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# Profitability Is a Choice

Profitability is a multi-faceted subject. Today, there are still opportunities left in the PCB fabrication business to regain profit margin—some large and systemic, and others small and incremental. One must make the choice to think differently about the business—and processes—to restore profitability.


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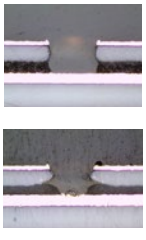

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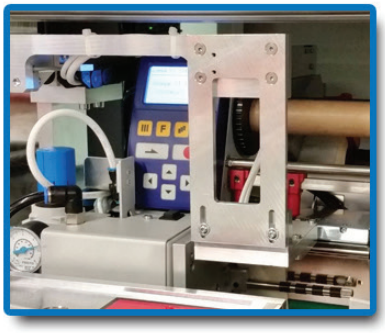

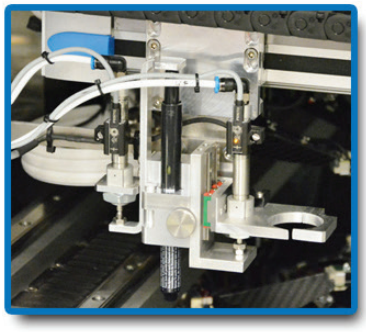

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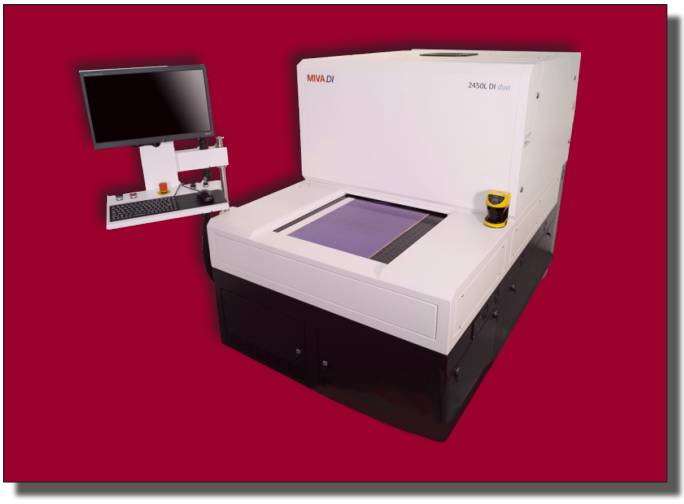


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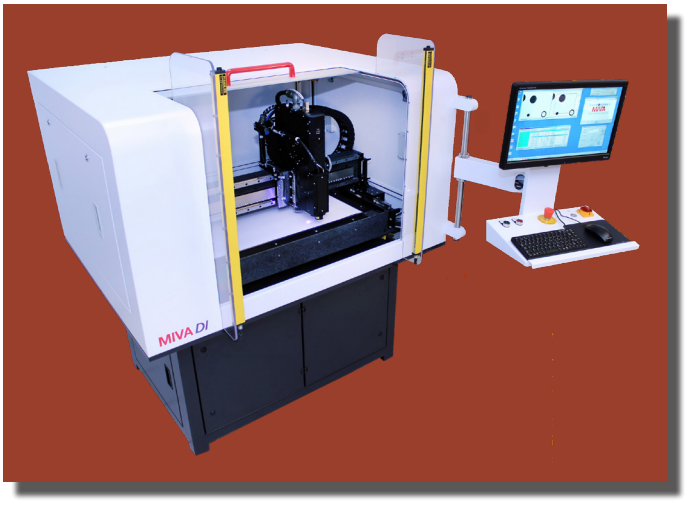


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# Profitability Is a Choice

## Nolan's Notes

**by Nolan Johnson,** I-CONNECT007

"The profit is all gone from printed circuits," said one industry executive. Another explained, "We have been forced into a commodity business, with margins to match."

The conversation happens time and time again. Get into a social setting with fabrication business owners, and many of them will share that their profit margins are awfully thin these days; however, not all of them are saying that. Some are finding plenty of business to be had with strong margins. So, why are there different opinions and results?

There seem to be two schools of thought among fabrication owners right now: those who are defensively hunkering down, and those who are assertively making changes. The old adage states, "With great risk often comes great reward," which holds true here. But the I-Connect007 team chose not to dwell on the reasons, motives, and philosophical differences between these two camps. Instead, we reviewed as many departments as possible within the PCB fabricator, looking for improved profits from the bottom up, so to speak. We also took a top-down view, exploring the contribution of company leadership on profitability.

Profitability is a multi-faceted subject. Ultimately, the profits return to the business based on good leadership. But I'm stating the obvious, aren't I? My personal takeaway from this issue was that there are multiple opportunities still left in the PCB fabrication business to regain profit margin—some large and systemic, others small and incremental.

However, one theme came through: You have to think differently about your business and your processes to make progress and restore profitability. Profitability is a choice.

We kick off this issue with a high-level discussion with Steve Williams, "Profit Is in Your Thinking." Then, we have a discussion with MacDermid Alpha's Bill Bowerman on the

business model advantages present in carbon-based processes. This conversation provides context for the technical paper on MacDermid Alpha's Blackhole process that follows later in the issue.

Getting more floor-focused, Dick Crowe, Kurt Palmer, and Thomas Kunz spoke with the I-Connect007 team on how the drill department can change their thinking and reconfigure for improved efficiencies, which leads to more profitable operations. Over on the laser drilling side of the department, MKS's ESI looks at "Trends in PCB Processing: A New Set of Technologies, Materials, and Challenges."

Incremental improvements don't need to end on the shop floor. In my previous life, in PCB fabricators, I saw just how much high-level labor time was committed to customer surveys and audits. Al Block and Naji Norde discuss the IPC PCQR$^2$ initiative, which could add efficiencies not only for the end customer's procurement department but also for the fabricators, releasing key management personnel to tackle other challenges.

Next, Chris Wall from MacDermid Alpha Electronics Solutions decodes inkjettable solder mask. We also bring you an event report and interview from Tulip Wu, PCB007 China editor, who recently attended an Orbotech event and secured an interview with Yair Alcobi, the president of Orbotech's PCB Division. In a roundtable-type discussion, the I-Connect007 team spoke with John Watson about "When Your Fabricator Is Late"—a look at the trickle-down schedule and cost impacts of missing a customer commit date. Further, Joe Dickson from WUS provides an update on "The Current State of VeCS Technology."

Our columnists joined the profitability party, as well. IPC's Dr. John Mitchell covers "The Future of the Electronics Industry," and Todd Kolmodin writes on "Waste Not, Want Not." Mike Hill asks "Have You Hugged Your Technical Review Board Lately?" Steve Williams presents Part 1 of "Guerilla Tactics to Pass Any QMS Audit." Lastly, George Milad dives into "Eliminating Waste From Electrolytic Acid Copper Plating," and Mike Carano shares "Material Challenges for PCB Fabricators."

Whether you have an appetite for major changes in your business or small incremental steps back to profitability, there's something in this issue for you to consider. As you read, you'll find—like I did—that even the tactical improvements ultimately lead to thinking differently about your business. Profitability truly is a choice. **PCB007**

**Nolan Johnson** is managing editor of *PCB007 Magazine*. Nolan brings 30 years of career experience focused almost entirely on electronics design and manufacturing.To contact Johnson, click here.

# 2020 EIPC Winter Conference

In this two-part series, Pete Starkey recaps how the 2020 EIPC Winter Conference, held in Rotterdam in mid-February, attracted around 90 delegates from a dozen European coun-tries—as well as a few from North America—to an outstand-ing learning and networking experience for members of the PCB community. The theme of this year's event was: "The Needs for Next-Generation Electronic Devices and Changes in Fabrication Solutions for PCBs, PCBAs, Materials, and Technologies." (Source: I-Connect007)

**Click for Day 1 and Day 2.**

# Profit Is in Your Thinking

**Feature Interview by the I-Connect007 Editorial Team**

The I-Connect007 editorial team spoke with Steve Williams, president of The Right Approach Consulting, about the difficulties around putting profitability back into PCB fabrication, what wake-up calls force companies to make that transition and look at their business differently, and the issues or roadblocks that can stop some from progressing.

**Nolan Johnson:** Let's start with perspectives on how to put profitability back into PCB fabrication. It seems a lot of pressure in the supply chain squeezes the profit right out of PCB fabrication. However, there's a bright spot in the industry of what's possible.

**Barry Matties:** At GreenSource, they have continuous flow manufacturing. They have moved down to a lot size of one. There's no work sitting around on carts, which eliminated a lot of the process steps of cleaning and of other costs associated with a larger lot size. By driving the waste of the process, there is profit to be had in PCB fabrication. Steve, what do you see?

**Steve Williams:** You're spot on, Barry. I can't tell you how many times I go into a place and they complain about their yields or how much money they're losing from scrap and rework; however, when I look at their process, they haven't embraced some of the stuff that could make them successful like Lean manufacturing, best practices, or workflow optimization. They should look at the process in a holistic manner and figure out what's the best way to get products from point A to point B. They're carting products all over the plant from this side to that side, and back to the other side, and it's not laid out in a good flow. They're doing a lot of reactive tasks instead of proactive tasks.

One of the things that I talked about not too long ago is getting rid of inspection. Inspection is a non-value process, but board shops will turn there first to try and solve a problem; they'll throw more inspection at it. That compounds the problem. Instead of looking at and fixing the process, they add more people to sort out the good stuff from the bad. They're never going to make any headway that way.

In a prior life, I worked for a very large contract manufacturer. Of course, we were always

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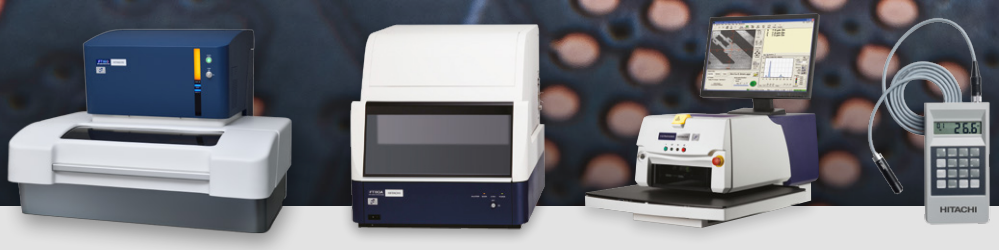

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concerned with cost downs, and we would pressure our suppliers for cost downs, but we knew that we couldn't expect our suppliers to take it out of their margins because we wouldn't be a very good customer any more, and the relationship probably wouldn't work. What we tried to do was at least start with the conversation that they need to try and take costs out of their process. They need to become leaner. They need to reduce their waste, and we want them to give us a cost reduction based on that—not take it out of their margins because one of us is going to go out of business. We did a lot of supplier development with companies on how to become leaner and work a little bit smarter instead of harder. That seemed to pay a lot of dividends.

**Matties:** Many years ago, when we were printing *CircuitTree Magazine,* we realized that blue-line was an inspection process. For those who don't know blue-line, it is a non-value added, expensive inspection process done before you would print a magazine. Utilizing TQM, we woke up and realized we could eliminate that step altogether by changing the poor process. It was exactly what you mentioned. Over our years in the business, we realized that we spent somewhere in the neighborhood of a half-million dollars on blue-lines, and all of it was waste or a loss in profit.

When we approached our printer at the time, they came back and said, "No, we have to do that." At that point in the industry, all printers used blue-lines. We challenged the status quo and had to find another printer that would be willing to eliminate blue-line and look at it not as losing revenue but gaining the capacity to bring on new business because their man-hours were freed up. Once we found the right partner, we soared. Our profits went up, as well as theirs, and it was a good working relationship. Why don't we see more of that thinking in the circuit board industry?

**Williams:** That's a great question. This thinking seems very specific to the PCB and manufacturing industry. Back when the quality gurus—Deming, Juran, Ishikawa, etc.—were reducing waste and improving processes, the industry leaders at the time didn't want anything to do with it; they were fat, dumb, and happy, so to speak. However, our quality experts then went over to Japan and pitched the same thing—only they listened. They started out-competing us in automotive, consumer electronics, and everything else. We saw it first and ignored it. There was a bit of arrogance there, as well as some, "That's the way we have always done things." People don't like to change.

**Happy Holden:** If you look at some of your recent columns, you're going back to the basics of Lean, TQM, and Six Sigma. I know people who don't remember these topics, or they thought they were fads. For some of us that got the religion, it became a way of doing business.

**Williams:** You're absolutely right, and repetition is the only thing that I can do. We can talk until we're blue in the face, so it's important to keep it in front of people and cite examples and case studies. We're being forced to look at how to make money in this business, and it's no different than 30 years ago. You have to throw less away, and you have to be more efficient. People are finally starting to embrace some of these concepts, even if it's out of necessity.

**Matties:** The industry conversation today is around 4.0 or the smart factory, but you have to start with basics first. You have to document and understand your processes before you can drive waste out and make them smart.

**Williams:** Sure, and earlier in my career, I would visit Asia a couple of times a year. The whole perception was that they were kicking our butts because of the low labor cost, but the factories were highly automated and controlled by process controls, and their waste was almost nothing. That's why they're still kicking our butts—not that they're paying their people nothing—their factories are extremely efficient.

**Matties:** Maybe there's an opportunity for new manufacturing facilities to be built and to drive yields way up. GreenSource is a shiny model. Their yields are as high as anybody, and their labor cost is probably the lowest domestically in the industry. The technology is capable and setting records.

**Holden:** They don't have any inspection.

**Matties:** When you start looking at that model, is this the blueprint for people to come in and start building new factories?

**Williams:** Absolutely.

**Johnson:** It becomes a question about how to fund that. Could this be where we start seeing a fundamental change and return back to captive facilities? Because the right OEM wanting to be in control of their manufacturing process can fund this better than somebody who's 40 years in the industry and ready to retire.

**Holden:** The brand new GreenSource facility paid back in less than two years. For their owner, PCBs are the most profitable product, even though Whelen also does aircraft and emergency vehicle electronics as an OEM.

**Matties:** And it's also a zero-waste facility.

**Holden:** It produces a profit.

**Matties:** That liability and labor risks are gone. The blueprints are there. Maybe we're on the tip of a wave here.

**Johnson:** Steve, in your work consulting on quality, I'm sure there are some parallels. Getting a company to transition to better quality management must be like getting them to transition to better operating processes for profitability. How do you qualify a potential client? There must be times when you meet a client and conclude that they're closed-minded, stuck in their ways, and aren't going to change. Meanwhile, there may be other clients who are on-point and ready. How do you tease that out?


Steve Williams

**Williams:** One of the first things I do is have them tell me what they think the culture of the company is, and that usually opens up quite a bit of discussion. Do they think that they're ready to make a big change? Are they able to make a big change? Do they think their employees will be able to make a change? If any of those answers were, "No," then that told me that the top management created a culture issue.

I've had a couple of customers tell me in the very beginning of discussions, "We want to do this, but it's going to require a culture change, and we're going to support it no matter what the employees say. If some of them don't want to make the change, then we'll find new workers." If you look at any organization, the culture is typically defined by the folks at the top, even the tendency to hire people who fit the culture in that organization. If you don't get that buy-in from top employees, it's not going to work.

**Johnson:** You start by looking at the executive staff to get an idea of their attitude. If they're not ready to go, then the company isn't ready to go.

**Williams:** Correct. If we're talking about if they want to get some type of certification, I ask

what their reason is for doing that. If their reason is, "We want to make the company better and improve our processes," then that's somebody I'm going to engage with. But if they tell me, "Our customers are telling us we have to do this, so we're going to do it to get the certification and hang it on the wall," then that's probably not a company I want to engage with because they're doing it for the wrong reasons.

I talk to companies all the time and get a sense of what their values are and how they operate the business. I think of Calumet Electronics, which is one of the last companies standing in the U.S., and there's a definite change in how they see the world of manufacturing. Either you decide that you need to change and do things differently, or you risk not being around any longer.

**Either you decide that you need to change and do things differently, or you risk not being around any longer.**

**Johnson:** What are some of the compelling events you've seen that helped the executive staff decide to change?

**Williams:** Two primary drivers are if they're losing money and/or losing customers. Those could come from throwing too many products away, having too much waste, or not being efficient, and those are directly related because the customer is going to pay for your inefficiencies one way or the other, and they're not going to be very happy. Losing major customers and seeing a downward trend in profitability are usually the wake-up calls that most companies need to finally look at their business differently.

**Johnson:** You talked about what motivates a company to get a certification. That's an internal locus of control versus an external locus of control conversation about what's going on in that situation, and you're touching on that again. Customer demand is probably the external factor that creates enough pressure and discomfort. But at some point, company management has to internalize that locus of control and make it about them, not just customer demands.

**Williams:** Right. I've seen a number of examples where people have gone through the certification process. Now, they're advertising that they're best in the world, but nothing changed. They did it for the wallpaper; they didn't improve their processes, and their customers know that.

**Holden:** In the last couple of years, have you achieved major successes working with customers where they have focused on eliminating waste, inventory, and other problems that usually go unsolved?

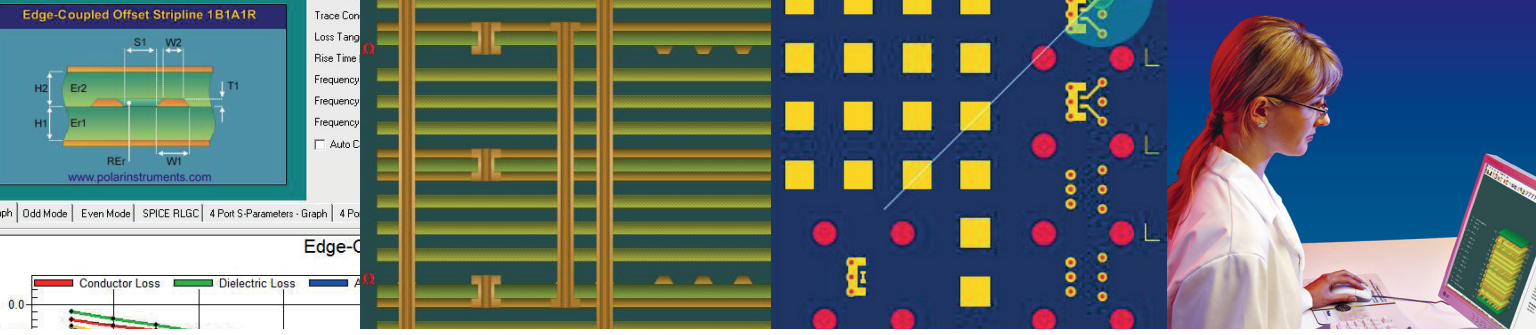
**Williams:** The majority of my clients over the last seven years have shown demonstrable improvement in productivity, quality, profitability, and/or customer satisfaction. Every time you throw a board away, it goes directly to the bottom line.

**Matties:** In the '80s, I worked in a shop, and their scrap rate was pretty high. They talked about profit sharing. I brought a pallet load of scrap boards into a meeting and started handing them out, saying, "Here's your profit sharing." Everybody has a vested interest in high yields, and scrap happens for a lot of reasons, but you have to think of it in those terms. Every one of those boards is money out the door.

**Williams:** Exactly.

**Matties:** What are the latest buzzwords other than Lean, TQM, etc.?

**Williams:** Branding is important because back in the day, Lean was the common buzzword; now, people are migrating to best practices, even though when you look at what they're

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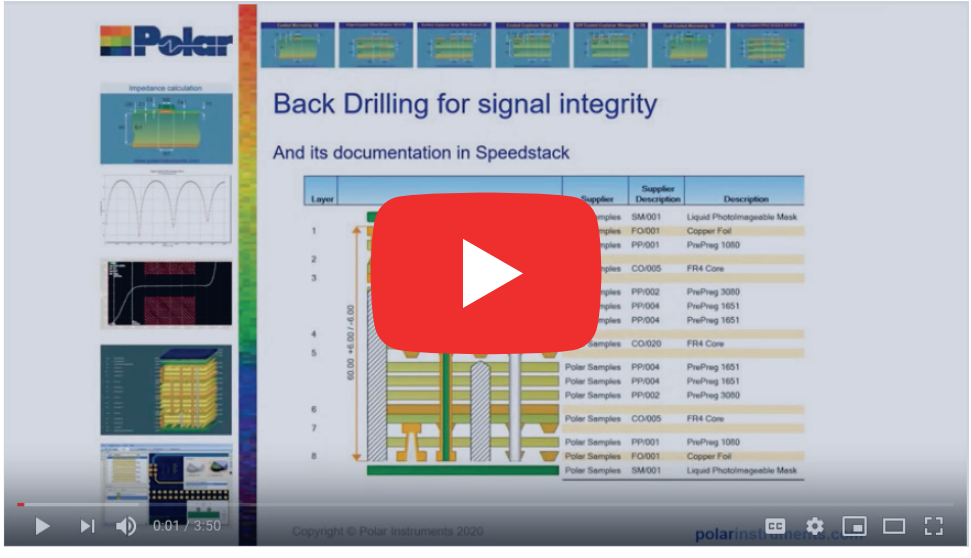


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doing, it's the same thing with a new name, so they're more energized.

**Matties:** None of it is new. Build the best products for the lowest costs possible. That's business.

**Williams:** Not too long ago, I ran into a good friend of mine who runs one of the aerospace plants for a major manufacturer, and we were talking about this exact same thing. He said, "We have a couple of facilities that are doing this work, and if I ran this terribly complicated board through this one shop, and they got a 50% yield, they would be slapping each other on the back, saying, 'We did such a good job.' But if I ran that same board through another one of my facilities, and we had a 99% yield, they would say, 'What happened to the other 1%?'" It's all about mindset.

**Johnson:** You also mentioned reaching out to a supplier and telling them you want to help get their costs down so that you pay less, but they preserve their margins. Does it come down to manufacturers having some customers push them like that?

**We embraced the fact that we're both going to be happier if the supplier becomes more efficient.**

**Williams:** There's some air to that for customers who don't often take that approach. They want the lowest unit price, period, and they don't care how you get there. We embraced the fact that we're both going to be happier if the supplier becomes more efficient. We didn't change suppliers for a nickel better price from somebody else. Customers—OEMs and ODMs—driving that mentality down to their suppliers are one of the reasons companies are able to change their mindset; they can see that it's not just them. It's relatable.

**Johnson:** At the risk of oversimplifying, one of the major drivers for this change in every company is finding a customer that cares enough to push their supplier.

**Williams:** Yes.

**Matties:** You have to be willing first because if you go back to the blue-line printing example that I mentioned earlier, we were forced to go find another supplier, and the customer has to be willing to change suppliers, too. If we continue to reward inefficient suppliers, then we're perpetuating the problem and become a part of the problem.

**Williams:** And that's hard to believe because customers are getting more sophisticated. They know that a supplier with an inefficient process is somehow passing that cost along to them, and they have to be willing to go someplace else; in most cases, they do eventually.

**Matties:** Where do you go to find a PCB fabricator that's truly more efficient?

**Williams:** You have to set foot in a facility, not just choose your suppliers based on a quote. You have to see what they're doing, but a lot of customers don't. I keep going back to my prior life, but one of the things that set us apart from other contract manufacturers was we did supplier development. We looked for long-term relationships.

We went through a whole bunch of predictive tools to make sure that we were selecting the right company, and relying on ISO was okay for a first filter, but that didn't tell us anything about their technology or if they did it for the wallpaper. Were they going to scale with us? You have to be in their facility, not originally, but ongoing to make sure that they are still performing at a high level because without walking through, you don't know.

**Matties:** Maybe part of this is that North America, in particular, is a business climate made up of low to small prototype volume, and, ultimately, price doesn't matter all that much on

the circuit board. It matters more in the production run, and that's where you're going to validate a larger Asian fabricator because you can't do the large volume here in the U.S. Maybe it doesn't matter.

**Williams:** In some market sectors, you're right. In other cases, such as medical and military, price is not that big of a deal, but there are still customers in North America that add a lot of price pressure.

**Matties:** That's what's left here in the U.S., and they may be putting pressure, but unless you're going to turn into a state-of-the-art facility and be head and shoulders above everybody else—bringing in capabilities that nobody else offers—then it comes down to if they like you. Are your processes stable enough to produce a quality product? I don't care about all your wasteful steps because, in the end, the board cost doesn't affect us at this level. What do we change? What's going to motivate somebody to want to change?

**Williams:** Again, losing customers or money, as well as a willingness and desire to stay in the time. That shouldn't be overlooked because that was a factor with some of the companies that are not here anymore. They got tired of the process.

**Matties:** You have to understand what necessity is. Does necessity mean producing a good board? Because I can do that in a very wasteful process and come up with a high-quality board.

**Williams:** You can, but you're not going to have a high level of customer satisfaction, and that's probably the key metric for anybody who wants to stick around.

**Matties:** I would argue, though, I could have a high level of customer satisfaction. If I'm building scrap, but I cover it with overage, they don't know it. As long as I deliver a quality product on time, they don't care how I get there. If we were to make a case for being efficient and eliminating waste, it comes down to the dollar amount, for a lot of people; however, it's also about reducing stress and raising the quality of life in the factories, and that's part of the emotional manufacturing intelligence.

**Williams:** Absolutely. The real motivator is money.

**Johnson:** Thank you for sharing your thoughts, Steve.

**Williams:** Thanks. It has been a pleasure. **PCB007**


Bill Bowerman

# The Business Case for Metallization

**Feature Interview by Nolan Johnson**
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I spoke with Bill Bowerman of MacDermid Alpha as he described a paper he helped write on direct metallization and other advanced processes—such as Shadow and Blackhole—the benefits of adopting such practices, and what type of shops might consider the switch.

**Nolan Johnson:** Bill, your team published a technical paper on your carbon-based processes. We're publishing that paper in this issue of *PCB007 Magazine*, but let's step up a level, and discuss the business implications. How does this process deliver more profitability?

**Bill Bowerman:** There is definitely an industry trend toward more acceptance of direct metallization and how it contributes to business operations. The process uses less water, less power, creates less waste treatment costs, and requires fewer operators on the line. It's a fairly small footprint for space utilization. And, as we're talking about the need for fabricators to expand metallization capacity for any-layer design or HDI, keep in mind that every time we do a buildup layer, we have to go through metallization and electroplating. If we're looking at a seeding process like direct metallization and that has a lower cost and smaller footprint, that's an advantage to them.

If there's less water usage, there is a very significant factor in certain regions globally, where they are restricted on how much water they can use. In some cases, if they want to expand in a plant, they have to take something out to put something new in the plant. Those facilities are at a zero limit for expansion on water usage.

The other factor, very simply, is that electroless copper uses palladium for the activator. Palladium is now at $83 a gram; it has gone up over 50% in the last year. A year ago, it was probably around $1,400 per troy ounce. It's at $2,600 per troy ounce today.

**Johnson:** It seems like the PCB fabricators are getting squeezed every which way.

**Bowerman:** Unfortunately, that's true. It's a tough business to be in right now.

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**Johnson:** For the fabricator management team evaluating the manufacturing floor, giving real thought to what works best, if they're looking at a process like Blackhole—which you addressed in your paper—what can they expect to see for an implementation plan? What's the project going to look like to convert?

**Bowerman:** There's a history out there of lines that exist today. We support over 600 direct metallization lines globally today, which is in excess of what we support for electroless copper lines. That has given us many years of experience to know exactly what kind of equipment is needed. We can go to the customer and say, "This is the plan for the piece of equipment that we want to design for your product mix," and we will sit down and talk to them. We ask questions like, "What is the product mix? What are your expectations, panel sizes, thicknesses, microvias, through-holes, material types?" These questions are at the front-end of the discussion about starting a plan for a new line.

**Johnson:** Let's talk about conversion time. Can I use a pre-existing line in my factory? Do I need to find open space to put in something in parallel? How complex is this?

**Bowerman:** The lines will be unique for the processes. We have separate specifications for Blackhole and Shadow. We also have a specification for our conductive polymers system. They're similar, but each line is specific with respect to the sequence of the modules in there. Thus, they can't use an existing line; it will require a new line.

**Johnson:** You're looking at a new line that will reduce the overall usage of local resources, such as water, and bring some additional capabilities. What's a typical ROI?

**Bowerman:** A lot of it depends. If we're putting a desmear line with it, or if we're talking about the direct metallization, the numbers could vary. I would estimate, though, that at a comparable cost, the direct metallization line is going to be about 50% of the cost of any electroless copper line going in a factory.

**Johnson:** You're going to get a faster ROI given the fact that you're not spending nearly as much money up front to buy the line.

**Bowerman:** For the same production output, the cost is going to be about half. The cost of the desmear side of it, if that's going in new, is identical, but the cost for the direct metallization has half of the electroless copper.

**Johnson:** It seems like we're on the cusp of a return to more captive facilities. One opinion is that captives got out of the market because of the chemical-related liabilities and the environmental issues that created for them. Now, with processes like Blackhole and other techniques for reducing waste and recycling chemicals to create a zero effluent factory, we could see the return of the small- or medium-sized captive. Do you see that?

**Bowerman:** Absolutely. It's true, especially for companies in the aerospace or the defense markets. They build some very complex and highly proprietary designs that, frankly, they don't want to even let out to public fabricators. I can count about four or five new shops in North America, albeit small prototype shops, that have been installed in the United States.

However, I don't know if it's going to move the needle as far as total revenue for PCB production in the United States. This motion so far is on the very high end of what is being designed. But, from an intellectual property protection standpoint, captive is a significant factor.

**Johnson:** When an OEM is looking to build a captive facility for their production, they maintain control. They have the opportunity to build greenfield and put in state-of-the-art equipment and build for zero effluent. It seems to give the captive facilities an opportunity to be at the cutting edge and be very competitive for themselves.

**Bowerman:** That's true. Sometimes, the material sets that they're building on are quite unique and not commonly used in a standard PCB fabrication shop. That's another reason. Other

times, we talk to them about direct metallization as the seed layer because we're more of a coating process than a redox reaction. When they have exotic materials—there could be anything from PTFE to hydrocarbons—we're not very sensitive to the changes in surface energy on those materials.

**Johnson:** This whole situation does seem to put pressure on the existing job-shop fabricators to bring their processes up-to-date.

**Bowerman:** Yes. Our industry has changed so much in the last 20 years. If you're looking at a new process line, you have to keep that in mind. If I'm buying a line that is going to be on my floor for the next 15–20 years, how much is this industry going to continue to change and evolve?

**Johnson:** Are there any paper highlights that you'd like to bring to readers attention?

**Bowerman:** There are a couple of main points. We know that we're working with ultra-thin foil now to get our line width and spacing down. We're now at 30 and 30 in the industry; maybe some of the advanced packaging applications can go a little bit below that. But also we're working with a very square sidewall profile on the traces. The dominant theme in the metallization, whether electroless copper or direct metallization, is to have a very precisely controlled microetch as we go through the metallization line because we have as low as three microns of foil when we start. We walked through the process by completely reviewing the equipment package that we're recommending, with the goal of having this very tightly controlled amount of etch.

**Johnson:** Right. Are you delivering those tight tolerance results?

**Bowerman:** We have it in mass production today in Asia. There are multiple lines running MSAP today with this three-micron foil. In other words, we've already gone past the release point. We're in the commercialization of it, and we have production experience with it.

**Johnson:** Any other highlights?

**Bowerman:** It was fun working on the project because we used a lot of expertise from our people with both tech service and application backgrounds. We have facilities called global development application centers (GDACs). There are seven of them globally that work with metallization products. Most of them have some form of pilot line capacity for running full-size panels. We use those sites to make improvements in the equipment for our customers. We had a chance to work the processes out before we had the customer spend the money on the first mass production lines. Thanks to that process, we developed a couple of unique things that we had never specifically used before for direct metallization.

**We had a chance to work the processes out before we had the customer spend the money on the first mass production lines.**

**Johnson:** Interesting. How does Blackhole fit into the MacDermid Alpha product portfolio?

**Bowerman:** MacDermid is involved in both electroless copper metallization as well as this direct metallization and the step that goes beyond into electrolytic. We look at everything as a complete package for reliability. Reliability is a big topic right now in the United States, so we're very sensitive about the interface where the electrolytic copper is either on the target pad or on the electroless. We're doing a lot of work right now to ensure that we're meeting the expectations of designers building stacked microvias.

