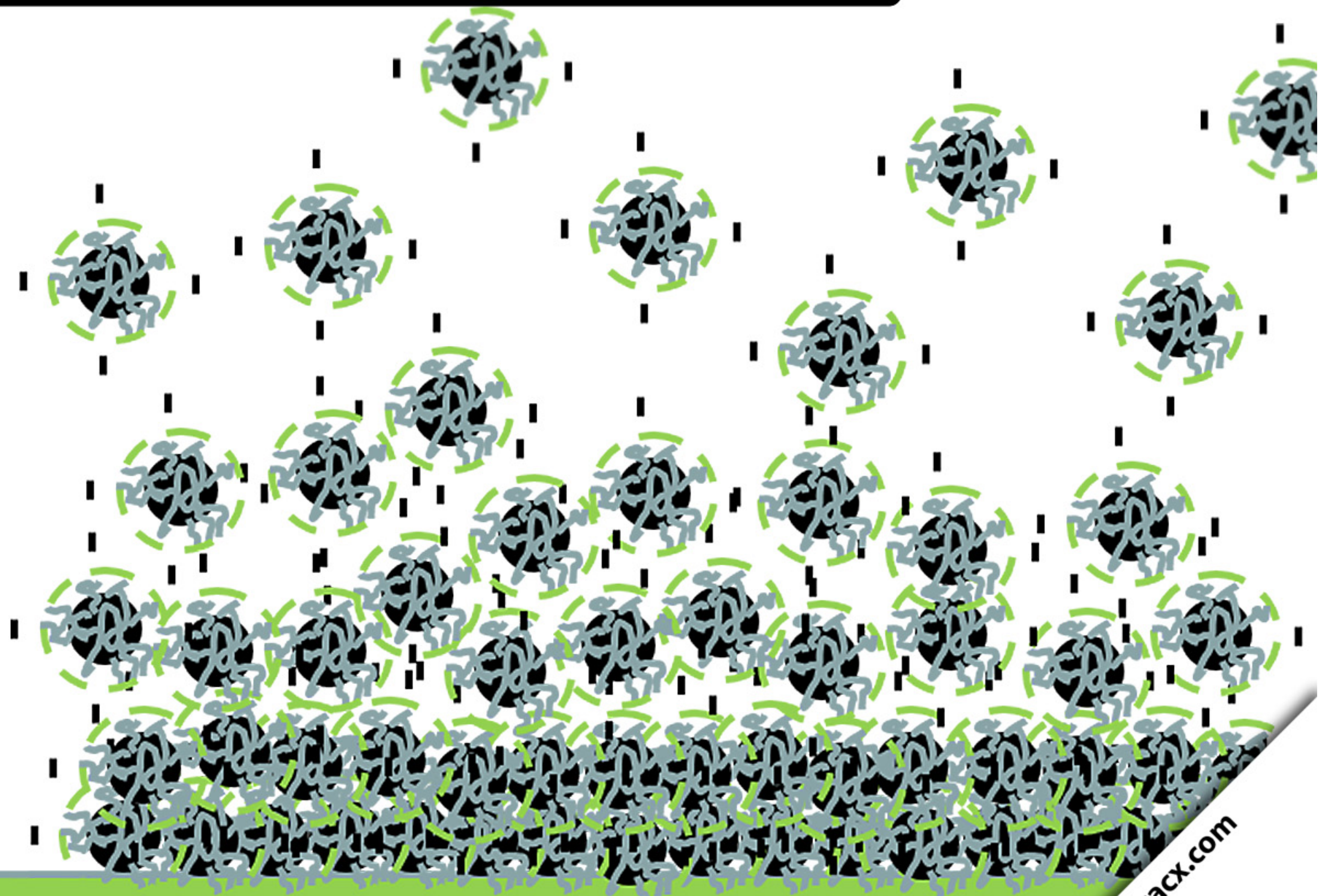
PCB007 PRESENTS

May 2014

the pcb magazine

AN I-CONNECT007 PUBLICATION

PLATING AND ETCHING ISSUE



Graphite-based Direct Metallization for Complex Interconnects

by Michael Carano, pg. 12


Why did you choose THAT fabricator?

MAY FEATURED CONTENT

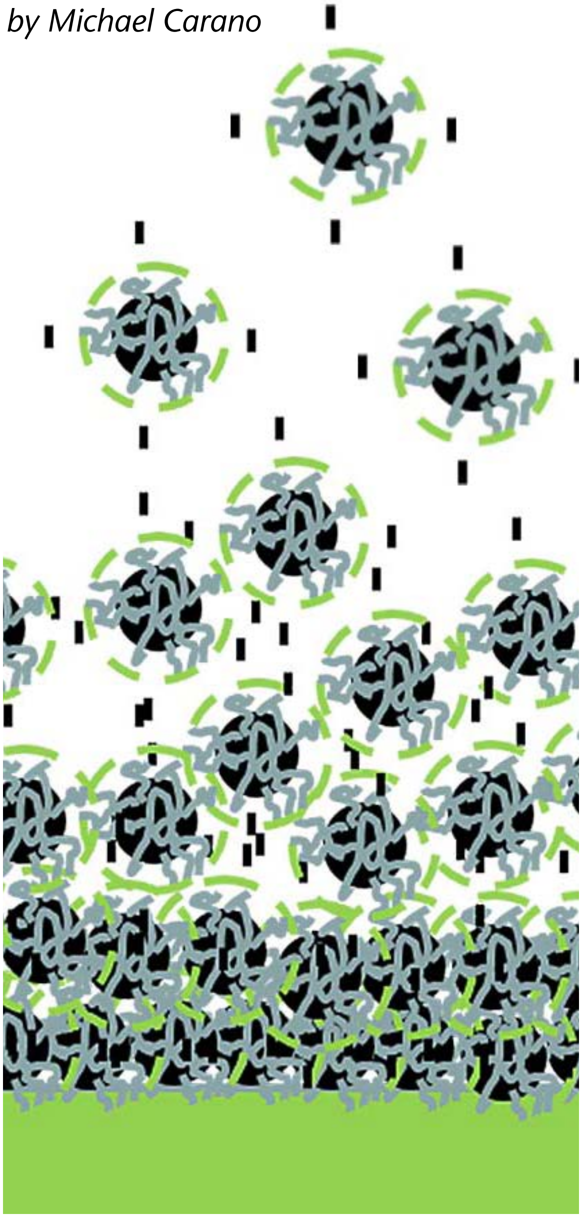
PCB007 PRESENTS

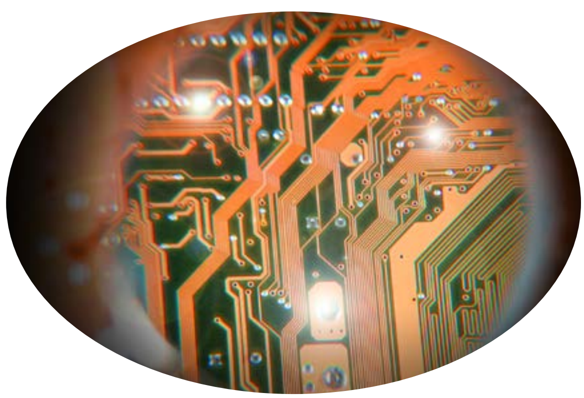
the pcb magazine

AN I-CONNECT007 PUBLICATION

Plating & Etching

Experts from OMG, Atotech and Coventry University lend their expertise this month, with features addressing a range of plating & etching issues, including direct metallization for IC designs, and more.






MECHANICAL DRILLING, RE-INVENTED FROM THE GROUND UP
Inspired by aviation and utilizing over 150 years of combined industry experience, our team has created a mechanical drilling system that changes everything.
THE INTERDYNE K6
Our systems are especially suited for high throughput small hole drilling (<100 micron), as well as high aspect ratio drilling for backpanels (up to 18:1 with NO peck or step drilling).
Welcome to the next generation of mechanical drilling!
SEE THE SYSTEM IN ACTION
INTERDYNE SYSTEMS
www.inter-dyne.com

CONTENTS

PCB007 PRESENTS

MAY 2014
VOLUME 4
NUMBER 5

THE DEFINITIVE INTERACTIVE MAGAZINE DEDICATED TO THE GLOBAL PCB INDUSTRY

thepcbmagazine.com

the pcb magazine

AN I-CONNECT007 PUBLICATION

PLATING & ETCHING

COLUMNS

VIDEO INTERVIEWS

NEWS HIGHLIGHTS

EXTRAS

Googlebotics

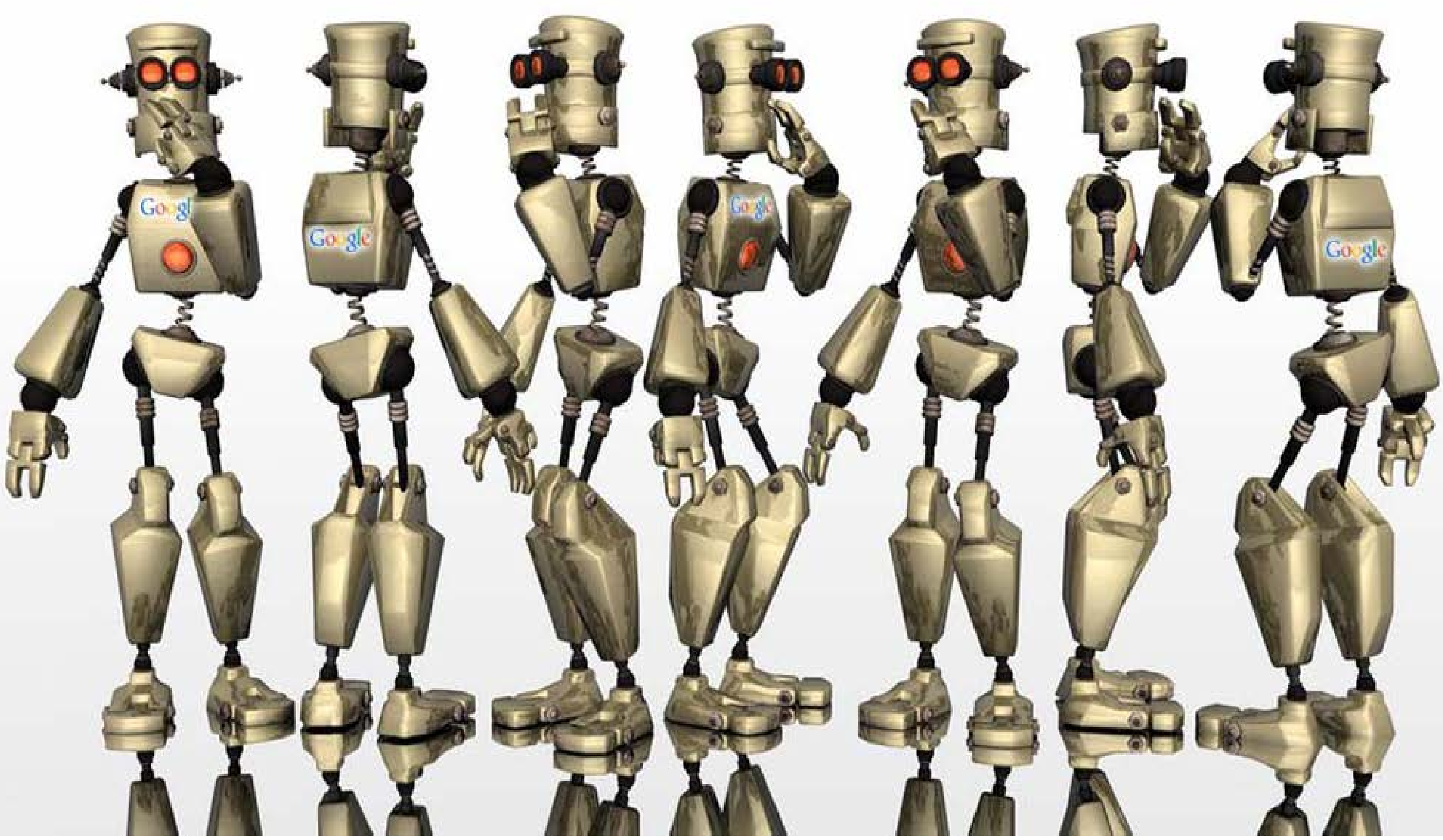
by Ray Rasmussen
I-CONNECT007

January's big news was that Google was getting into robotics in a big way with some very strategic acquisitions. In February we heard that Foxconn and Google were partnering to build the "factory of the future."

In an interview with The Observer, Ray Kurzweil, Google's director of engineering, believes that by 2029 computer systems (automation and robotics included) will be as smart as people and much more capable. Kurzweil, famous as a futurist and focused on the exponential changes in technologies, predicted the Internet, among other technology breakthroughs. He also predicts that that by 2030, solar energy will be able to meet all the energy needs of the planet. That's just 15 years away!

If you're interested in gaining a better understanding of the difference between robotics and automation, check out this link.

As I've mentioned before, robotics are going to have a profound effect on people, both positively and negatively. In fact, I believe the automated and robotic factory along with the evermore automated business will dramatically change our society—it has to. IPC APEX keynote speaker and X-Prize Founder Dr. Peter Diamandis talked about this very issue during his presentation. What's both exciting and scary at the same time is that, as he pointed out, technological change is accelerating and our society is transforming into what he called "technological socialism" as machines replace workers. Societies will need




POWERED BY FASTECHNOLOGIES
SMARTPARTS
IMPROVING PRODUCTIVITY AND PROFITABILITY
SmartParts Classics
Drill Rules Automation Solution
• Increase Productivity • Save Time
• Reduce Scrap • Take Control!
www.fastec.com
CUSTOMER FEEDBACK
"SmartParts minimized the variability in product while reducing training time for new operators"
CUSTOMER FEEDBACK
"I highly recommend FASTechnologies software, especially for shops that produce high tech boards."
Messages FASTechnologies Contact
Machine #3: End of load
Machine #17 stopped: error 301
Machine #8: End of load
Machine #2 stopped: low air, please help me!
PDF
SP_Monitoring
DOWNLOAD WHITEPAPER
Learn how your CNC machines can keep you informed of their status with SmartParts Monitoring.
FASTechnologies
Your Drill and Rout Process Experts
+1 (949) 551-4135
www.fastec.com

Figure 1: iRobot Ava 500 brings together iRobot's autonomous navigation with Cisco telepresence to deliver a new level of collaboration for office environments and other facilities.

to come up with ways to keep people busy. I think we'll figure it out over time, but there will be a rough patch as companies transition to the factories of the future and replace hundreds of millions of jobs over the next decade. In other words, it's here, now. We've arrived!

To understand where I'm coming from you have to let your imagination run a bit. You can start this exercise by thinking about where automation and robotic systems won't work. That's a bit easier than trying to come up with all the ways they will. The experts say that if you're into landscaping maintenance, that'll probably remain a manual task, mostly, for some time. Some form of robotics or automated system will likely transform most everything else.

The argument has been made for years, which the data supports, that as industries move toward more automation it will lead to improvements in productivity, which leads to greater growth and the development of new industries. This will offset the loss in employment and actually drive new jobs. As those industries grow, they will need more advanced automated systems for their next-generation factories. And on it goes. Of course, if we lived in an infinite world, that cycle would continue forever. But, what happens when the robots build all the robots (and they will) and there aren't jobs for people?

Think I'm crazy? When Google bought DeepMind, which develops "learning algorithms," as part of the agreement, Google had to set up an ethics board to ensure that once all this technology is in the hands of a company like Google, things won't get out of control. Think of this: Google already employs many of the world's experts on artificial intelligence. They have the horsepower to drive this. It's going to happen.

When you read articles written by futurists and experts in the field, you get a good sense of where this is headed. You don't have to work too hard to see that just about everything we do can be automated. Here are a few of the systems which have become commonplace in our society today, but not that long ago seemed a futuristic idea. ATMs come to mind first. They have dramatically reduced the need for tellers to cash checks, make deposits, withdraw funds, and even transfer money from one account to another. It's a great convenience for most of us. And these machines are everywhere. They're displacing hundreds of thousands of people worldwide. Now, we're beginning to see automated check-out stands at our grocery and hardware stores. Frustrating for some to use at first, they quickly have become a nice convenience, especially if you have a quick, simple purchase. Hospitals are under tremendous pressure to reduce costs and are beginning to invest in automated systems to monitor patients' vital signs, and deliver nourishment (IV) and medications, etc. Certainly patient care will improve (you would think) as a result. What about automated toll collection and parking lot payment systems?

How can a company like Foxconn successfully bring manufacturing to the U.S. and Europe? It has to automate. One highly trained U.S. employee in an automated factory will take the place of dozens of Chinese factory workers. Overall costs may be about the same but will come with far fewer headaches. No need for huge dormitories or cafeterias. No 30% annual employee turnover. No suicides, no underage employee problems. No collective bargaining, no wage increases (actually, the cost of automation will continue to decrease). Their customers (Apple) get the non-governmental organizations (NGOs) off their back. In fact, Foxconn is planning to use robots in their mega-factories in China, as well. I'm sure Terry Gou has done the math. An automated factory, wherever he decides to build it, makes good financial sense and will make his life and company stakeholders' lives a lot easier. Partnering with Google to accelerate this effort was probably an easy decision for him.

The growth of robotic systems is accelerating. The capabilities will continue to increase as prices drop. The combination of more capable systems at a much lower cost per function will provide the fuel needed to drive this industry at greater and greater speeds. Google's investment into robotics isn't altruistic; it's pure capitalism. And what the dozen or so smaller robotics companies could do on their own has now been coalesced and focused into building the robots of the future. In 10 years, this could be Google's biggest business. The potential is certainly there. At least, that's the way I see it.

Check out this link to learn more: A Peek Into Google's Plan With Robots. **PCB**

Ray Rasmussen is the publisher and chief editor for I-Connect007 Publications. He has worked in the industry since 1978 and is the former publisher and chief editor of *CircuiTree Magazine.* To read past columns, or to contact Rasmussen, click here.

