SEPTEMBER 2022

PCB007 MAGAZINE

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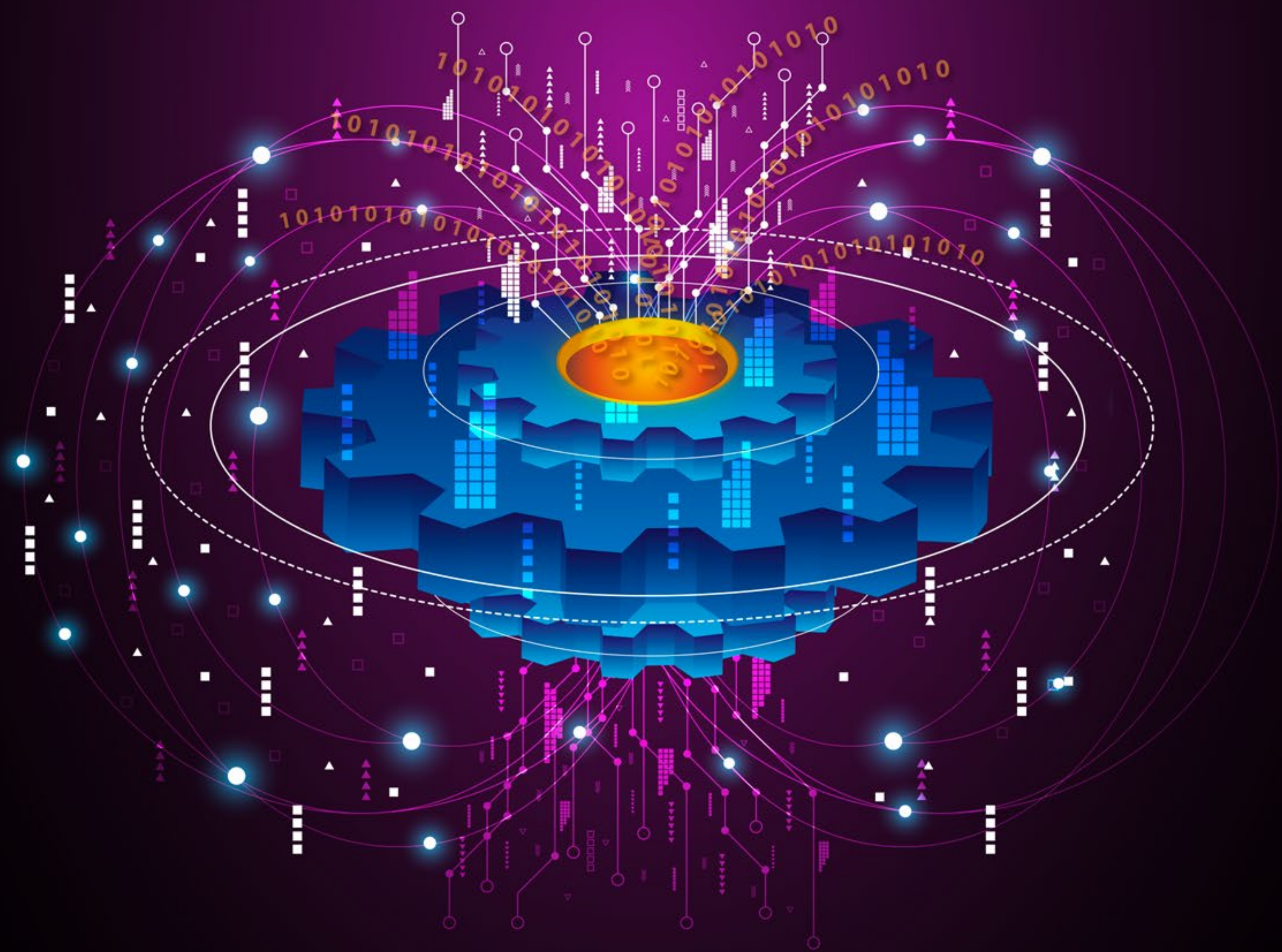
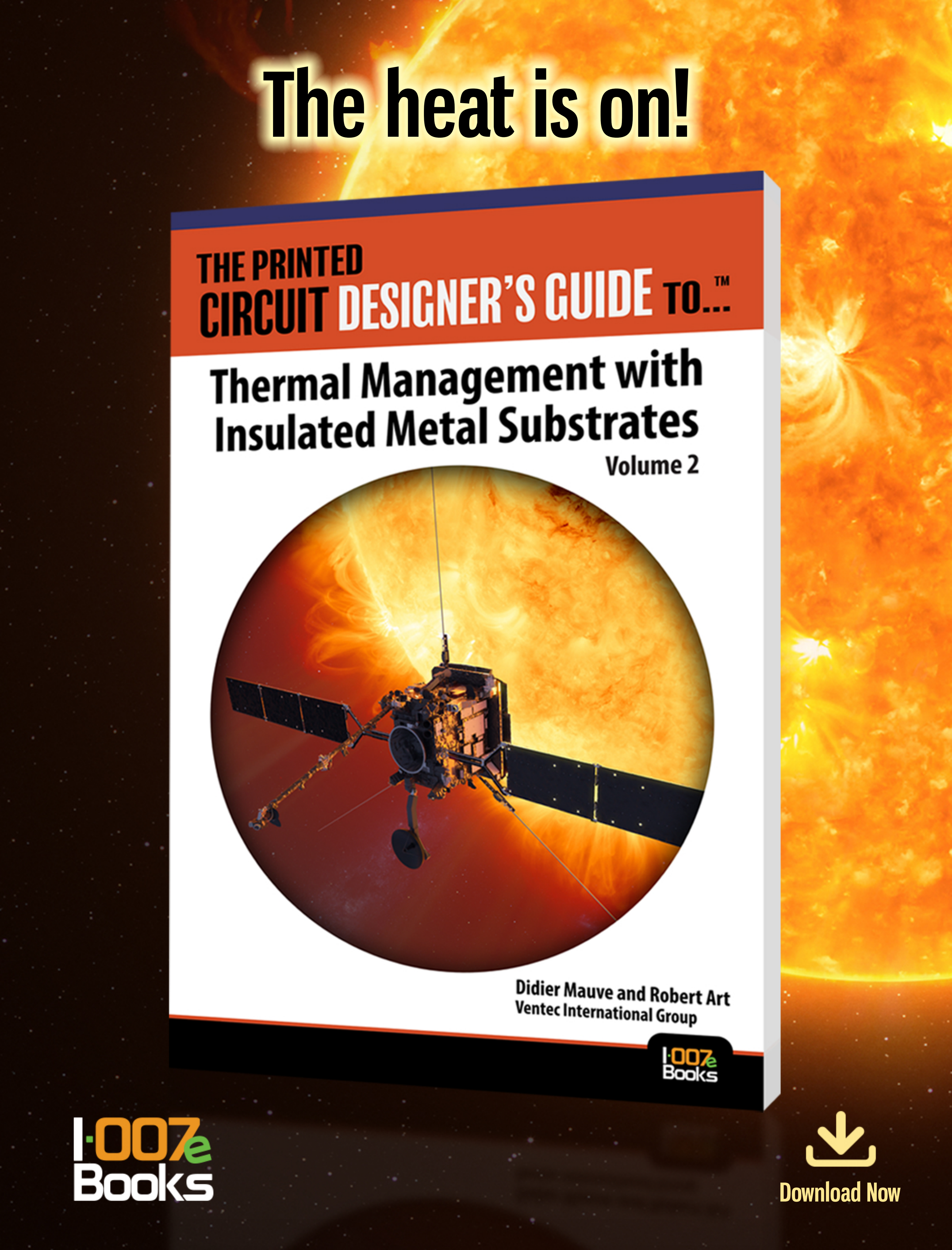


A NEW ERA IN MANUFACTURING



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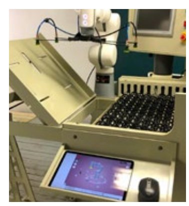
A New Era in Manufacturing

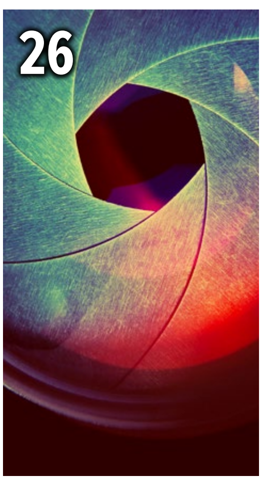
In this issue, we explore ideas for mechanization/automation of your existing facility. At first blush, this theme would suggest a major concentration on manufacturing floor details, or maybe a heavy dose of new capital equipment and line design topics. As you'll learn, it's much more than that.

FEATURE INTERVIEWS

FEATURE INFOGRAPHIC

FEATURE COLUMNS





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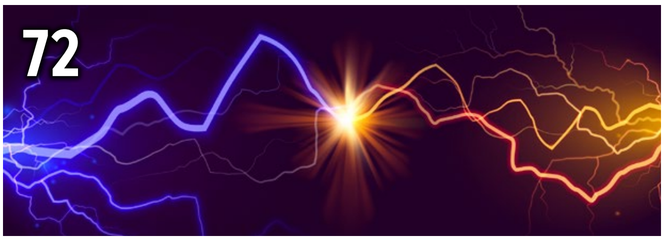

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New Era Manufacturing

Nolan's Notes

by Nolan Johnson, I-CONNECT007

In a 2010 *New York Times* article titled "Failing Like a Buggy Whip Maker? Better Check Your Simile," writer Randall Stross confronts the buggy whip analogy and unintentionally offers some perspective on our industry.