**Johnson:** Bill, thanks for setting the stage for your paper.

**Bowerman:** Thank you very much. **PCB007**

# The Future of the Electronics Industry

## One World, One Industry

**by Dr. John Mitchell,** IPC—ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

We're only two months into 2020, and the year has proven to be filled with changes and challenges for IPC and the electronics industry.

As you know, electronics are present in every workplace and home, and that presence will only continue to grow. Our industry has brought about many advances, such as medical breakthroughs, mobile computing, satellites, GPS systems, deep space exploration, and much more. We're building electronics better, and not just for company profit, but to make life better for everyone.

In my role as president and CEO of IPC, I have the privilege of working and speaking with experts across this industry: designers, manufacturers, suppliers, OEMs, and more.

When I speak to experts in the field, what strikes me most about our conversations is the accelerating pace of change and opportunity on so many fronts. This industry knows all about change. We are disruptors, and we are used to being disrupted ourselves. From smart factories to artificial intelligence and additive manufacturing, this industry will see its share of change in the coming years. IPC will be at the forefront of that change.

All of us will tackle changes in the years ahead, and the companies that will thrive will be the ones who take responsibility and lead the change. These companies will embrace diversity, change, and disruption, be the ones who build a stronger, more competitive workforce because if we are not open to diversity and change, we stop innovating.

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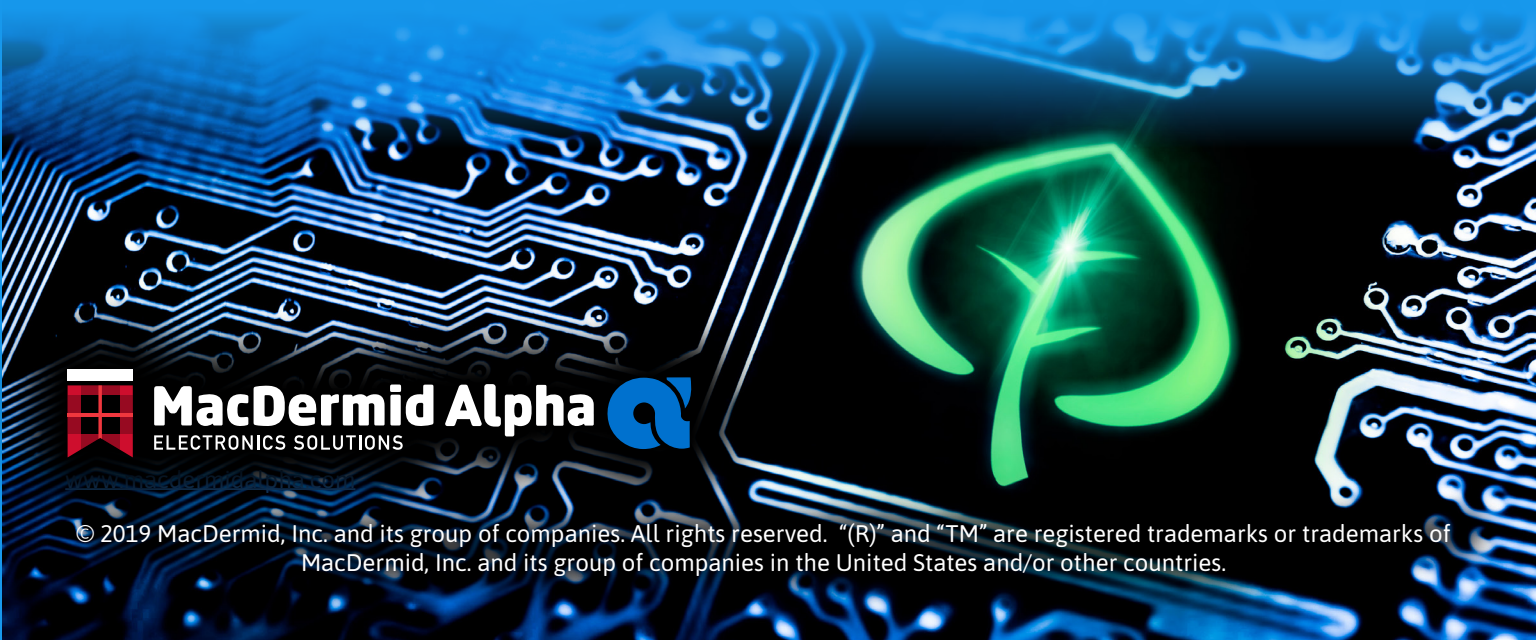

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help create a global market in which electronics-based products and services work together reliably, making changes easier to navigate.

We're vigorously addressing the skilled worker shortage issue, focusing on how we create a more tech-savvy workforce for the jobs of the future. IPC has decades of experience in facilitating worker credentialing programs; our global network of IPC-approved training centers educated more than 110,000 people in 2019 alone. We are now working to not only refine our existing credentialing programs but create new ones to meet future and current needs.

We created the IPC Education Foundation with a mission to expand our offerings for students in middle schools, high schools, and colleges so that we can attract the next generation of talent. Altogether, we are aiming to create millions of new skilled workforce opportunities over the next decade globally, and I invite you to join us and become an IPC Workforce Champion.

Another issue of concern that comes up in conversation is how to strengthen the global supply chain. Many of you have supply chains that span the globe for materials, technology, and talent. Our industry has a footprint in more than 75 countries and a presence in almost every nation and every sector of the $90 trillion global economy.

But along with a global supply chain comes a patchwork of government policies that affect our operations, from taxes to tariffs, environmental regulations, etc. IPC advocates for a fair, open, rules-based international trading system so that you can optimize your business to meet the needs of your customers throughout the world.

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We need to foster partnerships between diverse players of all kinds, including between government and industry, large companies and small, and actors in the Americas, Europe, Asia, and beyond. About 80% of IPC members are small- and medium-sized businesses. Other members are larger household names. Companies at both ends of the size spectrum need each other.

Perhaps you've heard the expression, "If you want to go fast, go alone, but if you want to go far, go together." At IPC, bringing the industry together is what we're all about. It's been our pride and joy for more than 60 years.

To the extent that we come together and work together—despite the winds of change blowing all around us—we will go farther and faster together. IPC will be your partner and supporter through all the changes that lie ahead. Come join us on that journey. **PCB007**

**Dr. John Mitchell** is president and CEO of IPC. To read past columns or contact him, click here.

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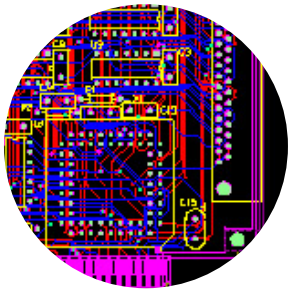

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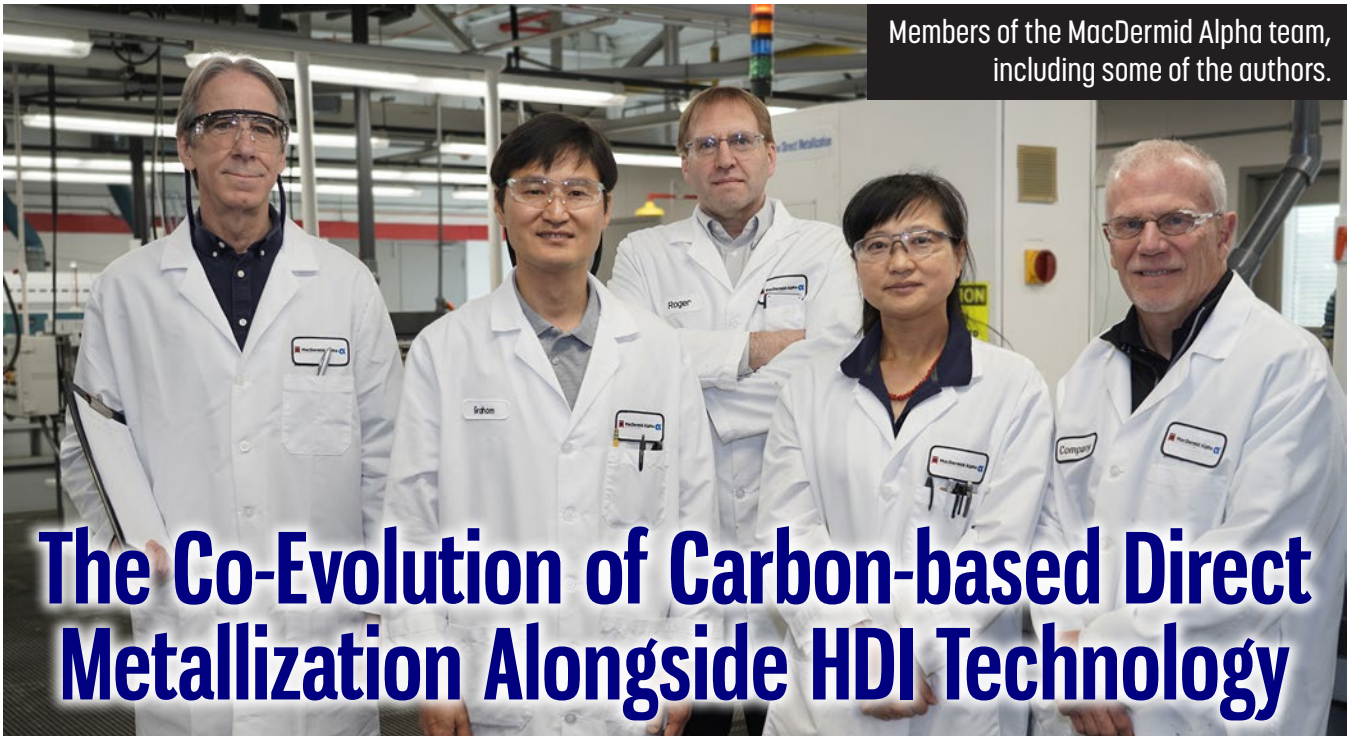

Members of the MacDermid Alpha team, including some of the authors.

# The Co-Evolution of Carbon-based Direct Metallization Alongside HDI Technology

**Feature by Graham Lee, David Chun, Albert Tseng, Charles Bae, Smith Han, Jordan Kologe, and Bill Bowerman**
MACDERMID ALPHA ELECTRONICS SOLUTIONS

## Abstract

Electronics manufacturers have chosen carbon-based direct metallization systems over electroless copper processes due to lower cost of ownership and easier-to-maintain equipment. Today, hundreds of high-volume, carbon-based direct metallization lines are in production around the world. The well-documented savings due to lower water usage, less waste generation, a smaller equipment footprint, and lower power consumption are why these systems became popular. In addition to this, these systems do not require precious metals such as palladium to activate printed circuit structures for electroplating, offering significant operations savings.

In the latest generation of smartphone technology, high-density interconnect (HDI) technology has pushed the line width and spacing to require the use of ultra-thin copper foils as a starting point. This thin-foil technology requires exacting precision in controlling the copper etch budget during the formation of copper interconnects. Direct metallization processes, like the latest generation of Blackhole, have begun production on 3-micron copper foils for modified semi-additive processing, improving the process overall.

In this article, we walk through a history of how the technology has evolved to this point, including the new breakthroughs in equipment technology that allow this process to create the extremely fine lines and spaces being implemented in flagship mobile designs today.

## The History of Carbon Direct Metallization

Carbon direct metallization processes have been widely used in the circuit board industry for more than 35 years. Widely utilized processes in the industry include Blackhole, Eclipse, and Shadow. The original Blackhole direct metallization technology was patented in 1984 and quickly became a commercial success as a horizontal process for seeding FR-4 through-hole panels for copper electroplating.

Since Blackhole is a coating process rather than a redox process like electroless copper, the technology is less sensitive to the surface energy of the different dielectric materials, contributing to its adoption for difficult-to-plate materials. Because of this, these types of

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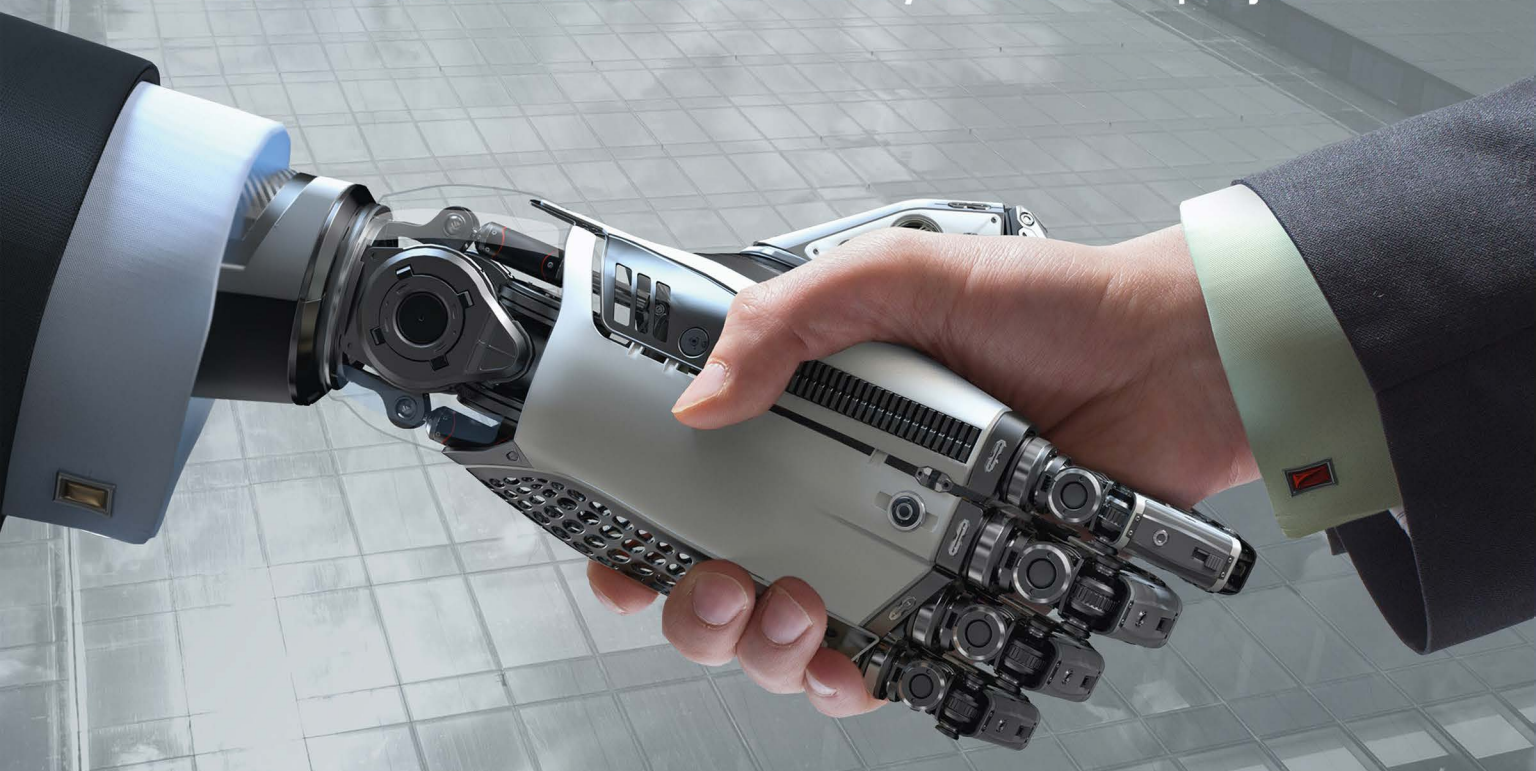

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processes became widely used on polyimide film in flexible circuits and on high-performance and exotic materials like PTFE. Carbon- and graphite-based direct metallization technology is approved for space and military avionics applications under the requirements of IPC 6012D, 3.2.6.1.

## Board Evolution

Leading direct metallization processes have continued to evolve throughout the years with the demands of PCB designs. As the drive for miniaturization resulted in the change from leaded to surface-mounted components, PCB designs evolved to accommodate smaller parts with higher pin counts. This then led to PCBs with higher layer counts, thicker panels, and smaller diameter through-holes. To meet the challenges of high-aspect-ratio holes, line specifications encompassed improvements for solution transfer in small holes. Upgrades, such as the use of ultrasonics to quickly wet holes and remove air bubbles, were implemented, along with in-line air knives and dryers specially modified to dry the small holes on the thicker panels.

After this, PCB designers reached the next stage: via starvation, the point where the pin count and grid density exceeded the available real estate to drill through-holes and route nets. As the industry moved from BGAs with 1.27–1.00 mm grid to CSPs with 0.80–0.64 mm grid, the microvia became the enabler for designers to meet the challenge of HDI technology.

In 1997, the feature phone began using a 1 + N_1 design in mass production. This is a one buildup layer with microvias over a multilayer core. As mobile phone production grew, microvias were formed by conformal etch and $CO_2$ lasers, and later by UV, UV YAG, and combo UV CO2 lasers. Microvias allowed designers to route lines under vias so larger pin grids could be redistributed without increasing layer count. HDI is widely used today in three platforms: miniaturization, advanced packaging, and high performance. The miniaturization seen in mobile phone designs is the current highest volume contributor.

## Direct Metallization to the Rescue

Direct metallization systems like Blackhole had to overcome technical hurdles to meet the challenge of metallizing the blind vias and small diameter features of HDI. The small microvia size presented trouble in the removal of the carbon black from the via target pad, which is essential to ensuring clean copper to copper bonds. From a chemical perspective, cleaner and microetch product developments were implemented to improve the lifting of carbon off the copper.

From an equipment perspective, the microetch spray modules of the process were completely reconfigured. The combination of spray–flood–spray bar configurations proved to be the most efficient design. The distance between the nozzle tip and panel surface was reduced, and the pitch of the fan nozzles was narrowed to increase spray impact force on the panel. This design proved beneficial for high aspect holes and blind vias.

With the next generation of smartphones, makers moved to buildup anylayer designs using stacked vias and no through-holes. This initiated a trend wherein starting copper foil thickness on panels has steadily reduced from 18 µm to 12 µm to 9 µm, as line and spacing has decreased from 60 µm to 40 µm. Each buildup layer in these processes requires a metallization and electrolytic plating cycle with more wet processing capacity.

Smartphones were also major users of flex and rigid-flex circuits. Adoption of direct metallization grew significantly in anylayer, FPC, and R/F board production due to the lower cost, less water usage, and less waste generation of the process compared to traditional electroless copper processes (Figure 1).

## Copper Budget: The New Metric for mSAP Process Performance

Fast forward to today, and the newest generation of smartphones and advanced packaging are utilizing a fabrication technique called the modified semi-additive process (mSAP). mSAP utilizes ultra-thin foils of 3 µm to reach line and spacing of 30/30 µm. The ultra-thin foils

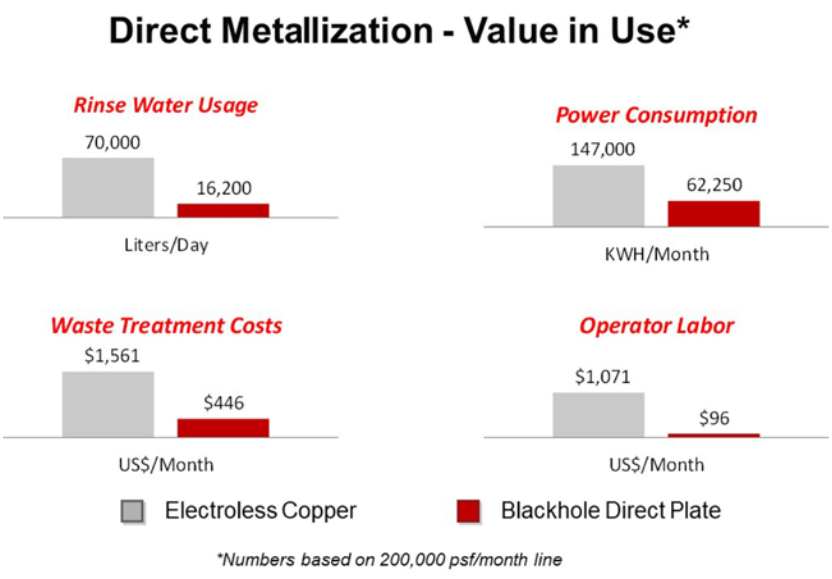



Figure 1: Direct metallization processes offer substantial environmental and financial benefits to fabricators.

require a very exacting copper etch budget in the fabrication process. Specifically, etching of the target pads must be precisely controlled for both traditional electroless copper and direct metallization processes (Figure 2).

The equipment team and product specialist group at MacDermid Alpha have now taken the development of the carbon black process to the latest stage of its evolution. The newest line configurations for Blackhole Advanced Direct Metallization are capable of mSAP on panels starting with foils as thin as 3 µm, and the entire process has now been optimized for thin foil HDI metallization.

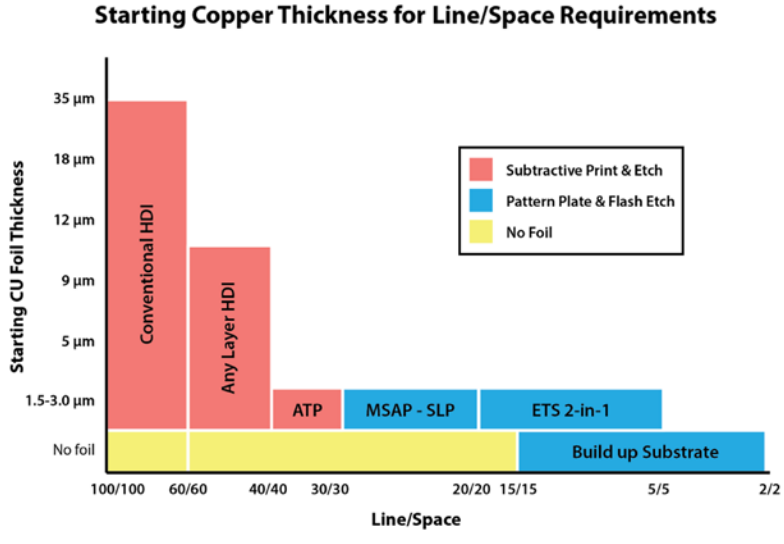



Figure 2: Shrinking line/space requirements for PCBs have created a need for stringent control of etch depth.

## Advancements in Equipment Configurations

To optimize the direct metallization to work with mSAP processing, several equipment designs were tested and evaluated in pilot-scale lines before ramping up to full production. The result of this is that the process can offer uniformity of the carbon black coating under a wide range of conditions.

Several equipment modifications were selected for the Blackhole Advanced Direct Metallization system, in particular. A new roller configuration in the carbon application module uses a patented roller with saturation control to ensure the uniformity of the carbon black seed layer. The result of this change is that the carbon dispersion is deposited as a thinner coating and with most of the excess carbon removed from the surface before leaving the module. This is to prevent excessively thick deposits in blind vias or under the knee of the through-hole.

The etch module was also extensively redesigned. Fabricators are quite concerned about the potential of leaving a target pad that has only been partially cleaned, which leaves carbon residue after processing. In this case, the panel would pass electrical testing but have a reduced cross-sectional area, resulting in the via not being as robust under assembly reflow conditions. With microvia diameters being reduced from a traditional 100–150 microns diameter down to 60–80 microns, the importance of the upgraded etching step is critical to product reliability.

Studies conducted on how to eliminate the chances of leaving carbon

residues in the target pad through modification of the etch module yielded process improvements that are now actively deployed in production. The first major improvement involves the use of a dual sump etching module to provide more precise etch depth controls. The first stage removes the bulk of the carbon from the copper surface, and the second stage contains fresh etch chemistry not contaminated with carbon, which may be redeposited onto the surface. A second improvement incorporates technology found in copper reduction lines for maximizing the uniformity of the etch amount across the panel surface.

Reducing variation in the etch depth across the panel surfaces helps to tightly control the total etch amount required to clean the target pads. The coefficient of variation in the etch is tightly controlled by chemistry concentration, spray bar design, and spray pressure parameters (Figure 3).

## Advancements in Chemistry

In terms of chemistry improvements, traditional cleaner/conditioner and etchant chemistries have been tested and designed with controlled etch capabilities in mind. Cleaners now feature an organic additive that selectively covers copper surfaces but is not attracted to dielectric surfaces. On the copper surfaces, the carbon black is adsorbed on the organic coating provided by this technology over the copper. When the panel enters the etch module, the carbon black is undercut by the etch and lifted off the surface. The organic coating is highly soluble in acid medium and is immediately removed by the microetching step.

In another improvement, two-component microetches are being implemented that remove the dried carbon and reduce the copper roughness. The copper surface is ideal for dry film adhesion, and testing has also shown a smoother target pad is better for microvia reliability. The target pad copper crystalline structure is ideally prepared as a substrate to form epitaxial growth of the electrolytic copper (Figure 4).

## Copper Grain Boundary Improvements

This combination of specific improvements to key process modules and chemistry has resulted in a line capable of running thin foil buildup layers for advanced HDI/mSAP. Microvia reliability is enhanced with a single interface of direct copper-to-copper bonding, forming a continuous metallurgical structure. The

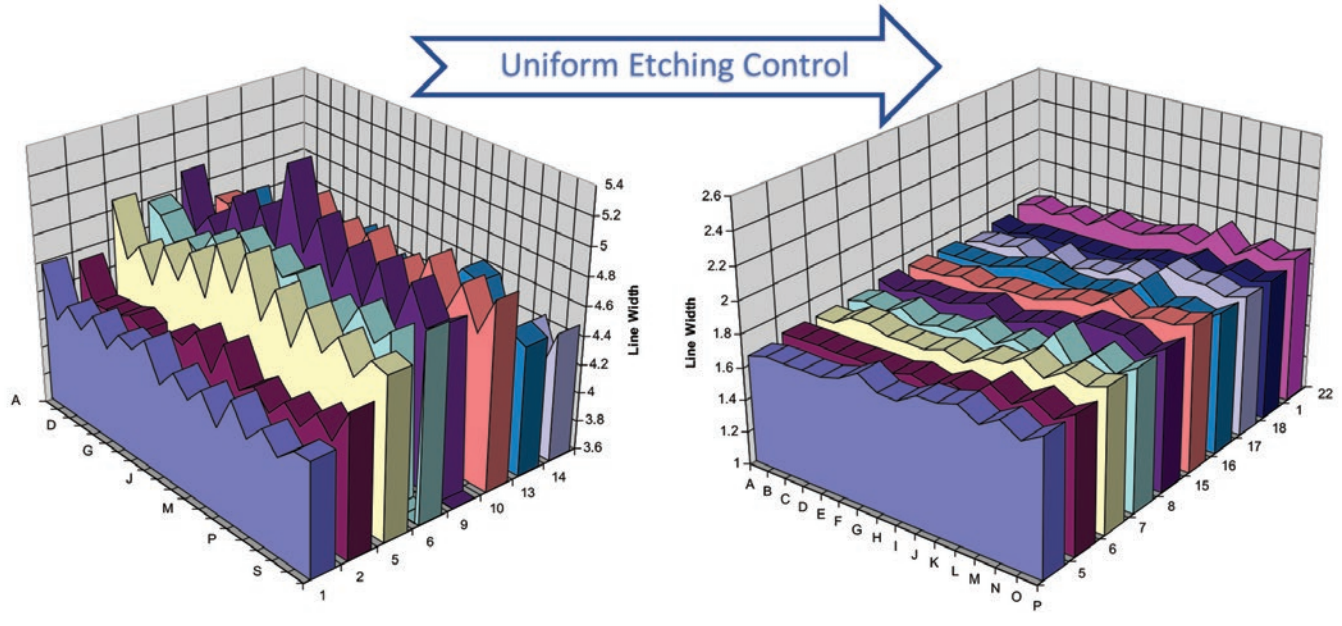
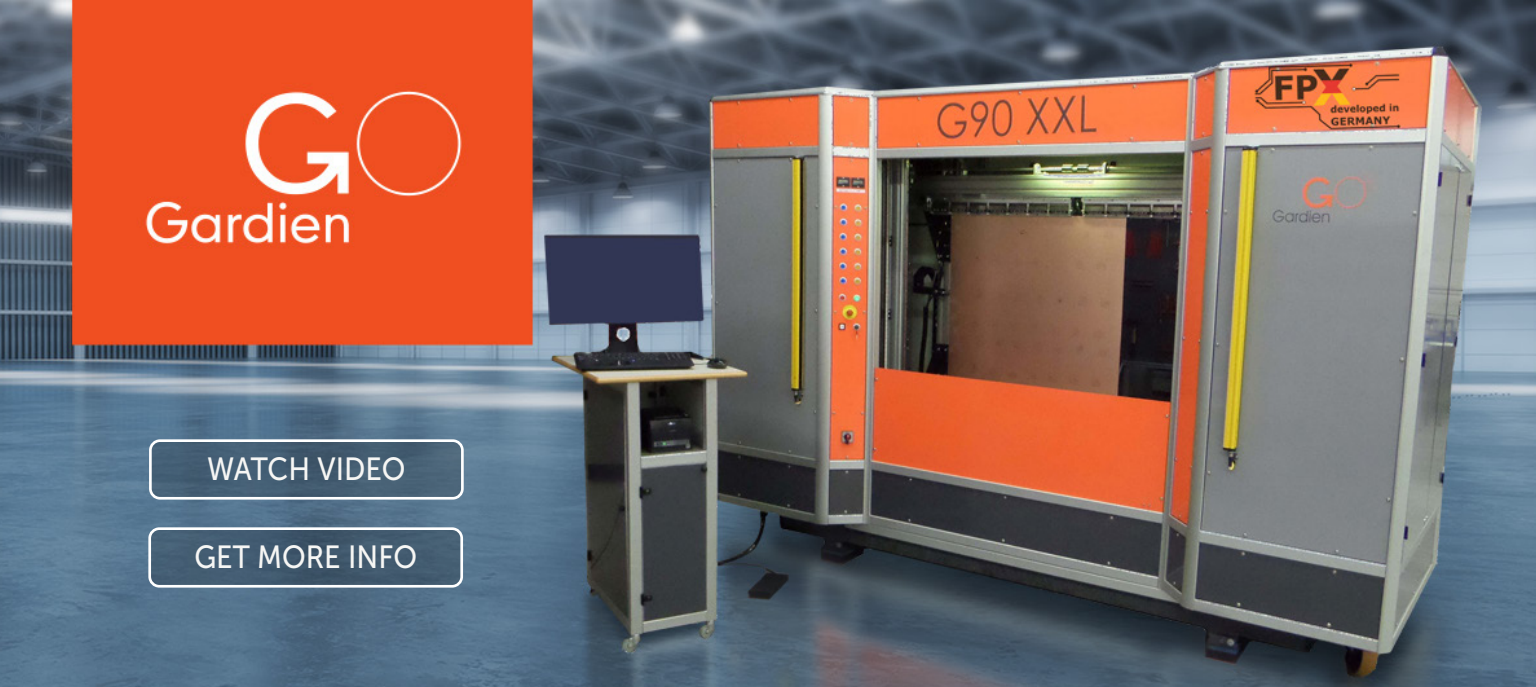



Figure 3: Uniform etching control through equipment and chemical improvements has allowed for the complete removal of carbon residues in target pads.

Gardien

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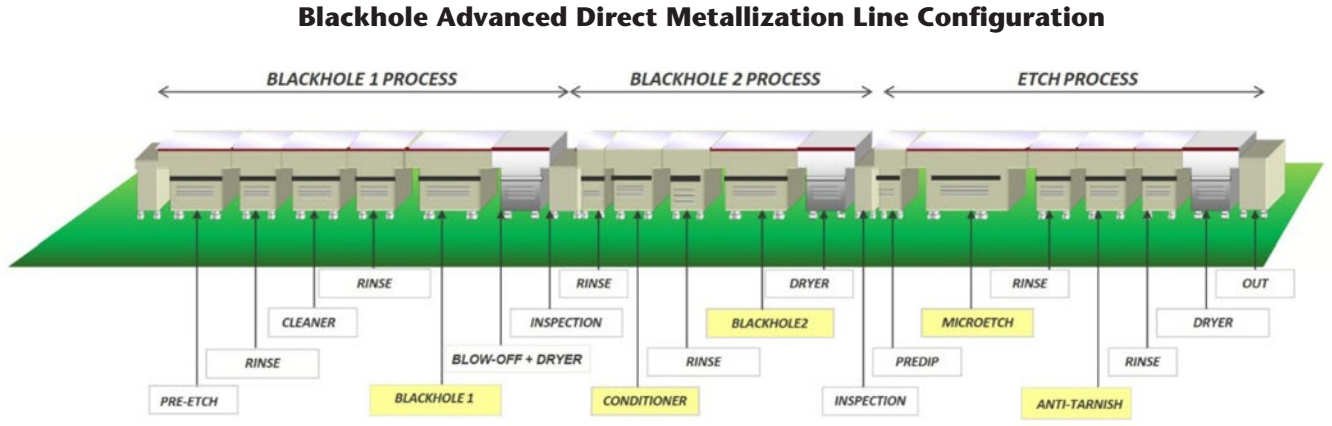


Figure 4: The microetch module has proven to be key to the increase in microvia reliability in direct metallization processes.

etch chemistry prepares the target pad with an ideal copper topography as the base for copper via fill plating. This promotes the well-defined grain growth of the electrolytic copper on the target pad. With normal thermo-mechanical cycling, the recrystallization of the copper grain orientation further promotes the desirable continuous metallurgical structure.