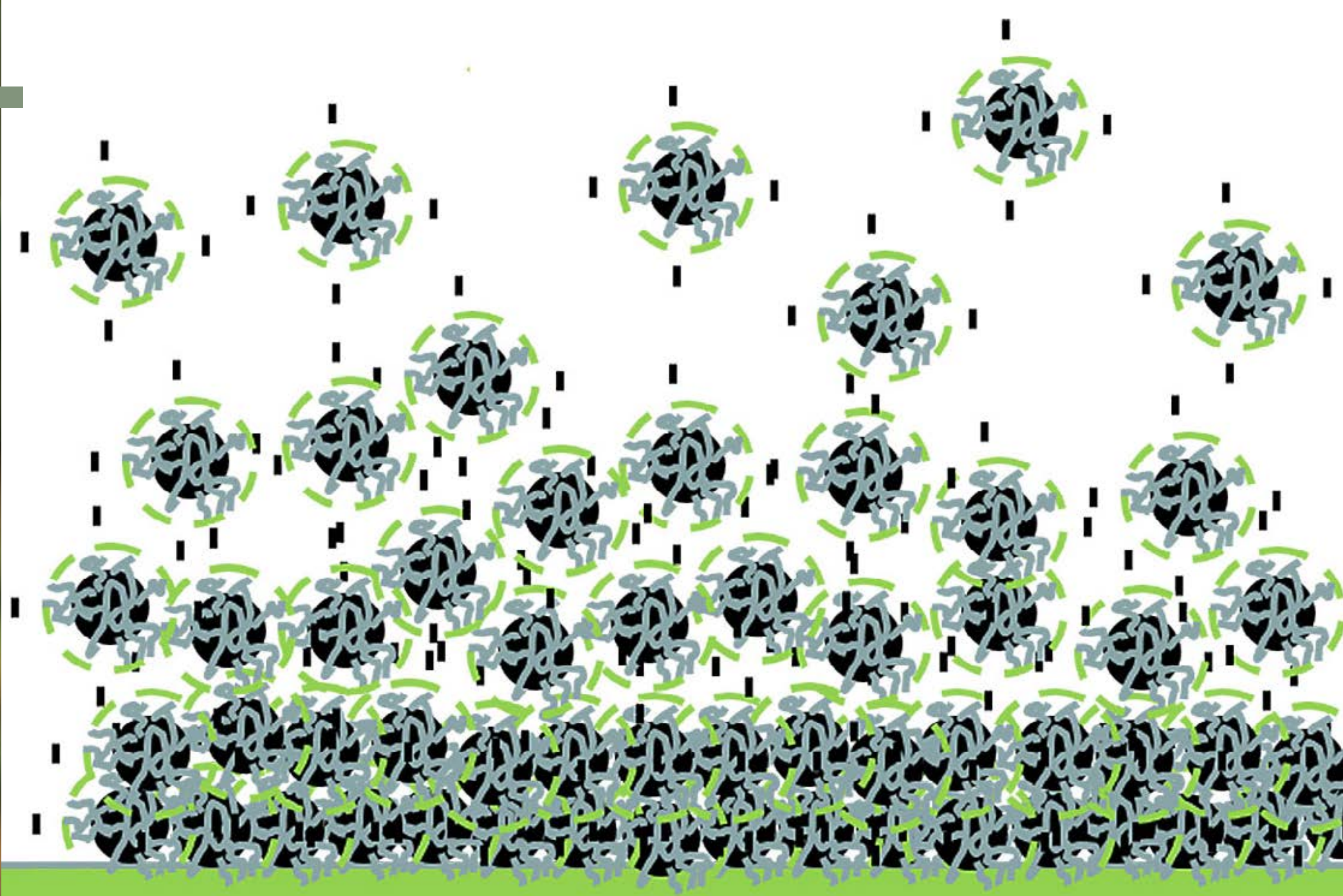
I-CONNECT007 PANEL DISCUSSION VIDEO

Has Outsourcing Lost its Luster?

Sponsored by: Prototron Circuits

Moderator Steve Williams, Dan Beaulieu and Joe Fjelstad discuss current trends in outsourcing.

CLICK TO VIEW



Graphite-based Direct Metallization for Complex Interconnects

by Michael Carano
OM GROUP ELECTRONIC CHEMICALS, LLC

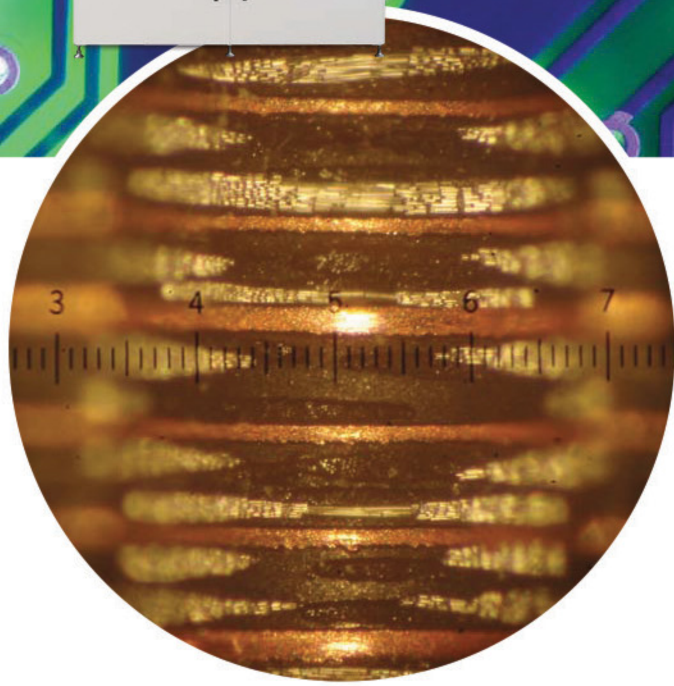
Introduction

The technology trends are unmistakable (Table 1), such as the need to move into higher functionality while reducing footprint of the PWB substrate. In turn, this triggers circuit designs with smaller vias, blind, buried and stacked vias, as well as any-layer technology. In addition, there is a call-out for more flexible and rigid-flexible printed circuit boards. Complicating matters for the fabricator is the proliferation of material sets designed to support the low-loss, high-frequency market segment. With all of these changes, along with heightened emphasis on end-product reliability and productivity, metallization performance is under the highest scrutiny.

Direct Metallization

Direct metallization of boards is a predominant process in flex circuit and microvia manufacture. This conveyorized process is fast and efficient. However, in North America, direct metallization is not as common as in overseas marketplaces, most likely reflecting the higher percentage of flex and microvia in the production mix. Regardless, direct metallization processes (most) offer lower consumption of resources over conventional electroless copper. This includes reduced rinse water and waste treatment concerns, lower power consumption as well as fewer chemical processes to maintain. For most direct metallization systems including graph-


Experience Plasma Performance
Nordson MARCH
ProVIA™ Series Plasma System
MaxVIA™ Series Plasma System
PCB Series Plasma System
FlexVIA™ Series Plasma System


3
4
5
6
7

Attribute	CURRENT 2012–2013		NEAR TERM 2014–2015		MID TERM 2015–2016		LONG TERM 2017–2020	
	RCG	SoA	RCG	SoA	RCG	SoA	RCG	SoA
Aspect Ratio Throwing power (%)	10:1 80%	18:1 70%	11:1 70%	20:1 70%	12:1 70%	22:1 80%	13:1	24:1
Blind via aspect ratio capability	0.75	1.1	0.9	1.2	1.0	1.3	1.1	1.4
Plating thickness tolerance (standard deviation μm)	3.0	2.0	2.75	1.75	2.6	1.6	2.5	1.5

Table 1: (Source: IPC Technology Roadmap, 2013)

ite based processes, the equipment footprint is quite small when compared to a conventional electroless copper line of equal productivity. This is indeed an advantage with respect to capex utilization and return on assets.

Graphite-Based Direct Metallization

Colloidal graphite direct metallization processes have proven their usefulness as a replacement for electroless copper. This is especially the case in high-technology and quick-turn applications. The ability of the colloidal graphite to successfully enable the direct electroplating of difficult to metalize materials such as polyimide, PTFE, ceramic-filled resins, PPO and PPE is well documented. Aiding this has been the improvement of the consistency of colloidal graphite direct metallization processes. This is accomplished through a better understanding of the influence of conditioning agents, the stability of the dispersion, and other process refinements that will be detailed in this article. The implementation of polyelectrolyte surface active agents that enhance the adsorption of the graphite to the non-conductive surfaces without causing excessive film thickness is quite critical. And the introduction of fixer technology further enhances the uniformity and conductivity of the graphite coating. These improvements are necessary as the industry migrates to more complex designs (Figure 1).

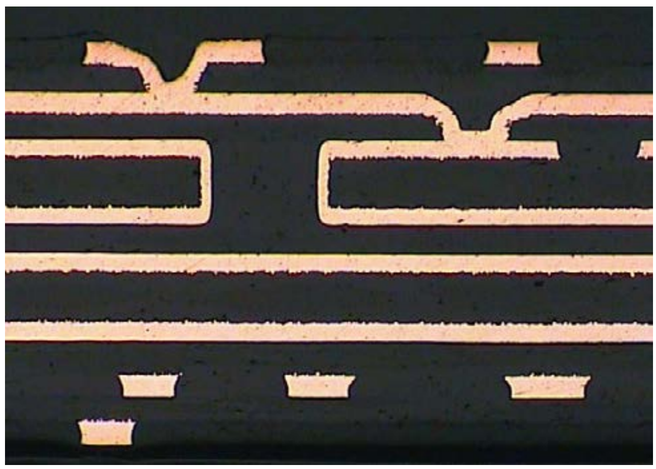


Figure 1: Complex HDI build-up.

Process Overview

The colloidal graphite direct metallization process involves the following steps:

1. Cleaner/conditioner
2. Colloidal graphite
3. Fixer
4. Dry
5. Microetchant
6. Anti-tarnish (optional)

The purpose of the cleaner/conditioner is to coat the hole-walls with a compound hav-

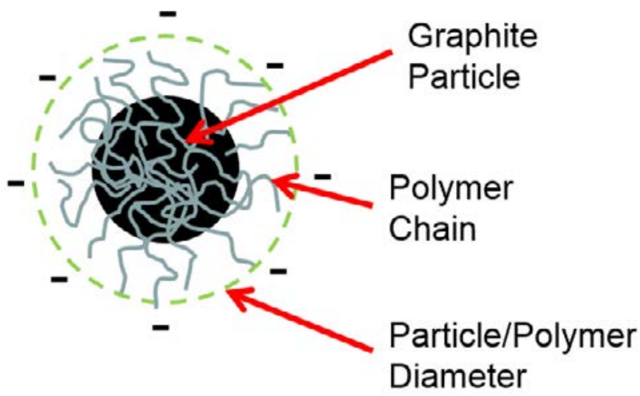


Figure 2: Core graphite colloid.

ing a positive charge. This is typically accomplished by the use of a cationic conditioner such as a quaternary amine polymer[1]. The cationic conditioner has a strong attraction to the slightly negatively charged resin and glass materials along the hole wall. But first, one should understand the graphite colloid as depicted in Figure 2.

The core of the graphite colloid consists of a highly conductive graphite particle which is plate-like in shape. Surrounding each graphite particle is a layer of high molecular weight polymer binder. Certain functionalities attach to the graphite. Negatively charged functional groups extend into the solution as the binder forms a polymer layer. The coating of conditioner is not easily removed and can withstand aggressive spray rinsing (Figure 3). Following conditioning, the printed wiring board is coated with the colloidal graphite. Since the colloidal graphite has a negative charge it is easily attracted to the conditioner and forms a uniform layer of graphite on top. The graphite particles themselves have a negative charge. This charge is further enhanced by the use of a binder attached to the graphite, which also has a negative charge. The negative charge is thus attracted to the polymer backbone of the conditioning agent (Figure 4). Besides the electrostatic attractive charge of the conditioner, there is a gel formation from the reaction of the graphite binder with conditioner.

The purpose of the fixer is to form an adherent coating of graphite. The fixer solution

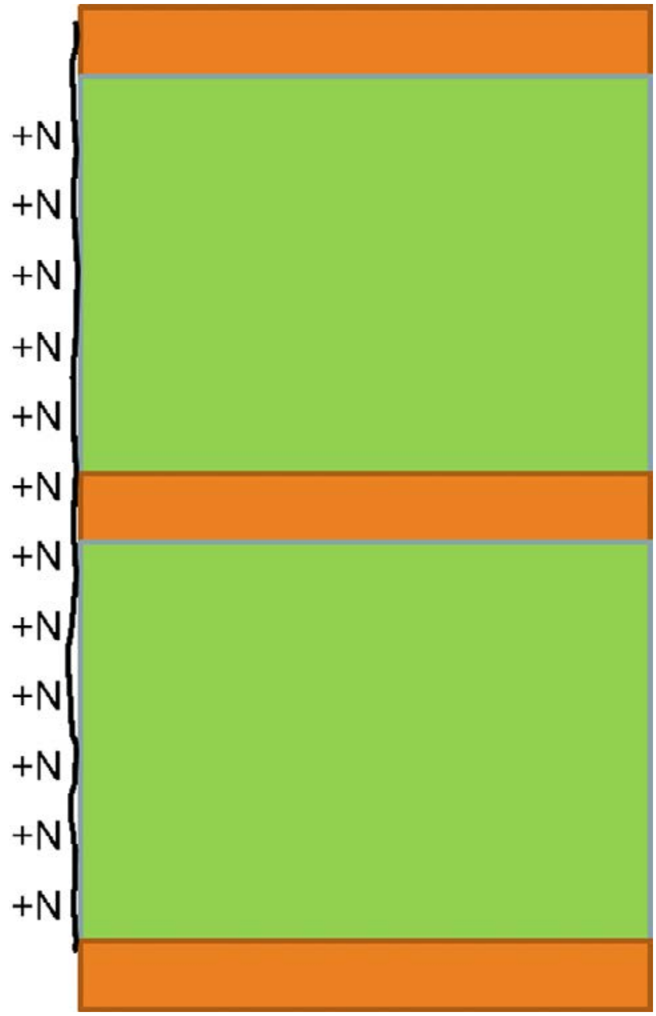


Figure 3: Positive charges due to the action of the polyelectrolyte in the cleaner/conditioner.

is an acidic solution having a fairly high ionic strength that neutralizes the negative charge on the binder. Thus, the fixer is used to set, or fix the graphite coating onto the non-conductive surfaces and remove loosely adherent graphite particles that did not bond with the cleaner-conditioner molecules. The binder gels and solidifies, anchoring the tightly bound graphite particles in place. Now the loosely held particles react in such a way that a salt is formed. The loosely adherent materials that have formed as a salt are easily removed with a water rinse with properly controlled solution flow. The remaining graphite is tightly adherent to the resin and glass and the fixer actually helps to thin out the

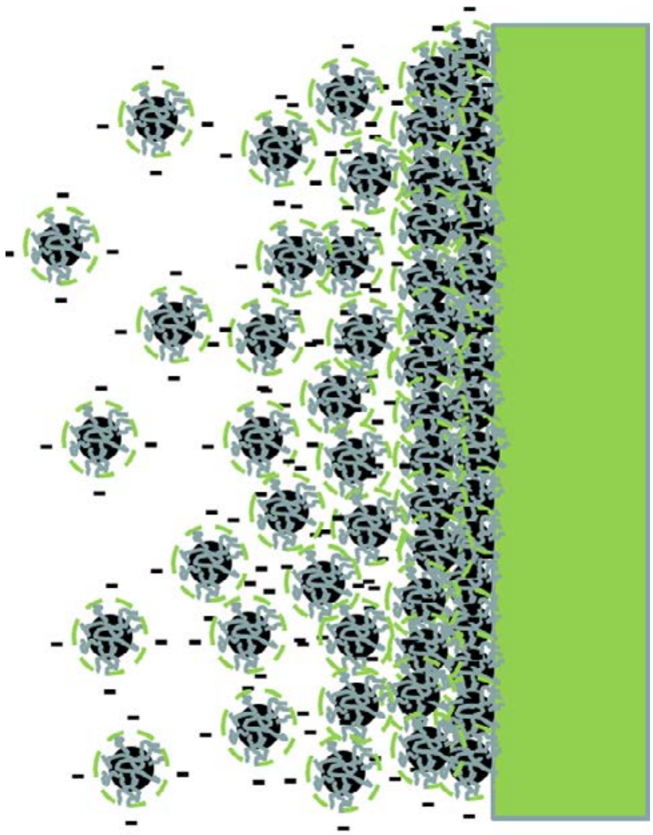


Figure 4: Graphite particles tightly bound to the substrate while other particles are loosely held.

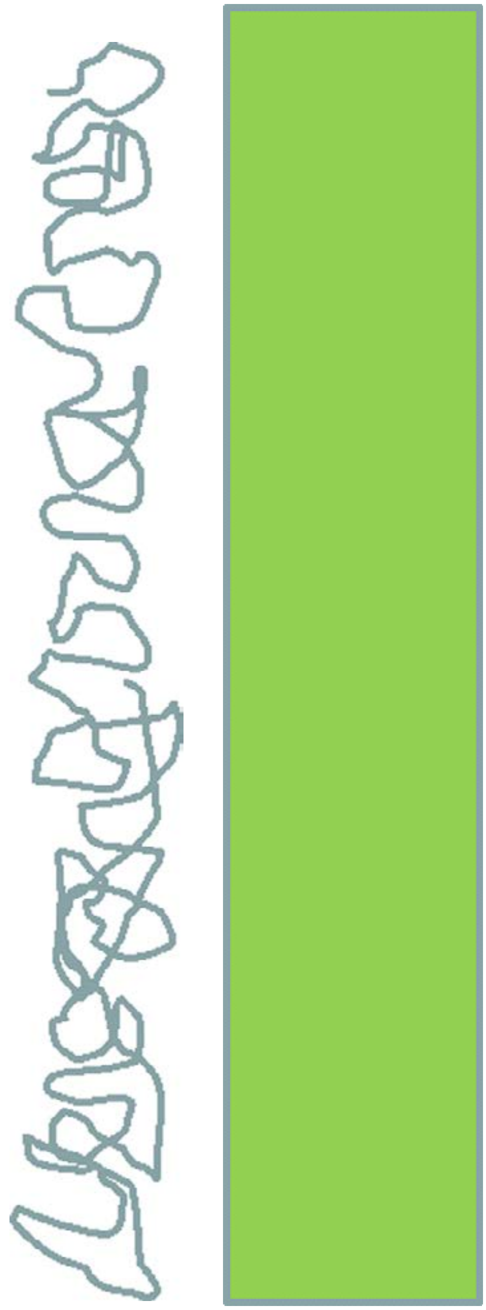


Figure 5: After fixer and rinse, a thin layer of conductive graphite has been tightly bound to resin and glass, and excess graphite has been removed.

coating and remove some of the graphite from the copper surfaces (Figure 5).

Following fixer, the graphite coating is dried to provide proper adhesion. The panel is then passed through a micro-etchant. The purpose of this step is to remove graphite from the copper surface and copper interconnections along the hole wall. This provides a good copper-to-copper bond during electroplating. As a final, optional step, an anti-tarnish coating may be applied to protect the copper surface during storage prior to resist application or electroplating. At this point the circuit board is ready either for primary imaging followed by electroplating of copper or panel plating.

Science of Colloidal Graphite Dispersions

What makes such a system function for today's highly complex PCB designs? First, as described above there must be a robust process. Secondly the chemistry of the system must be completely understood. This starts with a discussion of the consistency of colloidal graphite dispersion and the stability of the colloid. Stability is defined as 1) the ability to maintain a consistent particle size without aggregation and

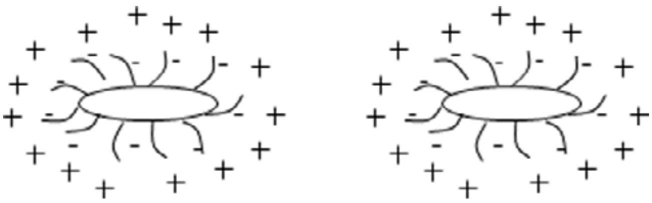


Figure 6: Electrical double layer surrounding the graphite particle.