Stross tells of Daniel M.G. Raff, an associate professor at the Wharton School of the University of Pennsylvania, who once said the buggy whip analogy is "an obscurity sitting on an anachronism." He says the buggy whip market was a fringe player in the overall carriage business to begin with as the bulk of the business centered on iron and wood fabrication.

So, where do we get this buggy whip trope? Turns out it originated with Theodore Levitt, a Harvard professor writing for the *Harvard Business Review* in 1960. In his article titled "Marketing Myopia," Levitt posits that buggy whip manufacturers should have seen themselves as being in the personal transportation business rather than the buggy whip business, and that this change in thinking would have allowed them to survive. Stross says that Levitt blamed the buggy whip industry for having a lack of imagination.

In an interview with Thomas A. Kinney, an assistant professor at Bluefield College and researcher on the carriage industry, Stross learned there were 13,000 businesses in the carriage sector in 1890. Kinney told him, "The people who made the most successful transition were not the carriage makers, or the accessories makers (such as buggy whips) but the carriage parts makers." Need an example? Timken Company, a manufacturer of roller bearings, originally made carriage bearings, hopped over to the car trade, and thrived in the automotive era.

While the carriage makers tried—with limited success—to transition into automobile manufacturing, the buggy whips simply "had no automotive analog," Stross wrote.

He concluded, "When it came to adapting to the automotive era, businesses like axle and

carriage lamp makers had the opportunity and succeeded. A similar mix of success and failure is unfolding today. Most camera makers, for example, have successfully switched to digital technology—no small feat. Those that don't make it to the other side in the digital transition could reasonably be compared to carriage makers and carriage parts makers. But the buggy whip makers never had a fighting chance."

This bit of history seems quite appropriate for our discussion this month. I've certainly heard the buggy whip analogy used to describe what's happening in the U.S. PCB fabrication industry. However, it's inaccurate. I believe it's more about the thinking of the speaker than the PCB fabrication industry itself.

For example, PCB fabrication is thriving on a global scale. Innovations are occurring regularly, mostly in Asia. It's not that the world has moved beyond needing printed circuits; the world is simply evolving its wants and needs from a circuit board fabricator. It makes sense that those who are leaning on the buggy whip analogy may have given up on the industry. Truth be told, however, we're more like the carriage parts manufacturers than like the buggy whip makers. Those companies who seize the opportunity to shift their skill set and expertise into the next new thing will survive and thrive.

What about upgrading a brownfield facility? At first blush, this theme would suggest a heavy concentration on the manufacturing floor details. Maybe a heavy dose of new capital equipment and line design topics. Well, not so much actually.

In our expert interview with Alex Stepinski, he makes the case for a specific set of duties by a chief technology officer (CTO), someone who is focused on more than technical details. The CTO's role is to integrate sales demand, technical capabilities, and finance into a business case for advancing capabilities that follow the market. Don't have a CTO? Someone on your staff likely is already fulfilling the role. However, are they doing everything they can to be successful? Alex's important discussion will help draw the parallels between PCB fabrication and the coach parts industry even clearer: It's the CTO who charts the course in this evolution.

To better understand what's needed in upgrading our brownfield facilities, Michael Carano, part of the IPC Thought Leaders Program, shares insights on the industry and why upgrading capabilities are essential, while Dana Korf discusses developments in materials that will influence manufacturing processes.

I also want to draw your attention to some of our columnists: John Mitchell, president and CEO of IPC, sends a dispatch from India, and newcomers Paige Fiet and Christopher Bonsell share critical insights on both the big picture and improving your process.

I would especially like to mention our interview with Gerry Partida regarding his recent research on stacked microvia behavior and his further insight after presenting at IPC APEX EXPO 2022. He's preparing a new paper on his findings and gives us a peek. Complementing this interview are Happy Holden's column on Nano-Cu paste for microvias, and Michael Carano's long-running column, where this month he discusses plating distribution and throwing power.

All these topics touch on the evolution of your existing facility into a new-era manufacturer of the kinds of components that customers are (or soon will be) demanding. We're not an industry of on-the-fringe buggy whip makers; we're central to the electronics industry. We're more like the metalworkers who shifted from carriages to cars—and thrived. **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 read other columns or to contact Johnson, click here.

The Brave New World of the CTO

Feature Interview by the I-Connect007 Editorial Team

In this conversation with the I-Connect007 Editorial Team, Alex Stepinski shares his insight on how to automate the PCB fab. Spoiler alert: It doesn't start with new equipment and panel handlers; it's much more strategic than that. Alex details the new role of a chief technology officer in the 21st century and cautions that we don't have nearly enough of them in the industry.

Nolan Johnson: Alex, the pressures are increasing on PCB fabs to mechanize, and it's coming from several directions, whether it's capabilities, labor, or staffing abilities. How does someone in charge of a PCB facility move this forward without breaking the bank, or having to hire a coder or software engineer?

Alex Stepinski: This is an interesting topic. It is the intersection of investment management: what a CFO does; and technology delivery: what a CTO does. You could say that an advanced CTO with a strong finance background is likely the key person to drive something like this in a company. You don't even necessarily need engineers on site; you just need one person who can architect the whole thing. It's all about intrapreneurship with the Lean startup approach. The question is, "How do I move my business plan forward to improve my efficiencies—labor, capital utilization efficiencies, return on invested capital, commodity strategy?" You need a plan for a particular process area: If we upgrade to X, what do I get out of it? What products and emergent

Alex Stepinski

capabilities can I get, and how can I monetize them? That's how you must look at it to get it done in a time-efficient manner.

For example, it's hard to watch people in an old factory with insufficient capital invest at a time when returns are high. They're working on a machine that's 30 years old, and it's great heroism to get the product through the machine because it's poorly designed and not capable of doing the product you currently build. Typically, you don't automate a 30-year-old machine. Instead, you get a modern machine that's capable of building the products that you're booking (or want to book) in your factory. The process must also be stable to be automated. It's that simple. That's the first step to overcome, especially for older shops where they rely on the operators to manipulate things to get the product through. Is the process stable and capable for the products that you want to build under automation? If the answer is no, then you must upgrade the process first.

Barry Matties: You must remove all the operator band-aids before you can automate it. Otherwise, even if you automate the process, it isn't going to work.

Stepinski: That's right. Honestly, in a lot of the older shops, this is predominantly the case. At the same time, you hear "there's not enough space for the automation," which stems from never having had an automation strategy when whoever started the business so many years ago. When you look at these two things—the band-aids and no space—(plus the process is not stable), usually the best thing to do is get a new piece of equipment. But how much of this equipment in your factory portfolio needs to be replaced? If it's a few percent, go do it. I'm sure you can find the financing/ROI. If a lot needs to be replaced, that's a different story. You really have to think about what you're doing. It might even be time to sell because valuation multiples are high now and you may find someone gullible enough to buy.

But if you think you have a way forward—maybe starting to build a certain type of board—and you can estimate your return on that investment, then you can finance a bigger project. Today's machines are typically smaller than the ones designed for the production days of the 1990s and earlier in the United States, so you need less space.

When you look at investing in mechanization, it's really about the process plus the automation. You don't just put loaders and unloaders on some machine that you deemed capable, or some machine that you upgraded. How much more sophisticated do you want to get with new products? What kind of product mix do you have? How many panel sizes do you have? In the North American market, we have huge numbers of panel sizes. In overseas locations, you don't see that. In places that are more highly automated, there are fewer panel sizes.

The material cost is typically a lot less than the processing cost, and panel size optimization is a big trade space. You can often reduce the number of panel sizes, which leads to supply chain economies and drop-charge reduction while not increasing TCOQ. It increases the mechanization cost to have excessive panel sizes because you put additional axes on the loader zone and make conveyor width optimization to improve quality via perimeter contact untenable. Loaders can have adjustable panel sizes that adjust on demand—or you manually do it, which then offsets the purpose of the automation.

With 24 inches as your common access, for example, you could go from 18"x24" to 24"x36". Maybe you could go for a smaller substrate type stuff and have 12"x18", 16"x18", 18"x24", something like that. That covers line cards, HDI, and substrates. Having a strategy for the panel sizes will reduce the automation costs. Reduce the size of the equipment, because the more panel sizes you have, the bigger the automation kit gets. What kind of loaders/unloaders are you looking at? There are robotic systems, and systems that are based on fixed axes. These systems also have high, low, and no-code interface options.

Cobots are also popular nowadays. We have recently evolved from free-standing units to units in an enclosure like the Kuttler model from 20 years ago but with lower cost of ownership, with added sensors for more safety factors so you don't double-feed slip sheets, pick up two things at once, etc. You can maybe check a 2D code and make sure it's the right job, too.

Beyond that you get into higher end robotics, or systems with a mechanical clock approach to things. But once you get into the higher end systems, you become beholden to suppliers to do the coding for you, which is part of their strategic matrix to take your money. You need to understand that. If I step into that space, will I have to pay the supplier a premium to do all the work for me and maintain my equipment? Am I willing to go there?

If you're an older shop, you don't go this far; you stop at the cobot and the enclosure. If you're a greenfield OEM, you typically go all the way, and you have an internal engineering team. Some go with the code from the automation supplier, while others want to code it themselves. The internal code capability is the safest, most sustainable route long term, because you never know what could happen to a supplier.

Strategically, this is how it looks to me. Full Industry 4.0 is not in the cards as a first step if you're an older shop that doesn't have any mechanization. You must go through these phases first, get your payback, and then let's just see if you want to do anything more.

Matties: What's the roadblock?

Stepinski: What I've found in the past year is that the system architect in a given fab shop does not normally have the combination of technical, financial, and sales skills to do these kinds of things. You don't have one person who does it all. That makes it hard when you need teams of people. In a smaller place, these teams may not exist; people are too busy.

