse, (PPR) rectifier that supplies current with complex features. Such functionality makes it possible to eliminate voids and dimples in the fill (or bridge) between boards. This is a distinct improvement, and is a validated solution that provides simplicity, efficiency, and a high-quality finish.

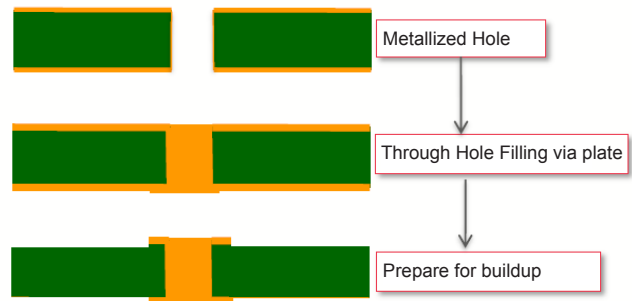


'Bridging' is an example of filling techniques

A pulse rectifier with the complex waveform functionality is a proven solution to effectively bridge and gradually build up the filling in the through holes, while maintaining optimal plating thickness on the surface of the PCB.

With quality improved, the manufacturing process is simplified

Using solid copper to fill the through-hole, rather than filling paste, improves conductivity and heat dispersal – copper is four times more efficient than paste. Not only that, but this technique enables a simplified production process.



*Simplified process for via filling, also known as **Through Hole Filling (THF) technology***

Image courtesy: MacDermid

Advancements in complex waveform rectifier technology have played a significant part in making **5G innovation** possible, while **reducing scrap by up to 40%**, and increasing PCB and IC substrate production **efficiency by up to 5,6 times**.

For complex specifications, a more sophisticated solution is needed. As an example, KraftPowercon ModuPulse™ rectifiers can deliver **highly complex waveform with precision** of up to 32 different steps in 65,000 milliseconds.

They can be programmed to provide multiple waveforms and phase shifting, effectively simplifying and streamlining the plating process from an operational perspective.



Meeting the future needs of PCB and semiconductor manufacturers

With ever increasing demand for miniaturisation, semiconductor components and accessories are becoming smaller, and so are the boards on which they are assembled. The main difference between a PCB (printed circuit board) and an IC substrate (used to deliver the platform package for semiconductors) is feature size, especially line and space (L/S). However, specifications for lines and spaces (L/S) within PCB boards are now approaching those of current IC substrates as scale continues to reduce.

Precision plating is essential. To ensure accuracy and quality in IC substrate plating, it's imperative to reduce deviations. This might be achieved by separating the anodes to control the current flow to each one individually and increasing the current resolution to tune the exact output needs at each anode. Communication speed will be key to controlling current to multiple anodes at the same time.

The creation and application of sophisticated rectifier technologies, to meet increasingly complex and precise requirements, requires a holistic understanding of the science involved in the plating process; the chemical and electrolytes involved; and the technical expertise to apply this knowledge to achieve the desired outcomes. It's a specialist field, but due to the ongoing collaboration and innovation by leading industry manufacturers, chemical companies, and KraftPowercon, such capability is increasing all the time.

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“One of the many reasons we partner with KraftPowercon – apart from their expertise and incredible track record – is the positive mindset of their team. This makes them genuinely enthusiastic innovators, ready to apply their in-depth knowledge and understanding to solving challenges that the industry faces.

They understand the ‘why’ as well as the ‘how’, and that extra insight makes all the difference.”

*General Manager,
Global Chemical Company*

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Smart power from the dedicated specialists

KraftPowercon's experts cover every aspect of power optimization, from scoping high-level technical requirements to delivering the practicalities of upgrades and installations.

With over 85 years of experience in rectifier technology, we support the electroplating industry with sophisticated power supply solutions that ensure quality, reliability, and efficiency. Customers appreciate our way of working, especially our can-do attitude and commitment to innovation, delivering the outcomes they are looking for.

- We help you to achieve high-quality output, solving problems and optimizing processes to save time, energy, and raw materials.
- We support you with engineering from our global network, ensuring a quick response from local service personnel.
- We secure your most critical components in case of emergencies.

And we won't let you down.

For more information about KraftPowercon's solutions for PCBs and semiconductors, visit [**kraftpowercon.com/industries/pcb-and-semiconductors**](https://kraftpowercon.com/industries/pcb-and-semiconductors)

or email [**electronics@kraftpowercon.com**](mailto:electronics@kraftpowercon.com).



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