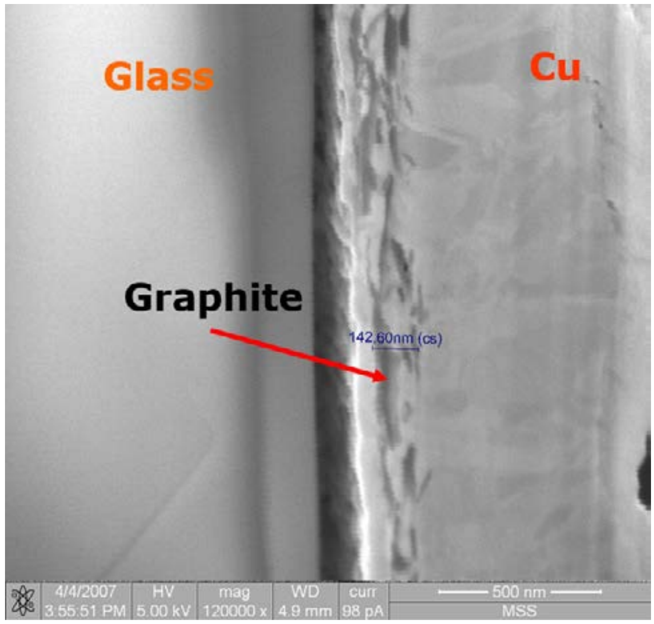


Figure 7: Final graphite coating showing tightly packed structure and 0.15 µm thick.

2) the ability of the particles to remain suspended in solution without settling. Each definition of stability involves different factors and will be discussed separately.

1) Consistent Particle Size

Colloidal graphite is a hydrophobic colloid, which means it is not strongly attracted to water. Hydrophobic colloidal particles are repelled from each other in two ways: sterically and electrostatically. Steric repulsion involves forming physical barriers to prevent the particles from aggregating. Electrostatic repulsion involves an electrostatic charge preventing the particles from coming into contact with each other. While both methods of stabilization are involved in keeping colloidal graphite particles from aggregating, electrostatic repulsion is of most interest due to the influence of contaminants on the electrostatic charges.

As previously stated, the graphite particle has a net negative charge. This negative charge is further increased by the addition of a proprietary binder, which at the operating pH also has a negative charge due to the presence of carboxylate groups ($R\text{-}COO^-$). Surrounding this particle is a cluster of counter-ions, which have a net positive charge. This unequal distribution of electrical charges sets up a potential across the interface and forms an electrical double layer. A schematic representation of this electrical double layer is shown in Figure 6.

The electrical double layer is critical with respect to the stability of the graphite dispersion. The binder with its negative charges subsequently enhances the attraction of the colloidal graphite particles to the resin and glass surfaces of the PCB. Of course, the charge density imparted to the non-conductive surfaces (glass, resin) by the cleaner/conditioner action is designed to promote the flocculation of the bound graphite particles to the surfaces. The charge density of the key additives in the polyelectrolyte must be carefully optimized in order to minimize the amount of graphite that coats the non-conductive surfaces. Uniformity of the graphite coating is more important than thickness (Figure 7).

Graphite occurs as a highly crystalline substance as opposed to carbon black, which is amorphous. The hexagonal lattice of the graphite is documented to be a honeycombed arrangement of carbon atoms. This arrangement (and a key electronic property of graphite) promotes anisotropy, which is the property of being directionally dependent. An isotropic material conversely implies identical properties in all directions. What this means for through-hole and blind via plating is that the graphite is highly electrically conductive and suitable for metallization. When the resistance through a plated through-hole or blind via is low, the electroplating of copper progresses at a much faster rate (plating propagation) thus enhancing throwing power.

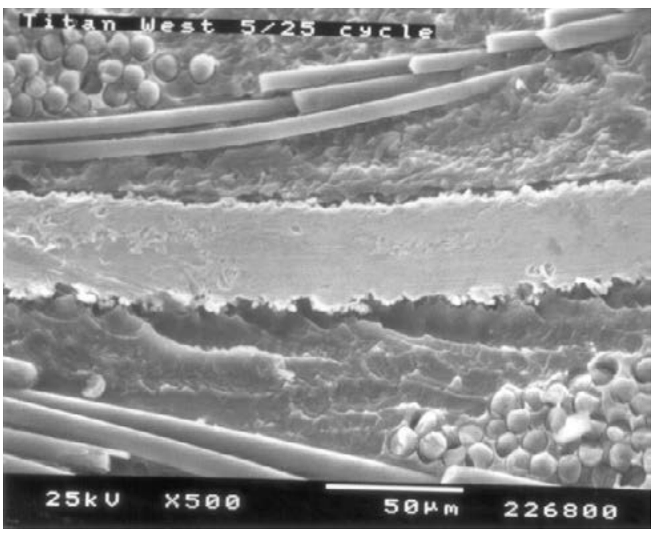
Comparison to Conventional Electroless Copper

There are few similarities between the graphite based direct metallization system and conventional electroless copper. Differences in water consumption, chemical usage and environmental concerns have been well documented in the *Design for the Environment Project on Making Holes Conductive,* conducted by the United States EPA[2]. However, what are not clearly defined are the limitations of the processes in terms of ability of the process to successfully metalize small diameter, high aspect-ratio blind vias. Plating copper in 6-mil diameter, 3-mil deep blind vias is not a routine task. However, with respect to conventional electroless copper, significant improvements have been instituted in rack designs, filtration and solution movement to ensure that larger blind vias can be metalized. The real challenge is in the 3-mil diameter and smaller blind vias. Depositing a uniform coating of copper is compromised because it is believed that hydrogen gas bubbles (hydrogen is a by-product of electroless copper reaction) lodges in the via, inhibiting plating. Any discontinuities in the electroless copper deposit lead to high resistance. The high resistance will lead to thin plating in the electrolytic copper process.

Conversely, the graphite coating is continuous and has very low resistance. Since the graphite process functions as a coating technology and not an electroless process, hydrogen gas evolution is not an issue. The electrodeposition of copper proceeds by way of a moving front mechanism. The high conductivity and continuity of the graphite coating permits the rapid deposition of copper, thus minimizing any tapering effect in the hole-wall. This is extremely critical as aspect ratios of blind vias reach 1:1 and greater. Also, the higher aspect ratio through-holes present additional challenges as gas bubbles may lodge in the PTH, potentially leading to voids. This is not an issue with a graphite-based direct metallization process.

Application of Graphite Metallization for Flexible Circuits and HDI

While graphite based direct metallization is a production-proven process for rigid PCBs, the process is gaining a much larger share of the new capacity coming online for HDI and flexible circuits. A major reason is driven by the cost of equipment for electroless copper versus direct metallization. In addition, as has been described elsewhere in this paper, the productivity of a graphite-based direct metallization process is much greater than conventional electroless copper. Most importantly, however,



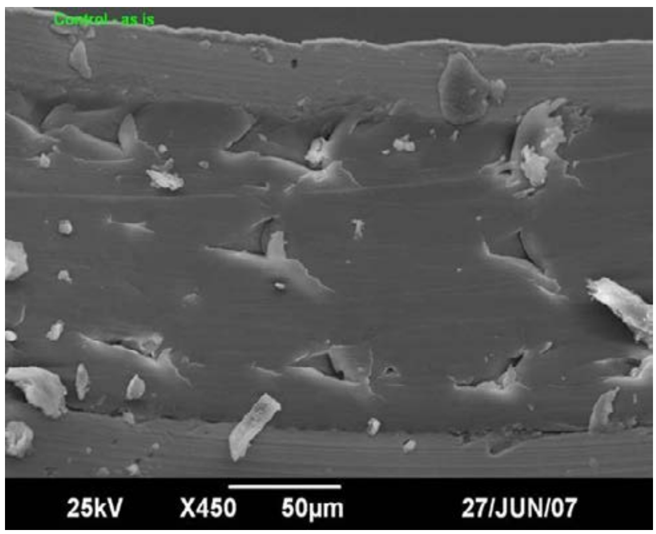


Figure 8: High T_g FR-4 after permanganate desmear (left) and polyimide flex after plasma desmear (right).

is the inherent ability of the graphite system to readily adhere to a wide variety of laminate substrates and materials, including polyimide, PTFE, ceramic filled materials, PPO, PPE, halogen free and many other materials. As laminate suppliers continue to reinvent themselves in order to stake out a position in higher technology, a versatile metallization process is critical to success.

So why be concerned with the different laminate materials? Aside from the obvious, successful metallization requires that excellent adhesion between the conductive coating (either electroless copper or conductive graphite) be achieved. It is well documented that adhesion is favored when there is sufficient surface topography to promote the bond. This is especially true for electroless copper as the seeding of the palladium required to initiate the copper deposition. However, as one views the SEM in Figure 8, the topography visible after permanganate desmear is rather smooth and unremarkable, further impacting the adhesion factor. A critical advantage for the graphite-based system is that the colloidal graphite binds to resin and glass without the need for a high surface area. It is important to recognize that electroless copper is a plating process, whereby a series of reactions take place in order to affect a deposit. In the case of the graphite based metallization system presented herein, the mechanism is primarily a coating process whereby the binder technology acts to promote adhesion of the graphite particles to even the smoothest of surfaces[3].

With growth in flexible circuit fabrication outpacing that of rigid and the continued trend towards miniaturization (tablets, smart phones,

Figure 9: Reel-to-reel flexible circuit metallization system.

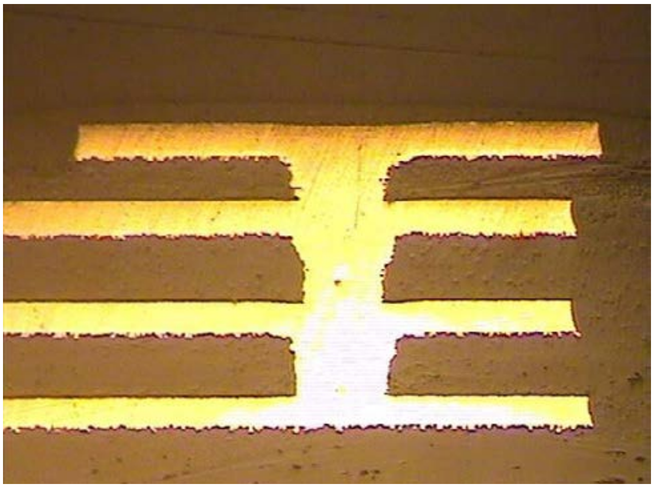


Figure 10: Any-layer circuit design for a smart phone, fabricated with graphite direct metallization followed by electroplating copper via fill.

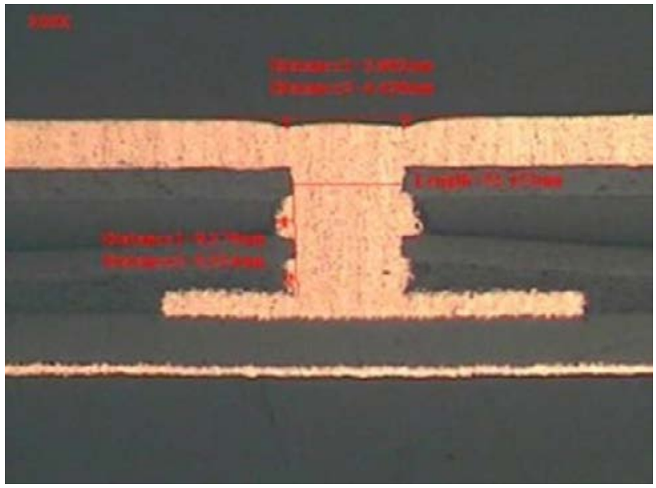


Figure 11: Rigid-flex with blind via.

telecommunications), graphite-based metallization has found a significant growth avenue. With sequential lamination for HDI a critical aspect of the manufacturing processes, each sub-lam must be metalized. Direct metallization offers a much faster process compared with conventional electroless copper. In addition, flexible circuitry is often manufactured in continuous roll-to-roll configuration (Figure 9). Graphite-based metallization is particularly useful for the higher productivity needs and the excellent adhesion to polyimide materials.

Figure 10 shows the any-layer circuit designs fabricated with a graphite-based metallization process followed directly with copper via fill plating.

Figure 11 depicts a rigid-flex design fabricated with graphite system.

Summary

Graphite-based direct metallization has proven to be particularly useful for flexible and HDI circuit market segments. Combining the process's high productivity, the ability to coat a wide variety of resin systems and substrates as well as providing significant environmental advantages over conventional electroless copper, has allowed for rapid growth of graphite-based direct metallization during the last five years.

With improvements in colloid stability and conditioning of difficult to metalize substrate materials such as flex polyimide, PTFE, ceramic filled and other higher performance materials, graphite-based direct metallization systems are an enabler for the direct electroplating of complex interconnect technologies. **PCB**

References

1. U.S. Patent #5,476,580.
2. "Printed Wiring Board Cleaner Technologies Substitute Assessment: Making Holes Conductive," U.S. EPA, Washington, D.C.
3. Burger, L., Carano, M., et al, "Enhancing the Performance of a Graphite-based Direct Metallization Process," IPC APEX EXPO, 2007.

Michael Carano is with OMG Electronic Chemicals, a developer and provider of processes and materials for the electronics industry supply chain and regular columnist for The PCB Magazine. To contact Carano, click here.

Copper Filling of Blind Microvias and Through-Holes Using Reverse-Pulse Plating

by Henning Hübner, Ramona S. Mertens, and Dirk Rüß
ATOTECH GERMANY

Abstract

This article describes the different techniques of via filling and their characteristics. It points out the advantages of reverse pulse plating and how the technology was modified to approach new market requirements such as thicker core substrates and laser drilling of through holes. The current capability of the system for inclusion-free filling and the areas where development is ongoing is demonstrated.

Introduction

Laser drilling of blind microvias (BMVs) and subsequent copper filling has become the standard manufacturing technique for high density interconnects. In order to reach the required interconnect density and to provide the necessary surface for reliable solder attachment in IC packaging, copper-filled BMVs are used. For smartphone production, the use of multiple lamination and typically 10 layers of stacked copper BMV filling is now the preferred technology. This is also known as the "any layer" filling process. To maintain the development in circuit miniaturisation together with the reduction in overall processing costs as expected by Moore's Law and to meet the demand for ever more filled BMVs on each plated layer, advances in filling processes are required.

Via Filling Process

Copper plating and filling can be described as shown in Figure 1.

Capture pad is the connection area of a surface feature to the inner layer beneath. Recess describes the remaining non-copper filled area on top of a copper filled feature (trench, microvia, through-hole) in relation to the copper plated on the board surface. Inclusions are non-copper filled voids within PCB features.

The filling of blind microvias without additives (normal deposition) will usually lead to the formation of a void (Figure 2, a). Copper is


"No great thing is created suddenly."
-Epictetus

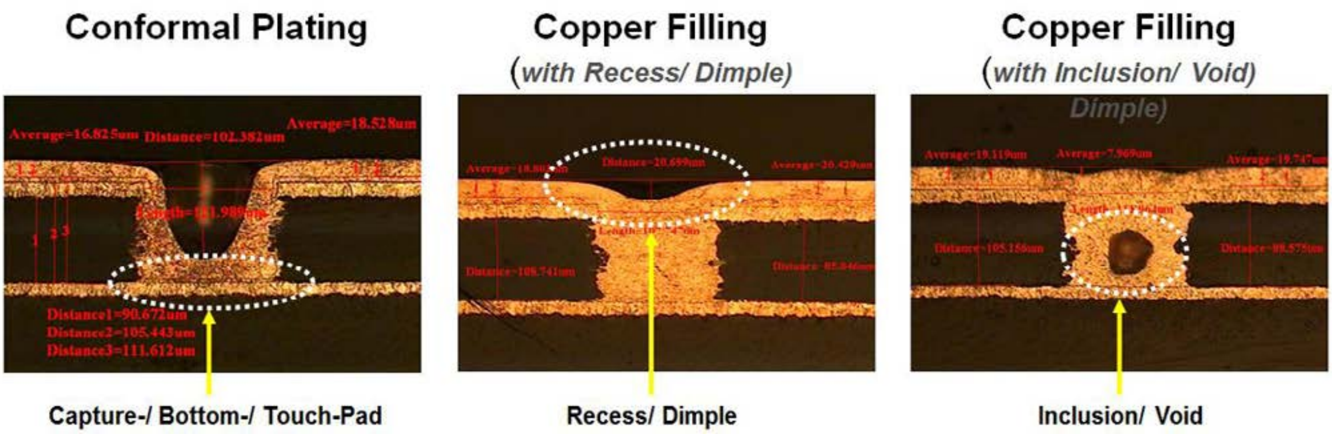


Figure 1: Description of technical terms for via filling.

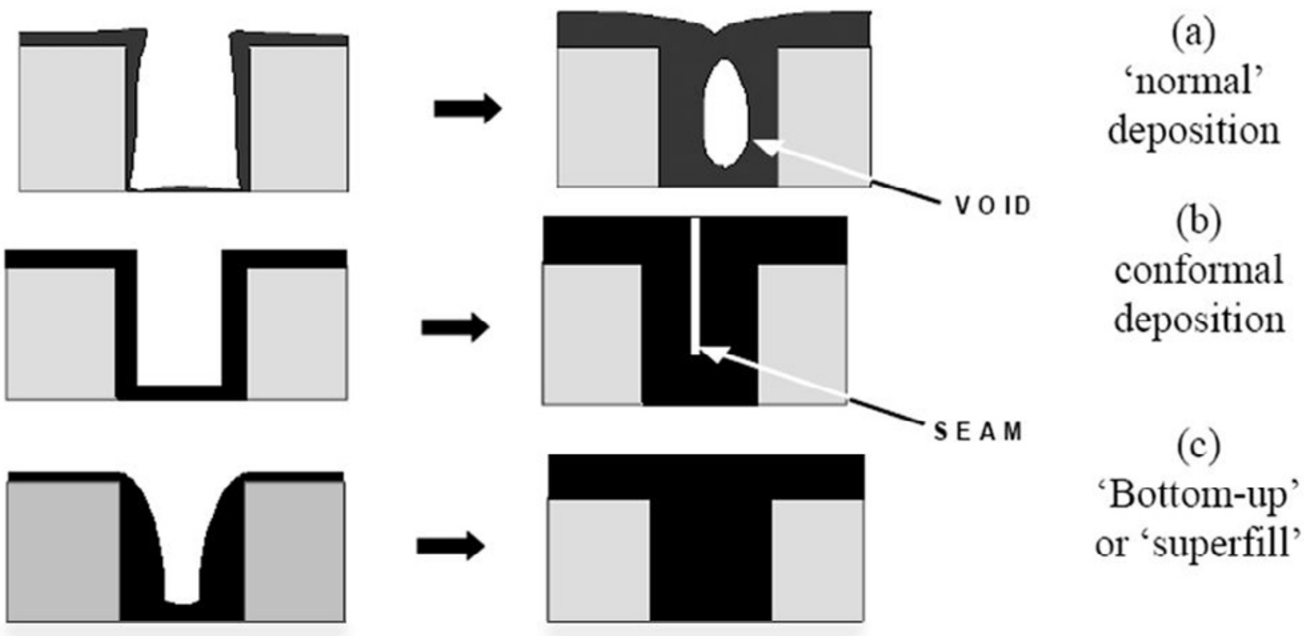


Figure 2: Schematic of BMV filling process.

deposited until the via is closed, but without additives less copper is deposited inside the BMV than on the surface and voids may occur.