> **Current estimates say that anyone coming out of school right now will go through 10 to 14 jobs by the time they're age 35.**

To me, that's the biggest roadblock. A solid CTO role is probably the highest ROI investment and leading the pareto frontier for organizational value in 2022, because if you're an older shop trying to hire young people right out of school, it will be hard to retain them. Current estimates say that anyone coming out of school right now will go through 10 to 14 jobs by the time they're age 35. That's the prediction I heard from one of my professors at London Business School, which is based upon a recent Princeton study.

So, it's a very thought-provoking path. Hiring younger people into an apprenticeship program might have been the way you did it in the past. Yet it's not such a good idea anymore because you already have a challenging work environment unless your factory is the only game in a small town, and even then, remote work is a competitor to you. Inevitably, you must deal with people constantly changing jobs. In this environment, it is generally better to hire a CTO who can be the architect. They're responsible for the technical part, but they also have some finance background to plan the investments, look at the return on invested capital, and how to balance any necessary financing for new equipment. If they do not have the finance background, pay for the classes so that they can get it.

There's tremendously high demand in the United States for anyone who can help upgrade a factory; it's just about connecting the dots in the plan. From my recent experience, there's a strong ROI right now, and it's a great environment to do business. We just need someone who can connect the dots.

Johnson: Alex, it sounds like some of the fabs may have optimized R&D right out of their organization.

Stepinski: R&D groups are generally only present in big companies with a portfolio of strategic projects. In smaller shops, it's not about having an R&D group that develops an automation process, or that you can't afford to have an R&D group; they're just not there. Say you want to replace your plating line, but you can't justify it. You need to say, "We can justify it if we can hold this tolerance and we get these new revenue programs." This is typically the CTO who should be saying this.

Then you talk to the customers and get some commitments and assurances—and not without risk/reward of course. Now you can say, "I'm going to do this because once I upgrade, I can get these programs." That's the risk-reward all business is based on. To me, this is how things should proceed, and that does not happen as often as it should. In many U.S. shops, the nature of our market is that it's often thrown into engineering's bucket to make bricks without straw. Also, suppliers are often leveraged as well, and they act in their own interests (which are not necessarily yours).

Happy Holden: I agree, R&D is a different set of skills than process and plan expansion where you've got to focus on the goal, and the business plan that's driving it. You need the practicality of keeping it simple.

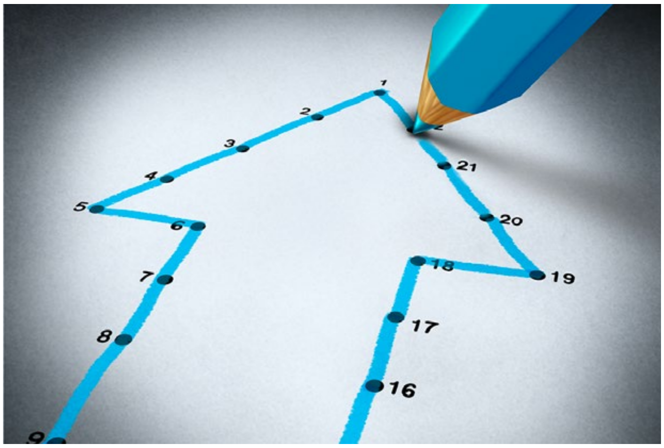
Johnson: My question was reflecting some of those myths or assumptions that mechanization is an engineering and process development-type activity; more technical/R&D work. You're saying this is a business plan approach?

Stepinski: Yes, completely. The market is ready for this. If you take that approach, you will take off right now. With all the supply chain disruptions and the current political situation, it's perfect timing.

Holden: That's why I emphasize the engineering economics of return on investment, cost of capital, and present net worth and installation.

Matties: How do you assess the current sales effort and talent within the industry? As CTO leadership, you're bringing in tech, finance, and sales.

Stepinski: These are the things a CTO should be doing in 2022. I've been taking courses myself on a regular basis and this is what the top schools teach. You're supposed to cover the



technology aspects, be quite strong in finance, and be a key salesperson. Basically, you're the integrator of these three functions for the company.

Because people who do this work are very highly compensated, you typically can't afford to have more than one. When you're in this role, you have a lot on your plate. Now is really the key time to get a position like this started. As the CTO, you work with the salespeople. Hopefully you have some market intelligence about programs you can get, then you find those programs and tie them to investments.

You can then say to a customer, "If I put this process in place, will it solve this problem for you? Can we do this project together or this family of products together?" I usually ask what technologies they need help with, and how I can help. What product families can you not build? Then, you engineer a process that builds that product's family, you take your existing kit, and you identify what needs to be upgraded. You make a portfolio of these investigations. To customer A, you say, "If I do this project with customer B, it requires the least modification and I get the fastest return, maybe it's more strategic than the others." This is usually what happens when you do this type of evaluation. This gives you the basis to make your business plan approach, and a portfolio of potential programs is always desirable to de-risk the investment.

It's not just calculating an NPV or internal rate of return on something; it's connecting the dots. As the CTO, you are the capex/op-ex improvement hunter: You find projects and tie them together to justify capital. Interestingly, there are not that many people doing this at the level required. In the worldwide PCB industry right now, I would say there are no more than 10-20 folks who really do this blended role well, and others just copy/tweak from the pioneers' successes. To develop someone with these skills just doesn't exist; there's no program to really grow our industry. That is missing.

Matties: You won't find this type of role in most small shops. Instead, you will have a process engineer or a president with an engineering background.

Stepinski: You still need a CTO, no matter how small your shop is. With the exception that the product mix is nonexistent, you're building one part number and the president has plenty of time on their hands. Another approach is that you're the president, and you get more education in these three areas so you can be the CTO and the CEO.

Matties: This isn't necessarily surprising; we've talked about benchmarking to have stable processes. You're jumping from the old paradigm to a new one, having forward-thinking rather than reactive management. Is there an area of particular interest that you're focused on?

Stepinski: No. To be honest, I turn down many projects because they aren't the right fit. But since I started my own business, I've learned this is what we were missing in the market—people who do something like this. It's the path to rejuvenation.

Holden: Could you share some of the initial steps you make? What step leads to the next one, and so forth? You've probably done this more than anybody else in the past 10 years.

Stepinski: I spent some time on a sabbatical before I started my business. I also went to finance school, engineering school, and some business schools, then synthesized everything I'd learned. I identified this big need in the market and developed my own plan. I developed myself in this way, and it seems to be working. I think it's a good model for others to do the same, because we need more of it.

Johnson: Alex, it sounds like you're a consulting CTO. You help companies put together a plan, possibly helping their CTO advance their skills.

Stepinski: I'm not a CTO of a factory. I help the CXO. But it depends how fast you want to grow. Do you want to constantly invest and reinvest? Okay, then you need these services, and you should have your own CTO too. If you just want something short term, then it's just connecting the dots to identify the right investments to improve the business plan and I can help out. Investments can be equipment and human capital as well. It's contract services for things like software. You know you don't want to hire too many people from that "10 to 14 jobs by age 35" group, and you realize that in this economy, contractors are the name of the game because it gives folks freedom to live where they want and do what they want and I have found that the capital investment-to-value efficiency is much higher. Certainly, having your own staff still has value, but many of the tasks nowadays are one-off items and do not justify full-time specialized roles. It also keeps your CTO less administrative and more technical with a smaller staff.

To be really successful in 2022, I think you need to embrace this trend. As the CTO, you say, "I don't need too many engineers, that's not going to work for me. I will identify improvement projects that pay for themselves, and then find a blend of contractors (not suppliers with conflicts of interest, by the way) and in-house resources to execute those projects." The burden on the CTO is developing those work statements for everything: the equipment, services to be provided, and any job/skill descriptions for associated people.

Your worth as a CTO is how well you can create these work statements for people, services, and equipment. Once you make the statements, you get the work insourced/contracted out, and follow up on your investment. Highly skilled people are a scarce resource. Help them get more education so they know how to manage this stuff. Putting together a program where CTOs get trained to integrate these three functions that then allows you to start investing in your business again is a big hurdle, but if you can put the right person in place, you will start to grow and improve ROIC to raise your business valuation.

Highly skilled people are a scarce resource. Help them get more education so they know how to manage this stuff.

Matties: Are you focused specifically on bare board fabrication?

Stepinski: I'm multi-industry; most of what I do is greenfield. I'm not doing anything in brownfield PCB shops directly right now, but I do perform worldwide process research and develop IP that is useful to them. I do some direct contracts with brownfield in other industries, but I'm a little all over the place right now in both the U.S. and EMEA. I never thought too much about doing the PCB brownfield job shop side directly because it is a hard-headed market in general.

Matties: I don't know if that bodes well for a bright future for the bare board shops.

Stepinski: Look at it this way: Why are Europe and Asia automated and the United States is not? Why is that?

Matties: What are your thoughts about that?

Stepinski: You have more production in those regions, so you get economies to scale from the automation, and the competitive landscape is based upon who can make the widget cheaper. The U.S. outsourced all its production. Europe outsourced too, but there are some German shops still doing significant production for the automotive market. In those shops, you see the automation. Other shops in Europe, even if they're not doing that mass production, see the automation in Germany, and they adopt those practices because they have something to reference. It's easy to visit the German shops, see how it's done, and learn from it. In the U.S., we don't have these reference accounts. Everybody locks their doors and they're not as friendly.

I find the EIPC conference, for example, to be a much friendlier place than perhaps IPC APEX EXPO when fab suppliers are talking to each other. I see a lot more cooperation on the European side than on the U.S. side, for instance. The U.S. and Europe are analogous in a lot of ways. Europeans outsourced, but they retained their automotive, and you saw advancements. In the U.S., we outsourced everything, and many of the shops that had automation closed up.

In Asia, they went full-bore automation, because this is where all the production is. You get scale economies from automation; you compete better when you add automation.