Studies with FIB using lamella cuts show the interface line to be uniform in grain size and structure (Figure 5). After thermal shock or cycling, the line between the target pad and electrolytic copper can be difficult to find. Nano-voiding is not present, except for instances where it would be due to factors like oxidization or contamination.

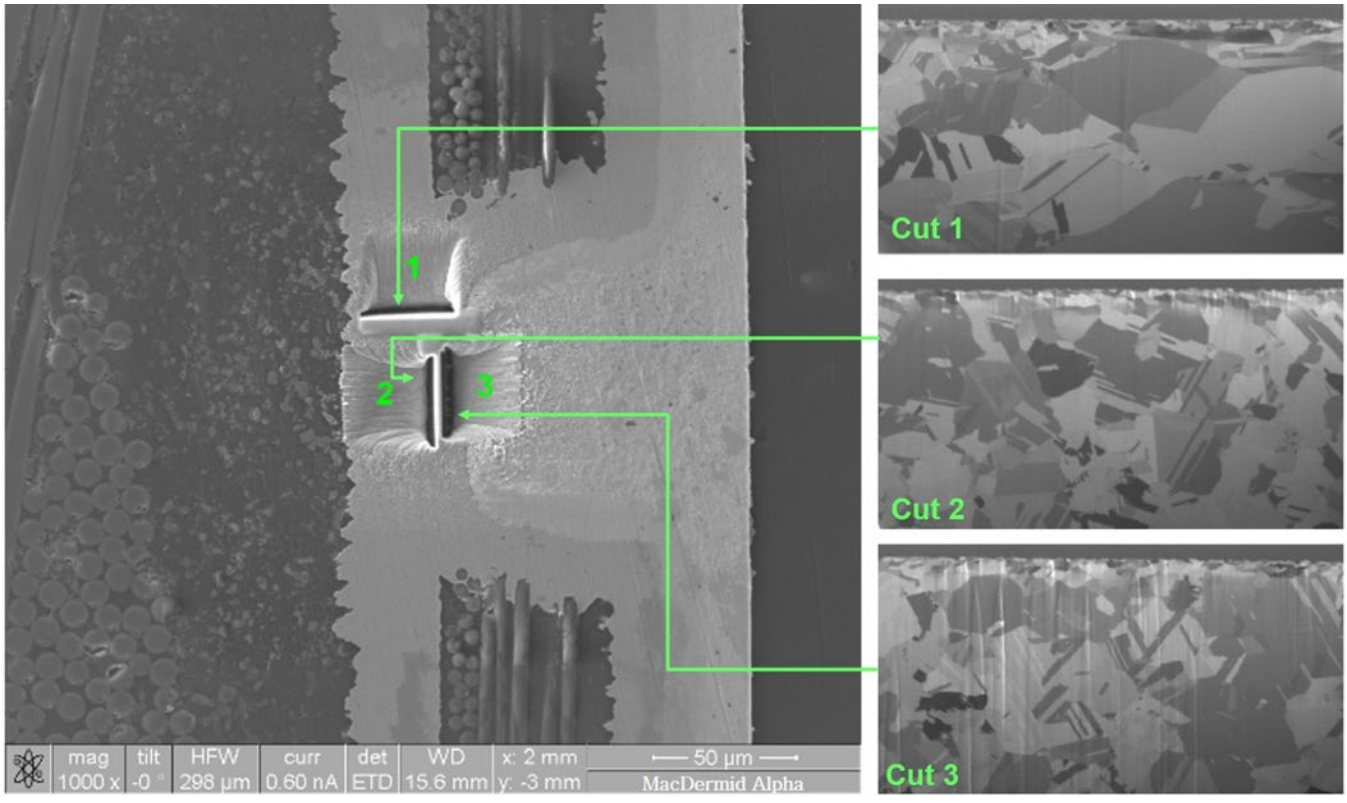


Figure 5: FIB imaging of the interface between the electrolytic copper plating and the target pad. Leading-edge direct metallization technology allows for strong copper-to-copper bonding that performs excellently under thermal stressors.

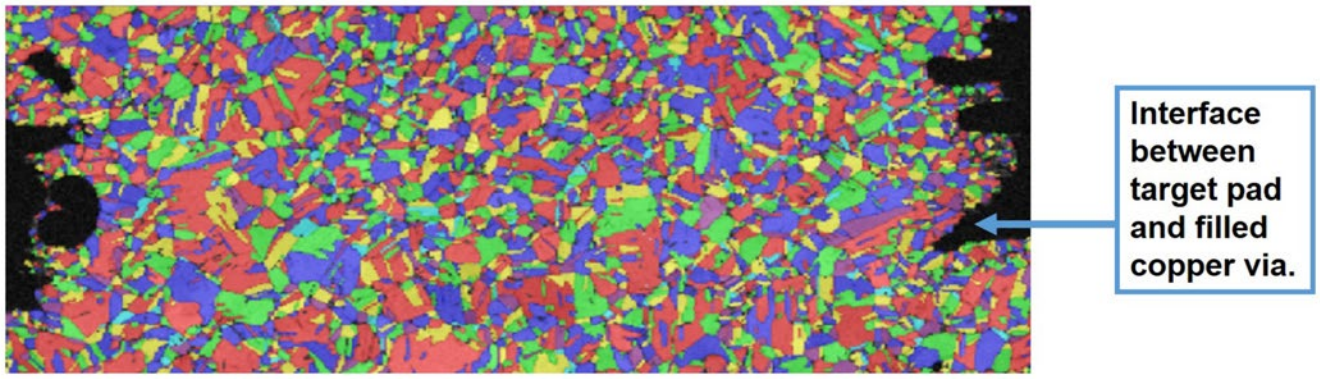


Figure 6: EBSD grain structure of via and target pad cross-section. Panel pre-conditioned at 260°C, followed by 300 cycles at 170°C. The average grain size is 3.12 microns.

## Full Steam Ahead

Leading-edge direct metallization process lines like the Blackhole Advanced Direct Metallization are now in mass production for mSAP with 3 µm Cu foil layups. These systems utilize controlled etch equipment configurations in mass production. Qualification testing on 12L anylayer panels processed with this equipment configuration passes IST testing through 300 cycles. In these designs, advanced direct metallization processing was done on anylayers L2-10 and mSAP L3-11. These designs have microvia hole sizes of 80–100 x 45 µm with approximately 2 million interconnects per panel.

The presence of any carbon residues is checked with AOI, and currently, zero defects have been detected on 5,000 PSM/month of production for this process. The electrolytic plating for these production boards is done on VCP lines with panel plating on the core through anylayers and pattern plating on the mSAP buildup layer. The electron backscatter diffraction (EBSD) image in Figure 6 shows the uniformity of the grain size at the interface between the target pad and electrolytic copper plating.

## Summary

As miniaturization has driven components to smaller packages with higher pin counts, PCB substrates have evolved to meet the challenge of increased connection density. The microvia has become synonymous with HDI design. As the change in PCB design progressed from through-hole to HDI designs like anylayer and mSAP technologies, direct metallization technologies have made advancements in chemistry and equipment configurations to keep pace with the industry.

The leading-edge, advanced direct metallization systems currently in production today are providing PCB fabricators of the latest generation mobile interconnection platforms the reliability and performance needed to compete. In new segments, such as those that utilize flexible and rigid-flex circuits or new hybrid materials, carbon direct metallization offers a cost-effective and technology-enabling solution for fabricators looking to expand their metallization capacity. **PCB007**

**Graham Lee:** Process Specialist—Metallization
**David Chun:** Equipment Manager—Asia
**Albert Tseng:** Product Manager—Asia
**Charles Bae:** GDAC Leader—Korea
**Smith Han:** Technical Service Manager
**Jordan Kologe:** Technical Marketing Specialist
**Bill Bowerman:** Product Director—Primary Metallization


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# Finding Profitability in the Drill Room

**Feature Interview by the I-Connect007 Editorial Team**

The I-Connect007 team spoke with Burkle's Dick Crowe and Kurt Palmer, as well as Thomas Kunz from Schmoll Maschinen, about making the drill and lamination departments more profitable through increased flexibility and automation.

**Barry Matties:** Today, we're going to talk about profitability and how the drill room can add to that. For some background, I have toured a couple of different PCB fabrication facilities, including AT&S and GreenSource, where they have automated loaders with all the material needed for the jobs the next day, which are then fed into single-spindle drill machines. The machines then run all night, operator free; in the morning, all those jobs are ready to process in the factory. Why don't we see more of that in North America?

**Kurt Palmer:** There's a lot of interest in that exact setup at a lot of board shops in North America. The challenge, when push comes to shove, is that it requires a bit of a change in thinking. You have to retool the way your panels are layed up on the drill tables. For example, when talking about introducing two automated machines into a drill room that already has 30–40 spindles, they have been doing their tooling a certain way. Now, all of a sudden, this automation requires something a little bit different.

It's not easy to say, "Today, we want to automate," and just start doing it. GreenSource was simple because they started from a greenfield and were able to build it out from the ground up. It's a little bit of a challenge when you talk about a shop that's existing, has a variety of equipment new and old, and wants to begin automating.

We're working with a customer in the Midwest right now who's buying one automated machine; it's a single table with automation.

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BY TAIYO

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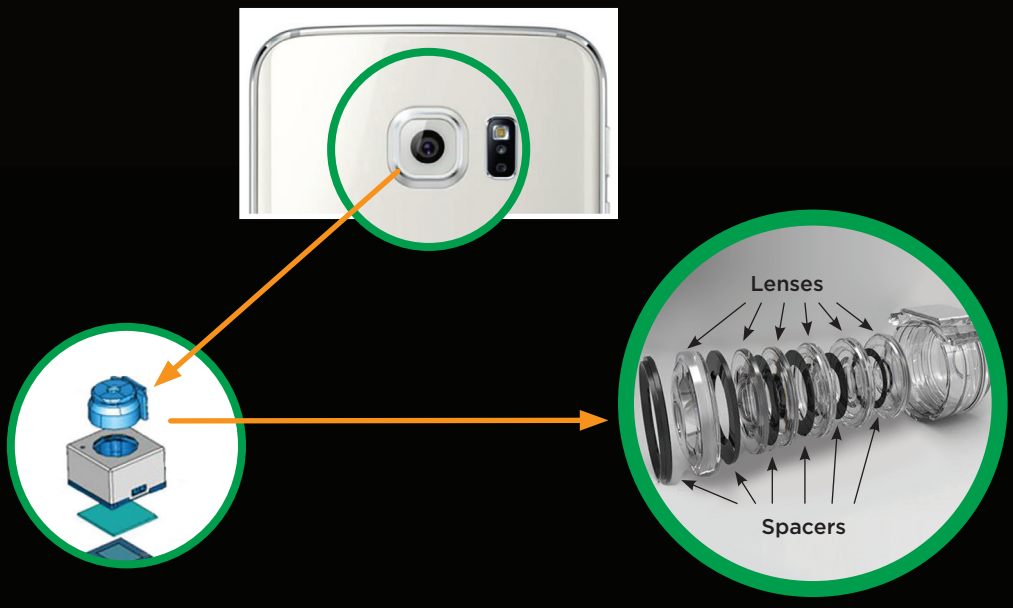


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But the beauty of it is that as they grow and develop their process, they can add new machines right beside it. Then, they can put in automation or further automate it by putting the panels on a carriage that moves back and forth. It's something they're considering doing. It is happening, but it's not going at the pace that you might think.

**Matties:** The return on investment must be pretty quick, though. Have you calculated out what that would look like compared to a traditional configuration?

**Palmer:** Sure. Especially if you get the automation component of a single-spindle machine, the automation is roughly 8–10% of the cost of the machine itself, so if you want to look at the return on that $25,000–30,000 automation piece, it's quick because you're eliminating one person. You can get a return in a year and a half very easily.

**You can get a return in a year and a half very easily.**

**Matties:** And those are all bottom-line dollars. That's profitability.

**Palmer:** Correct. But again, you have to think about the engineering and tooling changes that have to come up front; there's a little bit of cost there. You do that once, and each machine afterward is a very quick payback.

**Matties:** Is the resistance tied to the investment up front in terms of cash, or is it resistance in thought power? Do you need to have or hire a team with an automation mindset?

**Palmer:** I think it's the latter; you called it thought power. It's the engineering and the CAD support and whatnot that's needed to get it all started. It's not that expensive at the end of the day, at least as far as the equipment side of it goes.

**Matties:** Putting in one machine, starting with one toe in the water, if you will, is an interesting strategy. It will also be interesting to see how fast this company adopts the automation fully and replaces all the other equipment.

**Palmer:** Exactly. We put a three-year plan together with them to have all of their drilling and routing spindles replaced.

**Nolan Johnson:** How many spindles do you think there will be when they're done?

**Palmer:** They're at 54 spindles right now. It will be 38 when they're all done, but that's not just the automation. As a matter of fact, the automation might add roughly 10% productivity; it all depends on how long boards sit on the machine when they're done without automation, waiting for an operator to come change them out. When you look at going from 54 to 38 spindles, it's mainly due to the faster machine speeds these days. We have to put 50,000 holes in a certain board, and it takes 20 hours on an old machine that's been around for 20 years; new machines today can do that in four or five or six hours. That's where you're getting your big-time savings, thereby requiring fewer spindles.

**Johnson:** Combined with the fact that your drill department can be more flexible—each machine is running one spindle—you can get the maximum amount of mix on the floor at any given time.

**Palmer:** That's important when you have high-mix, low-volume. Those operators are doing a lot of handling. If you get a four-, five-, or six-spindle machine, you may not be getting great use of your machine unless you can put boards on all of the tables, all of the spindles, all of the time. In that case, single-spindle machines help. As we work with a customer who wants to move to automation, we have to look at their mix, their average lot size, their capabilities, and what they're trying to get to, and then design the perfect drill room for them with all these things that are known.

In the case I was speaking to earlier, the initial design that we put in place—which, of course, is subject to change—used six single-spindle machines. Beyond that, we put in three five-spindle machines and a couple of two-spindle machines. It depends on the mix. It's not efficient to go to most board shops, across the board, with all single-spindle machines.

**Matties:** I heard about a six-spindle machine, but each area of the table was independent in the movement for each spindle.

**Palmer:** We were the pioneers of that technology at Schmoll. Their MXY series of machines have been around for 20 years. We're very good at it, and it's primarily what we sell in the North American and European markets. But you can't drill six different part numbers at the same time. They all have to be the same part number.

**Matties:** Why wouldn't you be able to independently operate a six spindle as single-minded units?

**Palmer:** Keep in mind that, as a board's being drilled, those tables are all moving around in different positions, and then the spindle is coming down and creating the hole. If they were doing six different jobs, those tables would crash into each other. The tables are only roughly an eighth of an inch apart, so they're far enough apart to move differently on the same job. They move differently for scaling, shifting in growth in the panels, but you're talking mils—not inches.

**Dick Crowe:** Kurt, wouldn't the modul be more in tune with what Barry's thinking about?

**Palmer:** The modul is exactly what we were talking about earlier: a single-spindle machine that's very compact with nothing on the side so you can put them right up against one another in a series. That's what GreenSource has. They have the same thing going on both sides.


The compact Schmoll Maschinen Modul series. Optional dual head enables drilling and routing in one station for flexibility.

**Johnson:** It sounds to me like the independent adjustment on the multi-head unit is mostly to take care of panel-to-panel registration.

**Palmer:** Exactly. It's a natural part of circuit board processing, where you're going to have different movements of inner layers for a variety of reasons. You have registration, and no two panels are registered the same. Each spindle and table has its own camera, looking at targets on the panel and saying, "This panel is a little different. I'm going to drill it this way." Then, it goes to the next panel, looks at it the same way, and drills it independently. It's for different registration within the same lot.

**Matties:** If you look at the strategy as I described at the beginning of this discussion, you could have a drill department running 24 hours a day, virtually on-demand, short of stacking up the feeders.

**Palmer:** Yes. You take them in and out of the loaders; that's all you do. You have to pin the panels because the panels have to be locked in place on each machine, but loading the loaders is all done up front. You do a little programming on your computer to tell the system what job is where, and then everything is automated from there.

**Matties:** Including tool quality, tool condition, depth, and all the other parameters, all the inspection is happening as the machines are operating.

**You do a little programming on your computer to tell the system what job is where, and then everything is automated from there.**

**Palmer:** Right. All these machines come with a tool chain. Unlike the old days where you had 10 tools across the front of the table, you have 2,200 tools resident on this machine in a chain, and you load up the 2,200 tool chain, however you want to do it. You can put as many tools of one size in there as you want, but it's based on the jobs that you're going to be drilling. That tool chain will typically have enough available tools to drill through the whole weekend without an operator coming in and changing those.

**Matties:** What other areas of the manufacturing process would have an effect on profitability? We're talking about automating the drill room, but you're also in the lamination area. How else would a fabricator drive waste out and profit up?

**Palmer:** There's a lot of automation coming in the lamination area for presses. It's not us at Burkle, but it seems like four out of five press systems that we quote today have some level of automation. No more is it the operator pushing a cart over that has a crank on it so that they can lift the book up and then slide it into the press. The automation these days means you start at layup. The lay up itself is not automated yet, but you layup your book, and the layup operator is right there next to a computer. They push the book onto the conveyor and input into the computer what this job is. From there, it's handled automatically all the way through pressing and back to breakdown. At that point, an operator has to come and break down the book again. It's very automated past layup all the way to breakdown.

**Crowe:** We had that concept several years ago at Advanced Circuits in Minnetonka and Roseville, where they layed up and kept track of each book. They would be in a storage rack of some sort, and we'd pick and place and get maximum utilization of each lamination system automatically because the recipes and the physical size of the book were the same.

**Dan Feinberg:** Any change in the yields on things like raw materials—not only raw materials like laminate but also raw materials like drill bits? Any enhancement to that by automation?

**Palmer:** You get more use out of a drill because you're not doing things like sending a drill bit out for repoint when it's not been fully utilized. You have two management systems and an automation system that keeps track of the number of hits on a tool. Instead of using an ID tool for three hits and thinking it's got to go out for repoint, it goes back into a magazine or into storage and is identified in a software system that says this tool can still be used. There's a lot of benefit to the tool life and extension of tool life because of that.

**Feinberg:** Any numbers that you could use, or does it vary by the diameter of the drill?

**Palmer:** It varies by diameter because of the dimensions. With ID tools, it seems to happen

more. But overall, I would say it's somewhere in the 10–15% range.

**Johnson:** This line of thinking inside this conversation raises the question, "Where's the biggest payoff for drill technology, as far as adding profitability to the fabricator?" Part of it could be how you pre-engineer together that design you're running through a drill, and part of it could be operational expenses for things like being smarter with your use of consumables on the drills and being more configurable, or the capacity or maybe labor. Where is the biggest bang for the buck for the fabricator to motivate them to rework the drill department and automate?

**Palmer:** I think it's the labor opportunity. At the end of the day, that's what you're talking about. As we mentioned, on average, it's a year and a half payback on these machines. That's a huge profit enhancement right there. The better tool management to increase your tool's life and reduce the number of hits you get on the tool is nice, but it's the same bang for the buck that you get with automation and labor savings.

**Holden:** A lot of the yield loss is handling, which is labor.

**Matties:** As we hear more and more about HDI and a lot of people saying, if you're not doing HDI, you're about to be doing HDI, and lasers play a role in that. Do you see an interest in HDI capability in their product offerings?

**Palmer:** Absolutely. We have more than two types of laser drills. We have what we call the CombiDrill, it is our UV/$C0_2$ dual laser drill, which, for the most part, is used in microvias. We also have PicoFlex and PicoµDrill series lasers. We supplied a PicoFlex series laser to the North American market where they're going to do routing with that. But when you talk about microvia formation, our largest, fastest-growing product line is our CombiDrill laser in North America.

Thomas Kunz

**Matties:** People are investing in this technology. The market demands are there for them to make the investment.

**Palmer:** That's true. That's where we see the most rapid changes right now.

**Johnson:** Where do you see the product roadmap going in the next couple of years?

**Palmer:** That's a great question. Thomas can answer that.

**Thomas Kunz:** In general, we see registration for high-level applications and automation for mass production to be the main drivers in the world market. In registration, there will be a vertical integration of data flow through all relevant processes. In automation, we talk not only about physical automation but also the automation of data flow as the topic for the next years to come.

**Johnson:** Thanks for joining us today.

**Palmer:** Thank you all.

**Crowe:** Thank you very much. PCB007

# Waste Not, Want Not

**Testing Todd**
**Feature Column by Todd Kolmodin,** GARDIEN SERVICES USA

Spring is just around the corner! I'm sure many of us are already pondering our spring-cleaning projects where we will downsize and remove clutter and waste—the unnecessary junk or refuse. But were these things we clean out always junk? Probably not, but they became waste for one reason or another. Maybe those extra 2x4s in your shed or garage were not needed, had you estimated the project correctly, but then you had excess inventory, which led to wasted costs.

Any time we overestimate our projects, we lose costs. For individuals, it may not be as monumental, but for manufacturing, it can be painful. Building extra products exceeding demand is costly in both time and materials, which both affect the bottom line. There are multitudes of knowledge repositories out there covering everything from 5S to Kaizen. All these strive to reduce waste and streamline processes.

Many disciplines believe electrical testing (ET) means only performing electrical test, or, "Is the board electrically correct?" Of course, that is what ET does, but it doesn't have to stop there. ET failures are faults in the electrical signature of the PCB, but a knowledgeable quality assurance provider can provide valuable feedback on the root causes of the electrical failures. Just like the earlier example about having extra junk in your shed or garage, ET can provide quality feedback to critical processes that may be generating waste.

Once products have reached ET, it is pretty much impossible to correct core issues of the PCB; most times, the PCB is scrapped. That is money down the drain. Unfortunately, in manufacturing arenas where processes are not controlled or monitored, the site compensates and manufactures excess quantities to compensate for scrap or waste. Adding an overage

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to an order isn't necessarily a bad thing when compensating for acts of God, system/power failures, and variables such as those. However, when this is done because one is "rolling the dice" for a final yield, it is both reckless and extremely wasteful.

Today, ET can provide valuable feedback to core processes in the PCB. The advancements in 4-wire Kelvin, time-domain reflectometry (TDR), buried passive testing, and hi-pot testing can help isolate key areas where fatal detects can be addressed at their root areas before the point of no return has passed and the PCB continues through later processes, increasing cost when the PCB is already doomed for the scrap bin.

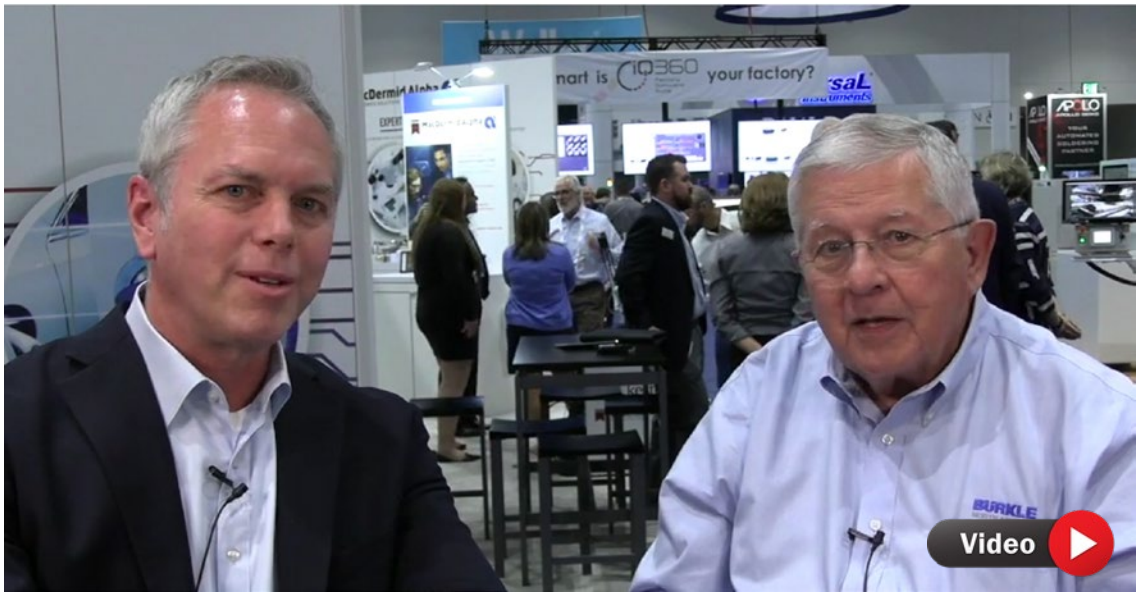
ET cannot be a "black box" in the overall process. Taking bets on whether the order gets through ET is not even what the lines in Las Vegas would take. Driving out waste takes a team approach, and ET can provide invaluable information to areas, such as plating, drill, print and etch, solder mask, all the way back to tooling. This can result in reduced material released for orders and higher first-pass yields, with the final goal being increased revenue to the bottom line.

Don't bet on the order getting through ET, but rather embrace the feedback, tweak the process, reduce the scrap at the cause, and know the products are heading for ET to get certified and not entered into the certification lottery. Increasing the profitability and driving out waste requires a team approach to encompassing more areas than just the root-cause area.

We all need to check our egos at the door and work the problem. Just because we own a process doesn't mean it's perfect. Repetition begets monotony, and sometimes, new input or outside review may identify the new way or solution. Remember, we are all on the same team in the end. **PCB007**

**Todd Kolmodin** is VP of quality for Gardien Services USA and an expert in electrical test and reliability issues. To read past columns or contact Kolmodin, click here.

## Kurt Palmer on His New Role, the Show, and a Younger Workforce




Dick Crowe and Kurt Palmer, president and CEO of Burkle North America, discuss Kurt's career history into his present role, equipment the company is exhibiting on the show floor, and the excitement about seeing a younger workforce at IPC APEX EXPO 2020. **Click on the image to view this video.**

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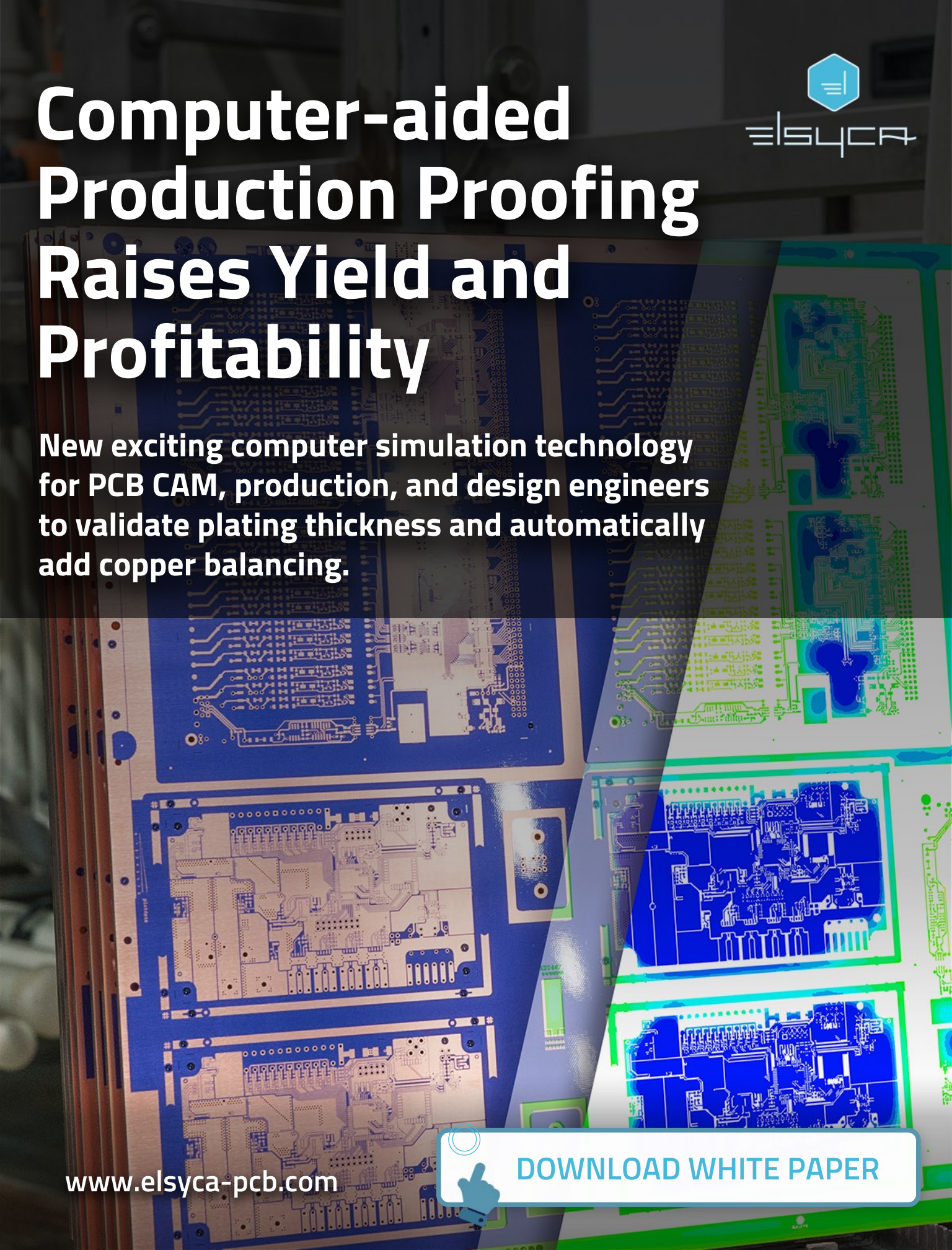

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# Trends in PCB Processing: A New Set of Technologies, Materials, and Challenges

**Feature by Patrick Riechel and Shane Noel**
MKS | ESI

*Editor's note: In this article, ESI's Patrick Riechel and Shane Noel address how new laser technologies and control capabilities are combining to increase productivity and address the challenges posed by new materials.*

The popularity of mobile devices and the growing use of other wearable/portable electronics have created an evolving set of challenges for flexible PCB manufacturers. We have phones, tablets, and other personal devices that help us to communicate, manage our time, and connect us to the internet, delivering relevant information when and where we need it. We rely on the sensors and technology in increasingly "smart" cars on the road to help keep us safe, and we leverage IoT devices to monitor and automate the world around us. Regardless of the technology, the market is continuously demanding smaller, more powerful and capable devices. These devices need to do more, last longer, use less power, and be more portable than the generation of technology that preceded it—all at a more affordable price.

These market demands are driven down through the value chain, forcing manufacturers to rethink their processing capabilities, reassess the processing technologies they deploy, and reoptimize the manufacturing steps they implement in production. While there's no analog to Moore's Law in the world of flex PCB manufacturing, it's obvious that, to keep up, manufacturers of flex and rigid PCBs need to put a high priority on innovation. They need to continue to innovate and keep up, or they will lose out to those who have. It requires a commitment to developing high-yield and high-throughput processing capabilities for new materials and to processing those materials at much smaller scales and higher precision.