Using organic additives that inhibit the deposition at the surface and increase plating into the BMV will lead to conformal deposition. However, by conformal plating the aspect ratio of the BMV is increased, limiting the solution exchange and mass transport into the BMV. The result can be a BMV with a seam in the centre where copper deposition was not possible due to the increase in the aspect ratio (Figure 2, b). The third way of BMV filling is the bottom-up method where the copper is deposited preferentially onto the capture pad, ideally creating a low dimple combined with a minimum of plated surface copper (Figure 2, c).

The filling of through holes is a bit different as there is no bottom area where copper plating can be increased. Therefore basically two approaches are possible: The first one is to use slow DC plating and conformal copper growth


ventec
8 1/2 Reasons You WIN with Ventec
Show Me
#1
#2
#3
#4
#5
#6
#7
#8
#8½
Ventec Europe
ventec-europe.com
Ventec USA
ventec-usa.com
Ventec International Group
venteclaminates.com

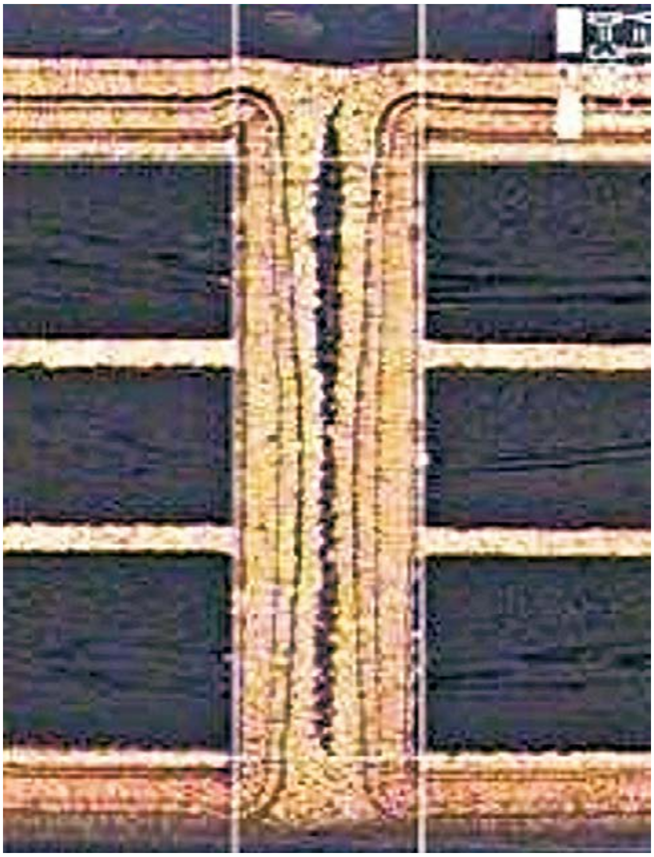


Figure 3: Seam in through hole filled in DC mode.

on the side walls to fill the through holes. But similar to the conformal BMV filling method, this method tends to create a seam or inclusions. It also takes more time (less productivity) and needs more copper on the surface as shown in Figure 3.

The other approach is to use conformal plating in the first step and then change to aggressive pulse plating in a second step in order to increase the amount of copper plated in the middle of the hole. The result is an X-shape in the hole built by two flat copper triangles on each hole wall. This X-profile can be seen as BMVs from both sides of the panel. These two BMVs are completely filled inclusion-free in the next step (Figure 4).

Additionally, the formation of the X shape or so-called "bridge" offers the possibility to significantly reduce the Cu overburden. That is achieved by applying a combination of reverse-pulse plating and etching in one electrolyte. This electrolyte contains not only Cu but also Fe^{2+} and Fe^{3+}. This inpulse system is described for a better understanding schematically in Figure 5.

Cu is deposited as usual on the panel (cathode) whereas the Fe^{2+} ions are used to carry the current at the dimensionally stable anodes and thus prevent oxidation of organic additives. The oxidation product Fe^{3+} is used to dissolve the consumed Cu chemically in a second chamber filled with pure Cu balls and reduced again to Fe^{2+}. Moreover, the Fe^{3+} cannot only be used to replenish Cu but also to reduce the plated Cu on the panel surface. The electrochemical

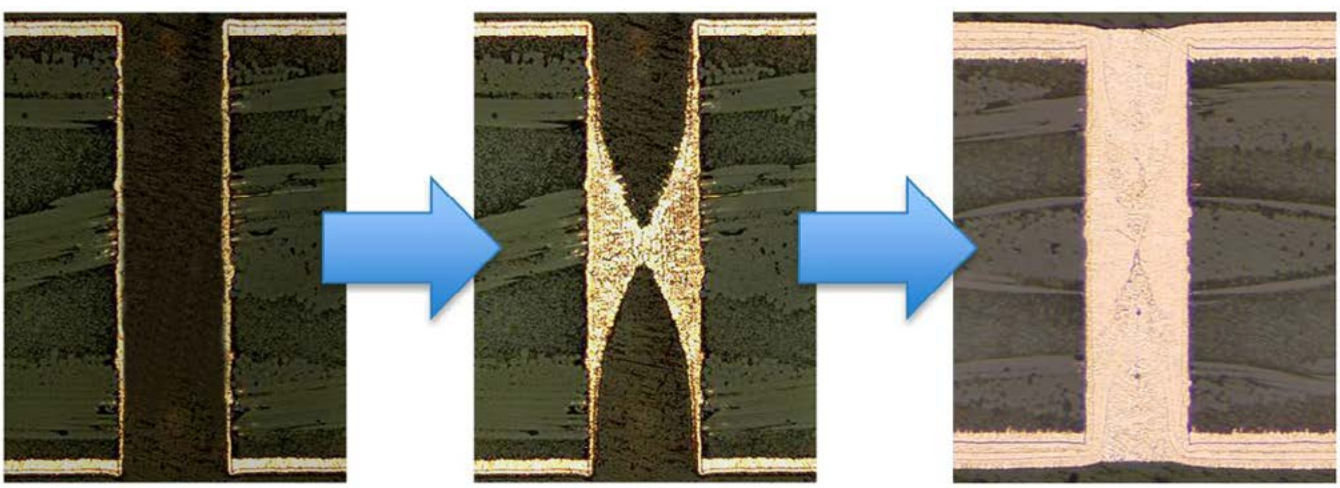


Figure 4: Steps of through-hole filling by formation of "X."

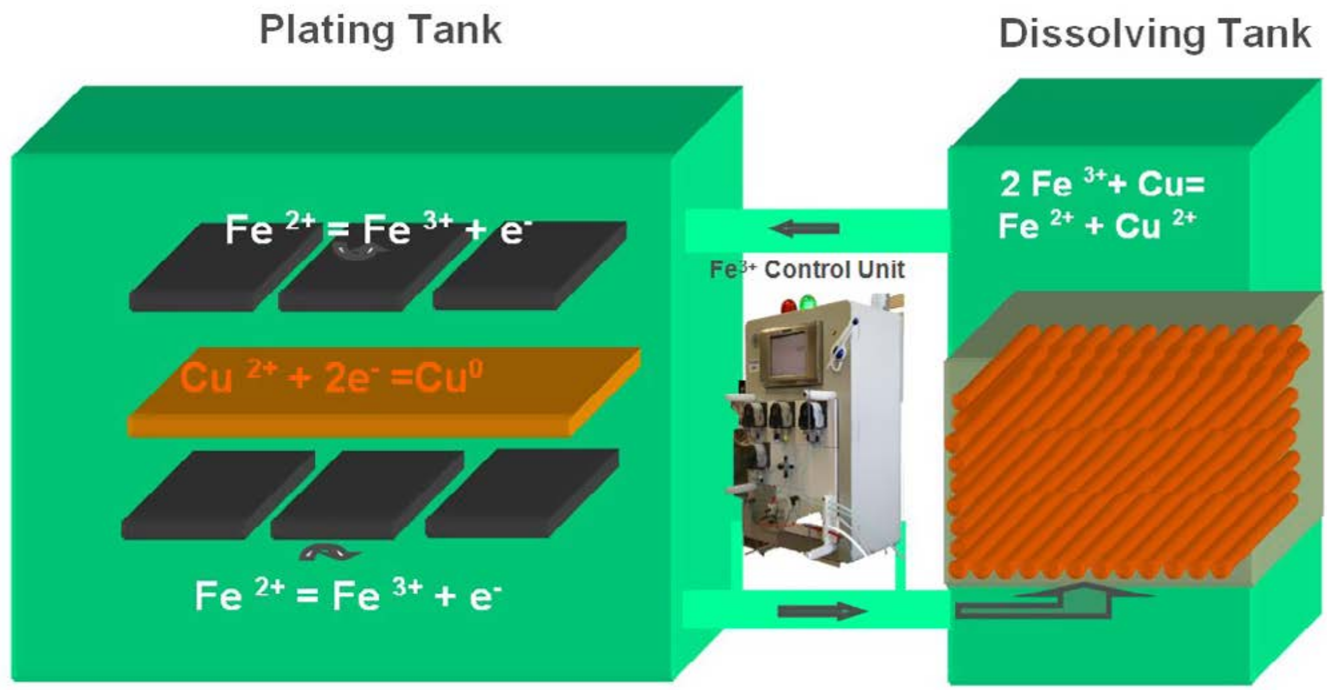


Figure 5: Inpulse plating system containing Cu and Fe.

reactions at the cathode in the Inpulse system with corresponding potential are given below (I) and (II) as measured against standard hydrogen electrode.

$Cu^{2+} + 2e^{-} \rightarrow Cu$ E = 0.340 mV (I)

$2\,Fe^{3+} + 2e^{-} \rightarrow 2\,Fe^{2+}$ E = 0.771 mV (II)

Electrochemically reaction (II) is favoured against reaction (I) and thus the amount of Fe^{3+} reduces and determines the amount of copper deposited onto the cathode (Panel). A Fe^{3+}-control unit between the plating and dissolving tank regulates the exchange between both compartments and controls the amount of Fe^{3+} within a range of ±0.1 g/l. This online control is a precondition for a good process control and has been proven in production scale. The solution exchange on the surface is much stronger than in a hole so the etching effect becomes effective mainly on the surface and not in vias and especially not in blind microvias.

With this technology we were able to reduce the amount of Cu overburden for a 100 µm thick core from 50 µm down to now 13–15 µm (Figure 6).

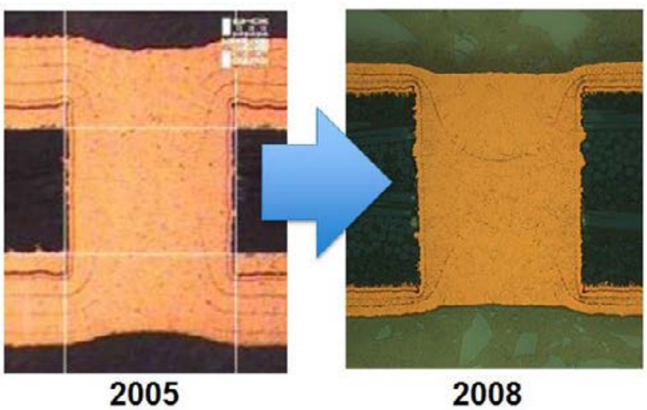


Figure 6: Surface thickness reduction during through-hole filling development.

Without this reduction, actual production would not have been possible as the surface plated copper thickness determines in the end the achievable lines and spaces. The reduction of surface thickness for filled BMVs allows the production of thinner stacked filled structures. As mentioned before, typically 10 layers of stacked copper BMV filling is the preferred tech-

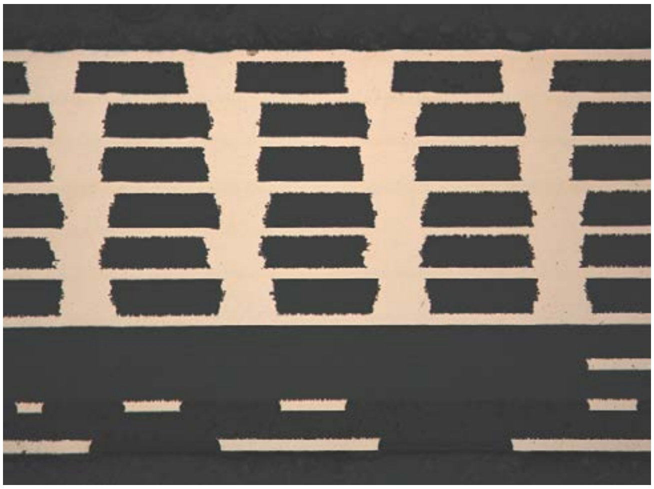


Figure 7: Filled stacked BMV, also called "any layer."

nology in smart phone production. It is one of the enabling production processes in the drive for miniaturization of consumer electronics following the expectation of innovation and invention given by Moore's Law.

New Challenges

The main core thickness for IC substrates is thicker than 100 µm; today's cores have a thickness of up to 400 µm or more. These are extremely difficult to fill without void formation and require a long plating time at a low plating current density. Up to 200 µm substrate thickness the industry now moved from using mechanical drilling towards laser drilled through holes. Laser drilling causes new problems when it comes to drilling quality. Often the time for the laser to vaporise the substrate is not sufficient to achieve smooth hole walls. Glass fibre protrusions occur, decreasing the diameter of the through hole but not always in the centre. During bridge plating the X-shape is made at the area where the diameter is minimum. When the gap is not closed at the centre, one of the two resulting BMVs will have a very high aspect ratio, increasing the risk of inclusions (Figure 8).

Therefore a new test matrix was carried out in a small lab tool to determine which of the following parameters might have a significant influence; the results of these tests were then confirmed in a production tool:

- Brightener (accelerator)
- Leveller (inhibitor) concentration
- Fe^{3+} concentration
- Cu concentration
- Cl^{-} concentration
- Sulphuric acid concentration
- Temperature
- Electrolyte agitation
- Current density and pulse parameters

For this investigation, we stopped plating after a certain time period and measured the thickness in the middle of the hole compared to the surface. Of course the organic additives have a significant influence on the filling performance, but for the improvement of the X-formation a change of leveller and brightener ratio did not significantly show a benefit. During our studies we found out that the effect of Fe^{3+} concentration is very strong. High ferric concentrations

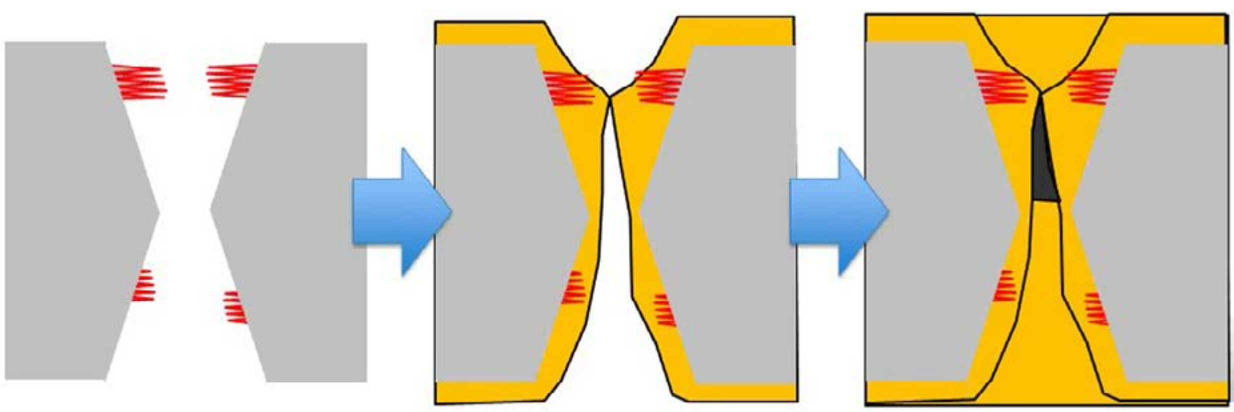


Figure 8: Challenge for filling of laser drilled through holes.

Figure 9: Effect of ferric ions on the X-formation: left 1.0 g/l and right 0.5 g/l ferric.

lead to very slow X-formation. Consequently the control of ferric ions is extremely important for handling the process. Therefore the online control unit between the plating and the dissolving tank is mandatory to keep the ferric ion concentration within ±0.1 g/l (Figure 9) and assure bridge plating.

Another interesting result is the effect of copper concentration on the X-formation. In contrast to the BMV filling process, a lower Cu concentration turned out to be beneficial. Its influence is significant for the X-formation.

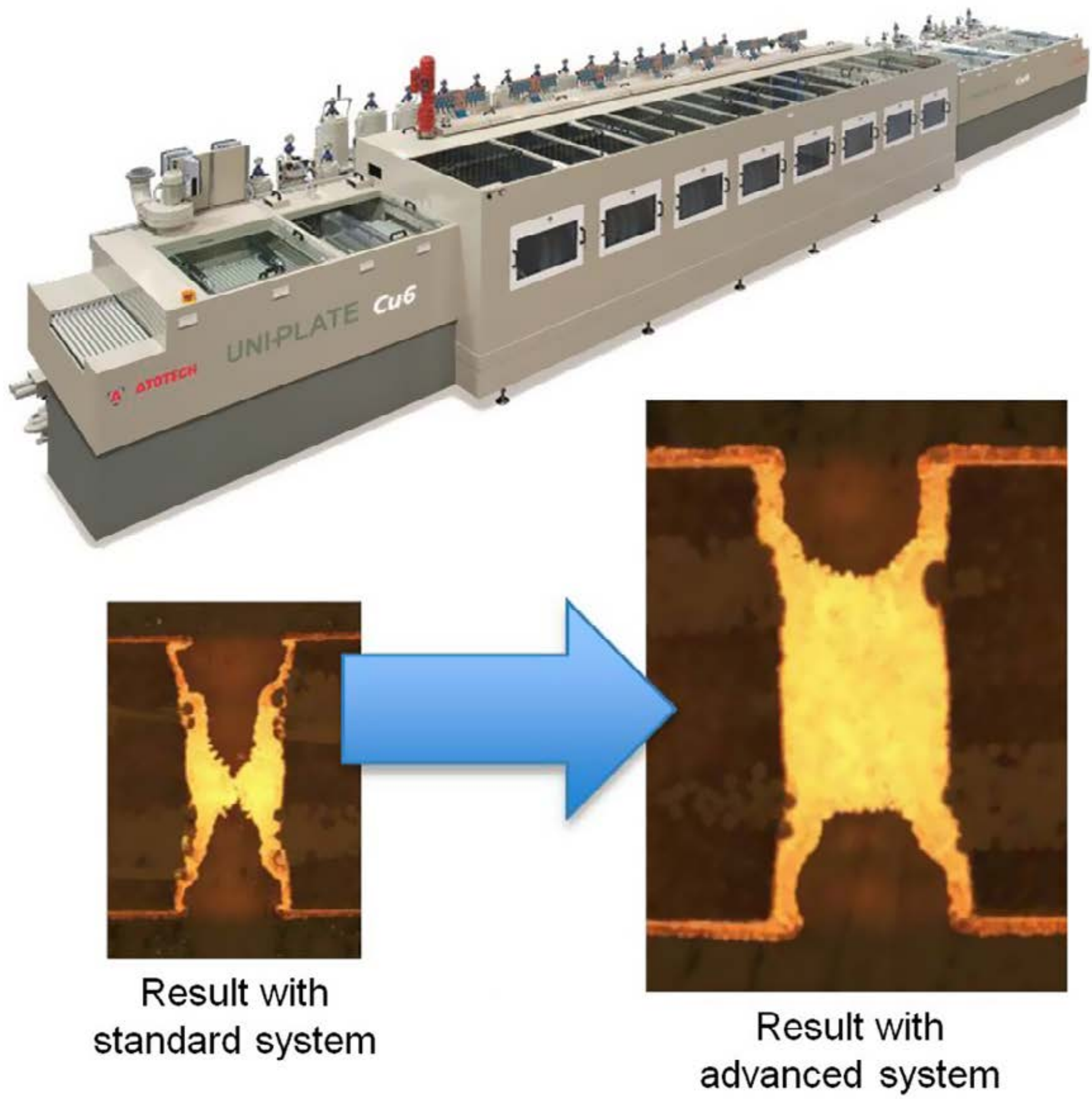


Figure 10: Bridging improvement by higher flow in advanced equipment.