If you're in an agile situation, you don't have the same automation strategy as a volume production shop. It has to be semi-automatic because you won't set up your process to build one part number all day. In this instance, you treat everything like a work cell, and the focus is this: What products go through what work cell, and when/how. From an operational planning perspective, in the U.S., you typically find that one machine will do many different processes. There are different recipes associated with different processes. If you have electroless copper, desmear, or something like that, those aren't just for desmearing the hole or putting electroless copper on a through-hole. They do blind vias, maybe a button plate, or a cap plate over epoxy via fill.

You also have pattern vs. panel applications, seed layer management, and it gets quite sophisticated. You can build products in the U.S. market that take 400 steps. This is typically not the case in production shops where they streamline things, have bigger lines, put more steps into the line, and standardize.

In the U.S., you could best accomplish this all through a good product lifecycle management (PLM) system. They're very cost effective, and you can use the PLM to architect your bills of process: how the recipes work, how things interact. You then have a nice framework for how to automate your factory. It's an excellent software tool with a very low cost to use as a framework. I would also complement this with a DSM (design-structure-matrix) optimization of the bill of process (BOP).

Without this disciplined approach, you automate based upon all the evolved operations, but the capital efficiency and ROI are less if you do it in this way over the long term. You can't just say, "I'm going to have these standard work cells, and put the same loader and unloader concept on every single one, because it's too agile for this." Instead, you must say, "Every machine is different, and I may need to have a different solution for each one, a different system architecture, and how I'm going to manage this system to maximize ROI." Don't do standardization for the sake of standardization even if it looks good on paper on the system level, but focus more on the subsystem level to get the savings. Each work cell has a distinct system. You take them one by one, based upon the return on investment. First, tie it into projects with clients and that's the approach.

How can we expedite it to improve the U.S. market? Like we discussed, training is a good idea, and there needs to be more brainstorming to develop a program. Another idea is having a site or two that's more open with automation, so people see the benefits. Schweitzer Engineering Labs might be the most open-minded site because they're very America-oriented, willing to show what they have. Most of the others have a lot of IP, or just a lot of sins, and they're more worried to share.

Holden: Here in western Michigan, there must be at least a dozen firms that focus on automating manufacturing, especially robotics. For example, JS Automation has a specialty that allows it to not only supply Detroit, but the Japanese, the Germans, and the world.

Stepinski: Yeah, I think we have more of it in the States than almost anywhere else.

Holden: Unfortunately, there's an endless supply of engineers needed, as our unemployment is down to 2.8%. They're leaning on the community colleges to turn out more skilled technicians.

Stepinski: But this isn't the right approach. It's what I would call an unidentified problem with an overall solution. It's better to think, "What action will fix this?" First, the industry can get together and write a statement of work to make domestic automation and equipment at a low cost. Let's make some standard specs for this essentially commodity equipment and get it made in the U.S. We pay twice the price of Asia for most tools in the United States. A lot of this can be mitigated by standardization of subsystems.

If we all had the same focus, everything would be highly automated and you wouldn't have to worry about all these technicians. Second, because you leverage the existing network of people who know how to do it; that's what you do. The next step is having people to run your factory. If you have cobot automation, it's not that highly skilled a force, to be honest.

We focus too much on skilled labor here (not that it isn't valuable and necessary), but we should be more focused on writing good statements of work to get simple automation in place and simple processes that anybody can run. That's a much more cost-effective approach. Then we leverage our own network of domestic automation people. It makes a lot of sense.

Matties: Do you have any final thoughts?

Stepinski: To help these factories turn things around, we need the type of discussion we're having now. We need a group to spend a couple days creating a good strategy for our industry to grow.

Matties: We will definitely carry this conversation forward. There's certainly enough time to put something like that together.

Stepinski: Great talking to you guys.

Johnson: Thank you, sir. PCB007

Alex Stepinski is principal and president of Smart Process Design, an international technical design studio.

Anatomy of a CTO

Here's what it takes to be a chief technology officer in the 21st century

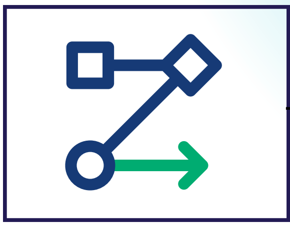
STRONG FINANCE BACKGROUND

The CTO integrates finance, technology and sales; one person who can plan the investments, look at ROI, and balance necessary financing.

A STRONG SALESPERSON

Today's CTO works directly with the sales team to acquire new programs and tie them to investment.

FORWARD-THINKING PROCESS PLANNER



The CTO needs to plan for each process area to achieve maximum results. Processes must be stable in order to be automated.

MASTER SYSTEM ARCHITECT

The CTO is the capex/op-ex improvement hunter, finding projects and tying them together to justify capital.

INDUSTRY 4.0 EXPERIENCE

Acquiring a quality CTO is probably the highest ROI investment an organization can make in today's market.

Source: "The Brave New World of the CTO", PCB007 Magazine

Opportunities in India for Electronics Manufacturing

One World, One Industry

Feature Column by Dr. John Mitchell, IPC PRESIDENT AND CEO

As president and CEO of the global electronics industry association, I have many opportunities to visit electronics manufacturing companies worldwide. Recently, while in India, I had the pleasure of attending Integrated Electronics Manufacturing & Interconnections (IEMI), a celebration of 10 years of IPC activities in India, Sri Lanka, Bangladesh, and the middle east Africa region. I was encouraged by how much growth has occurred over the past decade. Poised to become a global manufacturing hub, India is emerging as a dynamic market for our industry. The government has opened its doors to foreign investors, laying out the red carpet for manufacturing companies, and the industry is thriving.

John Mitchell delivering his keynote, "Electronics Manufacturing Embraces Digital."

Because it is estimated that manufacturing opportunities in India will bring the industry \$200 billion by 2026—a large increase from the \$75 billion India currently takes in—it's easy to see why the electronics manufacturing industry is looking so closely at India and all that it has to offer. Labor costs are low, the industry is very savvy technically, and English (a dominant language in the business world) is widely spoken.

India's transformation to a vital manufacturing hub includes Apple opening operations and manufacturing phones there, providing one of the largest products in terms of dollars that Indians consume from a "local" manufacturer. Government officials are reimbursing portions of company investments, based on objectives met by participating companies. Officials encourage semiconductor manufacturing and hope to entice companies to seek out India as a potential spot to set up shop.

To celebrate IPC's decade in India, I was accompanied to the inaugural IEMI by IPC staff executives Sanjay Huprikar and David Bergman. IEMI is a planned annual event encouraging designers, manufacturers, traders, suppliers, service providers, and technical experts to connect with one another and government officials through member networking events, workshops, and skill challenge compe-

During the inaugural session in New Delhi, John Mitchell participated in lighting the Nachiarkoil lamp, a symbol of how darkness will always be overcome by light and knowledge will overcome ignorance.

John Mitchell presents a bouquet of flowers to Dr. C.N. Ashwath Narayan, the Chief Guest at the IEMI event in Bengaluru.

titions as we continue to build an electronics community in India.

Part of those community-building efforts included signing a memorandum of understanding (MoU) with the Vidya Vikash Institute of Engineering & Technology in Mysore. This MoU ensures that diploma students take IPC's Electronics Assembly for Operators training as part of a new course the Institute has developed to expose students to more hands-on work with electronics. Because this initiative helps to develop a future pipeline of workers, it is actively supported by several Mysore-area EMS and PCB companies which are providing internship opportunities to these students to better round out their experience. The students will start the course in a few weeks and wrap up in November. We plan to share the results of the evaluation with Dr. C. N. Ashwath Narayan, the minister of Higher Education, Science & Technology, and skill development for the State Government of Karnataka, and his team. Dr. Narayan was the chief guest at the IEMI 2022 event in Bangalore.