## Five-year Technology Snapshot

Just five years ago, Apple introduced the first Apple Watch. At the same time, Amazon's Echo devices brought voice assistance technology into millions of homes. Google introduced Google Glass, and Oculus Rift brought VR to the masses. These devices demonstrated significant progress in interconnectivity and the role that seamless data delivery can play in our everyday lives. These devices—and others that

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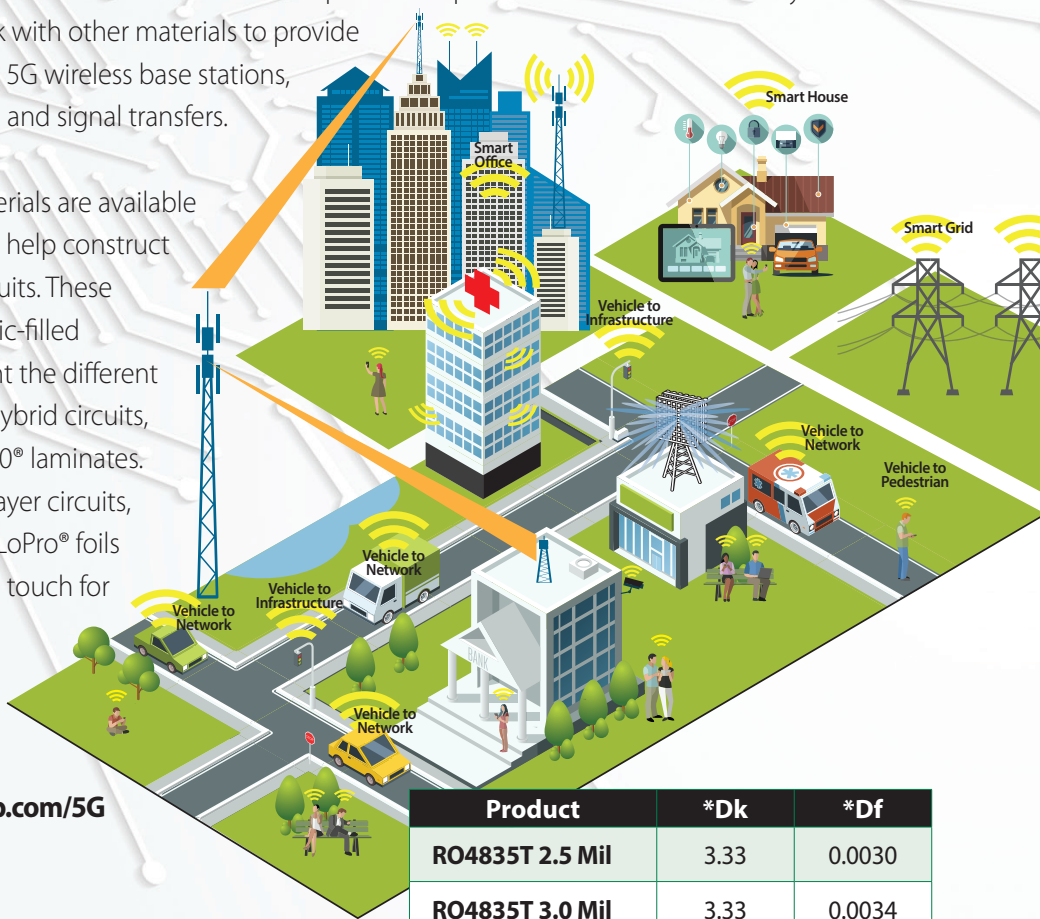


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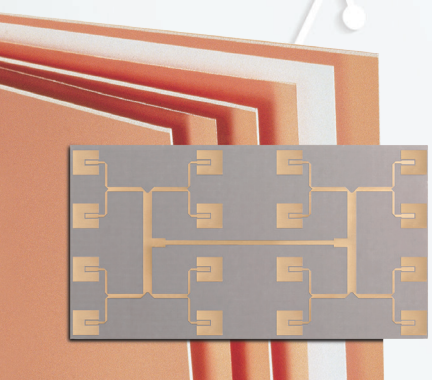

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were to follow—relied heavily on the use of flexible PCBs. They delivered the functionality required by the market and provided it in a wearable and portable form factor.

Around that same time, Apple released the latest flagship smartphone: the iPhone 6. It was equipped with an LCD display, a single-lens camera, and had 4G connectivity. The most common FPCB material for consumer electronics at that time was double-sided copper-clad flex laminate with 12-µm copper foil and 25-µm polyimide dielectric films, with over 80% of flex circuits in typical devices using this material construction.

Today, Apple's iPhone 11 utilizes an OLED screen, face recognition technology, multiple cameras, wireless charging, and limited 5G antennas. The flex drilling applications for consumer electronics have expanded to include a much wider range of constructions and more challenging materials. This broadening of material sets has allowed PCB manufacturers to create FPCBs with significantly smaller traces and vias to accommodate more compact circuit designs. It has also enabled new functionalities requiring thicker conductive layers, such as high-current wireless charging. A lot has changed in the last five years.

**The flex drilling applications for consumer electronics have expanded to include a much wider range of constructions and more challenging materials.**

As the demands for smaller scale and greater functionality continue to dominate the handheld device market, designs for flex PCBs are getting more complex and more challenging for flex PCB manufacturers to deal with effectively. They are increasingly forced to focus on innovation related to the processes they use, the materials they can process, and the technology they deploy. The need to pack more features into less space means that flex PCB designs have necessarily become more complex. Designs with higher via counts and smaller via sizes continue to push the limits of what can be packed into the same—or less—space and thinner material stackups are becoming the norm.

The continued movement to smaller, more densely-packed devices has put pressure on PCB manufacturers. Maintaining high yields in this environment requires them to implement more precise and advanced processing techniques and controls while they maximize production throughput and minimize production costs.

## 5G: A Case Study in Material Processing Challenges

The application of 5G technology is a good example of how the market for new feature-rich devices presents new challenges for PCB manufacturers, especially as it relates to incorporating new and difficult materials sets into production. Manufacturing previous generations of handheld devices leveraged established techniques and technologies for working with miniature coaxial cables and relatively easy-to-process dielectric materials, such as polyimide. That's not the case when processing many of the materials necessary to enable the 5G capabilities and ever more-compressed packaging on a state-of-the-art smartphone today.

The trade-off for using LCP and other low-K dielectrics, such as polytetrafluoroethylene (PTFE) and modified or fluorinated polyimides, is that many of the approaches used to lower their "k" value also can cause the materials to be difficult to work within production—especially high-volume production. As one example, the thermal properties of many of the newer dielectrics create unique processing challenges. Throughput can be hampered when the heat applied by the laser interacts excessively with the dielectric. Limiting that effect—minimizing that heat-affected zone—can be accomplished by implementing heat mitigation techniques, such as increasing the laser beam velocity to space the laser pulses farther

apart or adding additional steps to the process, thus giving the material time to cool down. These mitigation techniques need to be considered in the context of the effect they have on overall throughput.

## Rising Production Costs

Another challenge facing PCB manufacturers is the increasing costs associated with the addition of new production facilities and the expansion of existing facilities. The costs to accommodate the new capital equipment required to support an increase in production capacity have risen sharply in the past few years. Factors, such as increasingly stringent environmental regulation, make expansion more costly and time-consuming. While this has been the case in the U.S. and Europe for some time, it has only been recently that the cost of land and labor in what were traditionally considered lower-cost countries (such as China) increased.

These trends cause many PCB manufacturers to focus on optimizing existing facilities rather than adding new ones. This makes it imperative that they minimize their factory footprint while still maintaining or increasing production throughput, placing a premium on extracting higher productivity from their existing systems.

## Laser Technology Evolution

The first commercially-available UV lasers were lamp-pumped and characterized by a relatively low 1–5-kHz repetition rate and low 1–3 W average power. Although that performance profile met the need for the applications at the time, the reliability and lifespan of these lasers were notoriously low. These lasers would not be suitable to address the processing challenges presented by today's FPCB materials, 24/7 production environments, and high manufacturing volumes.

Today, advancements in laser technology have made available new state-of-the-art, diode-pumped solid-state (DPSS) and fiber-based UV lasers that operate at well over 100-kHz repetition rate and tens of watts of average power, often lasting tens of thousands of hours. These new high-performance lasers provide the basis for effective, high-volume production of flex circuits. However, they must be matched with similarly high-performance beam delivery and control capabilities to achieve the high productivity, yield, quality, and flexibility necessary to process the broad range of materials and applications that are typically used in consumer electronics.

## Laser Systems Rise to Today's Challenges and Technologies

Harnessing new laser technology for specific applications requires more than just the right laser. It also requires the right set of beam delivery and control technology to optimize the characteristics of the laser and its effect on the material. Not only have today's processing challenges increased, but so have the challenges associated with the much-higher repetition rates and higher average power available on today's state-of-the-art lasers.

## Optimizing for a Wider Range of Materials and Higher-power Lasers

Laser processing both thick and thin material constructions with a range of thermal properties and capture layer thicknesses at high yields is already a challenge. Doing so while integrating a high repetition rate, high-average-power lasers able to maximize productivity makes the challenges even more difficult. The ideal laser system offers improved methods of reducing the heat accumulation and laser energy variability presented to the workpiece (Figure 1).

Coupling high-rep-rate laser technology with faster beam steering capabilities, such as ESI's AcceleDrill™ technology, allows for better thermal management and minimizes the negative


Figure 1: Larger bite size equates to lower localized heating.

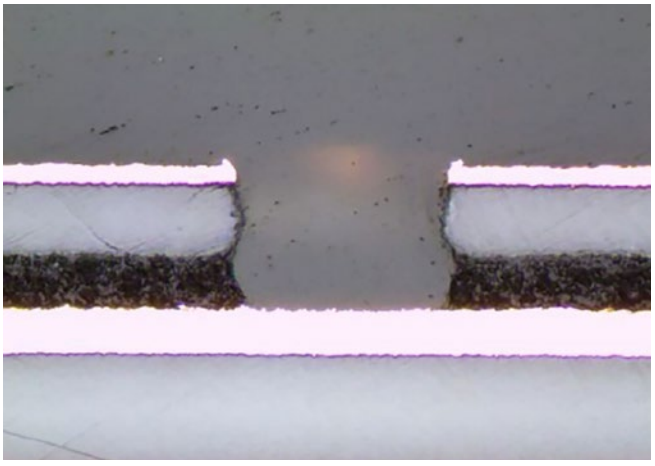

Figure 2: Minimal etch-back at the adhesive/bonding sheet interface.

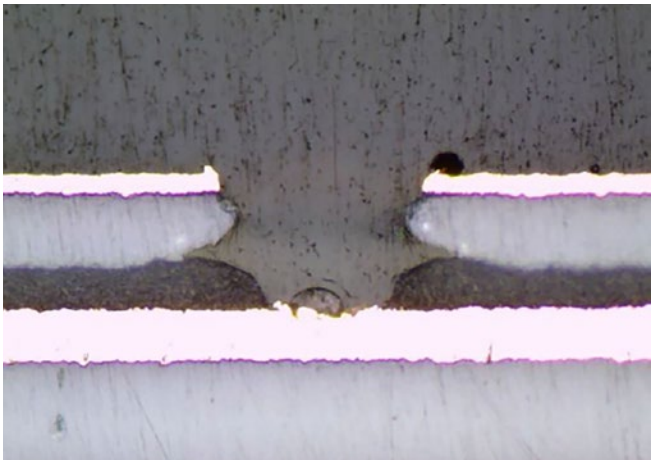

Figure 3: Unacceptable etch-back due to a higher localized heating effect.

effect of heat on the material. Having this level of control over the beam allows for the processing of newer materials that are more prone to thermal issues such as delamination and dielectric or adhesive etch-back since increasing beam velocity allows adequate pulse spacing to avoid excessive heat accumulation (Figures 2 and 3).

Natural laser energy fluctuations during laser processing must be mitigated to ensure the best possible quality and yield. This is especially important in sensitive depth-controlled applications—such as blind via processing—with thin, easily damaged, or delaminated copper on the bottom capture layer. Alternatively, this is also important in applications where the easily-processed dielectric is very thin (e.g., 15 µm or less), allowing for very little margin of error for overdosing the dielectric and starting to damage the underlying copper. The best methods of avoiding such energy fluctuations include real-time laser energy monitoring and compensation during processing, as with ESI's Precision Pulse™ technology.

## Addressing Rising Production Costs

With factory floor space at a premium and the cost of adding capacity increasing, productivity is a key area of focus. Systems that substantially increase throughput can delay the need to add more systems and enable PCB manufacturers to avoid the costs of acquiring new land, floor space, permits, and resources associated with expansion. New systems can match the capacity of previous-generation systems with fewer units. Reducing the number of machines needed can also reduce overhead costs in both utility usage and personnel requirements.

Improving laser system productivity can not only come from effectively using higher-powered lasers, as discussed previously, but also from reducing unproductive time spent moving the laser beam between features. Preparing to start laser processing with actions such as aligning to features on the workpiece and performing maintenance on the system also adds additional processing time.

Enhanced beam positioning—such as ESI's Third Dynamics™ technology, which decreases the time required to move the laser beam between features to be processed on the workpiece—is one way to minimize unproductive move time. Another more recent development in beam manipulation can have an even more dramatic impact on move time for processes requiring multiple effective spot sizes, such as blind via formation.

The ability to instantaneously shift the laser's focus, thereby changing the effective laser spot size, as with ESI's DynaClean™ feature, eliminates the need to pass the beam over each of the workpiece's features twice—one time in focus, and one time out of focus. The effective result is a 50% reduction in move time.

Advanced scale compensation algorithms, coupled with state-of-the-art vision capabilities,

can reduce the number of alignment points necessary to meet a given process accuracy target. Such capabilities can reduce the time required to process—by many minutes, in extreme cases—especially warped patterned work pieces.

Lastly, a robust system design—coupled with robust process development—can significantly reduce maintenance downtime, thereby increasing overall system productivity. Precision mechanical, optical, and systems engineering by reputable and experienced laser systems manufacturers can significantly reduce the amount of maintenance required for laser systems, especially the high-power UV laser systems that dominate the flex laser processing industry. Similarly, effective laser and optics protection mechanisms become critical for such UV laser systems. These extend the life of the laser and optics with minimal preventive maintenance downtime associated with cleaning and replacing the laser and optics.

## Summary

The world's growing appetite for technology products and the accelerating pace of change will continue to make it difficult for PCB manufacturers to see far enough ahead to know what challenges they will face next. However, one thing is clear; effectively responding to these new requirements—and doing so profitably—will require flexibility and a willingness to embrace innovation as a strategic tool to stay ahead. With the next generation of technology always being just around the corner, keeping current with technology and processes is the best way to stay competitive in a competitive market. Some things never change. **PCB007**

**Patrick Riechel** is director of product marketing for the ESI flexible circuit micromachining tools at MKS Instruments. He has over 15 years of experience in the design and manufacture of electronics, having held positions at Symbol Technologies, Motorola Solutions, and ESI. Patrick has an MBA degree and a master of science in systems engineering from the Massachusetts Institute of Technology (MIT), as well as a bachelor of science in electrical engineering from Brown University. As the inventor of seven patents, and the catalyst for bringing industrial head-worn computing to Motorola, he was the recipient of the Robert Noyce Fellowship at MIT for his contributions to the field of electronics.

**Shane Noel** is product marketing manager for the ESI flexible circuit micromachining tools at MKS Instruments. He has over 20 years of experience in the design and manufacture of electronics, having held positions at LPKF and ESI. Shane has a master of science in materials science from the University of Texas at Austin and a bachelor of science in materials science from Columbia University.

# Rolls-Royce Launches New Electronics Manufacturing Capability at Purdue University

Rolls-Royce has created a new engine controls capability near the campus of Purdue University to support its U.S. defense business, including the F130 engine competing for the U.S. Air Force B-52 program.

Rolls-Royce will assemble and test electronic engine controllers, which help manage in-flight engine operations. The first controller has been completed in West Lafayette, Indiana, and will be installed onto a Rolls-Royce AE 3007H engine, manufactured at the company's facilities in Indianapolis.

Purdue University is a designated Rolls-Royce University Technology Partnership that recognizes its collaborations on research, including advanced engine technology, materials and testing capability, and a Rolls-Royce investment at the university topping $18 million since 2015 and more than 600 Purdue graduates among the company's workforce in Indianapolis. Rolls-Royce and Purdue also have collaborated on initiatives in cybersecurity and digital technology, as well as the new controls project. (Source: Purdue University)

# Supplier Highlights

## Punching Out! Down to 199 ▸

According to the database at Tom Kastner's firm, the number of PCB companies in North America is now down to 199. This is a psychologically significant number for the industry. Tom unpacks this number, provides insights on trends, and shares his firm's predictions for the future.

## Language of Electronics: Enabling Customer Success in Manufacturing ▸

With market demands and expectations constantly and quickly evolving, every organization should take the time to look inward and evaluate the level of satisfaction it provides to its customers. In his debut column, Sharon Cohen explains how Orbotech West went through this process in 2017, including goals and results.

## Burkle North America: New Equipment and 'New Blood' in the Industry ▸

During the show, Dick Crowe and Kurt Palmer, president and CEO of Burkle North America, discuss Kurt's career history and responsibilities in his present role. Palmer also details the equipment that the company is exhibiting on the show floor and the palpable excitement that veteran technologists feel this year seeing younger engineers and students attending IPC APEX EXPO 2020.

## Nano Dimension Announces Closing of $3.5 Million Public Offering ▸

Nano Dimension Ltd., a leading additive manufactured electronics (AME) provider (Nasdaq, TASE: NNDM), announced the closing of its previously announced underwritten public offering of 2,333,000 American Depositary Shares at a price per ADS to the public of $1.50.

## Gardien: Selling Test Equipment and Services ▸

In this Real Time with... IPC interview, Pete Starkey spoke with Jason Posey, director of sales and service with Gardien. They discuss Gardien's range of flying probe testing and the introduction of AVI into the North American market.

## LPKF Presents Equipment at Embedded World 2020 ▸

LPKF Laser & Electronics' systems offer all the possibilities for PCB prototyping and micromaterial processing to achieve the desired results quickly and easily. The company demonstrated how this is possible at embedded world in Nuremberg in February.

## Ventec's Materials are Enablers for 5G, Industry 4.0 ▸

In this video interview from the show, Pete Starkey and Ventec COO for Europe and the Americas Mark Goodwin discuss Ventec's latest high-speed, low-loss, high-frequency materials as enablers for 5G and Industry 4.0.

## Uyemura Appoints Midwest Sales Manager ▸

Uyemura National Sales Manager Mark Eonta has announced the appointment of Troy McNulty as Midwest Technical Sales Manager for a high-activity sales region that includes Minnesota, Wisconsin, Illinois, and Michigan.

## Ucamco Helps Customers Dealing With Temporary Production Peaks ▸

Ucamco is currently offering an exclusive discount to all Integr8tor users with a maintenance contract to "pay one monthly license of additional Integr8tor workflow and get one month extra for free."

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# PCQR² Tool: A Scorecard for Suppliers?

**Feature Interview by Patty Goldman**
I-CONNECT007

Al Block and Naji Norder from National Instruments talk about the PCQR² tool, what that entails, and how companies can use the data-driven analysis to validate the quality of suppliers and potentially save millions.

According to IPC's website: "The IPC Process Capability, Quality and Relative Reliability Program is a unique supply chain management resource, developed by IPC and Conductor Analysis Technologies for designers, manufacturers, and users of printed circuit boards. The program is based on statistical data collected from industry-developed test patterns, which quantifies the capability, quality, and reliability of printed board manufacturers."

**Patty Goldman:** Al, you are the chair of the IPC PCQR² committee [D-36]. Let's talk about what's going on in that committee and some things you're looking to do, but first, start with your background and what you do at National Instruments.

**Al Block:** I'm a DFM engineer, and my background is in PCBs. I worked as a chemist at Texas Instruments for 20 years, so that's where my strong knowledge base is, and that has helped me now at National Instruments where we do PCB assembly.

**Goldman:** And Naji, you have been with National Instruments for how long?

**Naji Norder:** I've been with National Instruments for 20 years. I've been working with the PCB supply base as a commodity for about 10 and participating in our audit and qualification process for about five years now.

**Block:** At National Instruments, we buy our raw boards and assemble them. Before we joined the PCQR² program, we tried to evaluate our shops based on technology, so we came up with high/medium/low. While that was an improvement, it depended on someone like me to be able to evaluate the shops and the technology of the boards to decide where they would be appropriately placed, so we could get the cost down and still keep our quality up.

The issue was that our technology needs kept evolving. One person could not keep up with the increasing technology and widening supply base. That's when we started looking at the PCQR² benchmark database. PCQR² is

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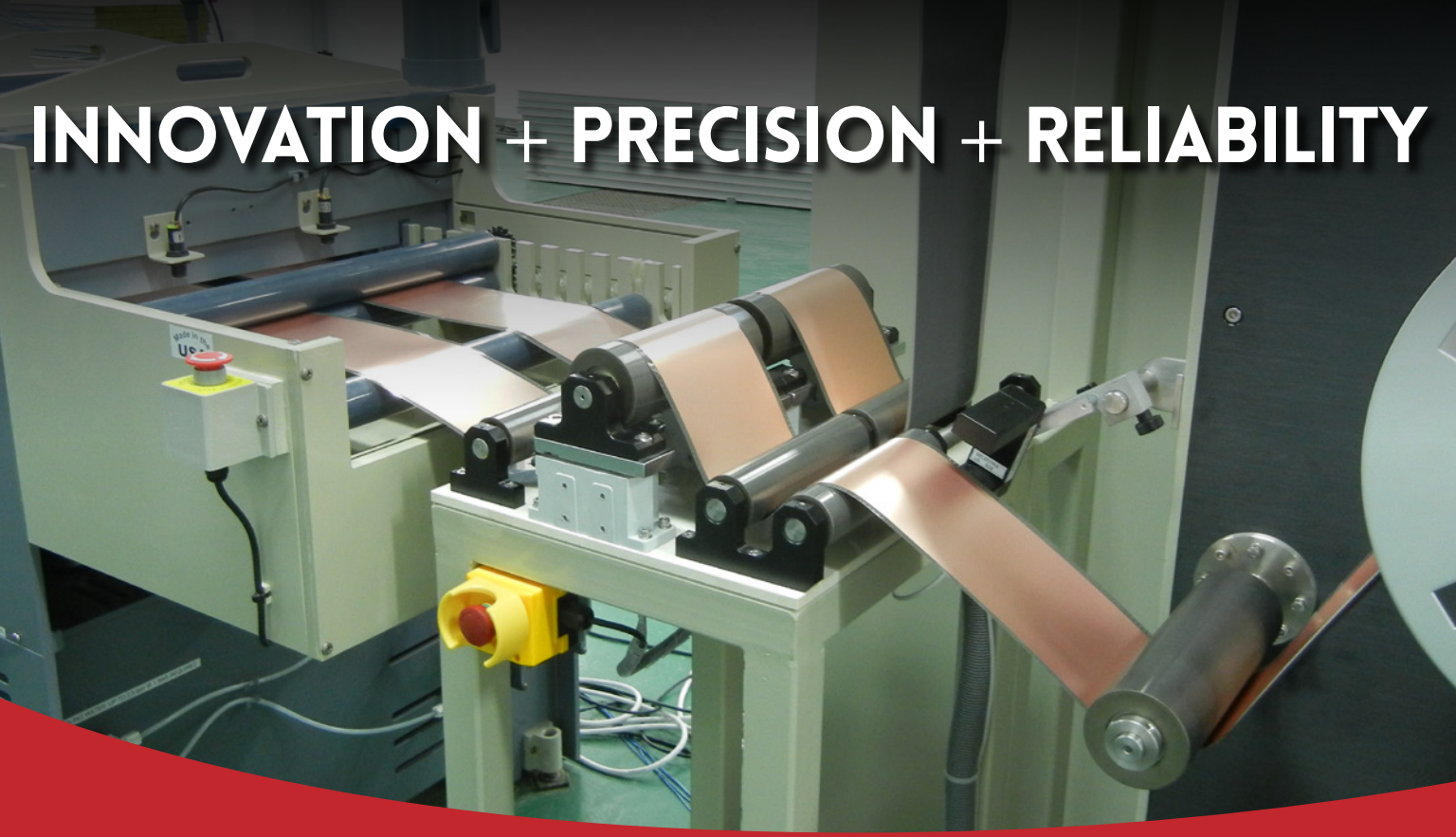

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a system that allows us to look at different PCB shops and evaluate their capabilities. It also allowed us to remove the expertise of someone like me. You do not need someone that's worked in the PCB industry to be able to evaluate the shops. You are able to look at their capabilities for doing these different board structures and evaluate them to say, "This type of board can go to this shop because they're excellent at it, and we know we're going to get great yields."

Al Block

A database helps us get the appropriate technology of a PCB into the right shop with the highest yield. That allows us to not put a board at a high-tech supplier when it doesn't need to be. If it's a two- or four-layer board, for example, it can go to the lower-technology PCB shops. We were able to create a quote model that drove this using the PCQR$^2$ data and their database of PCB suppliers. We're able to extract the information and load it into our quote model, so when our designers put in the variables, our system automatically sends the quote to only the suppliers that we have approved for a particular type of technology.

That allows us to make sure that we don't just pick someone that we like working with; we are picking the correct technology and cost, so we're more competitive now. Without putting a specific number on it, I can say that we have saved millions compared to if we had followed our previous course.

**Goldman:** Tell me a little bit more about PCQR$^2$. What does it stand for?

**Block:** It stands for process capability, quality, and relative reliability.

**Goldman:** You're now chairman of that committee. Tell me about the structure of the committee, who gets involved, and the purpose. I know you just told me about what it is to National Instruments, but tell me about the committee.

**Block:** In the committee, we're trying to make sure that the types of structures that we're testing are the latest structures that our electrical engineers are going to need in the future.

**Goldman:** Can you explain the whole basis of PCQR$^2$? There are a set of test boards and designs that companies build to, and then they're tested.

**Block:** Yes. Our committee has come up with these different structures; there are different board designs based on what you want to test a shop for. If it's a lower-technology shop, you're not going to give them the hardest board and let them fail at everything. You're testing them for what you're looking for and the technology of that type of PCB company. Then, you can develop the different structures on there, like lines and spaces. Let's say they're only good at 0.004"/0.004" on outer layers; on inner layers, they're 0.003"/0.003". You can put that in, see that, and then you see other shops can do 0.003"/0.002". That allows you to see that a particular board design is appropriate for this supplier.

We can evolve with the technology because when we first started, for example, we didn't have as many microvia structures. We started with microvias that just spanned layers one to two. Now, we have a complex board that's testing one to two and one to three. There are also staggered and stacked microvias on a sequential-lamination board. In the open committee, we discuss the technology with not only the subscribers that come in, but we also have a lot of our PCB suppliers that are interested in it because they know we're going to try to push the technology. The suppliers give us recommendations, but the subscribers are also looking at what's being driven by their electrical engineers and the complexities they need to produce their products.

**Goldman:** I presume that when you subscribe, you pay for access to the data.

**Block:** That's right. The subscribers are users of PCBs—OEMs, companies like us. A lot of large companies are using it for the same thing that we're doing. They're trying to validate the quality of a particular supplier. We also use it to see what's out there. When we need to add another supplier, we'll go look at the database for the technology we need to bring in and say, "This supplier looks pretty good. Let's start talking to them." It's a good way to find a new supplier and not waste your time looking at their websites, talking to salesmen. You just open up the database and can start screening through that to see what technology you need and which supplier you want to talk to.

**Goldman:** The people that have their boards tested are mostly PCB shops?

**Block:** Yes. It's only PCB shops.

**Goldman:** How do they get into this database?

**Block:** They have to be sponsored by a subscriber. My subscription comes with an allocation as to how many boards I can test. We use that subscription to test new suppliers that we want to add to the database. We also use it to monitor our current suppliers, and we test them and see how they're evolving because the only way you can move up in our quote database is to do better on the test board. Each time a PCB company does the test—let's say they add new equipment—they can slowly move up.

But we can also see problems; if they start having problems with something they could previously build, we can use that as part of our audit as corrective action. We'll send them data and say, "You're having problems with this structure. Why did it fail so early?" So it's a total picture of the capability of their shop.

**Goldman:** How many PCB facilities are there in the database?

**Block:** There are about 60 right now.

**Goldman:** How many subscribers are there?

**Block:** Currently, there are 12. It fluctuates up and down, depending on who's in the database. One thing nice about being a subscriber is I can see all the shops that everybody else tested; it's not just the shops I tested. It's good in that way since we're not "double-dipping" on a supplier, which is not economical to do. It costs money, so a board shop doesn't want to do a whole bunch of test boards for multiple companies. If I see one of the other subscribers run a test board, I'm able to look at the data and analyze it.

**Goldman:** And you don't have to test them yourself. The board shops then save money on evaluations because running test boards is expensive, as you mentioned. And then you save money because you don't have to be doing this for multiple suppliers. It's very efficient.

**Block:** Correct. Another benefit for us is that our cost has gone down on returns because now that we're putting the right technology with the right shop, we have fewer returns. And it helps the PCB suppliers. Perhaps they're not able to do certain structures and think they should—they're able to use the test system as justification to their management to buy new equipment, for example. We have seen our suppliers use it and tell their management, "If we do this, we're going to save this much money and be able to get this technology."

**Goldman:** This is all ongoing. Everything is fine, and you're still having committee meetings. What else are you trying to accomplish?

**Block:** What we would like to see is more subscribing members right now because if we have more members, we'll have a bigger database. That helps all of us to see where the technology is going; having a small picture of just a few subscribers, we are not seeing all the technologies that are hitting the industry. We need to evolve our test board to what the industry is doing.

**Goldman:** You're looking for more subscribers to this model, and when they become a sub-

scriber, they can have so many tests done, presumably using another group of PCB shops—plus they have access to the data from all the shops now in the database. All of the test boards are evaluated by Conductor Analysis Technologies (CAT) Inc.

Naji Norder

**Block:** Yes. Once you see the database and evaluating shops with it, you can see the true snapshot of a board shop. Everybody can sound good. You go on their websites, and they can all do everything. It's about whoever has the prettiest picture. But this is a true scorecard of them, and they can't cheat on it. The test boards are designed to capture the transition from success to failure, so you see at what point they fail, and then you know their capabilities and limits. We don't want to make a board that's easy to pass because if everybody passes, then you haven't learned anything.

**Goldman:** Exactly. That's very interesting.

**Block:** Right now, our committee is trying to advertise to get more subscribers. Once you try it and get involved, you'll know how good the system is. We are firm believers. Our management signed up for it because they know it's a great investment because it has saved us so much.

**Norder:** I'll add that PCQR$^2$ doesn't replace all other reviews and auditing. It's not something that you can use in a vacuum. Previously, we needed someone with 20 years in the PCB industry to be able to go to the shops and see what they could do and fully evaluate them. I don't have that background, but I can use the PCQR$^2$ data to be a guide for when we go to the facilities to look at their equipment and processes and be able to see that they were able to perform at this level.

We always like to have the PCQR$^2$ data before we visit the shop. Then, we can say these were areas that they did well; these are areas that they struggled a bit. We can map that to what we see as far as the equipment they have onsite and what they purchased. I can say, for example, that their solder mask capability was average. I'm expecting to see old imaging equipment—not newer LDI equipment. You can be there and correlate their performance with what you see at the factory.

Even though I'm able to do that and see that, I don't have to be able to inherently know every given step or process. I can see if they're failing at this, they have equipment that I recognize as being capable. Is there a process issue? And we can dig deeper as well. It gives us these tools so that we're not just going in blind to a factory where we're being walked around and being pointed toward fancy pieces of equipment—which is all I might have otherwise without that industry background. Instead, I know areas to focus on, and I can make better use of the time that we have there at the factories.

**Goldman:** You go around and audit the shops?

**Norder:** Yes. I've been traveling on our audits and picking this up for about five years now. I have nowhere near the background that Al has in the industry, but with the PCQR$^2$ data, I'm able to go in and get a good data-driven analysis of our different suppliers. When new submissions pop up in the database, I'm the one that goes and reviews them.

CAT Inc. provides a lot of data on their website, as well as interactive images and analyses that have been prepared for you. They also provide raw data files, which is what we use. I pull them down, and we process them internally against our own standards—not necessarily what CAT Inc. wants us to call good/better/best, but our own internal standards for what good/better/best is for each structure or process. Then, we use that to grade the PCB facilities and decide how they fit into the quote model. We do this not just in general

for high/medium/low technology, but for specific technologies for each thing that they're capable of.