Tests run with 18g/l and 32g/l Cu on very thick panels (3.2 mm with 0.3 mm hole diameter) confirmed this result. With the 18 g/l we almost doubled the Cu thickness in the middle of the hole. For the Cl^- concentration an increase up to 90 mg/l was beneficial, too. For the sulphuric acid concentration we couldn't find a significant influence. The temperature influences the dimple performance in via filling which is depending on the adsorption/desorption ratio between accelerator and inhibitor. It turned out that the increase of temperature from 20°C to 40°C had a positive effect for the bridge plating. Besides temperature and chemical parameters the equipment has a major influence in improving the filling performance. Therefore the existing equipment was modified.

We use an optimised, highly flexible rectification system, which is capable of running very complex and aggressive current pulses. By that we could proof that a strong reverse pulse (80 ms cathodic pulse at 5 ASD followed by a 4 ms anodic pulse at 50 ASD) for 15 minutes leads to reliable closure of the X-formation on 400 µm cores with 100 µm diameter. In our tests the electrolyte flow direction onto the panel was 90° angle towards the surface. Doubling the flow rate resulted in a consistent X-formation and centralised bridging (Figure 10). For this reason we increased the pump capacity for our production tool and could confirm this result also in production scale. Moreover a continuous flow control in combination with frequency controlled pumps and automatic level control grant a stable process performance.

Summary and Outlook

Copper via filling is a critical process for the production of HDI panels and IC packages. The number of BMVs found on a typical substrate is increasing as well as the dimensions of through holes, which pushes the limits for the production process. Reverse-pulse plating in combination with the ferrous inpulse system offers a viable alternative to standard approaches as it is a consistent inclusion free technology for filling of mechanical as well as laser drilled through holes.

Flexible pulse shapes empower the system to plate the X-profile first and then fill the created BMVs with very low copper deposition on the surface with the same type of equipment. Solution exchange in the holes has a big impact on the results of through hole filling, a high exchange rate results in less inclusions. Available systems offer a supply of up to 20 m³/h at each anode and can be setup to the optimised volume flow to meet complex requirements. Today it is possible to fill mechanical drilled through holes up to a substrate thickness of 300 µm and diameter of 100 µm inclusion free within 60 minutes. Laser drilled through-holes of 100 µm x 100 µm can be filled inclusion free in less than 60 minutes, 200 µm thick substrates still need >60 minutes plating time to guarantee void-free filling (Figure 11). Further development has to aim at inclusion free filling of thicker substrates (>300 µm) and to further reduce plating time. **PCB**

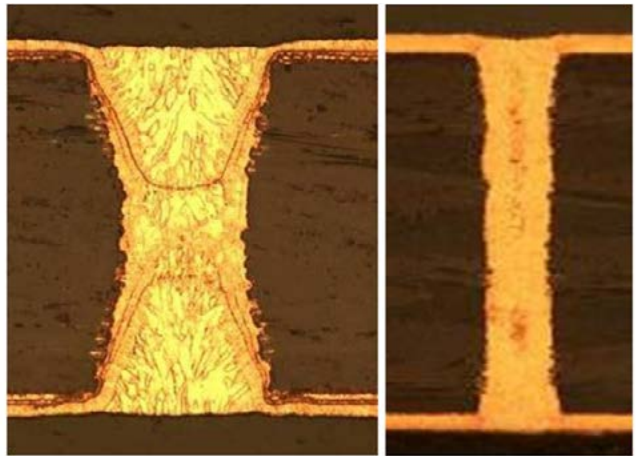
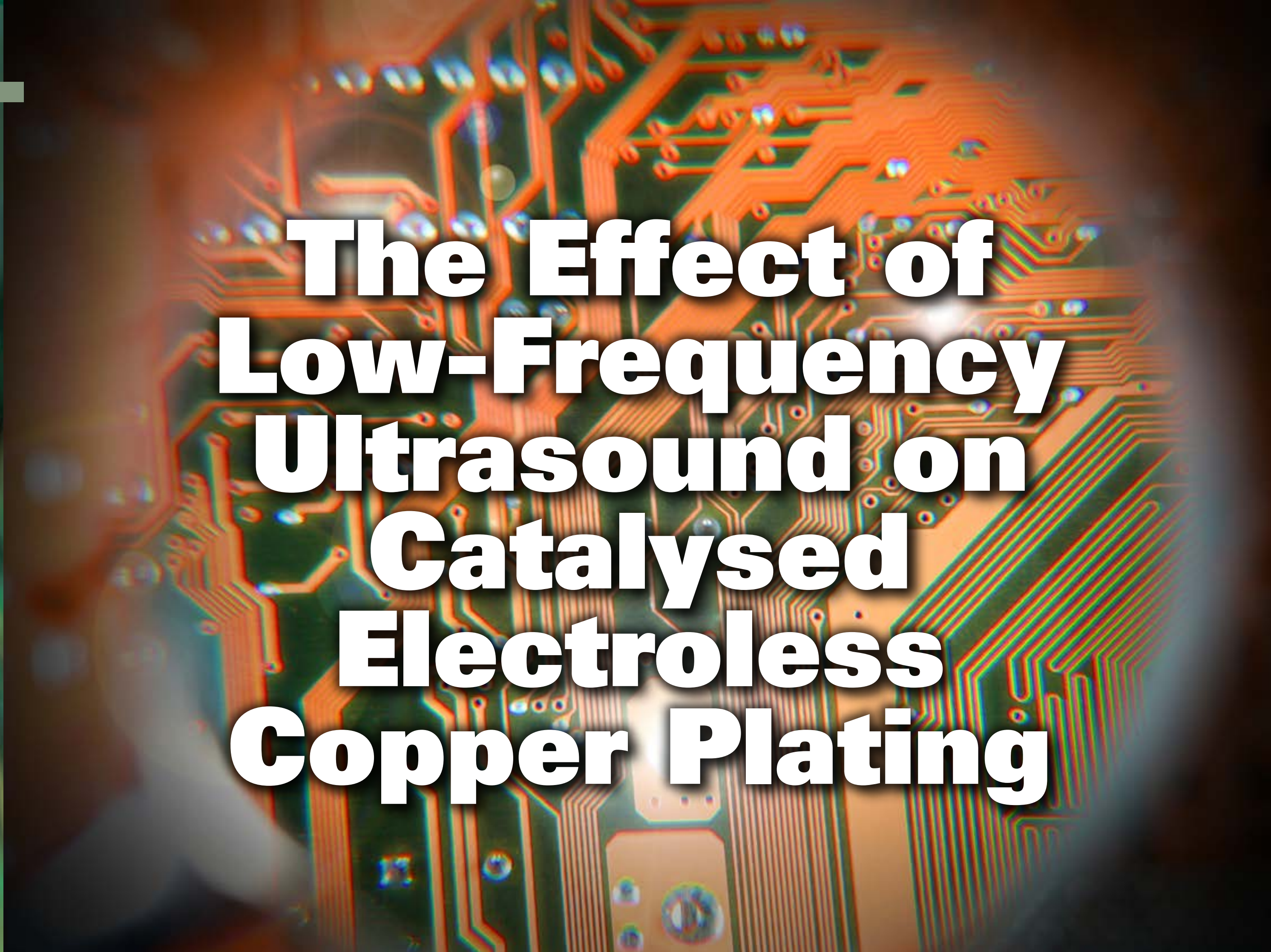


Figure 11: Laser drilled through-holes: (L) inclusion free 200 µm x 100 µm; (R) minor inclusions 400 µm x 100 µm.

Henning Hübner is global product manager, panel/pattern plating at Atotech Deutschland GmbH in Berlin, Germany.

Ramona Mertens is global assistant product manager panel/pattern plating at Atotech Deutschland GmbH in Berlin, Germany.

Dirk Rüß (Ruess) is sales manager for horizontal equipment at Atotech Deutschland GmbH in Feucht, Germany.



The Effect of Low-Frequency Ultrasound on Catalysed Electroless Copper Plating

by A. J. Cobley, B. Abbas, A. Hussain, and B. Mkhlef
Functional Materials Applied Research Group
Coventry University, U.K.

One of the most advantageous features of the electroless copper process is that it enables the metallisation of non-conductive substrates. It has been employed in the electronics industry for decades because it enables the plating of through-holes and vias in PCBs. The non-conductive substrate must first be catalysed (activated) and this is normally achieved using a palladium (Pd)/tin colloidal solution. The tin is subsequently removed in either an accelerator solution or in the electroless copper electrolyte itself, leaving Pd on the surface. The chemistry of electroless copper plating on a catalysed surface is a complex mix of electrochemical and chemical reactions but a simplified model is shown in Figure 1.

Formaldehyde (HCHO) oxidises on the Pd catalyst generating electrons (e^-) which are then consumed in the reduction of copper ions (Cu^{2+}) to copper metal (Cu^0).

There are many potential benefits in applying ultrasound to an electroless process and this was the subject of a recent review by the author[1]. The majority of the previous studies on the effect of ultrasound investigated electroless nickel plating where sonication generally produced a significant increase in plating rate[2–5]. Studies on the use of ultrasound during electroless copper plating are less numerous and few take into account the catalysation stage, despite the fact that this is a critical part in the process. One notable exception is the papers published by Touyeras et al.,[6, 7]. They showed that if relatively high-frequency ultrasound (530 kHz) was introduced to the catalyst bath, then an increase in the subsequent electroless copper plating rate could be obtained. Indeed, by applying ultrasound in both the catalyst and

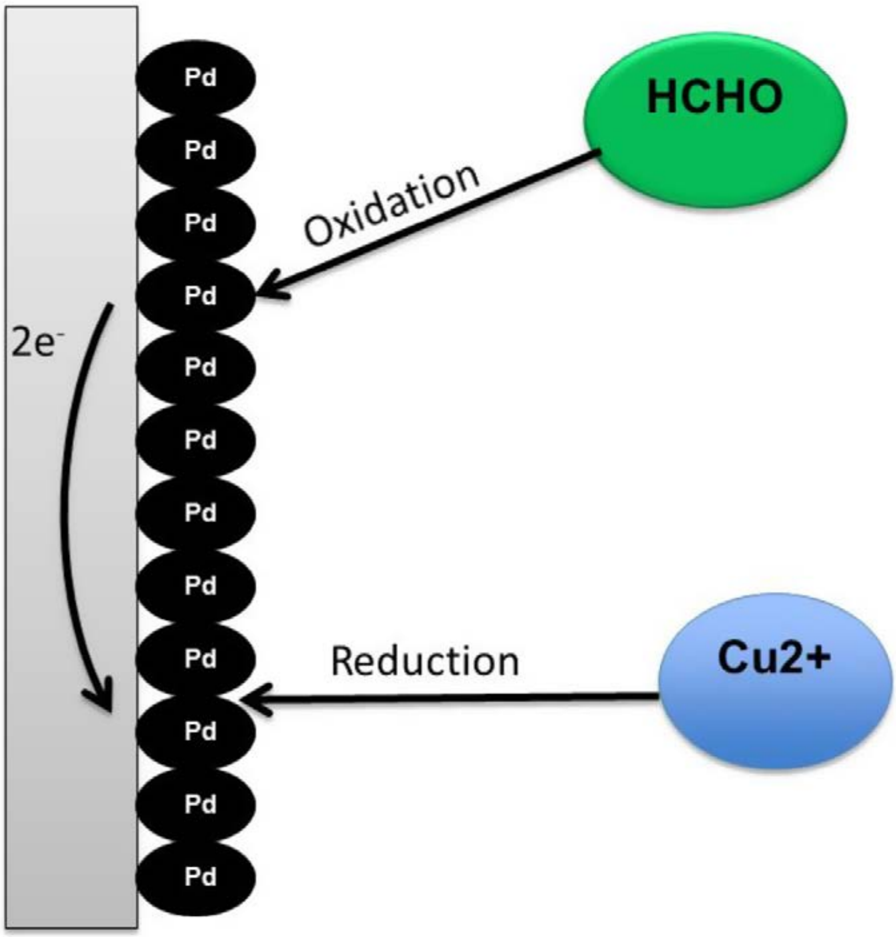


Figure 1: Oxidation/reduction reactions occurring on a Pd catalysed surface.

the electroless copper solution the plating rate could be almost doubled. These papers clearly demonstrated the importance of the catalysation step in the electroless copper process.

Studies at Coventry University

The Functional Materials Applied Research Group at Coventry University has carried out a three-year project funded by the Innovative electronics Manufacturing Research Centre (IeMRC), which investigated the effects of ultrasound on electroless and immersion plating processes. This work mainly utilized sonication at low frequency (40 kHz) which, for industrial applications, is preferred due to cost, availability and its more uniform effects in a bulk solution.

These studies quickly indicated that the effect of ultrasound on the catalysed surface must be considered if the beneficial effects of sonication are to be realised. X-ray photoelectron spectroscopy (XPS) analysis of the surface of the catalysed substrate after immersion in a simulated electroless copper solution (Table 1) showed that the application of ultrasound had a dramatic effect on the concentration of Pd on the surface. It can be seen that the catalysed substrate that had been immersed in the sonicated electroless copper solution had almost no Pd remaining on the surface after 10 minutes.

When ultrasound is applied to a liquid medium, a phenomenon known as acoustic cavitation occurs that leads to the creation of cavitation bubbles. The collapse of these cavitation bubbles near a solid surface produces microjetting, which is the driving force behind ultrasonic cleaning, as these microjets have a scrubbing action on the surface of material

	After Catalyst	4 minutes in Simulated Electroless Copper		10 minutes in Simulated Electroless Copper	
		Silent	Ultrasound	Silent	Ultrasound
Pd (Atomic %)	4.3	4.5	4.8	2.9	0.1
Sn (Atomic %)	17.0	0.6	0.7	0.4	-
Pd/Sn	0.2	7.5	7.0	7.2	-

Table 1: The effect of ultrasonic agitation in a simulated electroless copper solution on Pd and Sn concentrations on the surface of epoxy test coupons.

resulting in soil/dirt removal. Microjetting is also beneficial in electrochemical systems, enhancing mass transport and thinning diffusion layers. However, Table 1 clearly shows that in this catalysed electroless copper process it can have a negative effect by removing catalyst from the surface of the substrate to be plated (Figure 2).

These effects were reflected in the practical plating tests that were performed. Using an electroless copper solution operating at 40°C, the application of continuous sonication resulted in only a modest 8% increase in plating rate compared to the plating rates obtained using conventional agitation. However when a seven-minute delay time was introduced before the electroless copper solution was sonicated, a significant 38% increase in plating rates was observed. Indeed, the plating rate obtained at 40°C using delay time sonication (3.2 µm/25 minutes) was equivalent to those obtained using conventional agitation at 46°C.

A change in the grain structure of the electroless copper deposit was also recorded on test coupons that had been sonicated. Figure 3 indicates that a much finer grain structure occurs on samples that have been subjected to ultrasonic irradiation.

For electronic applications this modified grain structure has the potential to bring benefits in terms of lower porosity, better coverage, increase conductivity and a reduction in signal attenuation.

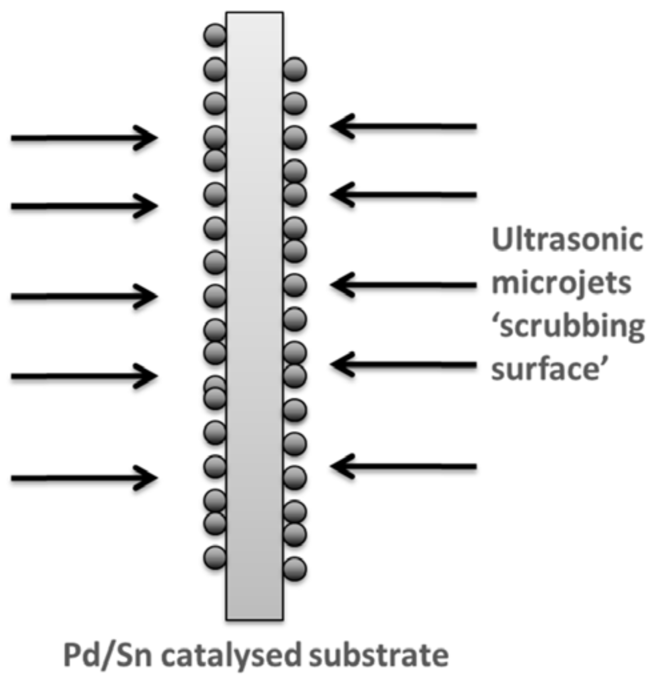


Figure 2: Ultrasonically induced microjetting scrubbing catalysed substrate.

www.gardien.com
GO
Gardien
UNIQUE
Acceler8®
Scanner
NEW Flying
Probe Range
Electrical Testing
Fixturing
CAM and CAD Services
Automatic Optical Inspection
Automatic Visual Inspection
Equipment Sales and Servicing
Consulting
Global Quality Assurance Solutions
tailored to your individual needs
GO™
Gardien
Find out more at CTEX EXPO in Suzhou, May 14-16
Visit us at Booth #M28

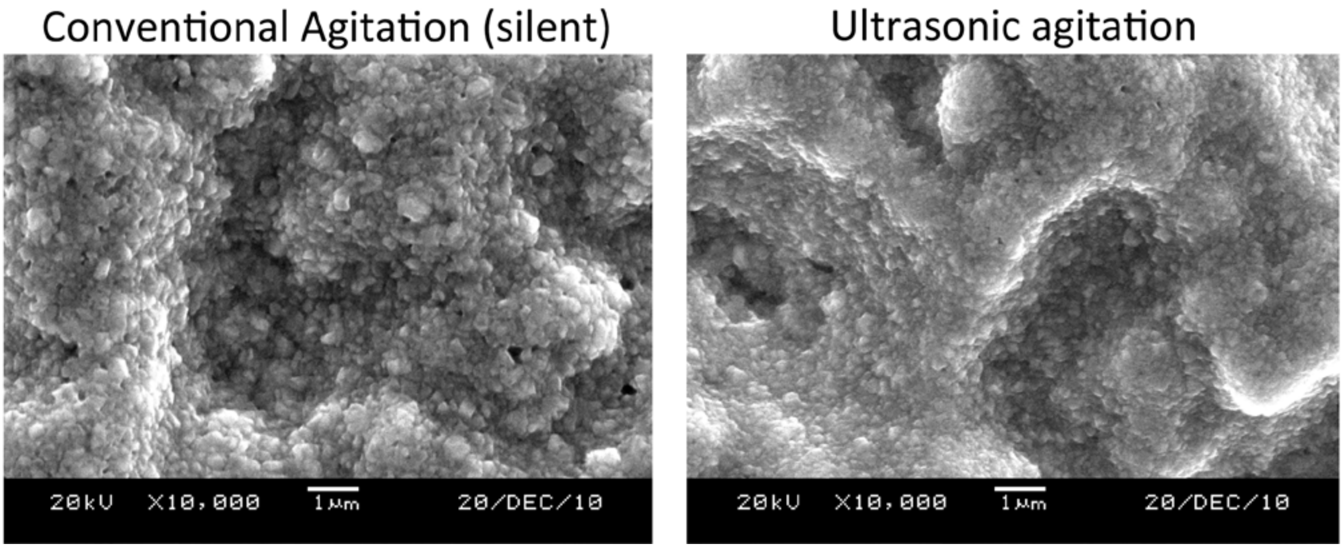


Figure 3: Electroless copper grain structure obtained using a plating temperature of 40°C.