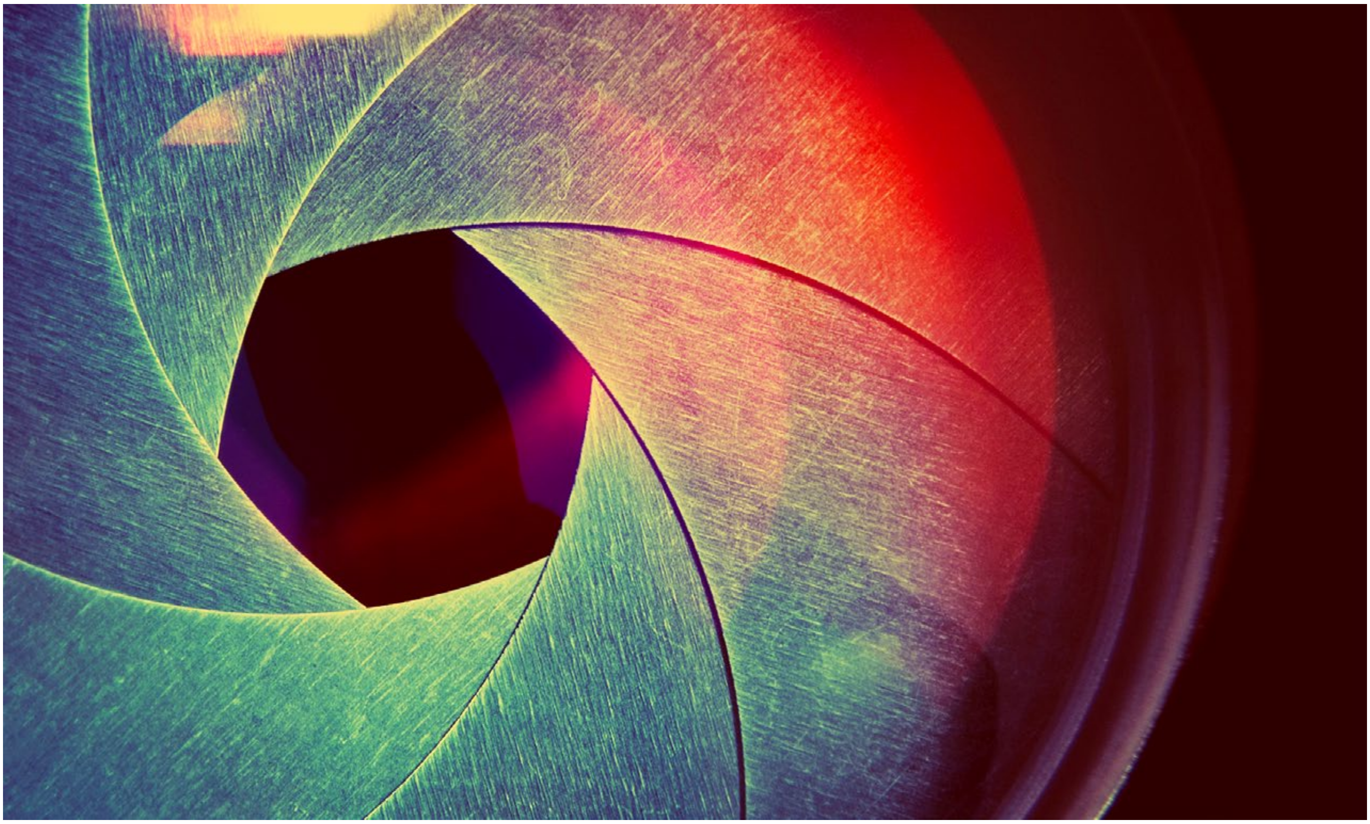
Other highlights of IEMI included encouraging attendees to become more involved in the creation and adoption of global standards and workforce development ("skilling" and "re-skilling") programs such as the government of India's "Make in India" and "Skill India," along with updates on the importance of IPC-CFX as the definitive data protocol standard for Industry 4.0 success.

My visit to India and attendance at IEMI illustrated how eager IPC is to support an electronics community that embraces the idea that big problems can be solved when trade associations, training content providers, academic institutions, local industry, and government collaborate in an influential hub for electronics manufacturing. I'd like to strongly encourage India's industry leaders to step up and volunteer their time to engage in critical activities around standards, education, advocacy, and solutions that will benefit the entire value chain.

For additional information on IPC's activities in India, contact Gaurab Majumdar, IPC India executive director, at GaurabMajumdar@ipc.org. **PCB007**

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

A Focus on Process Control



Feature Interview by the I-Connect007 Editorial Team

Michael Carano is a noted subject matter expert with respect to process control, electroplating and metallization technology, surface finishing, and reliability. So, it was only natural that we sat down to talk about mechanizing an existing facility given today's fickle environment. Will any of the CHIPS funding trickle down to bare board fabrication? What process can be adjusted on the factory floor? The focus needs to be more than just on manufacturing and getting work out the door, he says, but also process control.

Nolan Johnson: You have a wide-ranging view of the current market, and how fabricators should approach advancing their capabilities. Walk us through your IPC Thought Leaders Program paper.

Michael Carano: To start, everyone is talking about the $52 billion CHIPS Act, but our folks in the PCB industry say, "Hey, that's great, but chips don't float. Where are the chips going to go?" Unless we build out PCB capacity as well, the chips will "float back" over the ocean into an OSAT or something like that. There's no IC substrate capability here with any volume.

In my paper, I was asking about what it would take to double the capacity of existing fabrication by upgrading the equipment. It would be about $10 to $12 million per fabricator, with maybe 100 fabricators altogether—about $1.2 billion. Now if you include brick and mortar, then I would double that number to about $3.5 billion, then double again to a $7 billion market over a couple of years by making this invest-

Michael Carano

ment, whether it comes from government, in-kind states, or whatever.

Upgrading of the opportunities would include horizontal equipment, new plating technologies, reliability, testing internally, materials handling, via formation, laser drilling, and more. I looked at all new equipment, state-of-the-art flying probe testing. That's all included.

Now, if you just started with the greenfield, that might be more like a $25 to $40 million investment. But take our key five or six fabricators out there—such as TTM, Summit, APCT, FTG, Calumet—that have several fabrication sites under their ownership. They have quality people and engineering. If the DoD really wants to have some safety and security, then we need some help. There's a way to do it that doesn't even put a dent into that $52 billion.

Johnson: For the CHIPS Act, it's about 2% of the funding.

Carano: Exactly. Let's use that to get into the technology and what it will take to make this work. Our fabricators are capable and stable. They're well managed, but in making that investment, they need some help to minimize or de-risk some of the investment they would have to make. I know they could do it and do it well.

The chemical processes keep evolving, materials keep getting better. When some say, "Look at what's going on in Asia, the chemistry works so well." Wait a minute, it's the same chemistry, so it's nothing secret; 90% of the chemistry in the world and materials were developed by U.S.-based companies. They may have facilities all over the world, but that technology is there. When someone tells me the plating technology doesn't exist here, that's not true.

Digital Factory

Barry Matties: Where does the digital factory come into your thinking for bare board fabricators? There seems to be a lot of reluctance, a "we're small and that doesn't work for us" mentality.

Carano: You hear about CFX and the Factory of the Future. The assembly companies see the machines, the need for them to be interconnected, how the data is transferred, basic monitoring, and even if there's a glitch, how it can be repaired quickly.

Then there's blockchain. What will that do for me? This is a big part of the security of any transaction, software development, or factory operation. They don't see the connection, or the cost seems to be a concern. Furthermore, why aren't we investing in more semi-additive or additive processing? Often the fabricator doesn't see that CFX, digital factory, as a big move for them and as something that will enhance their position in this industry.

Johnson: Fabricators are having a hard time staffing the floor for their old processes.

Carano: Workforce development is extremely difficult across the board. I'm traveling here in

California and help wanted signs are out all over in manufacturing places, not just in the circuit board industry. We're not looking necessarily for PhDs or electrical engineers with master's degrees. We're trying to attract those who can do the job, want to be part of the CAD/CAM or drill operator teams; someone who can handle the chemistry and run the lines.

IPC is working very hard on workforce development by reaching out to students at the college and high school levels, getting them excited about electronics and what it can do. IPC has done a great job. We need more of that. Maybe all the fabricators and assemblers in California can combine efforts to share a common message, such as, "Here's what this industry can really do, it's a great career for you. You can advance. It's exciting. What we do makes things that change and improve people's lives."

Rebuilding Margins

Matties: We're already on thin margins and that's a barrier for capital investment. How do we help those margins?

Carano: As we know, there was a shift to offshore technology about 20 years ago and it hasn't really come back. Most don't realize that almost $20 billion of the circuit board value that gets reported, though, is in things like iPads, mobile phones, smartphones, and other things that we wouldn't make here anyway.

We've never really made cellphone boards here. However, this has evolved electronics overall. There's a melding between semiconductor and circuit boards, a convergence in the United States and Canada. There are opportunities for focusing on higher margin processes because those are protected. We wouldn't want those over in another country; we want them here. That's the military, aerospace, medical, automotive, and internet infrastructure that can be done here. But I'll ask fabricators, "What's the issue for you?" They say it's not so much about margins, but about yields. If they had higher yields, they would make more money. The problem is, though, how do you improve yields from 90 to 95%? That could be significant.

Much of it relates to workforce development, training, certification, equipment, instrumentation, and so forth. I've seen several fabricators that haven't made upgrades in their equipment, some of them for many years, and you can't go from 3-mil lines and spaces to 1- mil lines and spaces with an entry you had 20 years ago—it's just not going to help you. If the investment can enhance the yields, then we have the opportunity to do more. But the other thing is that with the approximately 180 fabricator buildings in the country, maybe 90 of those have fewer than 50 employees.

If a large OEM walks in and says, "I like your work and what you do here. I need 10,000 pieces a week," how will you help them? It will take up all your capacity. Your space is limited. That's why, in my Thought Leaders paper, I suggested that doubling capacity would include hiring more workers. That can help us bring the industry back to what we had several years ago.

Let's face it, the technology is much further advanced today than it was 15 or 20 years ago when the market started moving to Asia. The good news is we have this opportunity to stake out our position. We don't have to want everything, but it can be IC substrates, high-end aerospace, defense, medical, safety, and security, that's a big deal. Cybersecurity is at the forefront, and you have all these opportunities that would be protected-type industries. If you get the automotive companies behind it, along with the various software companies for security and then of course the military aerospace, we have an opportunity to rebuild this business here in North America.

Matties: Regarding yields, though, isn't it the management's discipline to control the processes that we already have? If we already have well-managed companies, but our processes are out of control, maybe there's a lot of improvement for management discipline.

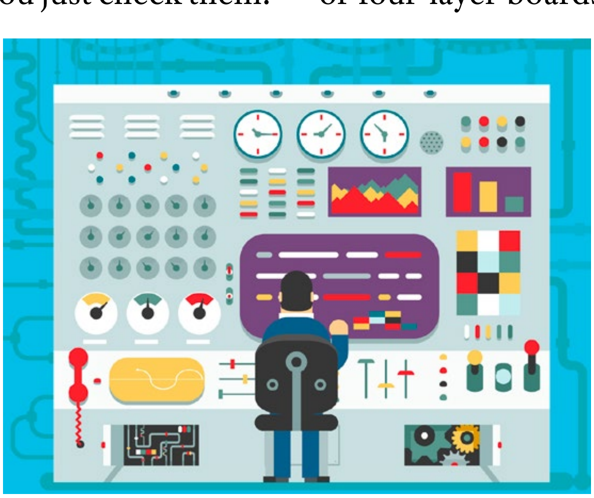
Carano: Oh, obviously. There are investments. One of the things I've shown folks over the years is I can completely automate the controls of a process, several lines, for less than $50,000. That includes controllers, online controllers, online monitoring, something as simple as a conductivity probe to measure the conductivity of the water when the rinsing is poor, and we got ionic contamination. Those little probes cost about $180. You carry them in your pocket, like a pen. You just check them. I don't see a lot of that. The focus needs to be more than just on manufacturing and getting work out the door, but also process control.