When our PCB designers are working on a board, they can put the technology parameters of that board into the quote tool, and it's directly matching. Suppose a board requires this very small, deep microvia structure. Which suppliers are able to do microvias with that size and aspect ratio so that only those suppliers are sent the quote? Now, our R&D teams have a selection of quotes—all of which they can have complete confidence in those suppliers' ability to produce the board. They don't have to worry at that level as far as the quality, so they can look at other factors that may matter to them: Lead time for quick-turn, long-term production costs, or whatever it may be that matters for their particular project. We've abstracted away from the technology and capability portion of the selection process so that they can focus on the things that they care about more, which is their project schedule, and getting their boards in at the time they need at the cost they want.

**Goldman:** How long has National Instruments been involved in this program?

**Block:** We've been using it for about 14 years. As Naji said earlier, it has now taken out the need for an expert like me. That's the great thing because in the future it will be hard to get someone like me. There are not too many people with my experience left in the U.S. Now, you're given a tool that anybody can become an expert in once they understand just the basics of it. That's the greatest strength and selling point of this tool: Anybody can become an expert overnight. Why do you need someone like me when you can just look at the data right there, and you could crunch it, too?

**Goldman:** When you do go visit, you definitely have an increased level of confidence in what your suppliers can do.

**Block:** And even without me there to do the audits, when you're looking at certain things where they're failing, you at least can ask the intelligent questions when you get to the supplier; they can't trick you. You're able to go straight to the problem and say, "That's not true," because you have the data there. Tim [Estes] and his team [at CAT Inc.] are able to educate you on what the failure modes are that caused a failure. That's another benefit; you have the CAT Inc. team to provide some guidance.

**Goldman:** That's a great resource to have.

**Block:** Yes. And that's part of the package—educating you on what the failure modes are when they do fail. The other thing it has saved us, which is hard to capture the cost of, is the returns. My customers are now happy. When I build a board with the type of technology that we're making, our customer expects to sit there and use it for 10–20 years, so if I have an early failure, they don't like that. I just had a battery on my lawnmower last four months, and the warranty on it was 90 days. I was not a happy customer with just a plain battery. Again, my customers are happy now because I have fewer returns.

**Goldman:** You have fewer returns to your supplier, but you also have fewer returns from your customer, which may be hard to put a number on, but it must be significant.

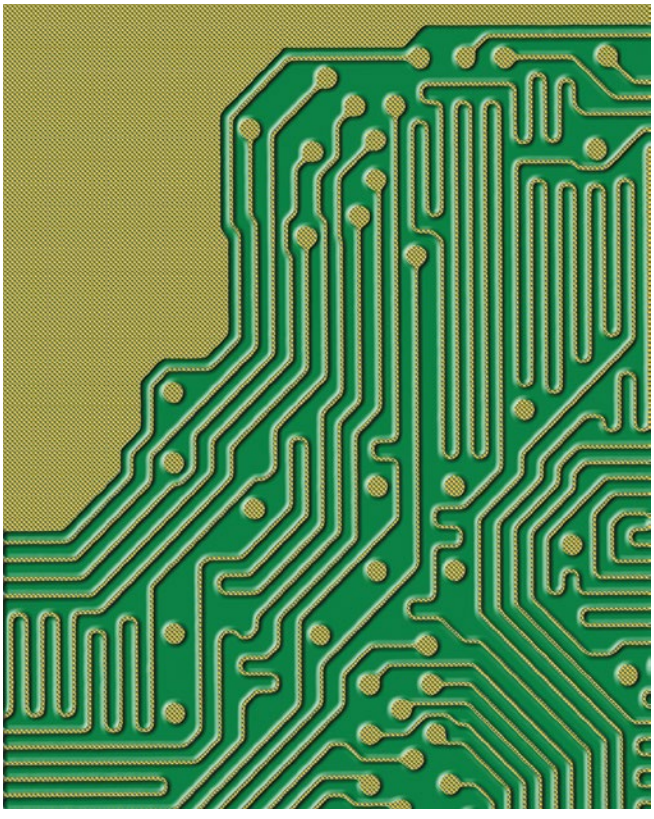
**Block:** It is. With the type of technologies that we're making, the customer expects a rugged product. We're not selling a cellphone or something like that; We're selling something that is very complex, and they expect it to work day in and day out.

**Goldman:** This has been very good information. Thanks so much.

**Block:** Thank you. PCB007

**For more information about PCQR², visit:**
**cat-test.info/ipc-pcqr2**

# The Advantages of Developing, Processing, and Using an Inkjettable Solder Mask



**Feature by Chris Wall**
ELECTRA POLYMERS LTD.

## Introduction

Electra Polymers has been involved with developing and manufacturing solder mask for over 35 years, starting with two-component epoxy-based materials, through single-component UV-curing products to LPISM, which are still in use today. Most of these products relied on screen printing as a means of application with some formulated for application by HPLV air spray, electrostatic spray, or curtain coating. In this article, I provide an overview of the development of inkjettable solder mask and the equipment to apply it.

The first attempts to develop an inkjet solder mask were in the early '90s. The technology, however, did not really take off at that time, due to inadequate performance from the heads and printers. This performance difficulty was, in part, due to a lack of the computing power to drive the multiple nozzles needed. Only relatively recently has the hardware been available to make the inkjet solder mask process viable.

This article briefly sets out the methodology used to develop and formulate an inkjet solder mask, the advantages of the process over the existing LPISM process, and the results achieved.

## Understanding the Inkjet Application Process

The first part of the method is to understand the inkjet application process. As mentioned before, the first attempts to develop an inkjet solder mask were nearly 30 years ago; printhead and printer technology has moved on dramatically in that time. The solder mask printheads used today are a drop-on-demand (DOD) piezoelectric type. With this type of printhead, a voltage pulse is applied to each nozzle, which causes the nozzle walls to flex and eject a droplet of ink (Figure 1).

Creating the right type of pulse—in terms of frequency, amplitude, and duration—depends on the acoustic characteristics of the nozzle chamber and the rheological properties of the ink; it's also critical to achieving good jetting performance. This calibration and tuning are usually done by the head manufacture/print-

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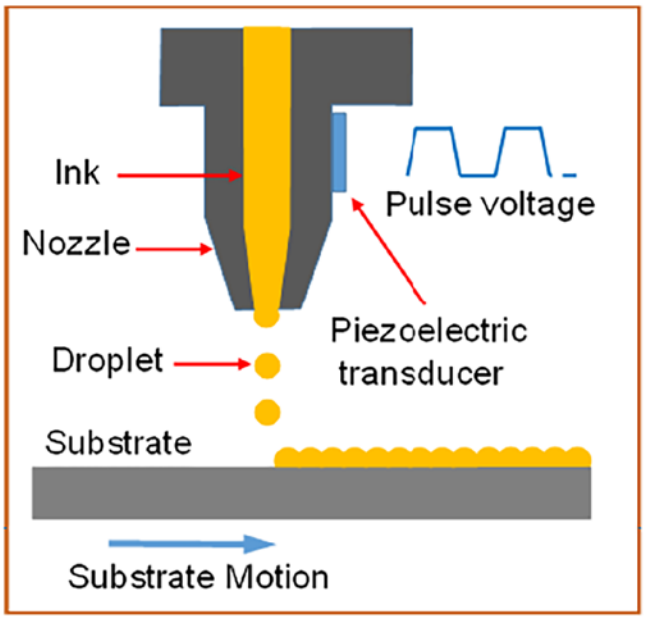


Figure 1: Inkjet nozzle structure.

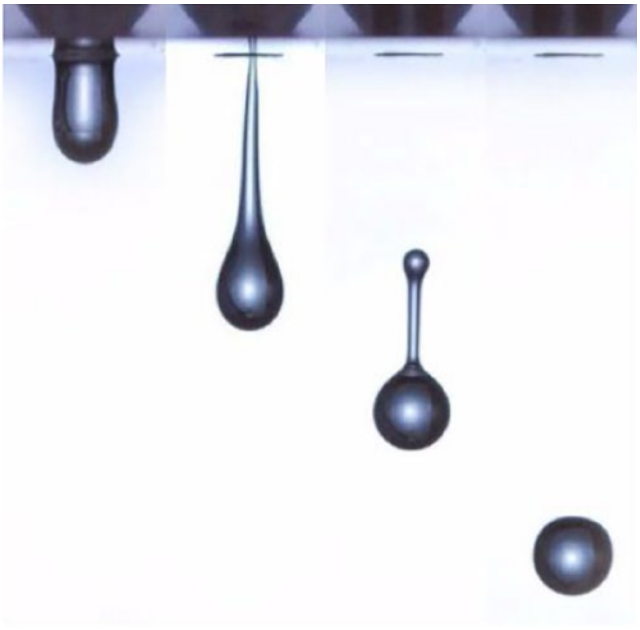

Figure 2: Achieving the perfect droplet.

head integrator in partnership with the ink supplier.

The objective of calibration is to achieve the perfect ink droplet. This means the droplet breaks cleanly from the nozzle plate when it is ejected with a nice clean tail, which is absorbed into the main droplet before it hits the substrate surface. Thus, you avoid "satellites," which are small droplets deposited in non-image areas (Figure 2).

Heads can be either non-recirculating or recirculating types and often include integral heaters to reduce the jetting viscosity of the ink. With the former, ink is fed to the head from a tank or sump, sometimes via an intermediate tank held just above the head to ensure a positive pressure to the head. A vacuum is used to prevent the ink from dripping out of the head when not printing.

With a recirculating head, as the name suggests, ink is pumped continuously through the head, making for a somewhat more complex system. The benefits claimed for recirculating systems are easier priming, improved degassing, temperature control, and prevention of sedimentation of pigment. The choice of printhead also determines the droplet size that is jetted, which influences the productivity and resolution that can be achieved.

## Identifying Inkjet Solder Mask Formulation Constraints

There are a number of significant constraints on the solder mask formulator when developing solder mask for an inkjet application. Viscosity requirements limit the choice of suitable raw materials. In general, only very low viscosity resins and monomers can be used. Such materials, however, can be more easily absorbed through the skin. Care must be exercised to ensure their hazard classification is acceptable.

The particle size of any pigments and fillers used is restricted to $<200$ nm, compared to 5–15 microns for conventional solder masks. The restriction on filler size and content is a considerable hurdle for solder mask formulators, as the fillers also contribute to the thermal shock and solder resistance and can also reduce the flammability of the material.

The ink viscosity requirements depend on the printhead being used, with recirculating heads requiring lower viscosity inks than non-recirculating heads. The surface tension of the ink is also restricted to a fairly narrow range for successful printing. Ink viscosity and surface tension—together with the ink density, velocity, and path length—can be used to calculate Reynolds (Re), Weber (We), and Ohne-

| | |
|---|---|
| Reynolds number | $Re = v\rho\alpha/\eta$ |
| Weber number | $We = v^2\rho\alpha/\gamma$ |
| Ohnesorge number | $rOh = \sqrt{We}/Re$ |
| Fromm Z parameter | Z = 1/Oh |
| Stable drop formation | 10 > Z > 1 |

Where:

| | |
|---|---|
| *v = drop velocity* | *ρ = fluid density* |
| *α = nozzle/jet diameter* | *η = viscosity* |
| *γ = surface tension* | |

Figure 3: Standard formulas for droplet formation.

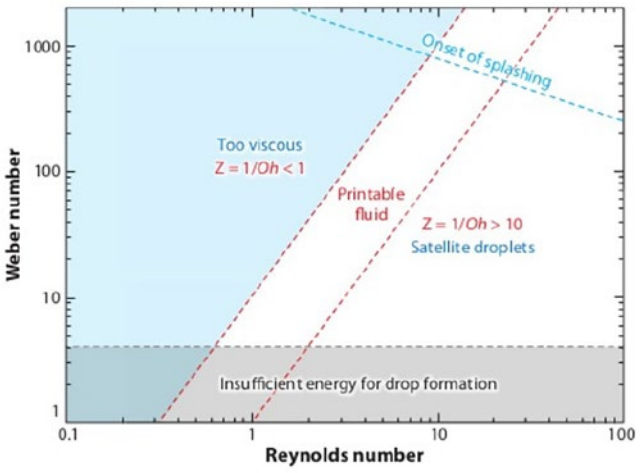


Figure 4: Physics of drop formation and ejection [1].

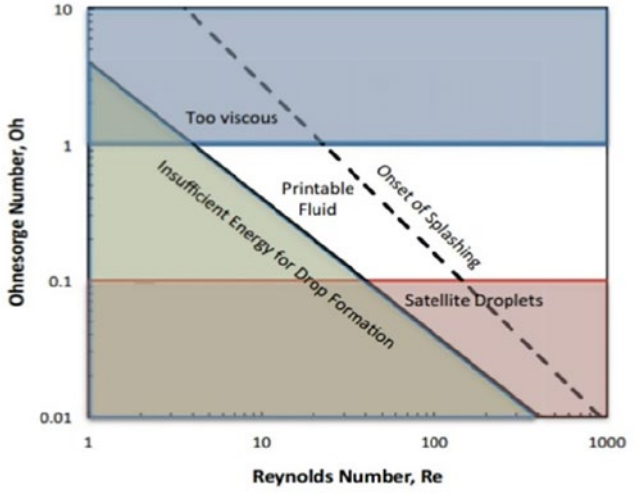


Figure 5: Physics of drop formation and ejection [2].

sorge (Oh) numbers, as well as the Fromm Z parameter. (Figure 3).

These are dimensionless parameters used to calculate an operating region for good droplet formation (Figures 4 and 5).

Low viscosity materials are also more prone to pigment sedimentation, and care must be taken to ensure a stable dispersion has been formed. The resulting contact angle of wet ink on either substrate or cured ink can be a useful predictor of coating performance.

The choice of curing mechanism must also be taken into account. Choices include UV, thermal, or some combination of both. UV curing is usually preferred, as it permits "pin-curing" of jetted solder mask, which helps achieve good image definition (Figure 6). The curing mechanism can be free radical using acrylate type monomers and resins, cationic using epoxy resins, or—once again—a hybrid of both.

The choice of photoinitiator used to generate the "polymerisation-initiating species" will reflect the type of polymerisation chemistry being used (i.e., acid type for cationic systems, free radical for acrylate systems). Most solder

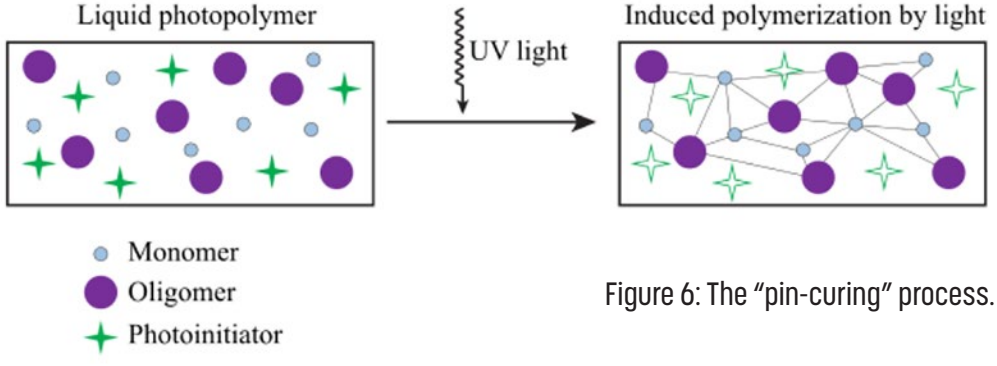


Figure 6: The "pin-curing" process.

masks also require a thermal bake after printing and UV curing to achieve the best possible final cure.

## Identifying and Sourcing Suitable Candidate Raw Materials

Once the formulation requirements and constraints have been identified and taken into account, suitable raw materials are then identified and sourced. As already mentioned earlier, the choice of resins and monomers is restricted to those with a low or very low intrinsic viscosity to enable a low viscosity product to be produced. Any solid or higher viscosity resins can only be present in small amounts.

The selection of the correct photoinitiator is crucial to obtaining good performance. The photoinitiator must combine a rapid cure—to minimize the UV energy required for pin-curing and thus avoid restrictions on print speed—with a good through-cure to avoid "wrinkling" in thicker areas (such as along track edges) and when building up thicker coats. Once again, toxicity can be a concern with several excellent initiators ruled out because of health concerns.

Pigments are usually pre-dispersed in a suitable medium before incorporating them into the ink. It is essential that any dispersing agents used are compatible with the other components of the solder mask fluid, the pigments are stable during storage in both pre-dispersion and solder mask, and they do not settle or separate out. The pigments themselves must be able to withstand the processing and service conditions of the solder mask and must take account of any low-/no-halogen content requirements.

Other solder mask components may include flow agents, debubbling additives, surface property modifiers, thermal curing agents, and many others, depending on the final properties desired.

## Formulating Test Products

The protocol used for formulating and developing an inkjet solder mask is similar to that used when formulating standard solder masks.

### *Screen Formulations for Basic Solder Mask Properties*

A number of trial formulations are mixed in the laboratory. These can be quickly coated using non-jetting methods such as a wire-wound rod (K-bar) to deposit a known thickness onto a test substrate. The coatings are cured using different UV light sources to identify the most efficient curing method, and then baked as required for final cure.

Basic solder mask properties (e.g., solvent/chemical resistance solder resistance, hardness, etc.) are then evaluated. Pigment stability and hotbox stability of the test formulations can also be assessed at an early stage of the development.

### *Modify Formulations as Required*

Following the assessment of the test formulations, poor-performing versions are eliminated or modified as appropriate and re-evaluated.

### *Select Formulations for Jetting Tests*

Once a number of suitable candidates are identified, these are then jetted using an inkjet printer. Electra Polymers uses the LP50 laboratory inkjet printer from Meyer Berger. This printer has an integral, water-cooled UV LED for pin-curing and permits a number of print settings to be modified for different formulations (Figure 7).

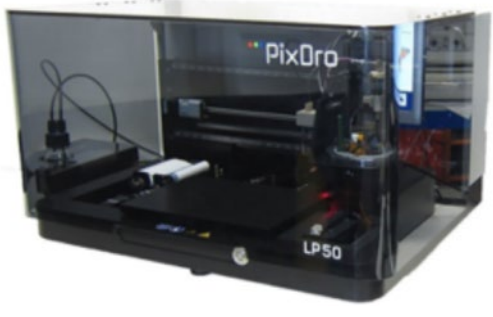


Figure 7: Meyer Berger DixPro LP50.

### *Evaluate Jetting Performance of Selected Formulations*

The jetting performance of the test formulations is assessed using the built-in drop watcher and by examining the resultant prints for image quality, coating smoothness, and a lack of "striping" and "stitching." The effects of

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- Low transmission loss

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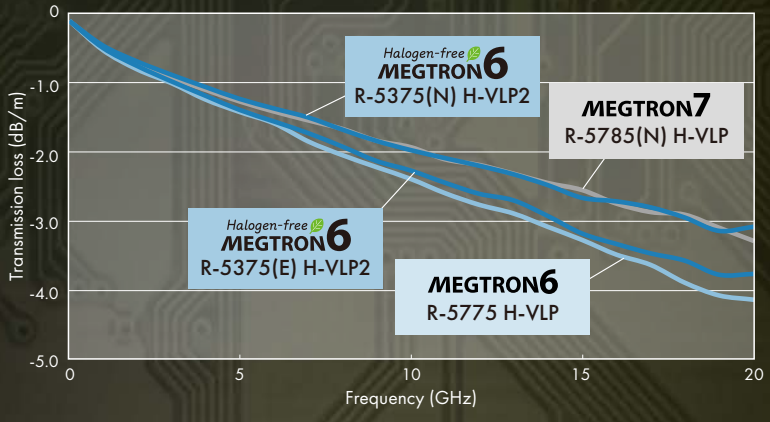
|---|---|---|
| **R-5375(N)** | 3.3 | 0.003 |
| **R-5375(E)** | 3.8 | 0.005 |
| **R-5775** | 3.8 | 0.005 |

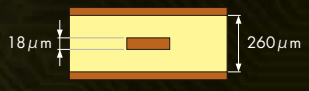
## Applications

- ICT infrastructure equipment, High speed networking(High-end server/ router, Optical network, switch), High layer count PCB, etc.

## Transmission Loss




• Construction




| | |
|---|---|
| Line length | 200mm , 100mm |
| Line width | 125μm |
| Impedance | 50Ω |
| Inner Cu treatment | No-surface treatment |
| Core | 0.13mm |
| Prepreg | #2116 56% x 1ply |

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relatively small changes in formulation properties, such as viscosity and surface tension, can be easily seen. The UV energy used for pin-curing can also be adjusted and optimized for good print performance and final properties.

### *Evaluate Cured Coating Performance*

Using the lab printer, suitable test coupons can then be printed, and the cured film properties fully evaluated. As well as the basic solder mask properties assessed at the basic screening stage, coupons for electroless nickel immersion gold (ENIG), immersion tin, and immersion silver are prepared and tested in different plating solutions.

### *Modify Formulations as Required*

After the jetting tests and cured coating performance results are assessed, further changes and modifications may be necessary. If so, these are made, and the effects of the changes reassessed.

As can be seen from the steps identified previously, the process of formulation is an iterative one, with many loopbacks and incremental changes. Designed experiments can be used where appropriate to speed the optimization of the formulation(s), but much of the work still relies on the skill and knowledge of the formulator and—some will say—is neverending.

### *Submit Final Formulation(s) for External Compliance Testing*

Once a "final" formation has been achieved, test coupons are sent to various external agencies for compliance testing to standards such as UL94 and IPC SM-840.

## Meeting Solder Mask Performance Requirements

Throughout the formulation process, the aim is to produce a product that meets all the performance requirements of a solder mask when applied on a PCB. These requirements are essentially the same for any solder mask, regardless of the type and application method—namely, to protect the (mainly) copper circuitry chemically, electrically, and physically from high temperatures, humidity, moisture, corrosives, dust, dirt, and contamination (Figure 8). Further, Figure 8 showed one example of why solder mask is needed.

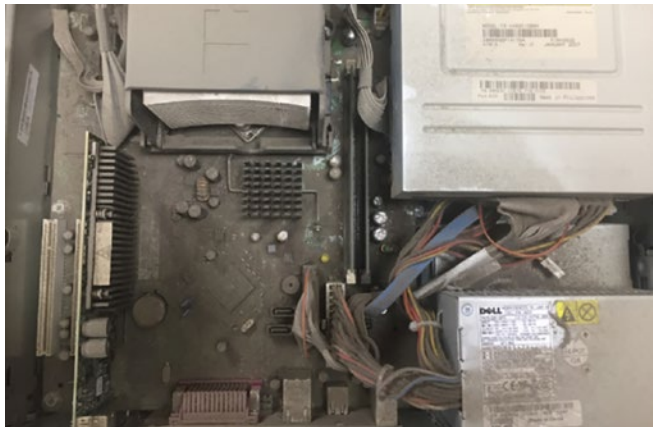

Figure 8: Solder mask can protect from real-world conditions, such as this.

Solder masks are also required to:

- Withstand ENIG, immersion tin, and immersion silver plating
- Enable adequate solder dam resolution
- Withstand lead-free soldering temperatures and multiple solder reflow cycles
- Be compatible with conformal coatings
- Contain low/no halogen

For a solder mask to be defined as halogen-free, it must contain less than 900 ppm chlorine or bromine and <1500 ppm total halogen. The phthalocyanine green pigments commonly used to produce solder mask contain 47–48% chlorine; even when used at typical levels of 1% or less, these contribute some 5000 ppm chlorine (Figure 9). For this reason, halogen-free solder masks tend to be either not green or a mixture of blue and yellow pigments to achieve a green color.

Ideally, an inkjet solder mask should also be a universal product, suitable for use on rigid and flexible, as well as with non-recirculating and recirculating printheads.

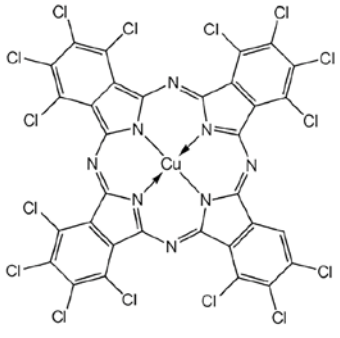


Figure 9: Phthalocyanine green molecular structure.

## External Compliance Requirements

Because the solder mask becomes a permanent part of the PCB during its service life, it is required to meet a number of external specifications on performance.

| | Bosch | | Hella |
|---|---|---|---|
| Specification | Test Conditions | Specification | Test Conditions |
| TC7 | -40/150°C, 1000hrs | G2 | 500 hrs, -40/170°C |
| TC8 | -40/160°C, 1000 hrs | G3 | 1000 hrs, -40/170°C |
| TC9 | -40/160°C, 2000hrs | G_? | 2000hrs, -40/170°C |

Table 1: Specification and test condition comparisons between two manufacturers.

### *UL 94*

UL94 is a flammability specification by U.S.-based Underwriters Laboratories. UL94 applies, in some form or another, to all electrical and electronic devices sold in the USA. For solder mask, UL94 specifies that the solder mask should not increase the flammability of the bare circuit board laminate by more than a permitted level, as measured under specific test conditions. Materials are rated V2, V1, or V0, with V0 being the highest-performing (least flammable) material.

Achieving a V0 grade can be more difficult for an inkjet solder mask—particularly on thin laminates—because of the lack of fillers. These can help to inhibit flammability, and their absence may require the incorporation of flame retardants in the ink to achieve it. The range of flame retardants suitable for use in solder mask inks is quite restricted, and patents exist to protect their use in this application.

### *ROHS Compliant*

ROHS compliance requires that the solder mask contain none of the heavy metals listed in the standard. This is usually not a problem, and products are easily certified to be compliant by an external test laboratory.

### *IPC SM-840E*

IPC SM-840 is an "industry standard" collection of solder mask performance and property-related tests covering temperature, chemical and electrical resistance, adhesion, etc.

### *NASA Outgassing*

Compliance with NASA specification SP-R-0022A/ASTM E 595 is required for polymeric materials—like solder mask—going into space. The specification requires < 1% loss of weight over 24 hours at 125°C in a vacuum.

### *Automotive Standards*

There are many automotive specifications, but some of the three most important, covering thermal cycling/storage of solder mask materials are shown in Table 1. Test pieces are cycled between low and high temperatures for a specified number of cycles and are then examined. Test pieces should not exhibit any cracks, blistering, or loss of adhesion.

Once again, the lack of filler in inkjet solder masks, which helps to prevent crack propagation, makes these specifications more challenging.

## Next Time

In the second part of this article, I will discuss the advantages of inkjet solder mask processes and present testing data.

## References


1. G.H. McKinley & M. Renardy, "Wolfgang von Ohnesorge," *Physics of Fluids*, 23, 127101, 2011.

2. B. Derby, "Inkjet Printing of Functional and Structural Materials: Fluid Property Requirements, Feature Stability, and Resolution," *Annual Review of Materials Research,* 2010.



**Chris Wall** is technical director and general manager for Electra Poymers Ltd. Wall is responsible for all aspects of the day-to-day operations of the company and for development activities including equipment, materials and processes.

# Have You Hugged Your Technical Review Board Lately?

## From the Hill

**Feature Column by Mike Hill,** MIL-Q-CONSULTING LLC

Increasing revenue is generally the general manager's top thought. It's seemingly the only lifeline to a sustainable enterprise. However, the other side of the equation is managing the risk of losing existing cash streams. For the most part, preceding such losses are multiple times of failing to meet customer expectations. This "longer" time frame gives management time to react, develop, and implement a get-well plan.

Typically, however, the sudden loss of a revenue stream is not part of the company's risk management plan. Maybe it should be when one of your streams is tied to PCBs fabricated to MIL-PRF-31032, and just maybe, the counter risk action might be as simple as periodic recognition.

The topic for this month's military column is the function of the Technical Review Board (TRB) as it pertains to MIL-PRF-31032 (military requirements for printed wiring board fabrication). The TRB's duties and responsibilities are the glue that connects the dots between the site, the Defense Logistics Agency (DLA), and the associated military revenue stream. Understanding these duties will help with resource allocation, general support, site priorities, and, most importantly, yearly re-certification to MIL-PRF-31032.

### The TRB Defined

The site forms a team of in-house experts to make decisions regarding printed board acceptability and certification. The TRB is a cross-functional team made up of responsible individuals selected from the different areas covered by the quality management (QM) program for MIL-PRF-31032. The TRB assumes full

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responsibility for managing the QM program. Thus, the TRB is the mechanism that the qualifying activity (DLA) uses to reduce oversight.

The TRB members must be identified by name and title. Since the TRB will be making important decisions about qualified materials product list (QML), a method for making decisions (majority rules, unanimous approval, etc.) must be documented. Other aspects of the TRB operation must also be described, such as how often the TRB meets to evaluate the status of the QM program, the standard meeting structure, and how records of these meetings are maintained.

Keep in mind that no two manufacturer's TRB will be designed the same. TRB membership, meeting frequency, etc., will depend on the size, structure, and capabilities of each manufacturing facility.

## The TRB's Responsibilities

The TRB's responsibilities are outlined in the following 18 items.

1. Implement and maintain the QM program: The TRB ensures the QM program is in place and working properly. The TRB monitors the QM program and makes any changes that it deems necessary.
2. Monitor the self-assessment audit: The TRB ensures results are effective and leveraged to contribute to continuous improvement.
3. Maintain certified processes: Through process controls, process monitoring, and continuous improvement, the TRB ensures the processes are producing high-quality products.
4. Manage process change control: The TRB must be privy to process changes and approve any major changes before qualifying activity notification.
5. Oversee reliability data analysis: The TRB must not only collect reliability data through lot and periodic conformance testing but also analyze the results to ensure continued compliance and product reliability.
6. Conduct failure analysis: When failures occur, the TRB must determine the cause of failure to help prevent reoccurrence.
7. Monitor and assess customer returns: At the TRB, these should be tied into the failure analysis and corrective action system as needed.
8. Ensure corrective action approvals: The TRB must ensure corrective actions are taken, that they are effective, and that any changes comply with the QM plan.
9. Address QML product recalls: When problems are discovered that may affect products in the field, the TRB must communicate with customers to help ensure continued operation and fielding of the affected weapon systems.
10. Review qualification status: At the TRB, this is done periodically as part of conformance verification inspection (CVI) to ensure the QML-31032 accurately reflects proven capability.
11. Dispose of test failures: The TRB ensures non-conforming products are properly segregated and oversees rework to make sure only fully compliant product is shipped.
12. Ensure communication throughout the process: The TRB ensures good communication and helps prevent costly failures later in the process.
13. Submit status reports to qualifying activity (DLA): A good status report involves all members of the TRB compiling data on the status of the QM program.
14. Assess the impact of changes in personnel and business plans: These changes can impact the QM program. Therefore, the TRB must be aware of them and determine if any actions are necessary.
15. Approve and update QM plan: The qualifying activity bases QML certification on the QM plan, so it is important that it accurately reflects the manufacturer's QM program.

16. Ensure a correlation between test coupons and printed boards: Testing is expensive, and the TRB must ensure that testing on coupons is accurately evaluating the product it represents and has traceability for future reference.

17. Approve periodic conformance inspection (PCI) test vehicles, frequency, and procedures: The PCI and CVI programs are important for long-term reliability assurance and process characterization. The TRB must ensure the program is meeting the specification requirements in a cost-effective manner.

18. Manage quality improvement programs: Continuous improvement is an active element of all QM programs. The TRB directs this by setting goals and monitoring the progress of activities.

## The TRB's Duties

The aforementioned responsibilities generate multiple duties/tasks that have to be performed for MIL-PRF-31032 continuous compliance. There are too many to mention all, but this partial list of 26 is already quite extensive.

1. Establish and implement the site QM plan for MIL-PRF-31032.

2. Maintain the qualification and certification processes.

3. Review, approve, and communicate all major process changes.

4. Ensure there are test vehicles, process control measurements, and reliability tests that collect sufficient data to verify compliance.

5. Ensure failure rates, customer returns, and complaints are collected and monitored on production parts compliant to Mil-PRF-31032.

6. Ensure that corrective actions are effective.

7. Review all associated MIL-PRF-31032 data at least on a quarterly basis and determine any actions necessary to maintain compliance.