Conclusions

Experimental studies performed by the Functional Materials Applied Research Group at Coventry University have shown that the introduction of low-frequency ultrasound to an electroless copper process has the potential to bring about many benefits in terms of increased plating rates, low temperature processing and grain structure refinement. However it must be understood that ultrasound can remove Pd from a catalysed substrate and therefore the sonication procedure must be optimised if these benefits are to be realised.

Acknowledgements

The authors wish to that the IeMRC and EPSRC for funding this project and our consortium partners Graphic Circuits PLC, Solar Capture Technologies Ltd, Chestech Ltd, LSA Ltd, The ICT, The IMF, The SP Technical Research Institute of Sweden and The Université de Franche-Compté. **PCB**

References

1. A. J. Cobley, T. J. Mason and V. Saez, *Trans. IMF* 89, 7 (2011).

2. G. O. Mallory, Transactions of the Institute of Metal Finishing 56, 81 (1978).

3. M. Matsuoka and T. Hayashi, *Metal Finishing* 84, 27 (1986).

4. M. Y. Abyaneh, A. Sterritt and T. J. Mason, *Journal of the Electrochemical Society* 154, D467 (2007).

5. K. Kobayashi, A. Chiba and N. Minami, *Ultrasonics* 38, 676 (2000).

6. F. Touyeras, J. Y. Hihn, S. Delalande, et al., *Ultrasonics Sonochemistry* 10, 363 (2003).

7. F. Touyeras, J. Y. Hihn, M. L. Doche, et al., *Ultrasonics Sonochemistry* 8, 285 (2001).

Dr. Andrew Cobley is a reader in Sonochemistry and Materials at Coventry University and Director of the Functional Materials Applied Research Group. He may be reached at a.cobley@coventry.ac.uk

Bahaa Abbas is a research associate in the Functional Materials Applied Research Group at Coventry University.

Azad Hussain is a research associate in the Functional Materials Applied Research Group at Coventry University.

Bilal Mkhlef is a former research associate in the Functional Materials Applied Research Group at Coventry University. He has now taken up another post.

MAGNA SERIES

THE NEXT GENERATION IN PCB ETCHING

MAGNA FEATURES

- *No CF4 for Operation*
- *Faster Etch Times*
- *Lower Operating Costs*
- *Lower Power Requirements*
- *Incredible Process Uniformity*
- *PC Control with Touch Screen*

PATENT PENDING DESIGN

100%

CF_4 FREE

The Magna Series is the world’s first plasma etching system used in the manufacturing production of PCBs that requires no CF4. This new technology from Plasma Etch, Inc. completely eliminates the need for CF4 gas that is presently used by PCB manufacturers using plasma systems for desmear and etch back processing.

PLASMA ETCH
PROGRESS THROUGH INNOVATION

3522 Arrowhead Drive
Carson City, NV 89706

775.883.1336

WWW.PLASMAETCH.COM

NEWS

PCB007 Market News Highlights

Conference Board Labor Market Improving

The economy generated a gain of 192,000 jobs in March. Undoubtedly, there was some catch up in hiring following the inclement weather this winter. Still, the underlying hiring trend is encouraging, with more good news expected this spring and summer.

Energy Efficiency Retrofits to Top $127B by 2023

Efforts to reduce energy consumption and greenhouse gas emissions have led to increasing deployments of energy efficiency retrofits for commercial and public buildings. According to a new report from Navigant Research, the worldwide market for energy efficiency retrofits in commercial and public buildings will grow from $68.2 billion in 2014 to $127.5 billion by 2023.

Global TV Market Continues to Drop

The global television market shrank last year for the second year in a row after total shipments declined by 6% from already soft 2012 levels, accompanied this time by a rare deceleration in the liquid-crystal display (LCD) TV space in China, Asia-Pacific, and Eastern Europe, according to a new report from IHS Technology.

3D Printing Market to Reach $16.2B in 2018

Canalys predicts that the 3D printing market, including 3D printer sales, materials, and associated services, will rise to $3.8 billion in 2014, with the market continuing to experience rapid growth, reaching $16.2 billion by 2018.

BBVA Compass: U.S. Economy Not at Risk of Deflation

As experts debate what the Federal Reserve should do about inflation, BBVA Compass economists say in their latest research that the policymaking board shouldn't divert from its timeline on tapering because the U.S. economy is not at risk of tipping into deflation.

Global Smartphone Market to See CAGR of 15.3%

The analysts forecast the global smartphone market will grow at a CAGR of 15.3% over the period 2013-2018. One of the key factors contributing to this market growth is the declining ASP of smartphones. The global smartphone market has also been witnessing increasing demand for large-screen smartphones. However, the high production cost could pose a challenge to the growth of this market.

Industrial Electronics Chip Market Rebounds

Powered by the freshly fueled gears of reviving economies, the global market for semiconductors used in industrial electronics applications overcame a serious fall in 2012 and roared back to life last year, boding well for an even more energetic 2014, according to a new report from IHS Technology.

Report: Test & Measurement in the Global EMS Market

This study analyzes growth opportunities and trends in test and measurement for EMS providers, as increasing complexity of assembly and miniaturization of components bolster demand for testing services. OEMs are increasing reliance on EMS partners for product quality assurance. The study includes a detailed analysis of opportunities for EMS providers and test and measurement vendors as well as market challenges.

MEMS Combo Sensors Revenue Continues to Climb

Combo sensors are headed for another major growth spurt this year in the global microelectromechanical systems (MEMS) sensor market as revenue climbs an expansive 37% after two years of already phenomenal increases, according to new analysis from IHS Technology.

Dell, HP See Growth in Worldwide PC Monitor Market

"Dell and HP both saw increases in unit shipments for the worldwide PC monitor market for the second time in a down year," said Jennifer Song, research analyst, Worldwide Trackers at IDC. "At a regional level, EMEA experienced the largest positive growth during the fourth quarter, with Italy and Spain posting the biggest gains."

Making Holes
CONDUCTIVE

Electronic Chemicals, LLC

Via Dep 4550 Electroless Copper

Electroless Copper for Difficult to Plate Substrates

Ready to Handle... The Most Challenging Surfaces On the Planet.

Advantages:

- Blister and Stress Free Copper Deposit
- No Harsh Pre-treatment Chemicals
- Low Temp, No Accelerator

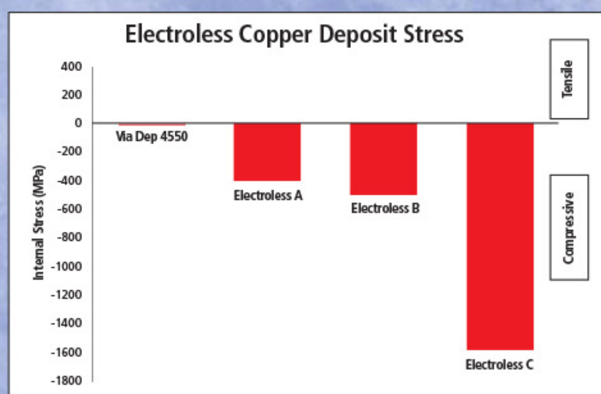
SUITABLE FOR FLEX, RIGID-FLEX, AND RIGID PWBS; COMPATIBLE WITH CONVENTIONAL EQUIPMENT.

LARGE POLYIMIDE FLEX WINDOW.

DIFFICULT SURFACES CAN BE PROCESSED WITHOUT THE USE OF HARSH CHEMICALS SUCH AS HYDRAZINE.

POLYIMIDE FLEX WINDOW IN RIGID FLEX CIRCUIT BOARD.

VIA DEP 4550 HAS SIGNIFICANTLY LESS INTERNAL STRESS THAN CONVENTIONAL ELECTROLESS COPPER PRODUCTS.



We've Got the Whole Process Covered

OMG Electronic Chemicals LLC

5630 Pioneer Creek Drive
Maple Plain, MN 55359
P: 800-321-9050 • F: 763-479-3344

400 Corporate Court, Suite A
South Plainfield, NJ 07080
P: 800-536-1959 • F: 908-222-3344

Best Practices 101, Part 1

by Steve Williams
STEVE WILLIAMS CONSULTING LLC

Introduction

In the global economy that is today's business environment, there are no guarantees as indeed, survival is not mandatory! The need for best practices is present in every industry, but mandatory in technology industries such as printed circuit board manufacturing.

In this new series, I will convey some of the personal lessons gained through my intimate involvement with more than 1,000 manufacturing companies, which has allowed me the unique perspective of truly understanding best practices by witnessing both the best of the best and the worst of the worst.

Best Practice—n. In business, a technique or methodology that, through practical experience, has proven to consistently lead to superior results over other means. Applied as a system, it combines all the collective experience, knowledge and technology at one's disposal.

—Williams Business Dictionary, 2014

Process Analysis

One could argue—actually, *I would* argue—that before any improvement to a process can be made, the current state of the processes must be understood. Process analysis is just a fancy way to say this. If we consider waste to be anything in a process that is not adding value, then the question becomes, how do I identify waste in my process? The most effective method of identifying waste is by process mapping: from basic process flowcharting to advanced value-stream mapping. These two powerful tools will help any organization take the first step toward identifying the value, and non-value, activities in their processes. As my esteemed high school classmate Dr. Shigeo Shingo once famously said, "The most dangerous kind of waste is the waste we do not recognize."

Process improvement is the key to achieving both short- and long-term gains, which result in a significant increase in overall operational performance. By analyzing your current processes, you can determine which steps add value, as well as where and when defects occur. Process analysis is a careful evaluation of each step of the process from the input's perspective as it is transformed into the output. Each step needs to be questioned on both why and how it is being performed. Just because the standard, "we have always done it this way" may apply, does not mean that it is the best way, and this is the part most organizations struggle with the most. *Quantum improvement sometimes requires quantum change,* and the willingness to approach process analysis with an open mind is critical to

the degree of success that can be achieved. Process analysis involves utilizing a team approach to map each of the processes at the appropriate level, and then analyzing each step for its value from the customer's perspective.

Most organizations have many processes that work together to bring a specific product from the point of a customer purchase order through the conversion process and ending with order fulfillment to the customer. The conversion process is simply turning (converting) inputs into outputs. From a big-picture perspective, raw materials are turned into finished goods, but within this macro-process there are many conversion cycles taking place as each process hands off a partially completed product to the next process. And again, remember that this could be one office function handing off to another just as easily as two manufacturing processes. The entire enterprise must be evaluated, from the problem-solving activity of taking a concept through engineering, to the information management activity involving order-taking and scheduling, to the physical transformation of converting raw material into finished product, delivered to the customer.

Process Analysis Terms

The following terms may be useful to an organization during the activity of process flowcharting, value-stream mapping, and analysis.

- **Blocking:** Occurs when the activities in a process stage must stop because there is no place to deposit the item just completed
- **Bottleneck:** Occurs when the limited capacity of a process stage causes work to pile up or become unevenly distributed in the flow of a process
- **Cycle time:** The average time between completions of successive units exiting a process
- **Make-to-order:** Process for producing in response to an actual order that results in minimum inventory levels
- **Make-to-stock:** Process for producing to meet expected or forecasted demand, shipped from stock, which results in high inventory levels
- **Process:** Any activity within an organization that converts inputs into outputs
- **Starving:** Occurs when the activities in a process stage must stop because there is no incoming work
- **Takt time:** Setting the pace of production to match actual demand; Takt time = available work time per day/daily total customer demand
- **Throughput time:** The time it takes a discrete unit to go from start to finish in a process
- **Utilization:** The ratio of the time that a resource is actually utilized relative to the time that it is available for use

Process Flowcharting

Process flowcharting is the use of a diagram to represent the major elements of a process; in other words, it is a picture of the process. There are many symbols used in process flowcharting, but the basic elements are tasks or operations, decision points, queue or storage, and directional process flow (Figure 1). The first

Figure 1.

step in many process improvement projects is to flowchart the process as it currently exists, which may not have any resemblance to company standard operating procedures (SOP). The realization that their SOPs do not reflect how the operation is really running is generally an "Ah-Ha!" moment for the company. Flowcharting also determines the parameters for process improvement since a process cannot be improved before it is understood. Although turning a process into a picture may sound very simple, it is an incredibly powerful tool to see what is really happening in a process. After a flowcharting session, the people actually doing the job are always amazed at the difference between how they perceive the process and what is really going on. A common result is a spaghetti diagram that highlights excessive travel, motion and redundancy. A picture truly is worth a thousand words.

As a working guideline, a flowchart should be used to: 1) understand how a whole process works; 2) identify the critical points, bottlenecks, or problem areas in a process; 3) see how the different steps in the process are related; and/or 4) identify the ideal flow of a process.

Next month, *Best Practices 101, Part 2* will dive deeper into process analysis by exploring the value-stream mapping tool. See you in June! **PCB**

Steve Williams is the president of Steve Williams Consulting LLC (www.stevewilliamsconsulting.com) and the former strategic sourcing manager for Plexus Corp. He is the author of the books, Quality 101 Handbook and Survival Is Not Mandatory: 10 Things Every CEO Should Know About Lean. To read past columns, or to contact Williams, click here.

VIDEO INTERVIEW

IPC India Planning May APEX EXPO

by Real Time with...IPC APEX EXPO 2014

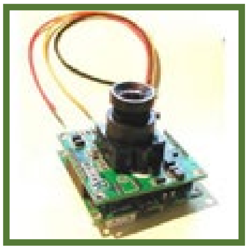
IPC's VP of International Relations, David Bergman, A. Vijayendra, managing director, IPC India, and Guest Editor Dick Crowe discuss IPC involvement in India and the upcoming show in May.

CLICK TO VIEW

realtimewith.com

CP 6080

LOW COST DIGITAL INK JET PRINTER



CCD CAMERA ALIGNMENT

CircaPrint

a printing legend

- Print size up to 600 x 800mm
- Up to 2 Inkjet-Heads 8 (32) channels each
- Up to 4 Colours depending on type of ink
- Vacuum-Table for hold down of flexible materials
- In line UV Curing
- CCD camera for accurate alignment
- Tooling pin registration
- 180 - 1440dpi

0 123456 789012

PRINT BAR CODES

LEGEND INKS • ETCH RESIST • UV BLOCK

www.circaprint.net
sales@circaprint.net

Viking

Does Corporate Lean Work?

by Gray McQuarrie, GRAYROCK & ASSOCIATES
and Jim Shaw, LEANFASTRACK LLC

"Leadership is influence."
~John Maxwell

It was the winter of 1984, Hoosick Falls, New York. I was sitting in a dark, cold office. Stacks of papers sat scattered on a large formal desk. Shelves were packed with books and other interesting things. And a sign, "Thou Shalt Not Whine," caught my eye. Like a bolt of lightning, Jim Shaw entered, and he walked behind his desk, sat down, looked at a piece of paper that had been faxed to him and said, "I didn't know you were coming." Still not looking at me, he got on the phone and made a quick call, during which he made a remark and a short joke, and then a specific request. He hung up. He repeated the process. All the while he talked on the phone he would occasionally turn and look out the window, as if staring at the person he was speaking to, who might be at the Oak-Mitsui plant, or the Teflon plant, or the flex material plant. After his last call he looked at me and said, "OK, here is the plan, you will meet with so and so...." And he went on in this way until he said, "And you will have lunch with me at exactly 12:30 pm." Then he was gone. I had never been so competently micromanaged in my entire life!

Jim was the boss of that laminate factory, and it apparent to me within the first microsecond of meeting him.

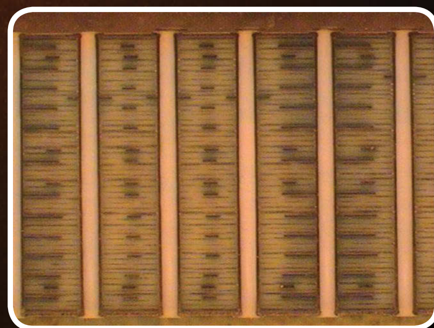
FILLING YOUR CHALLENGES ONE VIA AT A TIME

VIA FILL

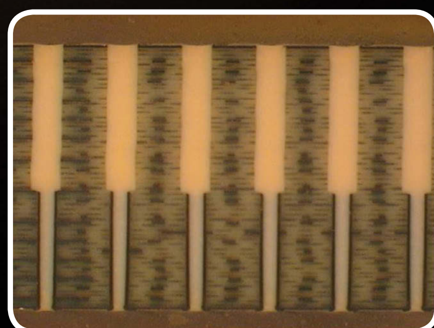
BY TAIYO

Via Fill Products

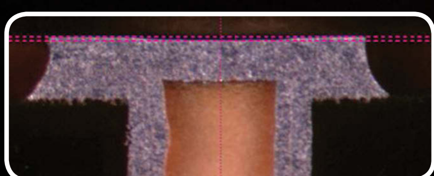
- **Thermal: THP-100 DX1 Series**
  - 100% Solids/Low Shrinkage
  - Hightest Tg (173°C)/Lowest CTE (19/56ppm) Available
- **LPI: PIHP-200**
- **UV: UVHP-100**



THP®-100DX1 VF (HV)



THP®-100DX1 (HTG)



TAIYO AMERICA

Your Ultimate Solution

2675 Antler Drive • Carson City, NV 89701 • Phone [775] 885-9959 • Fax [775] 885-9972

www.taiyo-america.com

And nobody had a problem with that, including me, the lost puppy who sat in his office not knowing what to do. I was treated as a VIP, and I knew why! In that short span of time with him I was both intimidated and inspired. I wanted to prove to him I was worthy of his attention and my treatment. If he had been my captain in the army during a battle, I would have had no problem running out of my foxhole firing off rounds if he had instructed me to do it. With his command I wouldn't have given it a second thought. Jim is the Johnny Bravo that Simon Sinek talked about in this video I shared in my last column.