I can't tell you how many times I went to a facility, walked over to the electroless copper line, and then looked at the electroless copper controller. "Oh, that's a nice controller, but it's not hooked up or not running properly and it hasn't been calibrated lately. Why do you have it if you're not going to use it?" That's where variation takes place, and when there's variation, there's a problem.

Matties: So, part of the investment that fabricators need to make has to come from thinking about process—process control engineers, process engineers, etc. But when you start talking about shops with 50 employees, you can walk into a facility and tune it up for $50,000. Do they not have the knowledge? Because $50,000 isn't resource limitation.

Carano: Right. It's not that they don't have the knowledge. The problem is the company has one engineer that does everything. That's it. Everyone else is in administration. You need a place with more engineering talent, ones who can understand the process and what happens in the process. But you have a young person who comes in and has to work on imaging one day, solder mask the next day, and then plating the next because a "fire" breaks out. It all cascades down. Something is out of control. What do I fix right now? With more automation on the controls, the instrumentation will give you online analysis.

Don't just depend on your supply base to do all this for you; you need it onsite and with much tighter controls. If you're building eight- or four-layer boards, maybe you don't need to do all that, but you need process control no matter what. Only a few processes are truly automated in terms of control. Maybe the alternate etcher has the feed and bleed. But even with that, you want to make sure the equipment is maintained so it gives you an accurate reading

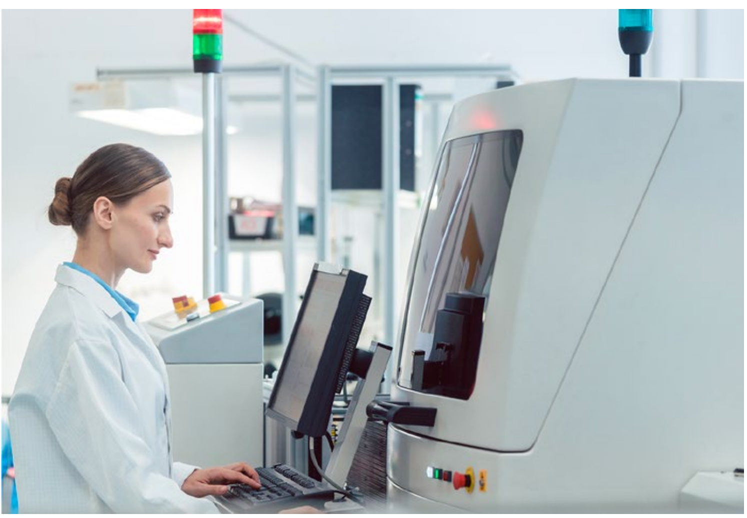


and keeps the chemistry within a tight operating window. The other one is much more extensive, and that's where engineering comes in. There's a lot to do with imaging. All the processes must come together. It's not just plating, the materials, or the materials handling. It's the etching, imaging, surface preparation, the workflow, and how people manage it. In this industry, there's so much going on at one time and it's all interrelated.

The Special Brownfield Challenges

Johnson: In the Thought Leaders paper, mechanization and automation is strongly implied. Such as, if you were to go through that $10 million upgrade, you'll have a lot more mechanization and automation available to you on the manufacturing floor. Can you do this in a brownfield site?

Carano: That's a good question. You walk in, you say, "Here's what I would do right here." You've got an etcher in this corner, and you've got imaging over here and you carry the panels from imaging to etching or developing. Early in my career, I was working with direct metallization horizontal processing. You start with bare copper, go through horizontal desmear and then drilling. So, it's horizontal desmear, down through the direct metallization line. You shorten the process because direct metallization really squeezed a lot of time and increased productivity as well as quality. From there, it goes into a slit in the wall, into a cut sheet laminator, the photoresist gets laminated, and the panel imaged. Then it goes into another room and gets developed, etched, and stripped, all automated, all horizontal.



You can do a lot with that. You don't have to say, "I must make this workable. I must make 10,000 panels a day." No, you don't. You can size the equipment properly, you replace the equipment with the latest in etching technology. It's probably a shorter footprint, and you just do it horizontally. In Asia, almost everything is horizontal processing in some way, shape, or form, except maybe for the electroplating. But I've seen people do electroplating horizontally, in a continuous fashion, and yet they have a lot of engineers. Those engineers are freed up to solve any technical issues because they're constantly watching that.

There's a grocery store by my house that has automated most of the cashiers, but they didn't eliminate the jobs. Instead, they put the people out in the aisles to help you find what you're looking for. They guide you to find what you need and if they can't find it, they go to the stockroom and get it for you.

That's where you get that personal touch. If you have engineers on the floor, instead of worrying about running the horizontal line, they're solving problems and keeping everything in tight control. Audit those processes on a regular basis. Is it getting out of control? Are the temperatures rising or is it out of control? It's all about variation. Some people, like Happy Holden, are firm believers in process audits and how to control things. As I've talked to Happy, I've learned it could be done in a reasonable fashion with less money. Most people think it's going to cost millions and millions. It's not.

Johnson: If it's a brownfield site that has a very difficult workflow, they've got a problem. They have to start at step zero and develop a workflow before they can take advantage of the automation.

Carano: That's exactly right.

Matties: It sounds like one of the first audits a shop should do is determine what the process engineer is working on. What's a typical day? How do we free them up from the things that are, as you're saying, not taking care of the customer, if you will?

Carano: Exactly. Remember that you have the line workers that are feeding the etchers and moving the panels on the floor. You want to invest in their training so when there's an issue, they will notice it, stop the line, and call the engineers. This is "customer facing," problem solving, and making improvements.

From an engineer, I always look at their total chemical costs and they tell me, "Oh, my costs might be too high." Well, how do you know? How are you analyzing it? How are you controlling it? If they're into a situation when the bath gets contaminated, we just send it to waste treatment. Well, that adds cost. At that point, it's contaminated and why? Maybe that's the first thing you do. That's the engineer's job. I've worked with some great engineers over the years who really understand how to control things and optimize processes. They spend their time doing that and educating folks on the line. I've seen these engineers improve how the chemistry is managed and added, how it's controlled. Not only does it improve yields, but it reduces waste and cost.

People always look at cost per liter, cost per gallon. It's not the price, it's the cost of ownership. What does it cost you to make this circuit board? That includes a lot of things, including the quality of the handling, the yields. You're looking for an efficient use of the processes and that can be done with people paying good attention.

I've had people tell me their electroless copper is $2 a square foot. I look at it and I can see why. They're wasting chemistry. The vats are not shutting down properly at night, so the chemistry is plating out. You could be doing

some simple things that don't cost you anything: Turn down the temperature and turn on the air pump to keep the baths stable overnight or clean out the tank on the weekend to prevent any doubt. That's waste, so don't get mad because your costs are high. When you get it back to running properly, then the cost per square foot goes down by 50% or more and the reliability is also there. Some very simple things can be done, but it's about education, training, certification, and getting everyone on board—including the ownership and management.

Matties: Right. If management doesn't buy in, it's not going to happen.

Carano: No, it won't and that's the same story. If an OEM doesn't come to them with the design and says, "I need you to build this. I want you to build the 20-micron lines and spaces," they won't make the investment into that next technology. It's a shame because there are some great opportunities to do this process-, chemistry-, and material-wise. It could be done.

Matties: In a brownfield site, what's the priority in terms of transforming the facility?

Carano: I would start with a top-down audit of all processes, including imaging materials, handling storage, and humidity chambers. How are you controlling the plating processes? Where are the matching processes. From there you make the recommendations. You need better controls and better lab equipment. You can't just have burettes and titrations; you need some other methods of controlling your processes.

To build high-end items, you must figure out reliability. How reliable are your processes? That's important. There are opportunities to do D-coupon testing, CITC, as well as IST. You can use outside sources to qualify that. I would look at the latest in registration and imaging. How could I automate more of the etching? Can I connect the etching and imaging processes together? At the very least can I improve the etcher? Can I get a better etcher that's not 20 years old? Can I enhance my electroplating knowledge and tank set-up with new via fill technology?

There is good electrolytic copper technology today and it's getting better. All the suppliers are pushing via fill technology with new equipment and chemistries. To upgrade, you must take a leap of faith.

To upgrade, you must take a leap of faith.

The mil/aero space is clamoring for some help by the North American fabricator, otherwise they will go offshore. They will argue to the DoD that if they can't get it built here, then what? You're going to shut down an entire fighter program? That would be devastating for this industry. To me, it would be the death of it.

Johnson: In general, does the ownership in the U.S. fabrication industry have the motivation to do this?

Carano: I've talked to several, particularly some who bought a new company or additional companies over the last couple of years, and they're committed, smart, and motivated. Their work is full, upgrading where needed, looking to hire, moving up to the level they need to, investing in some equipment, maybe plating equipment and flying probe technology.

The next step is with ultra-high density. It will be much finer lines and spaces, which translates into not just various layers, like signal layers, but into the IC substrates. That requires another level of investment. The current lasers are great, they're at 1 mil, but you will get below that, down to 0.5 or 0.8 mil. That will require an investment, which will typically cost more. Then you maybe add a new laser CO_2 YAG drill. That's another cost.