8. Address the effect of management or business plan changes on the QM program and communicate to DLA as needed.

9. Address product recalls if necessary.

10. Review all rework on the discrepant material report (DMR).

11. Hold periodic TRB meetings to review all aspects of military compliance with minutes.

12. Approve any change to the QM program through ECN or TCF.

13. Correlate test coupons to production parts with DPA analysis.

14. Conduct add-on qualification data reports to the qualifying activity.

15. Document customer deviations to the specification.

16. Address test optimization (sample plan reductions) as needed.

17. Monitor the self-assessment (internal audit) and follow-up within 30 days.

18. Purchasing process: Through system audits, ensure material and services conform to the purchase requirements.

19. Incoming inspection: Ensure procedures are reviewed and audited.

20. Material evaluation: Ensure new materials are evaluated before use in production.

21. Process and flow changes: Review and approve all major process changes.

22. Corrective actions: Ensure the timely closure of all corrective actions.

23. Once every two years (biannually), produce a capability verification inspection (CVI) report, indicating attribute compliance to the present QML will be completed and sent to DLA for review and approval.

24. Send yearly compliance reports to the qualifying activity.

25. Technical reports: From time to time, tests done for compliance-related activity will be documented in a report.

26. Add-on qualification data reports will be sent to the qualifying activity when the test data is accepted by the TRB.

## Summary

Please note that TRB membership, in general, is in addition to the person's normal workload. Such work occurs in the background of day to day activities and, as a result, offers little to no additional recognition. On the other hand, the minute a site loses certification, these TRB members are thrown under an uncomfortable microscope.

"Stop production" orders from the DLA occur for various reasons—all of which are deemed to jeopardize the integrity of the customer's finished PCBs. Most often, such "stop orders" are the result of the DLA triannual site audit when major supply chain issues are discovered. DLA audits last three days with the "stop production" order effective immediately. The corrective action is never easy and usually takes months. Such a loss of certification/revenue usually lasts a minimum of six months and could easily stretch to 12.

If your site's certification continues year after year in what seems like a simple, on-going, non-crisis process, every member of your TRB deserves a hug and recognition for the continuity of the site's military revenue stream. It's the simplest part of the company's risk management plan. **PCB007**

## Reference

1. Certification and Qualification Information for Manufacturers (MIL-PRF-31032); DLA VQE-31032, Revision G, DTD, August 2013.

**Mike Hill** is president of MIL-Q-Consulting LLC. He has been in the PWB fabrication industry for over 40 years. During that time, he participated in specification writing for both IPC and the military. Past employers include ViaSystems, Colonial Circuits, and DDi. To read past columns or contact Hill, click here or email Milqconsulting@outlook.com.

# Consistent Registration: CB Tech's New Direct Imaging System


Frank Medina, president and CEO of Technica USA, introduces Harry Kok, international sales director at CB Tech, who explains the features of the CB Tech "Titan" direct imaging system, which has very high throughput capability with best-in-class registration consistently maintained from the beginning to the end of the batch. **Click image to view this video**.

# Electronics Industry News and Market Highlights


## Raytheon Facility Earns First True Platinum Zero Waste Certification in Texas ▸

Raytheon Company earned the first TRUE Platinum Zero Waste certification in Texas for its advanced manufacturing center in McKinney. The site earned the designation for its innovations in resource management and waste reduction.

## Rockwell Automation Strengthens Control and Visualization Portfolio With Acquisition of ASEM ▸

Rockwell Automation Inc. announced it signed an agreement to acquire Italy-based ASEM, S.p.A., a leading provider of digital automation technologies. ASEM provides a complete range of industrial PCs, human-machine Interface hardware and software, remote access capabilities, and secure Industrial IoT gateway solutions.

## IPC Issues Call for Participation for IPC E-TEXTILES 2020 ▸

IPC invites innovators, technologists, materials suppliers, electrical engineers, and academicians to submit technical conference abstracts for IPC E-TEXTILES 2020 to be held September 29–30, 2020, at the University of Minnesota Coffman Memorial Union in Minneapolis, Minnesota.

## DARPA Selects Aerojet Rocketdyne to Develop Propulsion Technology for the Hypersonic Defense Program Glide Breaker ▸

Aerojet Rocketdyne has been awarded a contract worth up to $19.6 million by the Defense Advanced Research Projects Agency (DARPA) to develop enabling technologies for an advanced hypersonic defense interceptor known as Glide Breaker.

## Sypris Wins Contract With BAE Systems ▸

Sypris Electronics LLC, a subsidiary of Sypris Solutions Inc., announced that it has recently received a contract award from BAE Systems' Electronic Systems sector to manufacture and test electronic power supply modules for a large mission-critical military program. Production will begin in 2020. The terms of the agreement were not disclosed.

## Flagship Qualcomm Snapdragon 865 5G Mobile Platform Powers the Samsung Galaxy S20 Series ▸

Qualcomm Technologies Inc. announced that its latest flagship Qualcomm® Snapdragon™ 865 5G Mobile Platform is powering Samsung Electronics Co. Ltd.'s latest and most cutting-edge smartphones, the Samsung Galaxy S20 series (S20, S20 + , and S20 Ultra), for select regions.

## Bell Boeing Delivers First V-22 for U.S. Navy's Aircraft Carriers ▸

Boeing and Bell Textron Inc., a Textron Inc. company, delivered the first CMV-22B Osprey, which is the V-22 variant the U.S. Navy will use for transporting personnel and cargo to aircraft carriers at sea.

## Meet Six Smart Robots at GTC 2020 ▸

The GPU Technology Conference is like a new Star Wars movie. There are always cool new robots scurrying about. This year's event in San Jose, March 22–26, is no exception, with at least six autonomous machines expected on the show floor. Like C3PO and BB8, each one is different.

## Ground-breaking Solar Powered Unmanned Aircraft Makes First Flight ▸

PHASA-35, a 35m wingspan solar-electric aircraft, has successfully completed its maiden flight. The landmark flight paves the way to this new aircraft becoming a game-changer in the air and space market, plugging the gap between aircraft and satellite technology.


# DREAM BIG: 2019 PCB Global Executive Forum

**Article by Tulip Gu**
I-CONNECT007 CHINA

When the exhibition "Genius Relativity: Einstein's Whimsical World," came to Shanghai, I was able to take a close look at the piece of paper with the formula "$E = mc^2$" that was handwritten by Einstein, and I couldn't help but appreciate the innovative thinking of this scientific giant.

This came to mind when I attended the "Dream Big" 2019 PCB Global Executive Forum held by Orbotech in Guilin, Guangxi. Orbotech's ambition, enthusiasm, and enterprising spirit captured my attention. Over the course of the event, I gained a better understanding of the company.

The forum was divided into two days. The first day consisted of Orbotech's company history and technology development introduction, industry experts' analysis of global PCB market trends and the future of the Chinese PCB industry, roundtable discussions on the latest technologies, and more. The second day highlighted a new product release and technology announcement, and the technical presentation was on IC packaging.

## The Forum

In the opening speech at the forum, Meny Gantz, VP of marketing for Orbotech's PCB Division, talked about the "bamboo spirit" when describing the company's growth process, as well as developments in the electronics industry. He explained how the plant is "dormant for five years and born in one month."

Hot topics from the forum included: flex, IC substrates, and AI applications. On the first day of the event, industry leaders shared insights, and participants felt that the Chinese PCB market had great potential. Brian Swiggett, managing partner at Prismark Partners, said that he believes that the Chinese PCB industry will grow faster in the next five years and that the substrate market has shown signs of recovery. As was pointed out by Lei You, the Chinese domestic PCB industry has entered an adjustment period, with needs shifting from scale to efficiency. He continued with the point that, in the future, industrial production would be intelligent, and PCB and equipment would grow together.

The forum organizers also invited four special guests from the PCB industry who dis-

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Participants enjoyed a once-in-a-lifetime gala dinner in a 180-million-year-old cave in the spectacular town of Yangshuo.

cussed the development potential and prospects for the 5G era. The content detailed changes that 5G will bring to the PCB industry, including technical challenges, materials facing major development opportunities, and the production requirements of 5G product solutions. This session gave participants a wealth of knowledge and generated a series of questions, which were answered the following day.

Orbotech continues its long-standing investment in R&D, holds more than 600 patents, and is staffed with 350 scientists and engineers. The company has made continuous progress in LDI, anti-welding direct imaging for solder mask, AOI, AOS, inkjet printing, laser drilling, CAM and engineering solutions, and Industry 4.0 solutions, among others.

Orbotech also announced that, in 2020, six new products would go to market. These new products will be integrated into areas where Orbotech excels, using various unique technologies that are continuously perfected. These products will also provide solutions around the themes of high capacity, high yield, high quality, superior material transfer, and compact, integrated systems.

The IC substrates market is also a field in which many industry leaders compete. This is increasingly the case, as China's manufacturing continues to respond to customer demands. As Yole's CEO Jean Christophe Eloy pointed out in his speech, the IC substrate market is like a "giant waking from a long sleep." As a result, today's supply chain is improving.

Arik Gordon, Orbotech's corporate executive VP of growth, also pointed out during his session that IC technology is affecting the field of PCB design and that this deeply impacts the manufacturing process for PCBs. Leading PCB companies, therefore, will face reshuffles due to financial and technical reasons. It is expected that by 2023, the substrate market will reach 10 billion USD, and Orbotech will be ready with a range of solutions to support it.

## Dream Big

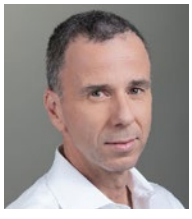
In his opening speech, Meny Gantz also said that to achieve dreams, we must first "plant seeds, have faith, and then take action." If we want to make more progress, Gantz said, we must work hard with our partners.

In his speech, Charles Shen, chairman and CEO of Avary Holding, also shared examples of cooperation between Orbotech, SAA, HIWIN, and other companies. Shen said that the development of the PCB industry so far cannot just rely on individual companies but must rely on the entire industry.

The speakers for this forum were all industry leaders, and the output in product and revenue created by their companies amount to approximately half of all of China's PCB industry.

## A Talk With Yair Alcobi

To further understand Orbotech's plans and perspective, I spoke with Yair Alcobi, Orbotech's PCB Division president, during the meeting.



Yair Alcobi

**Tulip Gu:** Since 2015, Orbotech has put forward the concept of "the language of electronics" and strived to create the goal of an electronic product language expert. Is this concept given a new meaning this year?

**Yair Alcobi:** The manufacturing of electronic products can be classified as a language because the foundation of language is reading, writing, and conversation; the literacy of electronic product manufacturing covers these foundations. The language of electronics contains a variety of solutions that Orbotech currently offers. Because we are experts in electronic languages, Orbotech is also an important promoter for realizing the great dreams of designers. Nowadays, this concept has more new sub-concepts and more levels of interpretation, including our understanding of the ecosystem, the understanding of the industry, and the understanding of solutions.

**Gu:** Orbotech was established 38 years ago, and during that time, Orbotech has continued to lead innovation in electronics manufacturing for mass production. In 2020, Orbotech is due to launch many new products. What is the significance of these intensive new product releases to the entire industry?

**Alcobi:** 5G development will generate new trends in the FPC market. For flex board production, Orbotech has automated solutions. For example, the roll-to-roll manufacturing process will promote the production of flexible boards to a higher level and help FPC manufacturers achieve better mass production.

At the same time, we are pursuing the goal of high precision. We will improve on the high-quality processing solutions and fault tolerance. In addition, the structure of RTR can realize full automation, ensure superior material transfer, and further ensure the production accuracy requirements. Also, the equipment is sealed and miniaturized to meet the current market demand. For the new products, we will have special projects and plans to launch in 2020 and beyond.

**Gu:** Each of Orbotech's eight major product series addresses the roll-to-roll requirements of flexible boards, high-precision line alignment, and increased automation. Lei You, chairman of the CPCA, mentioned a very interesting concept in his guest speech. He said that many current Orbotech devices did not exist five years ago, and numerous devices will be created in five years. What are Orbotech 's key considerations in R&D?

**Alcobi:** We must fully understand the major market trends in the industry. In addition, we will also address other factors, such as efficiency, resolution, accuracy, line width, line spacing, and quality requirements. To provide an accurate product, we must consider how to achieve mass production, how to achieve full automation, and how to connect with other equipment.

Therefore, we will integrate various technical parameters to combine market trends and customer needs. This is our method for future deployment. But no matter how the future changes, it can take six or seven years of continuous R&D work from the initial development of the technology concept to feasibility prototyping and productization of that technology.

**Gu:** During your speech, Orbotech promised that R&D would continue regardless of the market fluctuation. How can we better understand that?

**Alcobi:** We see how much of the company's revenue is used for R&D, which is an indicator of the company's efforts. In the past 10 years


Attendees took part in a cruise on the Li River that made the author feel like she was part of a small-scale bonsai landscape.

of Orbotech, we have gone through two cycles. Regardless of whether the economy is good or bad, our investment in R&D is very stable and has been maintained at approximately 12–14%. We know that the market is bound to fluctuate, but no matter how the market performs, we must invest in R&D.

I also mentioned earlier that the entire R&D process for a product from concept to market launch might take six or seven years, so we cannot interrupt this investment. If the market is in a downturn and you interrupt the investment, when the market is warming up, you may miss the opportunity, so we will continue to invest regardless of the degree of market prosperity, which is also a great challenge for us. For example, when the market is optimistic, it is easy to decide to invest, but when the market is down or not progressing, investment in R&D is indispensable.

**Gu:** We understand that investing in R&D is a smart business behavior. In fact, there is more industry responsibility behind it. Just like this conference today, everyone is emphasizing the ever more significant improvement of the entire industry chain and the technology brought by suppliers. Everyone agrees with this. This is consistent with Orbotech's own cultural values, and it helps customers succeed. We know from Shen's presentation that Orbotech has a long-term cooperative relationship with Avary. For other small and medium enterprises, how can Orbotech enable improvements from the perspective of suppliers?


Traditional dress, music and dance were part of the entertainment.

**Alcobi:** That is a good question. Today, Avary is the world's largest PCB manufacturer, but 15 years ago, when we started our relationship, it was not a big company; it was only worth 30 million USD. We have a total of more than 950 customers, including enterprises of all sizes, and these customers do not purchase from us every time, but we continue to provide support to our customers through a wide range of products to suit the needs of different industries.

We also have some smaller customers and tailor-made solutions that are suitable for them. If the customer has very clear needs and wants to cooperate with Orbotech, we can also co-develop with them. For example, some customers with an output value of 20 million USD may spend millions of dollars to buy our DIY products. SMEs come to us, hoping to grow with Orbotech while big companies come to us because they trust us. Different customers will have various purchase needs, and we will cooperate according to the situation.

**Gu:** Technology development in the PCB industry is particularly fast. Enterprise customization requirements are much greater than before. For this part, what characteristics of the Chinese market are different from other countries, and how does Orbotech adjust? Or what good experiences do Chinese enterprises need to learn where Orbotech can act as the promoter?

**Alcobi:** We have operations all over the world, but China's PCB industry accounts for a significant proportion, and it is an important strategic partner for us. In the past many years, some Chinese manufacturers may not be particularly good regarding initial technology and can only produce low-end PCBs, but the situation is completely different now. For Chinese PCB manufacturers, they can do almost everything. A small number of Chinese companies in the IC substrate sector are emerging.

For Chinese PCB manufacturers, we can start from process innova-

tion and work with companies to help them solve problems, improve product performance, provide better solutions, and enable equipment and systems to reach the optimal level. Chinese companies are characterized by learning fast and working hard to cope with the changing industry and world. I think the Chinese market is very good and can grow quickly. This is a great advantage. I think the PCB industry will become bigger and stronger in China. The future is bright.


In Guilin, the striking landscape formed a combination of hills, rivers, and caves the world's rarest type of karst scenery.

**Gu:** For suppliers, they are not only promoting products to customers, but they also want to be recognized for their culture. At Orbotech, cultural identity may be more important, including today's meeting, which emphasized the significance of a good relationship with customers. At this point, what differences in ideas between the two sides do you think need to be bridged when you talk about cooperation, business, and friendship with Chinese customers?

**Alcobi:** The largest branch of Orbotech is in China, but we are also a global company. In China's PCB business, there are 400 employees. From this perspective, our culture is not much different because we employ local employees. For Chinese customers, trust is key. We want to show these Chinese customers that they can trust us. How can this be done? Firstly, you have to give and help, and then you may get a reward.

Secondly, there must be good products. In the past few years, we have worked hard to build our relationships. Many of our customers present today have been working with us for 20 years. Of course, there are also some very young people who have established a good relationship with us as well. Cooperation is based on trust. We have also made great efforts to maintain the trust we have established with our customers. This is how we do business in Israel.

**Gu:** Orbotech gave a very easy-to-understand example—the growth of bamboo. I hope to see new products being launched to the market as soon as possible, which can help Chinese organizations respond to 5G and new market developments faster.

**Alcobi:** The next few months will be very exciting, and we plan to launch new products throughout 2020.

**Gu:** Yes, you release new products very quickly.

**Alcobi:** And not only do we have ideals, but we also have actions. If you only have dreams, you are a dreamer, but you must take action to make things happen.

**Gu:** Okay, thank you very much.

**Alcobi:** Thank you. **PCB007**

**Tulip Gu** is the executive editor of *I-Connect007 China. Prior to joining our team, she was an editor for CPCA where she conducted interviews and wrote hundreds of articles about industry leaders*

# Guerilla Tactics to Pass Any QMS Audit, Part 1

**The Right Approach**
**by Steve Williams,** THE RIGHT APPROACH CONSULTING

## Introduction

"Guerrilla tactics" was chosen as the name for this series to reflect a number of nontraditional, take-no-prisoner concepts, techniques, and tactics that were born in the quality trenches and will guide any company to a successful audit result. These guerrilla tactics are also framed around what I call the 10 Williams' Laws; my lessons learned in over 40 years of getting my hands very dirty in the quality trenches.

I would be so bold as to say that if the entirety of this series was truly embraced and flawlessly executed, an expectation of zero audit findings could be not only achieved but maintained! How is that for a pretty bold statement? Also, how do I know this can be done? Because I have done it more than once. Descriptions I would use to characterize the proven tactics presented in this series are words such as unconventional, focused, speed-based, tactical, dynamic, and high integrity.

## Character and Integrity

What this series will not present are quick and dirty ways to circumvent requirements, methods to "fool" an auditor, how to "buy" your ISO registration, the top 10 bribes most likely to be accepted by an auditor, or shortcuts for not doing the day-to-day work that is required for an effective QMS. What this series will present are legitimate, aboveboard techniques that pass the integrity smell test.

I believe that in life, character and integrity are everything. This belief was somewhat validated during a recent conversation with one of the few politicians worth their salt, J.C. Watts. Before he became a member of Congress, J.C. was quite the quarterback for the University of Oklahoma, and later professionally in the Ca-

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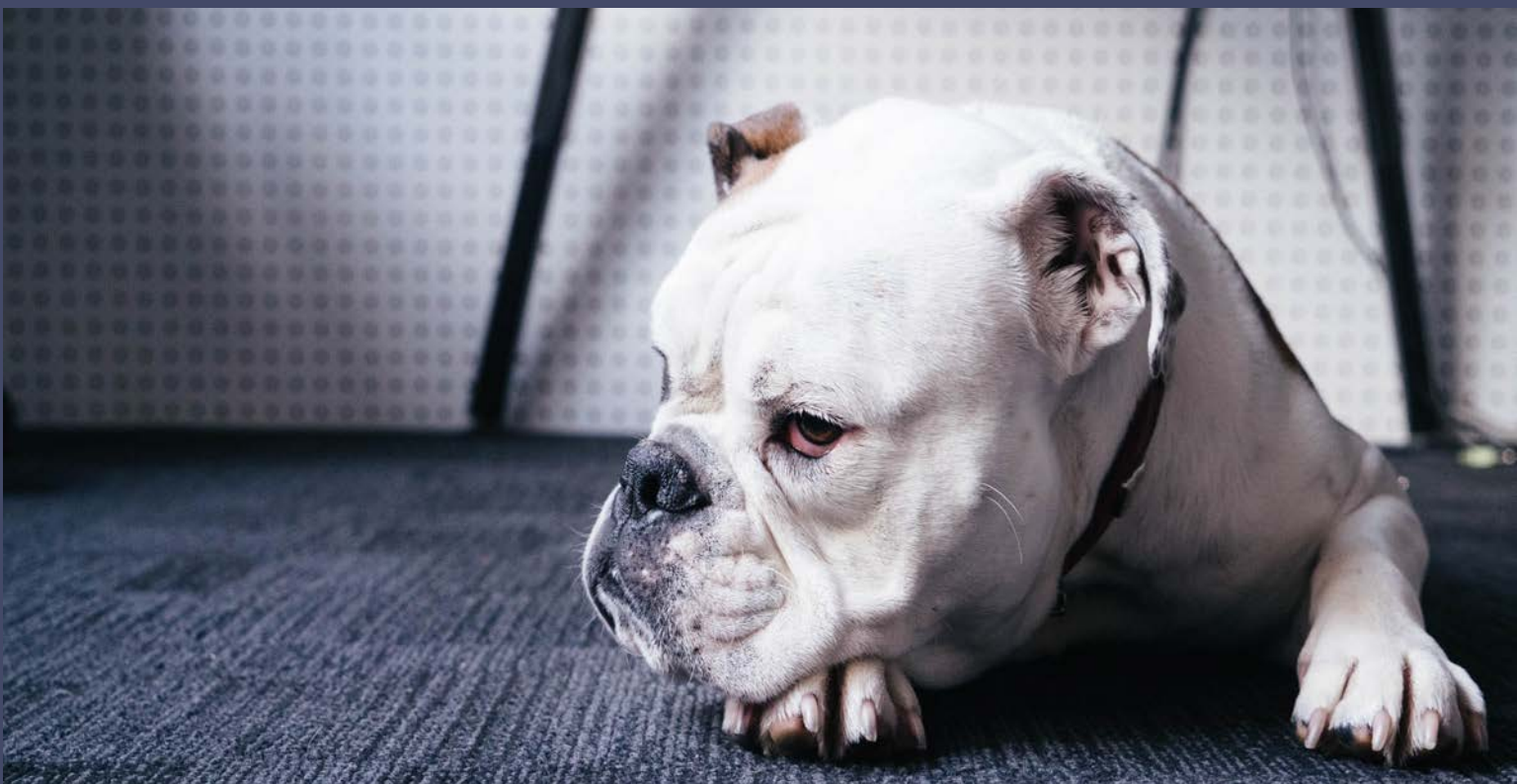

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nadian Football League. Over a cold beer one night, J.C. said, "Steve, I've always felt that character means doing the right thing when nobody's looking. There are too many people who think that the only thing that's right is to get by, and the only thing that's wrong is to get caught." Words to live by.

## Guerrilla Tactic 1:
## Quality Executive Skill Set

### Williams' Law 1

*Never fear an unexpected customer visit. If every employee lives and breathes the quality system every day, there will never be a need for an audit-prep panic.*

This first tactic/law was previously published as a standalone column titled "Steve's Particular Set of Skills (to become a World-class Quality Manager)."

## Guerrilla Tactic 2:
## Make It Fun!

### Williams' Law 2

*When things are fun, things get done!*

This second tactic/law was previously published as a standalone column titled "Making Quality Initiatives Fun."

## Guerrilla Tactic 3:
## Visual Management

### Williams' Law 3

*First impressions count.*

The Japanese word for visual controls is Andon, and visual management is key to success in any system. One of the mistakes many organizations make is to cultivate an environment of secrecy when it comes to organizational performance as if this knowledge is dangerous to share with employees. Quite the contrary is true. Displaying accurate, timely metrics on a visual management board will both engage employees and instill a sense of ownership in the company's performance (Figure 1).

Key visual management metrics include:

- Quality goals
- Revenue
- Internal quality defects/yield
- External customer returns and survey results
- Kaizen events
- SPC data
- 5S successes
- PIT crew activity and successes
- Continuous improvement awards
- Rally schedules, minutes, and pictures
- Audit (customer visit) schedules


Figure 1: Visual management dashboard. (Source: Crown Paints)

## Guerrilla Tactic 4:
## Internal Audit Strategy

### Williams' Law 4

*Find your own dirty laundry.*

While a robust internal audit system is a bit of a given in a good quality program, there are some strategies that, if employed, will provide a number of intangible benefits during any quality systems audit. It is easy for the management representative or department supervisor to have all the right answers, so encouraging auditors and customers to interact with the employees doing the job will demonstrate the strength and competency of the workforce and the quality system.

The internal audit program should be used to help condition employees to be comfortable in this situation. For example:

- Audit trainer should be formally "lead-assessor" trained
- No "conflict of interest" auditing (you cannot audit your own process)
- Train auditors to "see as the customer sees"
- Complete system cycle every six months (calibrate with six-month surveillance audits)
- Closed-loop follow-up audit for findings
- Develop procedure-specific audits
- Integrate common system-level questions into every audit
- Audit employees' ability to recite the quality policy and battle cry
- Audit line workers, not supervisors (supervisor can assist but not answer for employees)

### Conclusion

It is my desire that as we work through the various strategies, techniques, and tactics presented throughout this series, you will appreciate that these are tried-and-true, practical applications and lessons learned over the course of my career that I hope you will find some value in. **PCB007**

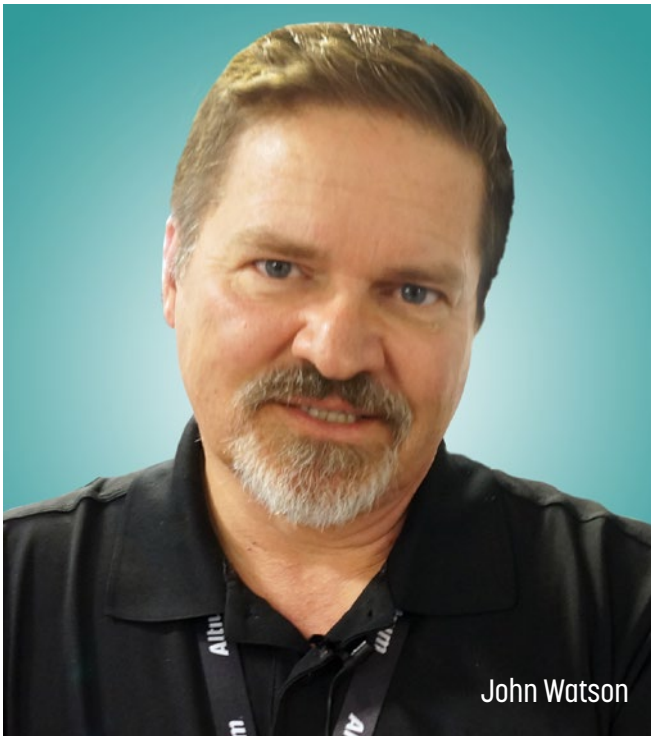
**Steve Williams** is the president of The Right Approach Consulting. To read past columns or contact Williams, click here.

# Taiyo's Solder Mask Developments


Pete Starkey and Don Monn, Midwest regional sales director at Taiyo America Inc., discuss progress with the establishment of inkjet solder mask as a production reality, now with OEM approvals. Don also addresses the development of crack-resistant white solder mask and new screen-printable formulations with very high thermal conductivity.

**Click on the image to view this video.**

# When Your Fabricator Is Late


John Watson

**Interview by the I-Connect007 Editorial Team**

The I-Connect007 Editorial Team recently had a wide-ranging discussion with John Watson, CID, of Legrand. Questions covered include, "What happens when your fabricator is late, whether it's a prototype or volume production?" and, "What are the costs and ramifications up and down the chain?"

**Andy Shaughnessy:** You and I have spoken before about time to market, and how we're all battling time. Let's talk about what happens when one cog in the system is late. What are the costs?

**John Watson:** Time is the big issue that I hear about. The VPs at my company say, "We need to decrease our time to market," because they see our competitors. The lead dog always gets that biggest piece of the pie if they can get out there with their product first.

**Barry Matties:** To that point, when you're working with your fabricator, you place the order, and they give you a delivery date that then goes one, two, or three days late. What happens if they miss it by one day?

**Watson:** That has a significant impact.

**Matties:** From a designer's point of view, what does that do to you?

**Watson:** It puts us in a place where you can't put a number on it for how much market share you've lost. We have a lot of external things involved in our design process that throw monkey wrenches into it, such as tariffs because we do work with China. One of our places is in China, so we have some outside influences on our designs, but we try to keep it to a consistent schedule. We identify what we call "blockers" in what we're trying to accomplish, meaning things that are blocking us both internally and externally. We need to identify those blockers and get them out of our way because those can constantly be problems. I would talk to the fabrication house about potential issues.

**Happy Holden:** The first thing you learn as a young engineer at Hewlett-Packard is break-even time. It's like ROI, but for designers. It came about because if design managers hit obstacles and they're going to be late, they go to management and say, "I need more resources,"

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and managers say no. Lo and behold, they are late. Hewlett-Packard made money off of being the first to market. Then, Stanford MBAs used Professor William Ireson's idea of break-even time, which the financial guys understood. Break-even time is when the profits have paid for all the R&D development money, so it's not a return on investment. After the break-even time, you're truly making a profit.

**Matties:** You had your schedule.

**Holden:** And if they were too late, they would pay us more.

**Matties:** Do they agree to that in advance?

**Holden:** Yes, before they ever took the orders. If they didn't, they didn't get any orders.

**Matties:** I don't know many board shops that have a money-back guarantee for on-time delivery, so to speak, because it's more than money back.

**Holden:** That's right, but they only gave us money, not time, so they couldn't possibly compensate us. If they were one day or two days late, they didn't get the next order because time is so valuable, especially in being first to market. We were only going to make the profits in the early six or eight months before everyone else jumped in and lowered the price.

**Matties:** That was your highest margin period.

**Holden:** Many times, we'd design the second generation at the same time as the first generation. The first generation was about time to market, and the second generation was about lowering in cost. As everybody copied our first generation, we introduced the second generation and dropped the price dramatically, so they all dropped out of the market.

**Matties:** Back to external blocks, if you have a fabricator that you think is going to be on time, and then they wind up being a few days late, how do you handle that?

**Watson:** We do our fabrication internationally, so we have less control over the fabrication processes than I would like.

**Matties:** But when you place an order, they give you a delivery date and miss it, there's a consequence for you.

**Watson:** Right. Often, we have to do a root-cause analysis to try to solve some of those issues in the future.

**Matties:** If the manufacturer caused you to be late, what is the ramification?

**Watson:** The main ramification, if they continue doing that, is I would drop them and find another fabricator that can follow the schedule. The fabrication industry is such a dog-eat-dog world. They will make any promise to get that contract.

**Matties:** When you place an order, do you look for some sort of guarantee?

**Watson:** We can't do that in our situation, but I think it's a good idea for structuring.

**Holden:** What if they're one day early? You have to accept that if you're going to charge them for being late, you have to give a bonus for being early.

**Watson:** Exactly.

**Holden:** The companies that do it can take advantage of it because they're giving you a conservative time. But if they get a bonus for doing it earlier, they'll carry the stick.

**Watson:** Right now, we are getting more and more into high speed, and that is going to require us to have specific material and control our design, especially in fabrication. The biggest problem I have in dealing with international fabrication houses is there's this "curtain" of an image that they put out. The fabrication house will say, "Yes, we can do it." Later you ask, "How did it go?" They some-

times respond, "Everything went perfectly! We'll ask our fabrication or assembly house, "How many boards fell out of the design process?" Again, they'll say, "We had 100%."

**Matties:** I was born at night, but not last night!

**Watson:** I fell off the truck, but not the turnip truck. Statistically, it is impossible that everything was perfect. That's not good information or feedback for us to operate on because we're looking to improve, and I know it's not perfect. Working with international suppliers is very difficult.

**Matties:** How are you handling your prototypes?

**Watson:** We handle our prototypes domestically, which comes with its own problems. Understand that a prototype is only the beginning process because you design, fabricate, and assemble it with more of a controlled situation. When we do things domestically, I talk to the fabrication and assembly house to find out the details because we want to make sure that we monitor everything in detail of this design; I was just on the phone this morning doing that with our fabrication and assembly house in Germany. That works well to get a high-quality board. Next, the board will be put forward in the process, and a lot of times, we look at compliance and certification.

Then, you switch everything over from domestic to international and lose control of our entire design, fabrication, and assembly. We may lose compliance. Compliance is not something you want to redo, so we have to take it down to a point before it gets into compliance and then transfer it over to the international level and get that certified. We want the certification based on what we're going to be building, not just a prototype. It's great if you have a product you can verify, but somehow, that has to be translated into the international area.