Jim is an operations guy too, and in my interactions with him over the decades, he frequently said, "Get to the end." So here it is. Corporate Lean doesn't work and it doesn't work for two reasons: First, it is a solution outside of the four walls of the plant and second, Lean is about change. You can't manage change; you have to lead change.

What follows is Jim's story, in his words. It is a story about a plant that rose out of the ashes and became one of the best PCB laminate plants in the world. And it is a story about how Jim changed to become the plant's true leader instead of remaining its highly competent micromanager.

The Jim Shaw Story: Turning a Dog of a Plant into a Shining Star

Can Lean work with a corporate Lean manager? Not really. The plant manager has to be the change agent—the true leader of any important mission. That is what my story is about. But I was once one of those people who come in from corporate to show the plants how to change. It doesn't work! There is resistance (or resentment) from the plant manager, hesitation from employees to trust an outsider, and a general dislike from headquarters for the expert. Someone once gave me the definition of an expert that stuck with me: X is an unknown quantity and a spurt is a drip under pressure. Not very flattering.

Because this corporate approach seems to be the way these days with Lean, I have developed what I call PowerLean to differentiate it from corporate Lean. PowerLean means the following:

1. The plant manager is trained in Lean and leads the charge
2. The plant manager has complete support from his boss and executive leadership
3. The focus of the Lean effort is on empowering the employees

In my story, I will hit on each of these points as they come up. I will be using the term PowerLean, which refers to the three points above, even though back in the day it was just called Lean. Here we go.

> ***"Somehow my plant had slipped to the point of having the worst quality, worst customer service, and the highest costs, by far, of all the plants in the company. This bothered me a lot. One plant had tried Lean and I had participated in a Kaizen event."***

My plant wasn't performing and I didn't understand why. So I worked harder. Things got worse. I was perplexed. Somehow my plant had slipped to the point of having the worst quality, worst customer service, and the highest costs, by far, of all the plants in the company. This bothered me a lot. One plant had tried Lean and I had participated in a Kaizen event. It seemed to work, too. This was way back in the mid-1990s and was one of the first Lean events ever held in our industry. Based on this experience, I thought Lean could help my plant, so I set out to learn as much as I could. But something bothered me.

I drove in one day and as I got out of my car, I felt more than ever that this was my plant. I had to play an active role in its change, and my conscious would not allow me to be a passive participant to some Lean consultant who would tell me what to do. I had to learn this Lean stuff and lead the charge or things would just stay the same. This was foremost on my mind when I walked in to my office. I knew my people were ripe for change. I could see it in their eyes. They knew that if things didn't change, chains would be wrapped around the front doors. Knowing that this could not continue, I talked to people every chance I could, telling them our livelihoods were intimately linked and that the seemingly never-ending strategy of perpetual firefighting had to stop!

But change wouldn't happen solely because the people in the plant were ripe for change. I needed to know if I would have complete air support from above when it came to using Lean and conducting Kaizen events. Without that support, it would be no more than a suicide mission. I was fortunate enough to have a vice president of operations as my boss who understood and had experience with what I now call PowerLean. He let me know by his words and actions that I was the right guy. He trusted me. I trusted him. This was a big deal too, because I soon discovered that he was under some serious fire because of my poorly performing plant. For example, within days of making my decision that I was going to change, I got a call from our corporate parent company, and it is rare you get any attention from these guys who like to fly around in helicopters and private jets because their time is so valuable. He said, with little introduction other than his name, "What the hell is going on there?" and hung up.

Jerry Garcia of The Grateful Dead once said something like this: "Somebody has to do something and it's just incredibly pathetic it has to be us!" My plant and I were the "us"! It chilled me to my bones! You can imagine the word I uttered shortly after he hung up on me. I felt extreme gratitude that I had a boss who, even under this immense pressure, would stay out of the way and let the process work instead of take the easy road and fire me on the spot! The question I had in my mind at that moment was whether or not I would stay out of the way and let this process work. Would I commit to leading the charge?

"There is no such thing as a cowardly leader. Leadership demands bravery and the courage to stand at the front, knowing full well that instant annihilation is possible, because the front position is always fully exposed. And if you decide at the last minute to throw a body out in front to take the blow for you, at that moment, nobody will follow you. It takes integrity."

A charge doesn't really mean too much when it is just one crazy person running out onto the battlefield with a flag. But in that moment, that is exactly what I wanted and craved. I wanted to take control. Take charge. Order everyone around. And I knew nobody would follow me. In that moment I didn't care. I just wanted to have that comforting illusion of control. I wanted to micromanage the crap out of the plant! But an effective and powerful charge requires people—people that are so manic in their pursuit that they will do anything, because they completely trust their manic leader who is willing to do the same thing—have their backs and stand out there in front and suck it up and take it no matter what. The easy way out would be to hire someone else to do this while I sat passively in the peanut gallery and criticized in the hope of buying me more time while I continued to collect my paycheck. But I knew if I wasn't the one leading it, then it just wasn't going to happen. There is no such thing as a cowardly leader. Leadership demands bravery and the courage to stand at the front, knowing full well that instant annihilation is possible, because the front position is always fully exposed. And if you decide at the last minute to throw a body out in front to take the blow for you, at that moment, nobody will follow you. It takes integrity. It defines who you are and it is only revealed by the actions you decide to take while you are under pressure.

As I sat there staring at the phone, I had some soul searching to do. I had to lead the charge—for real! I knew what that meant: I would have to spend time communicating and building trust with the people in the plant. I would have to work long hours by myself at home working out materials for training, calling people for reports on costs at the plant, hashing over stuff, preparing stuff, and planning the Kaizen events. I had to figure out how the operations of the plant were going to run and be maintained, when so much of my staff's time would be tied up in these Kaizen efforts. And I had to be there for the events, and on the floor, and make myself completely available to everyone at the plant. I had to be there when people were down, when people weren't measuring up, and I had to be there to celebrate their success. I had to be there to push them a little bit further and always be the one that helps them find their confidence in themselves, maybe even beyond what they thought possible. That is what Kaizen is all about: change for the good of all. That is what it truly means to lead the charge: having people willingly follow you through change for the good of all. More importantly, that is the work required to build a truly engaged work force. An engaged work force that I knew one day would be able to run the plant almost entirely on their own! This was the vision in my head and it was 180° opposite of how I had been running the plant!

But with this decision and commitment, I also knew there was a downside and cost. All of this change effort would require patience and time. Time, which I feared I did not have, and patience I would try to find deep inside myself. By making the decision to be the true leader of this effort, I would effectively be making myself a temporary plant manager. My plant manager role would be subordinate to my role as the PowerLean leader and all of the work and time and training and meetings that would be required would mean an executive summary that my boss demanded, no matter how urgent his request, would have to wait.

In any plant today, in any industry, despite all of their proclamations about how they support Lean, few companies would tolerate having a plant manager behave as if their management job was subordinate to the Lean initiative. For PowerLean, this requirement is non-negotiable. It is a big reason for not even starting when I mentor plant managers in my consulting work. But this requirement of commitment, to lead the charge, is the only way to achieve real, sustained change with a really significant and sustainable business result. If you don't have this then what you have is a bunch of pretty slides, some funny number manipulations, and some hand waving. Slides and presentations don't lead people. Leaders lead people and without leaders there is no real change. This is an absolute undisputed fact.

What were the results of my efforts? Feast your eyes on the following:

- Capacity increased an average of 25%
- Set-up time reduced by 50%
- Total cycle time reduced by 35%
- Distance traveled reduced by 70%
- WIP inventory reduced by nearly 70%
- Cycle time < Takt time
- Improved space utilization and equipment reliability
- Reduced labor cost
- Increased operating income and cash flow
- Improved employee satisfaction

These operational improvements had a significant impact on business results—results that got us all out from underneath the negative attention and pressure at the highest levels of the company. The business results included:

- On-time shipping approaching 99%
- Customer satisfaction above 97%
- First pass yield at over 97% (one percentage point was due to QA testing)
- Almost nonexistent WIP
- No OSHA lost workday cases away (LWDCA) for more than six years
- High employee satisfaction
- One of the best operating income percentages among the U.S. operations

Whew! It worked!

But all of this isn't what makes me most proud of my contribution back then. Let me explain. I have been in too many plants in my life where the employees really don't like their jobs, because their jobs stress them out. At some plants, I have seen all of the employees back their cars into the parking spots so that they can make the fastest exit possible. You can see why in this video featuring best-selling author and leadership expert, Dr. John Maxwell. Maxwell explains how the employees would rather be anywhere but work, and do not want anything to impede their goal at the end of the day.

This mindset changed radically at my plant after PowerLean was implemented. There was never a race out the door at the end of the shift; employees stayed after their shift for a few minutes to communicate information to the new shift in order to facilitate the shift transition. For me, this was probably the most important personal accomplishment—people who liked their job and took personal responsibility for the success of the plant. It isn't all of the amazing results that define PowerLean; it is the fundamental cultural shift in the plant that goes from uninvolved employees trapped in a victim mentality to one in which every employee feels significant and powerful and together they think anything is possible.

If this is the result you want in your plant, then the first step you have to make is to decide to commit yourself to being the true leader that will lead the charge. I would be happy to talk to anyone that is struggling to make that commitment and make that decision! **PCB**

Gray McQuarrie is president of Grayrock & Associates, a team of experts dedicated to building collaborative team environments that make companies maximally effective. To read past columns, or to contact McQuarrie, click here.

Jim Shaw is president of LeanFastrack LLC, a company dedicated to helping fellow plant managers achieve success through the effective implementation of PowerLean.

NEWS

PCB007 Supplier/New Product News Highlights

Excellon Installs HS-2L Intelli-Drill at Electro Plate Circuitry

The Excellon HS-2L Intelli-Drill System is a two-station high-speed drilling system with Intelli-Drill vision. It has a large work area of 32 x 28 inches per station. The Intelli-Drill vision system uses CCD vision for precise alignment to both inner and outer layer features.

Hunter Acquires Assets of Spectral Response

"With the additional acquisition of Spectral Response assets, we now offer design, NPI, volume manufacturing, test, tune, and integration in both California and Georgia, along with warranty, repair, upgrade, and third-party logistics. For OEMs who value 'Made in the USA,' we have them covered from coast to coast," said Hunter Technology President Joseph O'Neil.

Cotton Named Director, OEM Technology at Ventec

Well-known and highly regarded in the global electronic product design community, and acknowledged as a leading innovator in PCB technology, Martin Cotton's 30 years' experience in the industry further strengthen Ventec's presence as a world-class provider of high-performance copper-clad laminates and pre pregs.

Parent Selected for Biz Development Position at Insulectro

Ken Parent takes on a new role with the company as vice president of Business Development and chief marketing officer. Parent has been in the PCB industry for more than 30 years, holding high profile positions at Lockheed Martin, Morton International, Rohm and Haas, including 13 years at Insulectro prior to taking on the business development leadership. Parent is also president of Integral Technology.

Bay Area Circuits Intros Web-based InstantDFM Tool

Bay Area Circuits, Inc., a leading manufacturer of quick-turn PCBs, has announced the release of a new DFM tool named InstantDFM. This first-of-its-kind, fully automated, web-based tool enables PCB designers all over the world with the ability to upload their Gerber files and immediately receive a design for manufacturability (DFM) report.

Advanced West Acquires Comac Engineering & Design

With over 2,400 machines sold, Comac Engineering is a supplier of affordable, compact, and highly efficient conveyorized equipment to the PCB fabrication, chemical milling, and nameplate industries since 1983. Advanced West, no stranger to Comac, has been refurbishing and distributing the product line since 1988.

Isola Creates Certification Program for PCB Fabricators

Isola Group S.à r.l. has launched a new certification program for PCB fabricators. The program is open to qualifying fabricators in the United States able to demonstrate the ability to process such high-speed digital materials as Isola's I-Tera MT and I-Speed.

Eagle Electronics Purchases LENZ High-speed Micro Drill

Mike Kalaria, president and CEO of Eagle Electronics of Schaumburg, Illinois, announced his company has placed a purchase order for a LENZ DLG 615-2 two-spindle micro drilling machine.

Microtek Opens Test Lab at Gen3 Systems' UK Facility

Gen3 Systems Limited, a specialist British manufacturer and distributor, and Microtek Laboratories Inc., a resource for independent testing and verification services, have announced joint plans to open a new European Test Lab in Q2 2014. The European Test Lab will be located at Gen3 Systems' facility in Farnborough, UK. Graham Naisbitt will be the Operations Director - Europe.

Pro-Tech Installs New WISE Process Lines Through Hamlet

Pro-Tech Interconnect Solutions, LLC in Chaska, Minnesota, recently installed two new wet process lines from Wise, through their agent, Hamlet & Smith. Pro-Tech has installed a WISE (Stripstar) resist strip line and an (Etchstar) fine line alkaline etcher to further their commitment to high-end technology.

Why choose Fein-Line?

Because there is a Fine Line between winning ...and the alternative.

After more than 44 years in the industry, just about everyone knows the name Dan (Baer) Feinberg.

There are few in our industry that have his experience and expertise in just about every aspect of the business. Dan knows what works, and perhaps more importantly, what doesn't.

When additional expertise is needed, or when senior management just needs an independent opinion, companies large and small alike get the guidance of Fein-Line Associates, especially in the areas of New Product Market Entry and M&A Due Diligence.

In our business, there's a lot on the line, not just sometimes, but every time. The line between success and the alternative can be razor thin. That's why winning companies choose Fein-Line time after time.

Dan (Baer) Feinberg
Fein-Line Associates

Sales Training General Marketing Assistance · New Product Market Entry
Merger and Acquisition Due Diligence · Printed Circuit Technology assessment
Market Research (It may work but will it sell) · Expert Witness assignments
Technology Transfer

Fein-Line Associates, Inc.
P.O. Box 73355, San Clemente, CA 92673-0112
(949) 498-7866
baer@feinline.com
www.feinline.com

Pentagon Budget Aftershocks

by John Vaughan
CIRCUIT SOLUTIONS LLC

There is a striking similarity between earthquakes and military budgets. An earthquake is the result of a sudden release of energy in the earth's crust that creates seismic waves. The Pentagon budget is the result of fiscal realities, protracted negotiations and balancing priorities, combined with a good dose of lobbying and politics, that culminates in a sudden release of program funding data that creates seismic waves in the military electronics business community. Welcome to the aftershock.

Presented with a two-year forward DoD budget in mid-March, we now at last have firm funding guidance and are in a position to evaluate the aftershocks of the appropriation decisions and apply that reality to our businesses and formulate a game plan moving forward.

To state the obvious, in this post-war and post-sequestration era, the defense industry is in the midst of a major reshaping with federal defense spending far below recent levels. This is a huge consideration for defense contractors such as Northrop Grumman, Lockheed Martin, BAE Systems, Boeing, and Raytheon (any of your customers in that list?). Most of these military prime contractors derive 70–90% of their annual revenue from federal contracts. Fewer contracts at the prime contractor level results in less electronics manufacturing at the PCB and contract electronics manufacturing levels.

Clearly, the military electronics market is still a very large market, but it would be prudent for each of us—on both the business development and senior management sides of the equation— to take a few moments to reflect on the customers and programs we have been

IPC 2014 Events

Mark your calendars now for IPC events in 2014! While many of the programs are being finalized, you can sign up today to receive updates on select event news and special promotions as they become available.

SIGN UP FOR EVENT UPDATES

May 6 | Andover, MA
May 8 | Santa Clara, CA
May 13 | Chandler, AZ
May 15 | Schaumburg, IL
Critical and Emerging Product Environmental Requirements Seminar

May 7–9
ECWC 2014
Nuremberg, Germany

May 19–22
IPC APEX India™
Bangalore, India

May 28 | Singapore
August 20 | Penang, Malaysia
Southeast Asia High Reliability Conferences

June 10–11
IMPACT 2014: IPC on Capitol Hill
Washington, D.C., USA

September 28–October 2
IPC Fall Standards Development Committee Meetings
co-located with SMTA International
Rosemont, IL, USA

October 14–15
IPC Europe High Reliability Forum
Düsseldorf, Germany

October 28–30
IPC TechSummit™
Raleigh, NC

November 18–20
High-Reliability Cleaning and Conformal Coating Conference
sponsored by IPC and SMTA
Schaumburg, IL, USA

December 3–5
International Printed Circuit and APEX South China Fair
(HKPCA and IPC Show)
Shenzhen, China

Questions? Contact IPC registration staff at +1 847-597-2861 or registration@ipc.org.

supporting, their current funding status, and future funding allocations. Equally important, we need to learn the funding status on newer programs we may have supported through engineering and prototype engagements that now may be slated for increased funding.

Given that much of my activity is centered on C4ISR related programs (command, control, computers, communications, intelligence, surveillance, reconnaissance), I turn first to an overview analysis of the budget impacts to that technology set. Clearly, with the drawdown of troops from both Iraq and Afghanistan post-war, there was an expectation that our troop levels would be greatly reduced overall, and that the associated electronics manufacturing to support soldiers on the ground would be impacted. Both expectations proved to be true. Without exception, every single Army program my business is supporting has pushed out to the right at least into Q3, and in several instances into Q4, for procurement activity.

“*Clearly, with the drawdown of troops from both Iraq and Afghanistan post-war, there was an expectation that our troop levels would be greatly reduced overall, and that the associated electronics manufacturing to support soldiers on the ground would be impacted. Both expectations proved to be true.*”

However, it may surprise many to learn that the cost of the wars is not accounted for in the defense budget. These funds are contained in the Overseas Contingency Operations budget (I still prefer the original name under President Bush—the Global War on Terror). At its current level, that budget contains nearly $80 billion for military operations in Iraq and Afghanistan in 2015. Negotiable with Congress, this could potentially yield funding for small systems and technology upgrades.

A clear budget winner from a program standpoint is the Joint Strike Fighter (F-35 Lightning II) manufactured by Lockheed Martin. Easily the most costly and ambitious acquisition in Pentagon history, Lockheed Martin and engine-maker Pratt and Whitney are developing multiple versions for the U.S. military and our international partners. The F-35 is funded in FY 2015 at $8.4 billion for twenty-nine aircraft and an additional $31.7 billion for additional units over the next several years. This program touches all service branches, as the Marines plan to replace F/A-18 Hornets and AV-8B Harriers with a vertically landing F-35B. The Navy is onboard with an F-35C tail-hook version, and the Air Force will fly a conventional version. From an electronics content standpoint, the F-35's sensor and communications suite is said to possess situational awareness, command-and-control and network-centric warfare capabilities. The main sensor on board is the AN/APG-81 AESA-radar, designed by Northrop Grumman. It is augmented by a nose-mounted Electro-Optical Targeting System (EOTS). The AN/ASQ-239 (Barracuda) Electronic Warfare suite (BAE Systems) provides sensor fusion of RF and IR tracking functions, basic radar warning, multispectral countermeasures for self-defense against missiles, situational awareness and electronic surveillance. Translation: lots of printed circuit boards.