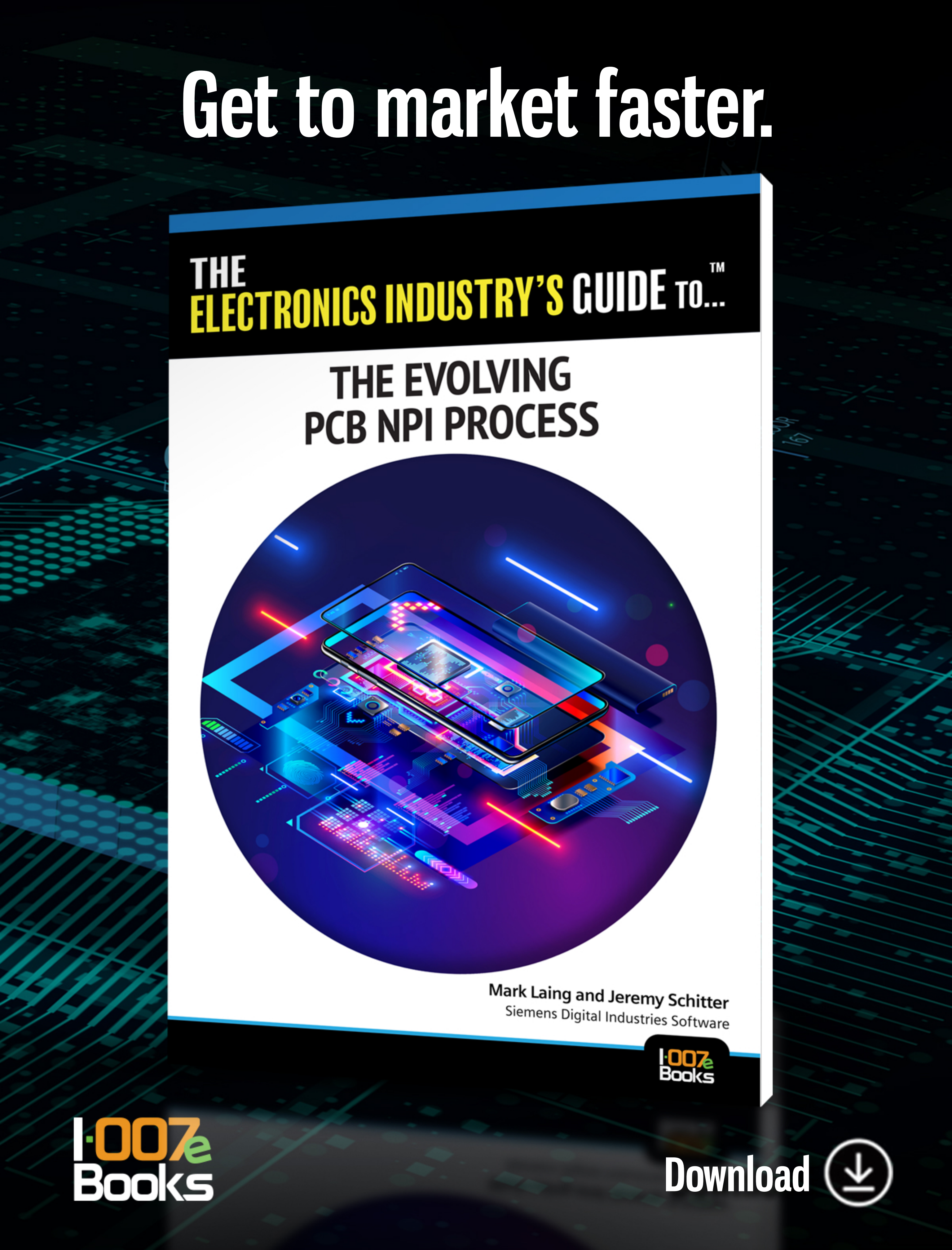
I'm sure the military aerospace group will get some help. There's money to be spread around and it's not going to cost a billion dollars per fabricator. With $10 or $20 million, it can be done. Then, get people excited; instead of working in a foundry, which is not rad, come to our circuit board business, our electronics business, our interconnect business. We can give it something that says, "This is really cool."

Johnson: With an automated factory, now you're starting to talk about more of an engineering function than just an operator function.

Carano: Exactly. Folks can come in from a technical school or a two-year program and say, "Hey, this is fun. I want to do more. I want to learn more." They might want to take night classes or other training so they can do more on the job. It's life-changing, knowing the products they make are helping somebody. If it's for the medical industry, for example, making stents more reliable for the human body, making heart monitors more reliable. While it's not the end product, those stents go in someone's body and they need to function. They can't corrode or cause problems. That can make your work more enjoyable.

Matties: Thank you so much. We greatly appreciate your time.

Carano: Thank you. PCB007

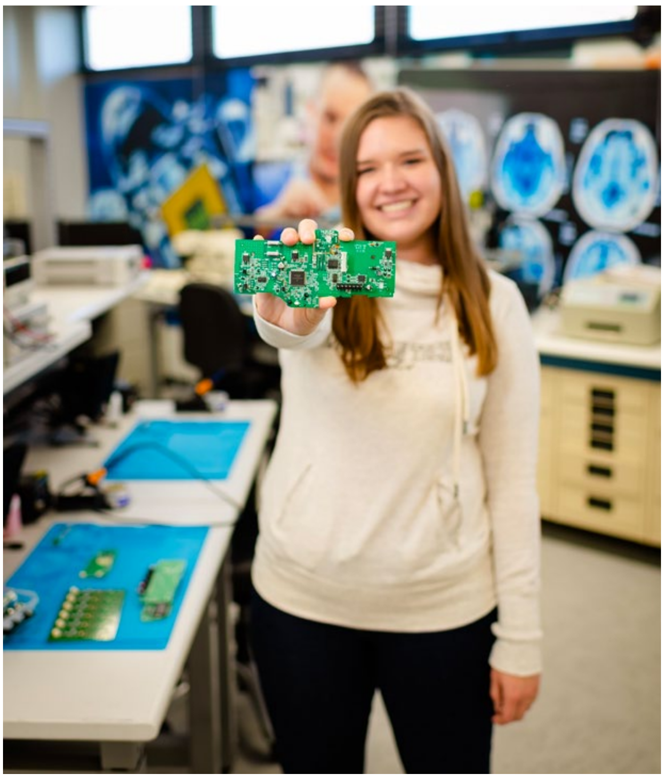


Let's Make Manufacturing 'Cool' Again

The New Chapter

Feature Column by Paige Fiet, TTM-LOGAN

Sometimes I imagine I could have learned about PCBs by tinkering with a double-sided board in my garage. Although it may seem silly, I'm intrigued by wave-soldering machines and through-hole components. Within each of these elements lies innovation and pioneering—a blast to a not so long ago past. Electronics have evolved over the past 50 years more than any other industry ever has. Whereas my parents' generation grew up with simply-designed video games, my generation grew up with apps that teach toddlers how to code. If hardware was the past, software is the future. It's trendy, complex, and neatly packaged in a work-from-home environment.



Computer science has become the new "cool." Today's students were groomed to want jobs in tech at big companies with happy hours, big paychecks, and high status. They were taught that they could design anything their heart desired from behind a computer screen without a second thought for the person who had to manufacture it. Let's face it, manufacturing just isn't sexy. It's dirty, manual, and—for electronics—has a history of low margins. The pipeline into the field is broken. What was once a self-sufficient stream has dropped to a pitiful trickle.

The first step in rebuilding the pipeline into electronics is awareness. Prior to my first internship on an SMT line in my hometown, I didn't think twice about what made my cellphone work or how my computer was powered. During my first week, my mentor gave me a handful of spare components from the scrap bin. They were so different from the through-hole components I had been working with. I had no idea this was how most circuit boards were made today, nor had I given thought to the companies that assembled them.

The next summer I applied to a circuit board manufacturer under the pretense that they were also in assembly because they had "electronics" in their name. What a shock during the interview when they showed me that the PCBs they made were the ones I had assembled just the summer prior. (Funny enough, I interviewed a potential intern this summer and he had applied under the same pretense.) That summer, I learned so much about the electronics

Long gone are the days of employees looking for as much overtime as they could get. Tomorrow's engineers are placing a higher value on a work-life balance. They care more about experiences than belonging, and if something doesn't feel right, they are quick to get rid of it. In fact, Gen-Z is estimated to change jobs 15–20 times during their career.

The generation entering the work force now wants to be challenged. They want good managers, and to feel like they are making a difference in the world. However, they are very interested in flexible schedules, the amount of PTO hours and, for some, the option to work from home. It also appears that budding engineers are looking for careers on the edge of technology. Research and development is becoming more desired but that will need to be balanced with a strong foundation of understanding. How then do we keep the basics interesting?

In the age of miniaturization and digitalization, it's important to keep up with the awareness of the people behind the hardware. Let's make manufacturing "cool" again. Who cares about designing the newest and coolest tech gadgets if we have no one to build them? The future is electronics, but we can't get distracted behind the user interfaces and fancy software without risking the end of our hardware innovation. PCB007

Paige at the TTM Logan golf tournament in August.

industry; it brought the awareness that I was missing previously. Suddenly, it was not just a summer internship for me but a future career. The endless opportunity and job security of the industry excited me. What my peers saw as a dying field, I saw as a limitless challenge. I have yet to be disappointed.

An Opportunity to Engage and Excite

After students become aware of the industry, it's time to engage and excite them. This is where mentorship is huge. Although each of my mentors holds a place in my heart, there is one mentor who sticks out because they were closer to my age and showed me what was possible as a young person in the industry. Watching their success encouraged me to see where I could be in the next three to five years. Maybe that's putting the cart before the horse, but I think placing less-senior engineers with their peers is one of the best ways to excite and retain them.