**Holden:** Why do you go to international companies?

**Watson:** Price.

**Holden:** If you could get the prototype for the same price as the high-volume international, would you use the same source?

**Watson:** I think we would.

**Matties:** More and more offshore fabricators offer that. We see the lot size move down to 40 in some of these big places.

**Watson:** These are some of the conversations that I'm going to have in a couple of weeks in China. I'll be in Shanghai to discuss it with our board house.

**Matties:** This is bad news for U.S. fabricators.

**Watson:** True, but there are so many restrictions on U.S. fabricators, especially in California. The restrictions on chemicals and processes that can be used have killed PCB fabrication in the U.S.

**Shaughnessy:** Of course, state regulators would say it was because they dumped everything in the river for many years.

**Holden:** Even the Chinese are learning that PCB fabrication has a lot of nasty chemicals. Now, the Chinese are moving to Vietnam because they can't meet their own emissions standards.

**Watson:** It's starting to impact China like what we have gone through here in the U.S.

**Matties:** When you do prototypes, this is a race for time as well. If a prototype house is late, what impact does that have on you?

**Watson:** It has much more of an impact on the beginning of the project than it does later on because everything is lined up waiting for this hardware and ready to move forward with that prototype. That's the reason why I was on the phone with Germany this morning: They were a day behind. I asked them some very serious questions about what was going on with the delay.

**Matties:** That's typically their issue, not yours.

**Watson:** Right. A lot of times, the biggest issue is the procurement of parts, especially when you're doing a quick prototype. When you have a fabrication that only takes a day or two, especially a simple four-layer board, you're doing a day or two of fabrication, and you have a day or two to get parts in.

**A lot of times, the biggest issue is the procurement of parts, especially when you're doing a quick prototype.**

**Holden:** When we wanted to beat everybody in time to market, one of the big problems was that the time delay in getting a solder paste stencil was two weeks. Somehow, they magically couldn't get that time down in the printed circuit, so we put the solder paste on while it was still in the board shop at the panel level. The prototypes never have any solder paste stencils; they flux, place the part, and reflow. That saves all of these days that our competitors put in that we never had. Think outside the box and consider how you can get past the bottleneck.

**Watson:** They have solder paste stencils now. I understand that they're 3D printed onto the board.

**Holden:** But they don't print it at the board level, where you have all the things already in the panel. That's a much higher resolution when it's a panel. That was one reason we were always interested in jetting solder paste rather than stencil; however, it interferes with the components, but not in the bare board state because there are no components at the bare board state. The simplest solution is right here, not fighting the powers that be.

**Matties:** When you have a string of vendors lined up, and you're a day late, that hurts.

**Watson:** For every fabrication and assembly build, we do a post-mortem analysis covering how well we did and what issues arose. We find the root cause of the problem and try not to do that again. A lot of that is done now through managing projects in Altium and the collaboration tools. Everything is documented inside the PCB design. If we have problems, then that communication about solutions happens inside.

**Holden:** I think the key thing is you have a post-mortem. We had a post-mortem after every design at HP. We would review the problem and write down how we could do this better and faster the next time.

**Watson:** Those post-mortems are fantastic because that's where you start to analyze yourself, including how well you did and what the issues were.

**Matties:** This is where the truth really matters, though. You have to realize you're attacking the process and not the people because when they feel so connected to their work, it's hard not to take it personally.

**Watson:** Right. And you constantly keep trying to improve that process.

**Matties:** Thank you for your time, John.

**Watson:** This has been great. Thank you all. **PCB007**

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# Eliminating Waste From Electrolytic Acid Copper Plating

**The Plating Forum**
**Feature Column by George Milad,** UYEMURA

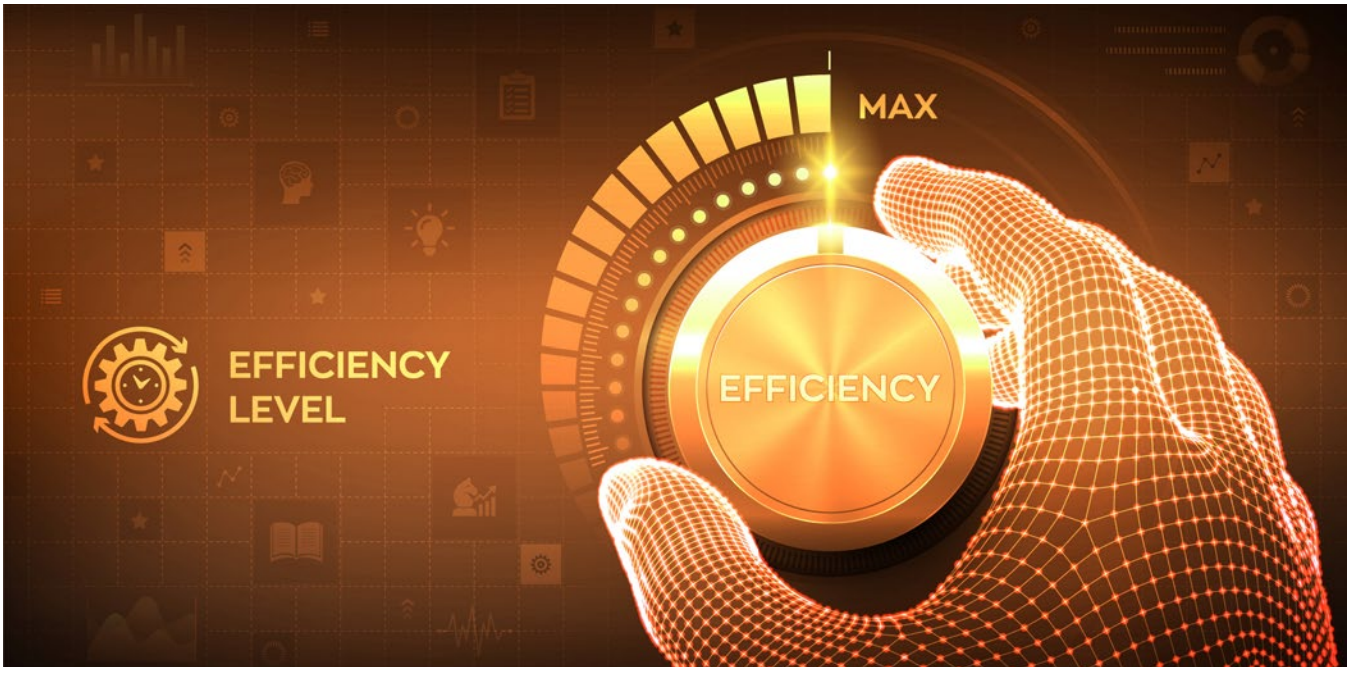
Acid copper plating in most shops is done in vertical plating tanks. Acid copper solutions are not dumped but are continuously used with occasional carbon treatment to remove organic build-up from the additives and from dry film leaching. Anodes used are commonly copper balls in titanium baskets. The copper metal at the anode is continuously oxidized to the copper ion and goes into solution. The copper ion is then reduced to copper metal at the cathode (the panel):

- At the anode: $Cu^0 \rightarrow Cu^{++} + 2e^-$
- At the cathode: $Cu^{++} + 2e \rightarrow Cu^0$

The plating reaction requires vigorous solution movement to maintain the replenishment of copper ions at the plating interface. This is normally done by strong uniform air agitation. Air is a mild oxidant and would help the anodic oxidation and the dissolution of copper.

Over time, the copper content of the electrolytes will continue to rise to the point where it would violate the upper specification limit for copper concentration to meet the throwing power and integrity of the plated copper. When this occurs, the bath is diluted down by a partial dump and remake to reduce the copper concentration. The dumped electrolyte is then waste-treated by the use of alkaline precipitation. The copper falls out of solution as copper hydroxide. Then, the precipitate is filtered out using a filter press, bagged, and disposed of by a certified waste disposal company. This is labor-intensive and costly; it also does not help the environment.

The use of air sparging creates an acidic mist that pollutes ambient air in the plating area and is hazardous if not properly removed. This is accomplished by an exhaust system above the tank. Exhaust systems are costly to build and maintain.



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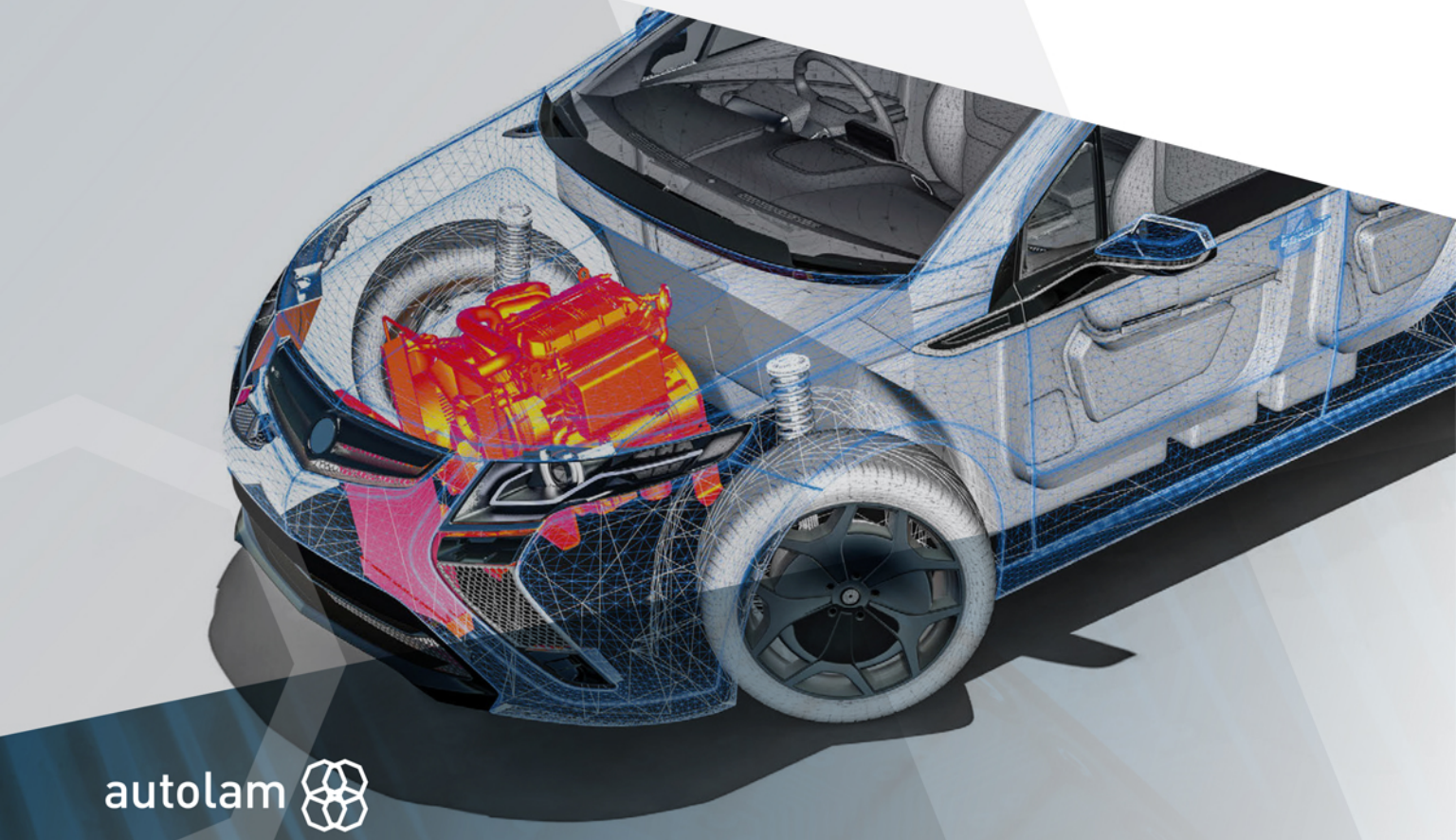

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The copper balls in the anode baskets will continue to recede as they are dissolved in the electrolyte, which will require replenishment of copper balls on top of each anode basket. This activity is unsafe and usually requires additional dummy plating to film the newly replenished balls. Dummy plating is also required after prolonged inactivity to release any organic additives that get tied up in the anode. Dummy plating is a non-productive activity that is wasteful.

**Dummy plating is a non-productive activity that is wasteful.**

With continuous plating, the anode balls will eventually be reduced in size, particularly at the bottom of the basket. These very small balls would be surrounded by anode sludge, causing the bottom 3–4 inches of the anode basket to become inactive, which has the effect of shortening the total length of the anode. This will have a direct effect on the thickness distribution of the plated copper. The corrective action taken is referred to as "anode maintenance."

Anode maintenance, depending on the size of the plating line, could take two or three individuals 3–8 hours. The anodes are removed from the electrolyte, the bag is removed and discarded, and the contents of the basket are poured out. The basket is refilled with new balls as well as some of the larger dumped-out balls. This will leave the smaller balls, which are usually sold as scrap. New balls are bought at a premium.

Once the anodes are refilled, they are bagged with new bags. The entire anode maintenance activity is extremely wasteful in labor, scrap copper, and the cost of new bags. The use of insoluble anodes with eductor sparging will eliminate waste in labor and material and will afford a cleaner ambient air environment in the plating area.

Insoluble anodes are made of a titanium mesh that is coated with MMO. MMO is a proprietary, mixed-metal oxide layer. This anode does not require any maintenance and will perform without any dimensional variation day in and day out for months on end. The insoluble anodes must be sized and properly located in the plating tank to give optimum copper thickness uniformity. The anodes should be placed evenly across the anode bar. They should also be 3-4" shorter than the panel and must be tucked 3–4 inches inside the cathode plating window. Insoluble anodes require the continuous addition of copper to the electrolyte; this is accomplished by the controlled addition of copper oxide based on ampere-hours of plating.

The use of bottom eductors to replace air sparging will eliminate all acid mist and the need to exhaust the air above the plating tank. Eductor size and location must be designed to ensure adequate and uniform solution replenishment at the plating site.

With insoluble anodes and eductor sparging, waste in acid copper plating is eliminated as follows:

- No variability in anode dimensions
- No copper waste; every gram of copper added will be plated on the parts
- No anode maintenance or the labor and hazard associated with the activity
- No dummy plating required
- No polluted air requiring exhaust
- No bag replacement

This system with insoluble anodes and eductor sparging is maintenance-free and non-polluting and is presently in use in vertical dip tanks in a couple of large U.S. shops. It is also used extensively in conveyorized acid copper plating equipment. **PCB007**

**George Milad** is the national accounts manager for technology at Uyemura. To read past columns or contact Milad, click here.

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# MilAero007 Highlights

## Will Moisture Management Expand to the U.S. Market? ▸

Rich Heimsch, Super Dry director, chats with Nolan Johnson about the growing demand for moisture management in North America versus its earlier adoption in Europe, and how moisture management fits into Industry 4.0 and the smart factory.

## I-007e Micro Webinar: Primary Flight Control Case Study on Condensation and Coverage ▸

The seventh episode of the popular webinar series "Coatings Uncoated!" is now available to view. Author of The Printed Circuit Assembler's Guide to Conformal Coatings for Harsh Environments and topic expert Phil Kinner from Electrolube shares highly focused educational information on conformal coating and encapsulation. If you are in the assembly business, an EMS, or responsible for specifying conformal coating and/or encapsulation, then this free series is for you.

## What It Takes to Be a Milaero Supplier, Part 1 ▸

The decision to pursue military and aerospace (milaero) certification impacts every facet of the organization, and not every shop is prepared to make this transformation. This is the first article in a four-part series, breaking down what it takes in sales and customer service, engineering and CAM, purchasing and quality, and manufacturing. Anaya Vardya starts by exploring sales and customer service.

## Burt Rutan's Keynote: SpaceShipOne ▸

In this video clip from his presentation, Burt Rutan discusses some of his aircraft's revolutionary flights that drew the most public attention, including SpaceShipOne, which flew three of the five manned space flights launched by man in 2004. He also explains the benefits of working with Microsoft's Paul Allen, who agreed to fund SpaceShipOne based on a simple handshake.

## Parrot Chosen by Swiss Army for the Supply of Micro-drones ▸

Parrot, Europe's leading drone group, has been chosen to equip the Swiss Armed Forces with micro-drones as part of the "Swiss Mini UAV Program" (Swiss MUAS) call for tender against major civilian UAV players.

## Global Technology: The Importance of Laminate CTE in PCB Design ▸

All material expands and contracts with temperature change, which is called the coefficient of thermal expansion (CTE). Eran Navick explains where and how the laminate expands effects the operation of the printed circuit in different ways.

## IPC's Raymond E. Pritchard Hall of Fame Award Presented to Steve Pudles of Zentech Manufacturing ▸

In recognition and acknowledgment of his extraordinary contributions to IPC and the electronics industry, Steve Pudles, president and CEO, Zentech Manufacturing, was presented with the IPC Raymond E. Pritchard Hall of Fame Award at IPC APEX EXPO in February.

## DoD Releases Fiscal Year 2021 Budget Proposal ▸

On February 10, 2020, President Donald J. Trump sent Congress a proposed fiscal year (FY) 2021 budget request of $740.5 billion for national security, $705.4 billion of which is for the Department of Defense (DoD).

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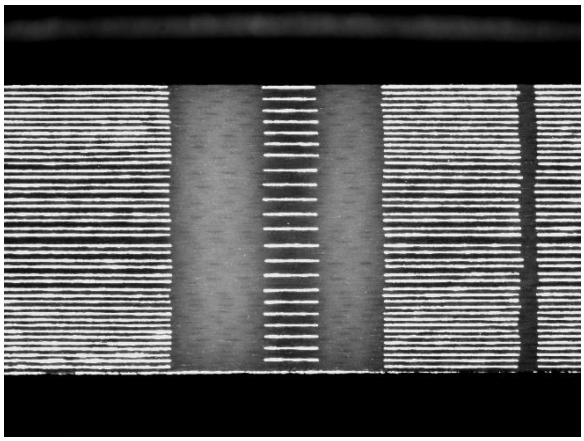

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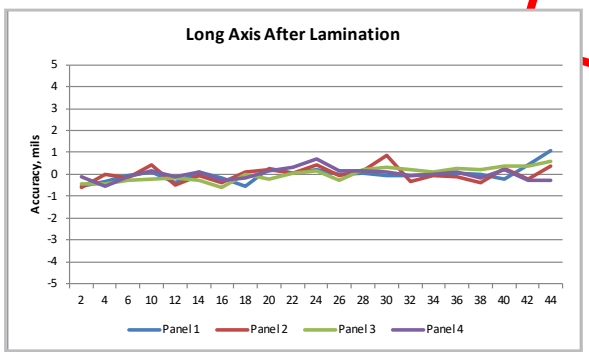


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# The Current State of VeCS Technology


Joe Dickson

**Interview by Nolan Johnson**
I-CONNECT007

I spoke with Joe Dickson, VP of product innovation at WUS, about the work the company has been doing on VeCS technology and where it stands today compared to standard HDI processes. Joe talks about the benefits VeCS can offer, such as moving past the 0.5-millimeter contact point barrier, and how VeCS promises to be a complement to HDI and through-hole techniques.

**Nolan Johnson:** Joe, Joan Tourné from NextGIn Technology has been writing a series for our magazine, documenting the VeCS technology. You have been working with him on that process. What do you see for reliability? What has the manufacturing experience been like for this technology?

**Joe Dickson:** We have been working on it for almost 3.5 years. In the beginning, we were trying to understand if the technology was even feasible, so we built structures to see what it could do from a routing and manufacturing standpoint, but it was very early in the learning curve. The tension became very high that this could be disruptive for HDI technologies or even replace them. I've always thought that they fit together. I believe that the collaboration of the two technologies is probably the most powerful application of this; however, many people thought, "I could get something dramatically lower in cost with single laminations and high-density routing." That was the focus of where it was, and we spent 1.5 years, attempting to optimize with basic manufacturing equipment—10-year-old routers and plating lines, not even pulse. We were able to build some sophisticated structures using them.

In the last two years, we have evolved into having more customized equipment, and the operational control of it is substantially better than what it used to be. In our early tests, the reliability we were looking for involved attempting to break it at every level because we wanted to understand if the interconnect of a VeCS signal would be reliable. That was the single biggest question. Anyone who understands VeCS can see how the traces are generated and could be built, as well as how you could plate deep blind slots because that technology is pretty mature. You can resin-fill the cavities because that technology involves

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the vacuum encapsulation, which has also been around for a while. It always came back to, "Is the interconnect going to pull off?" because it's a trace down the sidewall of the slot.

All of our early test vehicles were built around doing extensive thermal cycling, stressing it as much as we could; that's how we broke through-hole and HDI interconnects to understand the process in lamination. WUS has some pretty sophisticated algorithms for doing CTE expansion for both HDI structures and through-holes, where we can identify the weakest points in the design and the material set by glass filler type, resin type, and then the design features that are built around it. We have done four years of work on it. We already knew where the breaking points were for many different types of laminates and interconnects. We started working on that and found that when the VeCS interconnect was encapsulated in a similar CTE material to the laminate, the pressure point or stress point of breakage was not near the interconnect like it would be a through-hole, or at the base of a via like it would be with HDI.

**We have done four years of work on it. We already knew where the breaking points were for many different types of laminates and interconnects.**

It's the elongation of the trace, and because it's fairly uniform around the trace, the expansion and contraction are similar to what it would do on an outer-layer signal. The electrolytic copper we used had 14–17% elongation, so it took a lot to even attempt to break a VeCS signal.

**Johnson:** Doesn't that sidestep some of the critical issues right now with HDI?

**Dickson:** That's true. Where we're at right now is the industry is evolving in buildup technology and the maturity of HDI. I started working on HDI in 1992, and both mechanical and laser- formed vias have been around forever, but it's still relatively new to the large format BGAs. This application exposes concerns during thermal cycling primarily because of the issues of CTE mismatch between the plated solid copper via and the anti-pad area immediately next to the via. There are tricks that you can do, like IBM did, where you take two layers stacked, and then stagger them. We have even built a model where we can tell, in mils, how much expansion is happening near areas, and we can modify the design and materials to minimize stress on an HDI buildup. However, whether it's four, five, or six lamination cycles, at some point, you're putting extremely high stress on the single point of contact of the electrolytic plating to the capture pad and the source of either electroless or direct plate that you used.

That's very difficult. That's very high stress on that key contact. Usually, when it fails, it fails completely. You will see it separate. We have never seen it with VeCS. We've done 20 thermal cycles at T260, where the through-hole would have fallen apart, and HDI pads lift completely off, but the VeCS doesn't break. We have run it enough and cooled it quickly, as well as run it where we had the trace crack. It's so far beyond what traditional is that I feel pretty confident that the interconnect in this application is going to be a pretty high part of the reliability.

We also have techniques on how to form interconnects, and we can even make a three-sided VeCS connection, but the real benefit that people want with VeCS is that you can match the impedance down the sidewall of the signal layer. If you have 85 ohms running on the trace, you can match the 85 ohms down the sidewall and then come back in. That impedance continuity seems to be especially valuable for high-performance computing and PCI express applications.

**Johnson:** You talked a little bit ago about elongation to trace with respect to VeCS. To be clear, is that along the surface of the board?

**Dickson:** Yes. Typically, when people talk about elongation with copper, they discuss stress cracks built in, and I'm old enough to remember when there were additives that you had in your plating solutions that the elongation would get so high that it would crack from normal thermal cycling. But with the maturity of the chemistries we've had for the last almost 15 years, especially once pulse got in, the high elongation deposits were pretty easy to capture.

**Johnson:** Are you far enough into the process to give a general sense of reliability? Your qualitative statement was very encouraging, of course. I know you're not done yet, but are there some numbers that you can share?

**Dickson:** We have done our own testing, and we've been able to do IST thousand cycles that had very good results. WUS has done some industry-level testing. We're currently doing HDP User Group's, but that one is very aggressive. For example, it has a 2.7-millimeter deep blind via. A 0.1-millimeter HDI blind via is deep; this is 2.7 millimeters deep, and it's on a 0.5-millimeter pitch, and you couldn't even run HDI at that pitch.

**Johnson:** You're in a completely different ballpark with that kind of testing.

**Dickson:** We went to furthest possible limits of where it was—not necessarily manufacturing, but what we even understood about doing the blind innerconnect. We can do a through-hole VeCS, with back route to remove the stub, much thicker than that, but those are some of the deepest blind applications we have done. We're working through those tests now. We have had some limited success with it. The main issues that we have seen are similar to through-hole. We still have the issues where if you have metal features and you're routing a slot, the slot to the metal feature or drill to metal features is still critical. Those are there because the materials used included glass reinforcement, but the trace to the trace and the trace to the reference across from it has had pretty positive results so far.

However, we don't have enough detail yet. We're producing multiple design test vehicles now, building in a reliability structure, so we'll be able to publish more details by July with some sophisticated information. It's enough to warrant people to look at doing their own reliability testing.

**Johnson:** VeCS allows for some routing densities that are in line with what the industry is starting to demand. It allows for packaging that includes some of the larger, more complex, problematic packages. It also seems to address some of the via failure issues seen in HDI. Given that the OEMs are pushing on us, as an industry, to deliver two orders of magnitude more reliable than we can currently achieve, it starts to sound like VeCS is a technique that has found its time.

**Dickson:** That's why WUS dove in and pushed this. The difficulty with doing any type of new technology is there's so little history on reliability. Alternative mature technologies, even if the performance is bad or not perfect, if it's known, that has a large margin of security. People have said, "I need 10,000 samples at 1,000 hours of my special design before I'd even be interested." Okay, that's good. Two years from now, you'll have your point. The difference with this technology than other technologies is that we have many customers telling us, "We don't have an option. We need this because we must have it." And I tell them, "Look, it takes nine months to learn how to design."

That's your paradigm shift. You can't say to a designer, "Design me a VeCS board." Joan Tourné is brilliant. He's a designer, an engineer, and has two brains. Even with him, you need to be able to do this, and the customers that we have now are learning the things that we knew. We're building out a DFM rule base that is reasonable; if you follow that DFM rule base and not try to do something outrageous, we think the reliability numbers are going to be superior to what you would expect from performing through-hole and HDI.

VeCS is not a replacement for those two; it's in addition to those two. There are very few

designs that I've seen where I have recommended only using VeCS. You can use VeCS where you need the dense signal routing in a Faraday cage-type shielding, and then you leave these large channels open because of how it routes. Every other row, there are no vias so that you have very large channels. In those channels, you take advantage of high power, put through-holes that are only power, and allow yourself the channel escape there. People say, "The GPU technology and the FPGA accelerator technology both need 0.7-millimeter chips now, and they need 0.6 in two years." I'd ask, "Okay, what are the PCB solutions for buildup?" Their response might be, "But they don't give me the SI advantages I need."

**Joan Tourné is brilliant. He's a designer, an engineer, and has two brains.**

VeCS can do 0.5 millimeters—not just 0.6 with much thicker dielectric cores than HDI. You could run a trace that's 0.125 millimeters in width, smooth copper, and your loss values could be much lower. That technology is there. The previous revisions of SI high-performance materials that came out seven years ago were released before their time, before they were ready in terms of reliability. We became experts in reliability failures. It was amazing how little reliability data there was around that. It was, "Grab the material, stick it in a board, and run." This is going to be a similar scenario when they need it, but by the time that comes, we'll have a better understanding of how reliable it is and where the window of reliability is.

**Johnson:** The opportunity, though—the point in time when the decision is made to use VeCS—is in the design phase. This is something that designers can choose when building boards.

**Dickson:** We're spending a lot of time on applications with chip manufacturers. We have key OEMs that are visionaries, but we want to have the chip manufacturers coming along in line because their cost points are pressure, too. If you're going to have an autonomous driving board running quickly, you will run a high-speed 5G application and need something high reliability. You're going to need the potential to have high-reliability, high-density routing.

**Johnson:** Excellent. I'm going to ask you to look forward a little bit. Where do you see VeCS in the future?

**Dickson:** It will be a great technology to move us past the thick PCB and 0.5-millimeter pitch that limits HDI buildup has today. I think you will see boards that are currently 60 layers with one-millimeter pitch BGAs right now running at a 0.7-millimeter pitch in 32 layers. The simplicity of the process moves most of the PCB manufacturing back almost 10 years. People who have built boards for a long time tell us that we're moving all the technologies back.

**Johnson:** That's a good thing.

**Dickson:** I say, "Yes, that's pretty much what's happening. The equipment manufacturers get a chance to catch up." Now, the drilling and routing technology is evolving at light speed. Two years ago, we had our first CCD alignment routing machine and multiple CCD drilling. It's a routing machine and another level of quality for what we can do now with the VeCS technology because you can route to a depth we need to, as well as positional accuracy.

**Johnson:** Fantastic. Thanks for taking the time. This was a great update.

**Dickson:** You're welcome. PCB007


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# Material Challenges for PCB Fabricators

## Trouble in Your Tank

by Michael Carano, RBP CHEMICAL TECHNOLOGY

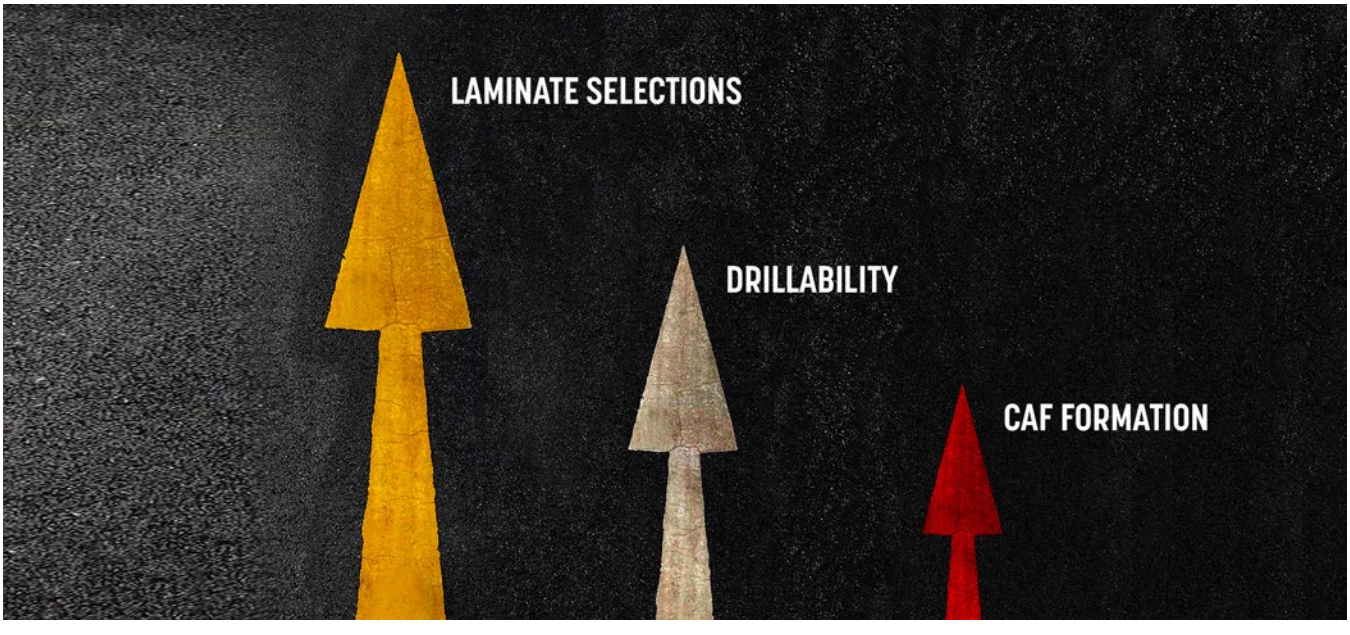
Laminate materials are the building blocks on which PCBs are manufactured. Circuit board designers rely on the critical electrical properties of the materials to design the interconnect. And with the drive toward the internet of things (IoT), autonomous driving, virtual and augmented reality, material properties take on a very high level of importance.

The crux of the issue is quite simple: Designers are looking for electrical performance, and printed board fabricators are concerned with manufacturability and yields. As the complexity of circuit technology increases (and it is not going to stop anytime soon), there will be a continual pressure to improve yields. However, that is the conundrum, or the "rock and a hard place" cliché.

For the purpose of this discussion, let's consider the requirements for high-speed data transmission. System designers are looking at several factors, most importantly signal speeds, loss characteristics, and laminate selections.