In a major win for Northrop Grumman, the Air Force's venerable U-2 spy planes will be retired and will be replaced with Northrop's Global Hawk Unmanned Aerial Vehicles (UAVs). While the two aircraft perform similar high-altitude ISR (intelligence, surveillance and reconnaissance) missions, the Global Hawks will need upgrades to its electronic suites to handle the mission to the tune of around $1.77 billion over the next 10 years. Approximately $500 million of that funding is marked for a universal payload adapter that would allow U-2 sensors to be attached to the RQ-4 Global Hawk.

Electronic warfare (E/W) is both elegantly and simply defined by Alan Shaffer, U.S. Secretary of Defense for Research and Engineering as, “the defense of spectrum and systems used by U.S forces and the attack of spectrum and systems used by our enemies.” To at least keep pace near term with the E/W capabilities of our adversaries, most notably China, there is a strong commitment to E/W capabilities across all service branches. In 2012, the Air Force announced the Advanced Components for Electronic Warfare (ACE) program. The program is focused on developing some of the world's most advanced integrated photonic circuits, millimeter wave and electro-optical infrared (EOIR) systems and reconfigurable, highly adaptive radio frequency (RF) electronics. In the current Science and Technology budget, both E/W and anti-access/area-denial (A2AD) initiatives are well-funded, as is the continued rebalance to the Asia-Pacific region. Additionally, counter weapons of mass destruction (WMD) funding is at $1 billion, high-speed kinetic strike vehicles ($300 million), effective cyber and space operations are at $900 million, E/W at $500 million and the aforementioned A2AD at $2 billion. These are all leading-edge solutions to protect our country and they require leading-edge PCB manufacturing and contract electronics manufacturing solutions.

We are above ground at the epicenter, the aftershocks and the tremors can be understood—and exciting opportunities are identifiable through your close review of the budget as it relates to your business.

Armed with this information, it's time to form a plan, allocate resources to programs with funding, provide innovative solutions, grow your business, and support our U.S. Department of Defense, our war fighters and our country. **PCB**

John Vaughan is president of Circuit Solutions LLC, based in the Washington D.C. Metro Military market and providing integrated supply chain and program management solutions to the military C4ISR, Unmanned Systems and IED detect and defeat communities. To read past columns or to reach Vaughan, click here.

VIDEO INTERVIEW

IPC to Release New Market Studies

by Real Time with...IPC APEX EXPO 2014

Guest Editor Dick Crowe and IPC's Sharon Starr discuss the newly released IPC Market Studies Report, and the global onshoring situation.

CLICK TO VIEW

realtimewith.com

Mil/Aero007 News Highlights

Viasystems Receives Supplier Award from Rockwell Collins

Viasystems Group, Inc. received the 2014 Printed Circuit Boards and Electro-Mechanical Solutions Build to Print Supplier of the Year Award at the Rockwell Collins Annual Supplier Conference. The award is an acknowledgement of significant contributions made during the year by suppliers and is based upon quality, delivery, total cost of ownership, lead time, and customer service.

IPC Releases Conflict Minerals Data Exchange Standard

"IPC-1755 is XML-schema based, which allows for more efficient communication and quicker application of data across companies, supply chain levels and industries," said John Plyler, chairman of the 2-18h Conflict Minerals Data Exchange Committee. "IPC-1755 will be compatible with several software tools and Version 3.0 of the CFSI Conflict Minerals Reporting Template."

Dragon Circuits Diversifies with Instagram and Bitcoin

Progressive circuit board manufacturer Dragon Circuits announces the implementation of Instagram to track the process of their drone department, Dragon Drones. The company is also partnering with Coinbase to accept payment via Bitcoin.

Innovative Circuits Acquires Orbotech Inkjet Printer

This next-generation Orbotech Sprint 120 Inkjet printer features DotStream Technology and UV LED curing while delivering consistent top-quality printing at high speeds. Registration accuracies of 35µm are achieved through automatic measurements and scaling.

Military Communications Market at $30.12B by 2019

The report "Military Communications Market—(SATCOM Terminals, Commercial off The Shelf (COTS), Military Communication Security, Tetra Radio, JTRS, Software Defined Radio, Radio Communication, Tactical Communication)—Worldwide Forecasts & Analysis (2014–2019)" is now available.

DARPA Selects Boeing Phantom Swift for X-Plane Program

Phantom Swift, a prototype Boeing initially built in less than a month, has been accepted to be part of the Defense Advanced Research Project Agency (DARPA) Vertical Takeoff and Landing X-plane program. DARPA is trying to mature a new aircraft configuration capable of both efficient hover and high-speed cruise.

Paving the Way for Unmanned Ships of the Future

Ships of the future will soon be steered across the seven seas—unmanned. A new simulator is helping propel these plans forward. Partners from five different countries engineered the design of the autonomous freighter. "In Europe, making a career in shipping is no longer a popular choice," explains Project Coordinator Hans-Christoph Burmeister. "This industry has successor problems."

DARPA Awards PARC $2M to Develop Vanishing Electronics

PARC, a Xerox company, has signed an up to $2 million contract with the Defense Advanced Research Projects Agency (DARPA) to develop and demonstrate PARC's disappearing electronics platform (called DUST), with intriguing implications for a variety of military, ecological, and commercial interests.

SOMACIS Intros R&D Project for Signal & Power Bus Bar

Engaged in the SAPBB project, SOMACIS, along with two other Italian companies, is developing an advanced technology bus bar type solution for automotive applications. The circuit board will enable both power and signal distribution between key components of the automotive power system.

M2M SatCom Market to Reach $4.76B in 2019

Increasing data communication need, rising M2M applications, and fast return on investments is leading to the creation of more and more avenues for the M2M satellite market. The global market is expected to grow from $2.98 billion in 2014 to $4.76 billion by 2019, at an estimated compound annual growth rate (CAGR) of 9.8% from 2014 to 2019.

Testing: Everything You Wanted to Know, but Were Afraid to Ask

by Todd Kolmodin
GARDIEN SERVICES USA

This month, *Testing Todd* presents some readers' questions about the basics of electrical test, including the different types of testing available today.

Reader: I recently found out that all points are not necessarily checked during electrical test. Why is that, and which types of boards do not get all of their points tested? Isn't there a chance that something will be missed? Is there a type of test that hits all of the points?

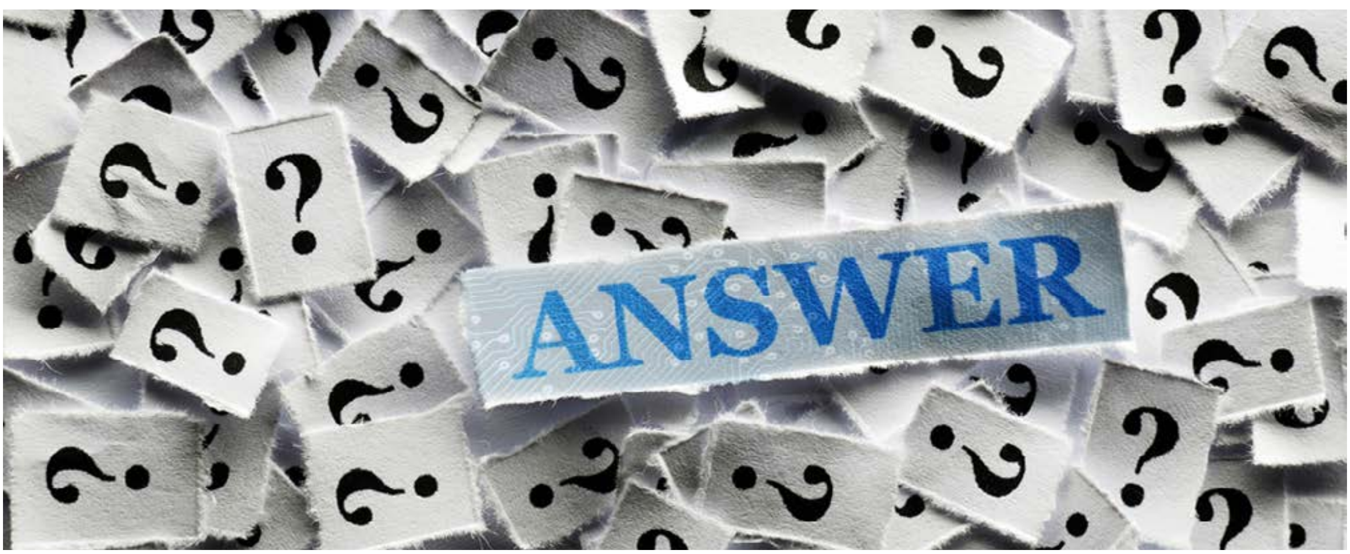
Todd: When a board is programmed for test, certain points of the board are de-selected. To properly answer this question, we need to revisit IPC-9252A, Amendment 1, which stipulates that Class I and II can remove the mid-points of a net on the board. What this means is that we are only concerned with the end-to-end connectivity of the net. With IPC Class III we need to include the mid-points of the net to quickly isolate any problems in the chain. However, this is cautioned by the additive properties of solder mask encroachment or via-fill. In these cases, although Class III, they cannot be tested and are allowed the waiver under the 9252A with Amendment 1 release.

Within the Class III requirement of 9252A with Amendment 1, we can add probes to validate each landing pad. With Class I and II we are only validating the end points of the net to make sure the signature is intact. By adding mid-points with Class III we validate that the connectivity is valid to all landing pads. This is in case there may be contamination to any of the intermediate landing pads in the chain of the net.

Adding all pads in the net is referred to as Class III per IPC-9252A with Amendment 1, which hits all of the points.

Reader: When and why do your customers decide to use the different kinds of testing?

Todd: Class III is the strongest requirement. In this class, basically zero downtime of the product is allowed—usually medical or aerospace. The utmost care in test and reliability is expected.



Reader: Is one type of test better than another? Why?

Todd: What it comes down to is the product itself: What is it designed to do and what precautions and life cycle does the OEM expect? I cannot speak for other service organizations, but with my group we are going to test the product as if it were going to keep us alive, keep our kids online with school and keep us informed when we need to be. There are minimums that PCBs need to be tested. The informational database with OEMs goes back years; notes and such just get re-pasted into new prints. My group continues to work strongly with these OEMs to make sure their product is tested to the most updated parameters.

Reader: What are the different types of electrical test that you can perform on a circuit board, and which is best for my product?

Todd: Let's start with flying probe testing. Flying probe direct will test the PCB 100% in resistive mode and isolation test 100% based on an adjacency window. (Industry standard .050.) Flying probe indirect will do a capacitive gather and full resistive test of first board; subsequent boards will receive capacitive gather and be compared to master. Possible faults will receive full resistive retest.

Flying probe is just another tool today for the test bureaus. Flying probe can test product without the use of the historic bed of nails fixture. There are tradeoffs though. Indirect testing with signature analysis does allow faster testing but does not subject the PCB to full resistive test. However, this is allowed under the IPC for Class I and II. On a Class III board it is allowed, but only after an agreement between the OEM and manufacturer, which is the hard part for service bureaus. This communication conduit does not exist for most. Many OEMs just expect their boards to be electrically tested but do not have any idea what options are available. When presented with the quandary they will opt for fixture test as that is historic. Unfortunately, fixture test also increases the price for their product, often without the OEM knowing why.

Reader: What is bed-of-nails testing and when is it used?

Todd: Bed-of-nails testing is the old-school test, and it is also stipulated as a requirement for a lot of military product. This is the "fixture" test. This is an apparatus that probes directly at all points necessary, simultaneously. These are large, costly machines that were the beginning of the solution of electrical test.

Reader: What is hi-pot testing and when is it used?

Todd: Hi-pot is a test used to verify that the dielectrics in the board are sound or that the power and ground layers are isolated. With the thin cores used today it has become imperative that these isolations are met or the PCB can fail in its duty cycle.

007: What is netlist testing and when is it used?

Todd: Netlist testing is the process where the electrical test equipment tests the product against a known good signature. What this means is that the electrical test machine already knows what to expect from the PCB. Years ago it was self-learn and compare. Today, the machines already know what to expect from the product based on the design data and will referee accordingly.

In an upcoming column, I will discuss what the future of e-testing will look like and I will elaborate on subjects such as testing requirements for embedded components, high resolution measurements, and Kelvin high-resolution testing.

Questions are encouraged and will be addressed in future columns. **PCB**

Todd Kolmodin is the vice president of quality for Gardien Services USA, and an expert in electrical test and reliability issues. His new column, *Testing Todd,* now appears monthly in *The PCB Magazine.* To contact Kolmodin, [click here](#).

TOP TEN

PCB007 News Highlights This Month

1 Q1 North American PCB Market Snapshot

More than 370 industry professionals answered the call to take I-Connect007's first-ever quarterly market survey. This one-minute survey is designed to provide a snapshot of the current state of the PCB and EMS industries. Based on the results so far, we believe, with your help, we've been able to capture a fairly accurate picture of the current state the market.

2 IPC Honors Volunteers for Contributions to the Industry

IPC presented Committee Leadership, Distinguished Committee Service, and Special Recognition Awards at IPC APEX EXPO at Mandalay Bay Convention Center in Las Vegas, Nevada. The awards were presented to individuals who made significant contributions to IPC and the industry through IPC committee service.

3 Advanced Circuits Gears Up with Orbotech's LDI System

Advanced Circuits has purchased Orbotech's Paragon-Xpress LDI system for use in the manufacture of key components for the commercial PCB arena as well as the high reliability, military/aerospace/defense and high-technology marketplace.

4 Viasystems Expects 10% Sales Increase in 1Q14

Estimated net sales for the quarter ended March 31, 2014 are expected to be in the range of \$290–\$300 million, representing a year-over-year increase range of 6% to 10% compared to the first quarter 2013, and representing a seasonal sequential decrease from the \$303 million net sales reported for the preceding quarter.

5 Replace Complex Wiring with Rigid-flex PCBs

Complex wiring needs space, which is often not available. The solution has arrived: Rigid-flex PCBs. They are the result of a creative interdisciplinary collaboration between the drive manufacturer WITTENSTEIN in Igersheim and Würth Elektronik in Niedernhall.

6 Sunstone Circuits Among Top Places to Work in Oregon

"[We are] thrilled to be one of the Top Places to Work in Oregon," said Rocky Catt, COO. "We want Sunstone employees to feel they are part of an organization that's moving forward in the right direction, that their everyday contributions are valued by management and that the work they do is a part of something meaningful."

7 PCi Acquires Microcraft Flying Probe Test Machine

The Microcraft flying probe machine will enhance PCi's technical capabilities for higher density flexible circuits, and at the same time will improve lead time and lower cost on smaller quick-turn builds. Eliminating the cost and time to assemble fixtures is a major improvement for the quick-turn prototyping environment.

8 Global PCB Manufacturing Market: $74.31B in 2018

The global PCB manufacturing market is expected to increase its market size from approximately $62.3 billion in 2013 to near $74.31 billion in 2018, growing at a CAGR of 3.6%. The market volume is also expected to increase to 32 billion units and 3.92 million tons by 2018, growing at a rate of 3.8% and 5%, respectively.

9 FTG's Circuits Segment Sales Up $1.6M in 1Q14

"The momentum from the end of 2013 has continued into the start of 2014 with strong results across the company, particularly at our two new aerospace facilities in Tianjin and Chatsworth," stated Brad Bourne, president and CEO. He added, "Our established Circuits facilities both performed well in the quarter and we are working hard to get our Circuits Joint Venture through its start-up and customer qualification phase so it too can contribute to our success in the future."

10 TTM Trims Q1 Forecast on Foreign Exchange Loss

While operating performance was consistent with its guidance, the company expects to incur an unrealized, non-cash foreign exchange loss of approximately $3.6 million, ($0.03) per diluted share, in the quarter due to the rapid depreciation of the Chinese RMB against the U.S. dollar.

CALENDAR

EVENTS

For the IPC Calendar of Events, click here.

For the SMTA Calendar of Events, click here.

For the iNEMI Calendar of Events, click here.

For a complete listing, check out PCB007's full events calendar.

Nordic SI Week 2014
May 5–9, 2014
Stockholm, Sweden

SMT Hybrid Packaging 2014
May 6–8, 2014
Nuremberg, Germany

SMTA Atlanta 18th Annual Expo
May 7, 2014
Duluth, Georgia, USA

International Conference on Soldering and Reliability
May 13–15, 2014
Toronto, Ontario, Canada

Internet of Things
May 14–15, 2014
Milwaukee, Wisconsin, USA

Toronto SMTA Expo & Tech Forum
May 15, 2014
Toronto, Ontario, Canada

2014 Technology & Standards Spring Forum
May 19–22, 2014
Seattle, Washington, USA

IPC APEX INDIA
May 19–22
Bangalore, India

12th Annual MEPTEC MEMS Technology Symposium
May 22, 2014
San Jose, California, USA

IPC Southeast Asia High-Reliability Conference
May 28, 2014
Singapore

RAPID Conference & Exposition
June 9–13, 2014
Detroit, Michigan, USA

IPC SE Asia Workshop on Soldering of Electronics Assemblies
June 9, 2014
Penang, Malaysia

IEEE ICC 2014
June 10–14, 2014
Sydney, Australia

CES Unveiled Warsaw
June 17, 2014
Warsaw, Poland

Upper Midwest Expo & Tech Forum
June 18, 2014
Bloomington, Minnesota, USA

CE Week
June 23–27, 2014
New York City, New York, USA

Symposium on Counterfeit Electronic Parts and Electronic Supply Chain
June 24–26, 2014
College Park, Maryland, USA

PUBLISHER: **BARRY MATTIES**
barry@iconnect007.com

PUBLISHER: **RAY RASMUSSEN**
(916) 337-4402; ray@iconnect007.com

SALES: **ANGELA ALEXANDER**
(408) 915-2198; angela@iconnect007.com

MARKETING SERVICES: **TOBEY MARSICOVETERE**
(916) 266-9160; tobey@iconnect007.com

EDITORIAL:
GROUP EDITORIAL DIRECTOR: **RAY RASMUSSEN**
(916) 337-4402; ray@iconnect007.com

MANAGING EDITOR: **LISA LUCKE**
(209) 304-4011; lisa@iconnect007.com

TECHNICAL EDITOR: **PETE STARKEY**
+44 (0) 1455 293333; pete@iconnect007.com

MAGAZINE PRODUCTION CREW:
PRODUCTION MANAGER: **MIKE RADOGNA**
mike@iconnect007.com
MAGAZINE LAYOUT: **RON MEOGROSSI**
AD DESIGN: **MIKE RADOGNA, SHELLY STEIN**
INNOVATIVE TECHNOLOGY: **BRYSON MATTIES**
COVER: **SHELLY STEIN**

PCB007 Presents

the pcb magazine

The PCB Magazine® is published by BR Publishing, Inc., PO Box 50, Seaside, OR 97138

May 2014, Volume 4, Number 5 • The PCB Magazine© is published monthly, by BR Publishing, Inc.

ADVERTISER INDEX

Coming Soon to *The PCB Magazine:*

June:
Flex and Flex-Rigid

July:
Embedded Components

August:
Printed Electronics