### Laminate Selection: Dk and Df

The Dk is the property that determines the relative speed that an electrical signal will travel in that material. A low dielectric constant will result in higher signal propagation speed while a high dielectric constant results in lower signal propagation speed (i.e., the lower the Dk, the less impedance there is to the signal propagation). The characteristic impedance of a PCB is determined by the thickness of the laminate and its Dk. Impedance control, and impedance matching of critical linked functional modules, becomes especially important in very high-speed designs (i.e., high-frequency designs). Dk also tends to shift with temperature, so heat generation by such designs is another important factor.



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The Df or loss tangent of the material is a measure of the percentage of total transmitted power that will be lost as power dissipated into the laminate material. High-frequency signals switch backward and forward rapidly. There is the switch between positive and negative, causing the molecules within the resin (dielectric) materials to polarize with the electromagnetic field of the signal. During this situation, there is heat loss. Thus, there are signal losses that become greater at higher frequencies. These losses are proportional to frequency and become more pronounced at frequencies higher than 10 GHz. However, today's technologies are requiring signal speeds in excess of 35 GHz for selected applications. Skin effect is real and must be considered as higher frequencies are used as part of the mainstream circuit designs going forward.

**Skin effect is real and must be considered as higher frequencies are used as part of the main-stream circuit designs going forward.**

What does all this mean? From a simplicity standpoint, these higher-performance materials are much more difficult to process for the PCB fabricator. Basically, it is not your father's FR-4 anymore! From a fabrication standpoint, processing a 140°C Tg material through the desmear/etchback process as an example is much easier to etch the resin, remove drill smear, and create sufficient topography to enhance the adhesion of the plated copper. As one moves up the laminate material technology curve (lower Dk, lower Df, engineered materials, including ceramic-filled), resin removal, or simply etching the resin becomes more difficult.

For the fabricator, this necessitates a change in mindset related to chemical desmear. If the end-user requires a significant amount of etchback, this may not be practical with current mechanical and chemical set-ups. The fabricator must resort to radical departures from the status quo. This includes extended dwell times in the desmear process, increasing the aggressivity of the chemistry and the use of plasma etchback as either a stand-alone or in combination with chemical processing.

Satisfactorily, bareboard fabrication now includes a variety of materials. Glass-reinforced laminate for rigid printed boards—and unreinforced laminates, used primarily for flexible printed boards—present significant challenges for desmear/metalization, as well as in lamination. Further, these higher-performance, thin-core materials are being combined in a variety of applications to achieve a thinner profile of the end-product. Thus, lamination of the combined materials (including adhesives) requires changes in the lamination cycle parameters, including time, pressure, and heat rise rate.

There are several additional material properties that the PCB fabricator must consider to optimize the process: drillability and conductive anode filament (CAF) formation.


Figure 1: Rough hole walls after drilling.

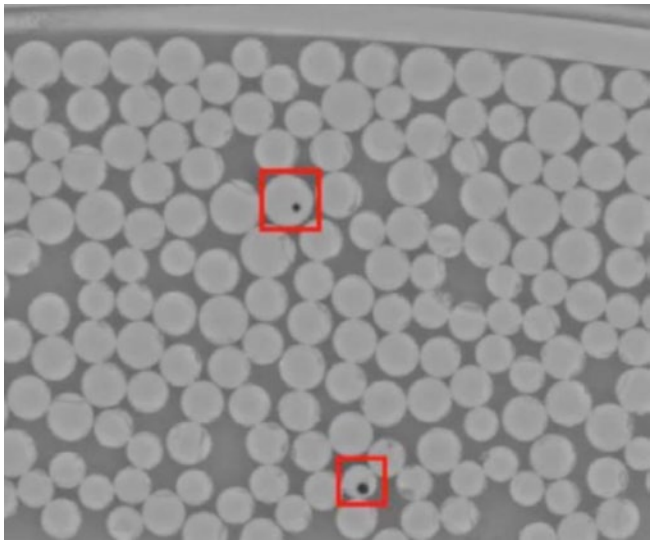


Figure 2: Example of the formation of hollow fiber. (Source: IPC TM-2.6.25A User Guide).

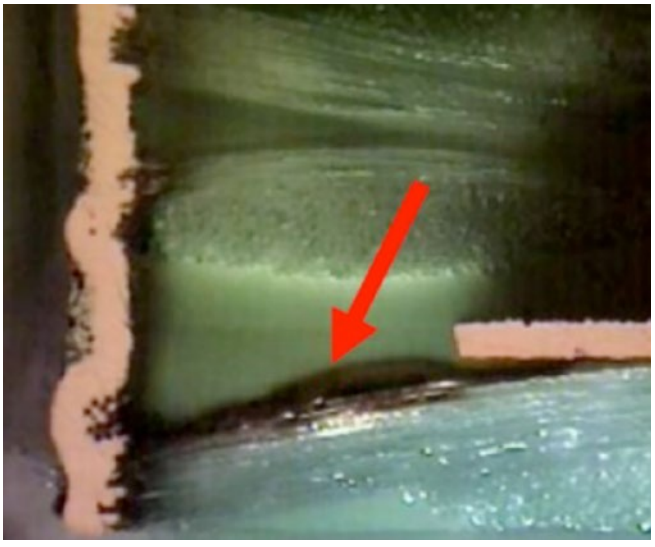


Figure 3: Arrow pointing to copper filament working its way to the internal layer to cause a short.

## Drillability

Drillability is an important consideration in the selection of a laminate for a backplane, particularly with high PTH aspect ratios and the increase in backdrilling. Constant diameter and clean finish are essential. The grade of glass fiber, fillers, and dielectric material hardness all contribute to the hole quality.

Ceramic-filled materials can also introduce extra cost in fabrications. The ceramic can reduce the lifetime of a drill bit from 5000 to 500 hits. There are concerns with hole wall quality as fabricators move up the material technology curve—most notably rough drilled holes along with deep gouges (Figure 1).

Drill quality—or lack thereof, as shown in Figure 1—affects several aspects, including solderability, plating adhesion, and potentially component insertion. Regardless, higher-performance materials are more difficult to drill. Hole wall roughness must be reckoned with.

## CAF Formation

CAF is caused by the separation or lack of bonding between the woven glass and the resin material. Essentially, the separation causes a hollow tube, so to speak, that allows moisture to provide sufficient conductivity under bias to form an actual copper filament. This filament can lead to an electrical short.

The hollow fiber shown in Figure 2 is the typical medium leading the conductive filament. The resin can separate from the glass due to the glass-coupling chemistry, resin moisture absorption, drill fractures, or the degree of effectiveness of the prepreg resin coating (no bare fiber ends should be exposed). Then, the pathway provides the ideal situation for the growth of the filament (Figure 3).

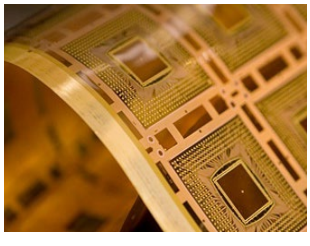
Recently, resin suppliers and laminators have made great strides in the understanding of CAF and even better methods to detect the issue. In addition, IPC-4101B helps to address the concerns with resin materials and the propensity to lead to CAF. Most datasheets now state whether materials are CAF-resistant.

Even with the development of CAF-resistant materials, higher-density circuit board designs, higher aspect ratio vias, as well as alternative glass styles, one should not assume that CAF will not occur. Always perform due diligence. **PCB007**

**Michael Carano** is VP of technology and business development for RBP Chemical Technology. To read past columns or contact Carano, click here.


# Editor Picks from PCB007

## 1 Catching up With Flexible Circuit Technologies ▸

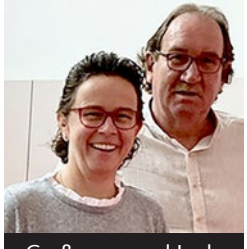


Dan Beaulieu catches up with Troy Koopman, president and co-founder of Flexible Circuit Technologies (FCT), and Carey Burkett, the company's VP of business development. FCT is a full-service flex and rigid-flex supplier.

## 2 IPC Honors TTM Technologies Inc. and Continental Automotive With Corporate Recognition Awards ▸

IPC bestowed its highest corporate honors on two IPC member companies, TTM Technologies Inc. and Continental Automotive. During IPC APEX EXPO 2020, the Peter Sarmanian Corporate Recognition Award was presented to TTM Technologies Inc., and the Stan Plzak Corporate Recognition Award was presented to Continental Automotive.

## 3 Not All Plating Lines Are Created Equal ▸



Großmann and Ludy

Barry Matties and Happy Holden met with CEO Michael Ludy and CMO Sarah Großmann from Ludy, a company specializing in galvanic plating equipment for PCBs. This interview gives an overview of Ludy and its latest advancements in PCB plating equipment.

## 4 Sunstone Circuits Now Offering ITAR on Limited Review PCBs ▸

Sunstone Circuits, a leading PCB prototype to production solutions provider, has just announced that ITAR controlled PCB jobs can now be ordered through its "limited review" products (PCB-Express and ValueProto).

## 5 Elmatica CEO Approved Member of the Swedish Cyber Defense and Export Control Groups ▶

Elmatica announced that CEO Didrik Bech is an approved member of the Swedish Cyber Defense and Export Control Groups.


Didrik Bech

## 6 IPC Government Relations: Focus on Supply Chain Resiliency ▶


Chris Mitchell

During IPC APEX EXPO, Nolan Johnson sat down with Chris Mitchell, VP of global government affairs, to discuss IPC's latest initiative with industry intelligence programs. As Chris explains, some of these efforts are focused on improving the DoD's supply chain. This includes moving the DoD from leaded to lead-free components to help avoid millions of dollars in rework. He also discusses the team's drive to unite with partners around the world and create a truly global organization.

## 7 Flex Talk: Additive PCB Technology for Next-generation Electronics ▶

Semi-additive PCB processes help to enable very fine features, with trace and space down to 25 microns and below, significantly reducing space and weight for next-generation electronics. Tara Dunn speaks with Todd Brassard and Meredith LaBeau from Calumet Electronics about how the company is the first domestic PCB manufacturer to license Averatek's A-SAP™ process.

## 8 Advances in Substrates for Thermal Management ▶

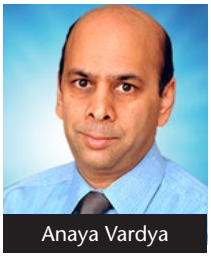

Aduardo Benmayor

Pete Starkey and Eduardo Benmayor, general manager for Aismalibar, discuss ways in which insulated metal substrates have been modified to relieve stresses on the solder joints of high-end LED assemblies during thermal cycling. Eduardo also describes a range of thermally conductive FR-4 laminates that can be processed like standard FR-4 for applications where thermal dissipation can be maximized without changing the design.

## 9 Three Long-time IPC Volunteers Receive Dieter Bergman IPC Fellowship Award ▶

Three IPC volunteers who have fostered a collaborative spirit, made significant contributions to standards development, and consistently demonstrated a commitment to global standardization efforts were presented with Dieter Bergman Fellowship awards at IPC APEX EXPO 2020.

## 10 American Standard Announces License Agreement With Averatek ▶


Anaya Vardya

Mr. Anaya Vardya, president and CEO of American Standard Circuits, recently announced that his company signed a licensing agreement with Averatek for their patented A-SAP™ manufacturing process.

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# Career Opportunities

# Looking for the purrrrfect applicant?

## Find industry-experienced candidates at I-Connect007.

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Potential candidates can click on your ad and submit a resume directly to the email address you provide. If you wish to continue beyond the first month, the price is the same per month.

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# Career Opportunities


## Field Application Engineer/ PCB Designer in Cresskill, NJ

If you know how to design, manufacture, and sell PCBs, and you enjoy engaging with customers, then we want to hear from you. We are looking for a PCB designer/field application engineer to join our team in New Jersey. This is a cool job, as you won't be just a PCB designer; you will also work with your local team, the customer, and our factory partners throughout the globe. It is critical that you have the knowledge and experience in PCB design and can also interact well with customers.

### Requirements:

- Self-starter able to work with minimal direct supervision
- We would like to see you bring 2-3 years' experience in a similar position
- An AA degree in electrical engineering, preferably in PCB design
- Good communication skills, both oral and written
- Working knowledge of PADS, Altium, Cadence, Genesis, CAM 350, impedance modeling, SPICE, and thermal modeling tools
- Understanding of PCB CAD layout software and current layout techniques, including micro-BGA, HDI design, and LED/thermal design

### What Will We Provide?

We are experiencing excellent growth, so come grow with us. We offer a generous salary with significant upside bonus potential, including a full suite of benefits.

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## Employment Opportunities

National Technology, Inc., a manufacturer of high-quality printed circuit boards, is currently looking for candidates for the following positions in our Rolling Meadows Illinois Facility:

### Quality Control Manager

- Manage QMS in accordance with the ISO 9001:2015 system.
- Manage inspection departments, including final inspection, pre-mask inspection, AOI inspection and all associated quality inspections.
- Maintain continuous improvement initiatives.
- Generate and maintain monthly quality reporting.
- Manage internal and external corrective and preventive action.
- Responsible for maintaining the ISO status, including audits, training, procedures, etc.
- Maintenance and scheduling of calibrations.
- Be a liaison to our facility in India regarding customer related issues.
- Customer contact with RMA and corrective action.

### Process/Quality Engineer

- Develop and document new processes and technologies.
- Review existing processes for improvement opportunities.
- Assist in identifying and addressing manufacturing issues.
- ISO internal auditing and process related audits.
- Set-up and monitor process controls through manufacturing.
- Maintain regulator compliances.

Candidates for these positions should have a solid background in printed circuit board fabrication. An in-depth knowledge of applicable IPC standards as well as ISO 9001 standard will be required.

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# Career Opportunities

I-Connect007
GOOD FOR THE INDUSTRY

## News Editor – Full Time Position

I-Connect007 seeks a positive, independent self-starter to manage news gathering process and work closely with editorial team. Qualified candidates will demonstrate strong organizational and communication skills and be able to work full-time remotely.

New hire will start with a portion of this work and ramp up with demonstrated mastery of the processes.

### Aptitudes

- Organized
- Time aware
- Team oriented
- Planning skills
- Meeting deadlines
- Good record keeping
- Problem solving skills
- Attention to details
- Strong follow-through skills
- Grammar and editing skills
- Knowledge of basic photo editing
- Knowledge of html a plus

### Attitude

- Ability to work remotely, often with only "virtual" supervision.
- Discipline to keep regular hours, communicate with team and deliver on deadline.
- Curious, investigative nature and interest in technology.

Objective: Submit editorial proof for the newsletter daily. This task includes news gathering, posting, categorization and simple editing functions.

- Gather news items from pre-planned primary sources for publication.
- Review and post all news items to the news manager prior to deadline.

**Interested candidates please submit resume by clicking below.**

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Have a position to fill? D.B.Management has the people you're looking for. Candidates currently available include:

- **Director of Operations, PCB and CEM**
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207-649-0879

or emailing him at:

danbbeaulieu@aol.com

more details

# Career Opportunities

FREEDOM CAD SERVICES

## Sr. PCB Designer–Allegro

Freedom CAD is a premier PCB design service bureau with a talented team of 30+ dedicated designers providing complex layouts for our enviable list of high-tech customers. Tired of the commute? This is a work-from-home, full-time position with an opportunity for overtime at time and a half.

### Key Qualifications

- EXPERT knowledge of Allegro 16.6/17.2
- Passionate about your PCB design career
- Skilled at HDI technology
- Extensive experience with high-speed digital, RF and flex and rigid-flex designs
- Experienced with signal integrity design constraints encompassing differential pairs, impedance control, high speed, EMI, and ESD
- Experience using SKILL script automation such as dalTools
- Excellent team player that can lead projects and mentor others
- Self-motivated, with ability to work from home with minimal supervision
- Strong communication, interpersonal, analytical, and problem solving skills
- Other design tool knowledge is considered a plus (Altium, PADS, Xpedition)

### Primary Responsibilities

- Design project leader
- Lead highly complex layouts while ensuring quality, efficiency and manufacturability
- Handle multiple tasks and provide work leadership to other designers through the distribution, coordination, and management of the assigned work load
- Ability to create from engineering inputs: board mechanical profiles, board fabrication stack-ups, detailed board fabrication drawings and packages, assembly drawings, assembly notes, etc.

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EAGLE electronics Inc.

## CAM Engineer

Eagle Electronics is seeking a CAM engineer specific to the printed circuit board manufacturing industry. The candidate should have a minimum of five years of CAM experience and a minimum of two years of experience in Frontline InCAM software. The candidate should also be fluent in PCB and CAM language pertaining to customer and IPC requirements. The ideal candidate has experience with scripting Frontline InCAM software.

This is a first-shift position at our Schaumburg, Illinois, facility; this is not a remote/offsite position. Any offer would include relocation costs to the Schaumburg, Illinois, area along with competitive salary and benefits.

If interested, please submit your resume to HR@eagle-elec.com and include "CAM Engineer" in the subject line.

About Eagle—Since 1979, Eagle Electronics has provided customers with the highest quality printed circuit boards at fair and competitive prices. From providing customers with short standard lead times to very low premiums on quick turns, Eagle strives to provide the best total value in high technology rapid turn-around PCBs in the industry.

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# Career Opportunities

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## West Software Application Engineer

This position reports directly to the Orbotech West software support manager and works with customers to support Orbotech's pre-production software products. Acts as a focal point for technical issues, manages product implementation projects, provides customer training, and supports the sales process. Advanced knowledge of Frontline PCB products, including InCam, InPlan, InStack, InSight, Genesis, and Genflex. Ability to travel and manage time to maximize results. Requires both written and oral technical communication skills. Skilled in the use of scripting languages, including C-Shell, Perl, or Python. Knowledge of relational databases and HTML/XML highly desirable. Knowledge of PCB manufacturing processes. Familiar with the processes used in front-end engineering departments at PCB fabrication sites. Requires use of project management skills to organize and complete projects that involve the implementation of sophisticated software tools used in printed circuit fabrication facilities.

An expected average of 35%+ travel. College degree or equivalent technical education, in addition to a minimum of five-plus years of related experience. Experience supporting sales and sales activities is a plus. U.S. citizen with the ability to work and travel within the U.S., Canada, and internationally.

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INTERNATIONAL GROUP
騰輝電子

## OEM Sales Manager
### Chicago/Home-Office-Based

Want to advance your career by joining a globally successful and growing world-class CCL manufacturer and help drive that success? We are seeking to hire an OEM sales manager to grow and manage key customer accounts with OEM's and Tier 1 manufacturers in the USA, focusing on Ventec's core market segments: mil/aero, automotive, and medical, offering a full range of high-reliability materials, including polyimide, IMS, and thermal management products.

**Skills and abilities required for the role:**
- Non-negotiable: Drive and tenacity!

**Required:**
- 7 to 10 years' experience in the PCB industry in engineering and/or manufacturing
- Detail-oriented approach to tasks
- Ability to manage tasks and set goals independently as well as part of a team
- Knowledge of MS office products

Full product training will be provided.

This is a fantastic opportunity to become part of a successful brand and leading team with excellent benefits.

Please forward your resume to jpattie@ventec-usa.com and mention "Technical Sales Engineer—Chicago" in the subject line.

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# Career Opportunities

FREEDOM CAD SERVICES

## Sr. PCB Designer–Mentor Xpedition

Freedom CAD is a premier PCB design service bureau with a talented team of 30+ dedicated designers providing complex layouts for our enviable list of high-tech customers. Tired of the commute? This is a work-from-home, full-time position with an opportunity for additional compensation for overtime work at time and a half.

### Key Qualifications

- EXPERT knowledge of Xpedition VX 2.x
- Passionate about your PCB design career
- Skilled at HDI technology
- Extensive experience with high-speed digital, RF, and flex and rigid-flex designs
- Experienced with signal integrity design constraints encompassing differential pairs, impedance control, high speed, EMI, and ESD
- Excellent team player who can lead projects and mentor others
- Self-motivated with the ability to work from home with minimal supervision
- Strong communication, interpersonal, analytical, and problem-solving skills
- Other design tool knowledge is considered a plus (Altium, Allegro, PADS)

### Primary Responsibilities

- Design project leader
- Lead highly complex layouts while ensuring quality, efficiency, and manufacturability
- Handle multiple tasks and provide work leadership to other designers through the distribution, coordination, and management of the assigned workload
- Ability to create from engineering inputs, board mechanical profiles, board fabrication stackups, detailed board fabrication drawings and packages, assembly drawings, assembly notes, etc.

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ROGERS CORPORATION

Advanced Connectivity Solutions

## Senior Development Engineer

Rogers Corporation is seeking a senior development engineer accountable for the development of more complex products and processes, the establishment of sound technical bases for these developments, and effective interaction with technology, process, and platform innovation; operations; sales and marketing; and process engineering personnel to commercialize these developments.

### Essential Functions:

- Design and conduct experiments and interpret the results
- Report on projects in both written and verbal formats at all levels of the organization
- Perform technical troubleshooting of new products and processes; act as new product/concept incubator for new technologies and platforms, identifying opportunities for improvement and incorporation design for manufacturing requirements resulting in a viable, scalable product
- Provide ongoing process and manufacturing support to newly launched products as applicable
- Provide support in terms of analytical equipment maintenance, methods development, material analysis, and documentation of new process or products
- Manage capital projects for the purchase and installation of new process or support equipment; train employees in new processes

**Required Education and Experience:**
Ph.D., Ch.E., M.E., or material science, or B.S. or higher in a technical discipline with accomplishment in product development and project management.

Rogers Corporation provides equal employment opportunities to minorities, females, veterans, and disabled individuals as well as other protected groups.

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# Career Opportunities

## Gardien Is Hiring!

The Gardien Group, a leading solutions provider in the PCB industry, is looking to fill multiple openings in their China, Japan, Taiwan, and United States service centers.

We are looking for electrical engineers, operations managers, machine operators, and sales executives. Prior experience in the PCB industry is beneficial but not essential. Training will be provided along with excellent growth opportunities, a benefits package, and periodic bonuses.

Our global teams are from diverse cultures and work cohesively as a tight-knit unit. With performance and initiative, there are plenty of opportunities for professional growth.

Gardien is an equal opportunity employer. Employment decisions are made without any regard to race, color, religion, national or ethnic origin, gender, sexual orientation, age, disability, or other characteristics.

Interested candidates, please contact us with your resume and a cover letter. Kindly note that only shortlisted candidate will be contacted.

Apply at careers@gardien.com.

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Opportunities are available in Canada, New England, California, and Chicago. If you love teaching people, choosing the classes and times you want to work, and basically being your own boss, this may be the career for you. EPTAC Corporation is the leading provider of electronics training and IPC certification and we are looking for instructors that have a passion for working with people to develop their skills and knowledge. If you have a background in electronics manufacturing and enthusiasm for education, drop us a line or send us your resume. We would love to chat with you. Ability to travel required. IPC-7711/7721 or IPC-A-620 CIT certification a big plus.

### Qualifications and skills

- A love of teaching and enthusiasm to help others learn
- Background in electronics manufacturing
- Soldering and/or electronics/cable assembly experience
- IPC certification a plus, but will certify the right candidate

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- Ability to operate from home. No required in-office schedule
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- Training and certifications provided and maintained by EPTAC

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# Career Opportunities

INSULECTRO

## Technical Account Manager Chicago/Minneapolis

Insulectro, the largest national distributor of printed circuit board materials, is seeking a talented sales superstar for a Technical Account Manager role based out of either our Chicago or Minneapolis office. This role will focus on maintaining the existing customer base and developing new business within the assigned territory in both the printed circuit board and printed electronics industries. We are looking for the perfect fit of education, experience, and attitude that matches our company culture and enhances the service level to our customers.

**Qualifications:**

- A self-motivated business professional who is driven to succeed with a minimum of 3 years outside sales experience in the PCB or PE industry
- Proven sales/business development record
- Excellent communication and interpersonal skills
- OEM and electronic assembly experience is a plus

**We offer:**

- Competitive salary and commission plan with a comprehensive benefits package
- A fun, high-energy company with an entrepreneurial spirit
- A great group of people to work with!

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APCT
Passion | Commitment | Trust

## APCT, Printed Circuit Board Solutions: Opportunities Await

APCT, a leading manufacturer of printed circuit boards, has experienced rapid growth over the past year and has multiple opportunities for highly skilled individuals looking to join a progressive and growing company. APCT is always eager to speak with professionals who understand the value of hard work, quality craftsmanship, and being part of a culture that not only serves the customer but one another.

APCT currently has opportunities in Santa Clara, CA; Orange County, CA; Anaheim, CA; Wallingford, CT; and Austin, TX. Positions available range from manufacturing to quality control, sales, and finance.

We invite you to read about APCT at APCT.com and encourage you to understand our core values of passion, commitment, and trust. If you can embrace these principles and what they entail, then you may be a great match to join our team! Peruse the opportunities by clicking the link below.

Thank you, and we look forward to hearing from you soon.

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# Career Opportunities


## Development Chemist
## Carson City, NV

Develop new products and modify existing products as identified by the sales staff and company management. Conduct laboratory evaluations and tests of the industry's products and processes. Prepare detailed written reports regarding chemical characteristics. The development chemist will also have supervisory responsibility for R&D technicians.

### Essential Duties:

- Prepare design of experiments (DOE) to aid in the development of new products related to the solar energy industry, printed electronics, inkjet technologies, specialty coatings and additives, and nanotechnologies and applications
- Compile feasibility studies for bringing new products and emerging technologies through manufacturing to the marketplace
- Provide product and manufacturing support
- Provide product quality control and support
- Must comply with all OSHA and company workplace safety requirements at all times
- Participate in multifunctional teams

### Required Education/Experience:

- Minimum 4-year college degree in engineering or chemistry
- Preferred: 5-10 years of work experience in designing 3D and inkjet materials, radiation cured chemical technologies, and polymer science
- Knowledge of advanced materials and emerging technologies, including nanotechnologies

### Working Conditions:

- Chemical laboratory environment
- Occasional weekend or overtime work
- Travel may be required

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## Multiple Positions Available

The Indium Corporation believes that materials science changes the world. As leaders in the electronics assembly industry we are seeking thought leaders that are well-qualified to join our dynamic global team.

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- Finance and accounting
- Machine operators and production
- Research and development
- Operations

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# Career Opportunities

Manncorp™

## SMT Field Technician
### Huntingdon Valley, PA

Manncorp, a leader in the electronics assembly industry, is looking for an additional SMT Field Technician to join our existing East Coast team and install and support our wide array of SMT equipment.

**Duties and Responsibilities:**
- Manage on-site equipment installation and customer training
- Provide post-installation service and support, including troubleshooting and diagnosing technical problems by phone, email, or on-site visit
- Assist with demonstrations of equipment to potential customers
- Build and maintain positive relationships with customers
- Participate in the ongoing development and improvement of both our machines and the customer experience we offer

**Requirements and Qualifications:**
- Prior experience with SMT equipment, or equivalent technical degree
- Proven strong mechanical and electrical troubleshooting skills
- Proficiency in reading and verifying electrical, pneumatic, and mechanical schematics/drawings
- Travel and overnight stays
- Ability to arrange and schedule service trips

**We Offer:**
- Health and dental insurance
- Retirement fund matching
- Continuing training as the industry develops

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U.S. CIRCUIT

## Sales Representatives (Specific Territories)

Escondido-based printed circuit fabricator U.S. Circuit is looking to hire sales representatives in the following territories:

- Florida
- Denver
- Washington
- Los Angeles

**Experience:**
- Candidates must have previous PCB sales experience.

**Compensation:**
- 7% commission

Contact Mike Fariba for more information.

mfariba@uscircuit.com

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# Career Opportunities

ZENTECH

## Zentech Manufacturing: Hiring Multiple Positions

Are you looking to excel in your career and grow professionally in a thriving business? Zentech, established in Baltimore, Maryland, in 1998, has proven to be one of the premier electronics contract manufacturers in the U.S.

Zentech is rapidly growing and seeking to add Manufacturing Engineers, Program Managers, and Sr. Test Technicians. Offering an excellent benefit package including health/dental insurance and an employer-matched 401k program, Zentech holds the ultimate set of certifications relating to the manufacture of mission-critical printed circuit card assemblies, including: ISO:9001, AS9100, DD2345, and ISO 13485.

Zentech is an IPC Trusted Source QML and ITAR registered. U.S. citizens only need apply.

Please email resume below.

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BLACKFOX
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## IPC Master Instructor

This position is responsible for IPC and skill-based instruction and certification at the training center as well as training events as assigned by company's sales/operations VP. This position may be part-time, full-time, and/or an independent contractor, depending upon the demand and the individual's situation. Must have the ability to work with little or no supervision and make appropriate and professional decisions. Candidate must have the ability to collaborate with the client managers to continually enhance the training program. Position is responsible for validating the program value and its overall success. Candidate will be trained/certified and recognized by IPC as a Master Instructor. Position requires the input and management of the training records. Will require some travel to client's facilities and other training centers.

For more information, click below.

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# Is your PCB documentation process outdated?

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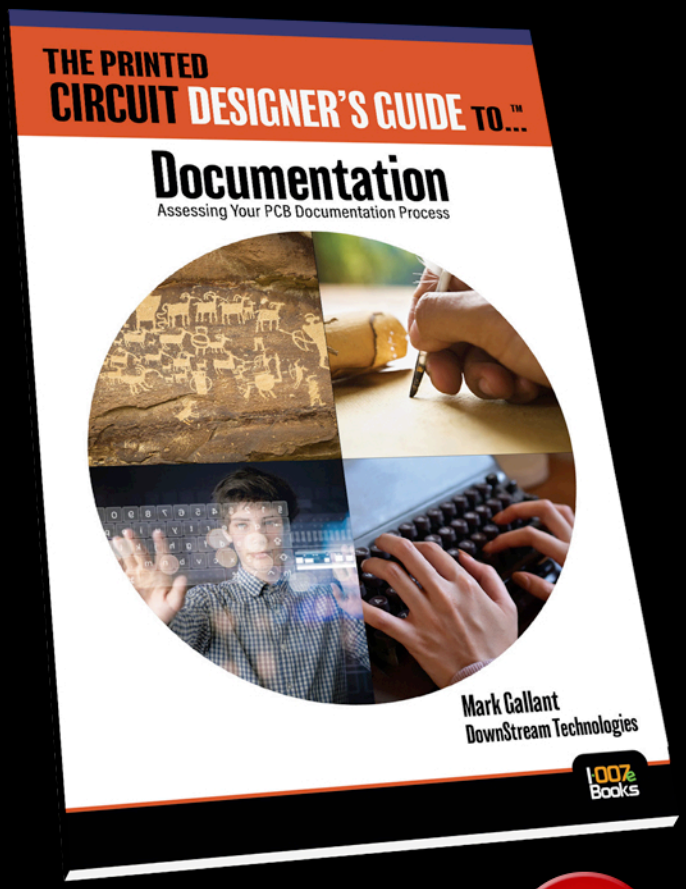


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# Events Calendar

**CPCA Show 2020** ▶
Postponed—Date TBA
Shanghai, China

**Electronica & Productronica China** ▶
Postponed—Date TBA
Shanghai, China

**LOPEC Exhibition and Conference (Driving the Future of Printed Electronics)** ▶
Postponed—Date TBA
Munich, Germany

**IMAPS High Temperature Electronics HiTEC** ▶
April 22–24, 2020
Albuquerque, New Mexico, USA

**IMAPS CICMT Ceramic Interconnect** ▶
April 22–24, 2020
Albuqerque, New Mexico, USA

**JPCA Show** ▶
May 27–29, 2020
Tokyo, Japan

**KPCA and KIEP Show** ▶
July 21–23, 2020
Incheon, Korea

**Productronica India** ▶
September 23–25, 2020
Bengaluru, India

## Additional Event Calendars

IPC | SMTA Surface Mount Technology Association | iNEMI | pcb007

## Coming Soon to *PCB007 Magazine:*

**APRIL 2020: Going Green**

Is there a return on investment in going green and protecting the environment? Going green can add profitability to your business, but it may not come from where you expect.

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COVER IMAGE: **ADOBE STOCK © ALPHASPIRIT**

PCB007 MAGAZINE

PCB007 MAGAZINE®
is published by BR Publishing, Inc.,
942 Windemere Dr. NW, Salem, OR 97304



March 2020, Volume 10, Number 3
PCB007 MAGAZINE is published monthly,
by BR Publishing, Inc.

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