Half the battle is attracting new talent. However, I believe the even harder part is retaining talent. Although the reason for quitting a job is unique to the individual, there are common themes among this new age of employees.

Paige Fiet is a process engineer at TTM-Logan and involved in the IPC Emerging Engineer Program. To read past columns, click here.

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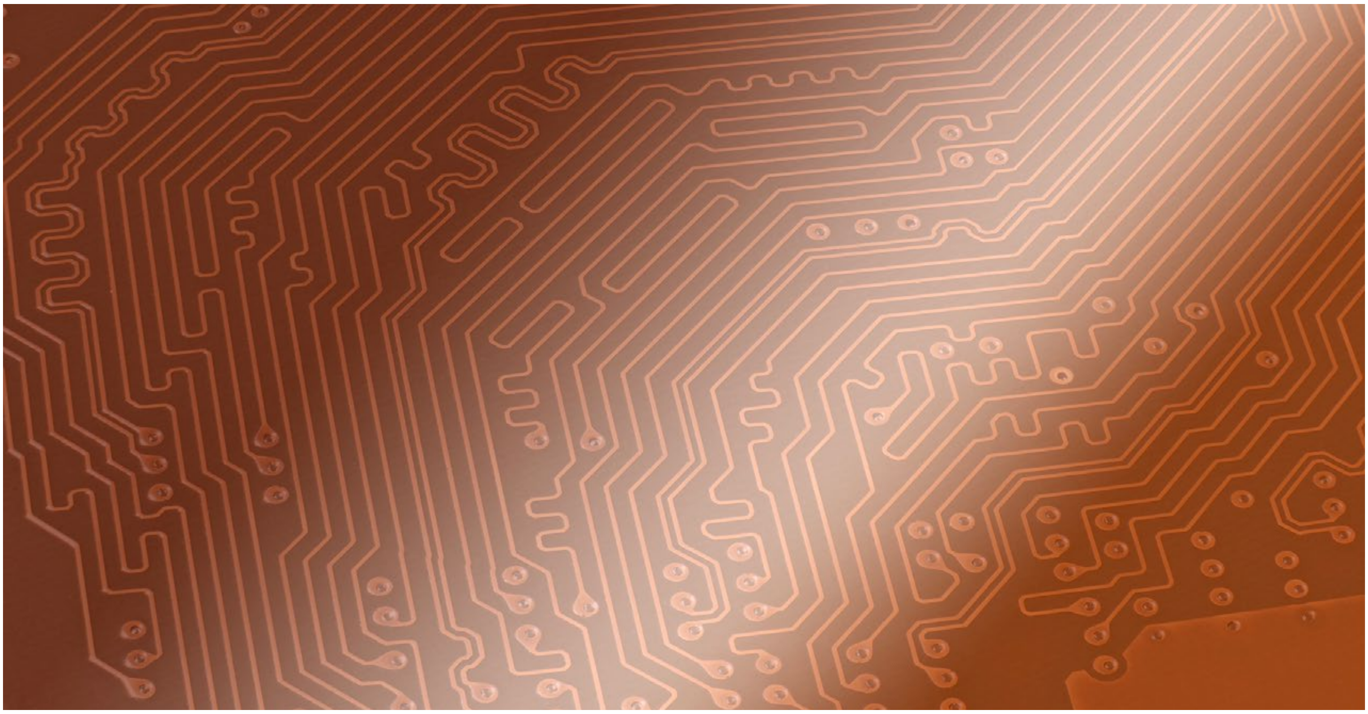

Korf and Strubbe: Material Witnesses

Interview by the I-Connect007 Editorial Team

Recently, columnist Dana Korf has been working with Taiwan Union Technology Corporation (TUC), one of the largest providers of copper-clad laminate and mass lamination services in the world. We spoke with Dana about the trends he sees in materials at TUC and around the globe, why copper is still king, as well as some potential non-traditional materials that may see growth soon. Dana invited John Strubbe, TUC VP of technology, to join in the conversation.

Nolan Johnson: Dana, what's new in the materials world? What are you seeing?

Dana Korf: If you look at straight FR-4, there's not much going on. There are more high-voltage requirements in the automotive, so there's a little bit of tweaking of FR-4 to handle voltages around 1,500 or 2,000 volts. Of course, they want long-term reliability, but that's a relatively minor technical requirement to obtain. With HDI, it's just a matter of working with thinner glass fabric with the traditional HDI resins, because layers are getting thinner and the number of required lamination cycles increases every year, but that's more of an adjustment of material properties.

Chip packaging is becoming a constraint. Many companies, like TUC, are now offering chip level packaging materials because there's just more demand for it than the market can handle. That has a fairly long approval process, just like automotive.

John Strubbe: Most of my work is in low-loss materials for digital. Trying to, as I often say, "get down to free space, no loss," for the same price as FR-4. There's a lot of work in copper foil and resins, and a lot of analysis on the glass fabrics. They're starting to look at quartz again and polymeric materials. They're trying to get down to really low losses for digital, but the designers are running into the problem

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that even if you get the losses down to that level, it's still not good enough. There's analysis about whether the loss-budget gains you get vs. the cost will be worth it or even possible. That's what most of the large material folks are working on now. In the RF space, they're pretty much just working on better controlled RF materials to get the cost down.


Dana Korf

Korf: When I was working in China, I was seeing digital designers looking at RF materials to get their losses down. The RF folks were looking at digital performance materials to get the cost down, and that's still going on. I see that most of the material development work is primarily being driven to reduce the loss, Df, primarily in the digital space. There are umpteen varieties of FR-4, so they seem to be covering the market well; the high voltage for automotive is stressing the specs a little bit, but not too much.

What's interesting on the material side is we're starting to look at non-glass alternatives. As John mentioned, we're looking at quartz again, like we did in the 1980s. The problem with quartz glass is that when you hit it with a laser, it melts and balls up. It doesn't evaporate away. That was a challenge many years ago when we tried it.

Johnson: That makes it tough for laser applications.

Korf: It does make it interesting.

Johnson: What are some of the nontraditional materials being evaluated?

Strubbe: We can talk about the coppers getting down to zero roughness, what's going on there, and limitations. Does it stick to the resin at the end of the day? Like a lot of technologies, they tend to cycle every 20 or 30 years, and improve with every cycle. Fundamentally, it's stuff that's been looked at before.

Johnson: What's going on with FR-4 and are there other materials being looked at? It seems a lot like Moore's law in ICs: We're on the verge of making it fail, and now what that we've made it fail?

Korf: I made a presentation last month on materials technology and attendees asked, "Why do we have all these different materials for low loss?" I said, "It's a result of how it was invented. We could only go this far, so we did. Then the next year we reduced the loss a little lower based on available material technology. Then we went a little lower. But as we achieved lower loss, the earlier materials suddenly became more attractive because they were less expensive than the newer low loss materials." Manufacturers could adjust the composition and it was still usable. We would have gone straight from A to Z if we could have, but we couldn't. The interim versions tend to hang around because they found niche applications for lower costs.

Johnson: What are your thoughts on a materials pivot?

Korf: The goal is to not go into fiber optics. The industry is trying to keep away from fiber optics as much as they possibly can. The battle cry is, "Stay on copper."

Johnson: How does this address materials, material choices, in general, for designers? We were just having a conversation about additive and if you redesign to what's available in additive, you can often eliminate multiple layers from your design, from 16 down to eight, for example.

That's not only good for your costs and better for your yields, but it's better for the capacity of the industry, because now half the materials you once required are available for other designs. Where's that confluence of what designers can do to change how they do their job and materials come together?


John Strubbe

Strubbe: It really hasn't changed much over the years, it's just the requirements which have changed. Fundamentally, additive is nothing new; it was built in Kollmorgen (PCK) in the '70s. The process has improved and it's better. You can start knocking layers out if you can use 2-mil lines and spaces and run them 30 inches. Not all designs can. Their signal will survive that tiny little trace, but if you don't have to worry about current, which is with a lot of applications, they all work just fine. If you look at the technology and materials from a designer standpoint, the drivers are primarily signal integrity (SI) and power/heat. We're seeing more applications of coins and thicker planes. Because there are more electronics being packed in the same area, the heat goes up.

Korf: The SI engineer says, "I need to lower my losses and I can only get so much out of this material, so I must keep my copper traces wider, maybe make them a little bit thicker. I can only go down so far in layer thickness to increase density, but if I go too far, my impedance drops down. That creates another problem." A lot of the work is trying to control some constraints from timing, from a loss budget standpoint, from the trace with materials. When materials run out, now you start playing with the trace and that's where you get difficulty because you can only bring a trace width down so far and that creates another set of problems. You have plated through-holes to transition signals between layers. These holes require pads which consume a significant amount of real estate.

The SI folks are continuously looking at copper: copper roughness, the grain structure of copper, and the roughness on all four sides. The challenge is to make traces wide enough to reduce losses, but that causes all these density questions. The challenge from the designer standpoint is to keep the traces wider because of SI reasons but they've got to keep their 50 ohms, which constrains two of the five constraints. I can get you a lower-loss copper foil, lower-loss glass, and lower-loss resins. It's just a matter of how big your checkbook balance is. Signal integrity drives most of these changes.

Strubbe: On the automotive side, it's a matter of asking, "I've got a lot of current, so what do we do with all this current we need to get from the batteries back to motors?" That's their challenge. The sensors and everything else, existing materials, could be tuned from a cost standpoint for the various frequencies required—you see a lot more people in the microwave space now because it's getting so huge due to automotive. It's a matter of the signal integrity standpoint from the designer, "I need to keep my traces wide, but my BGA pitch is going down." It's a natural conflict. We're seeing some 3D technologies coming out now, and it's true 3D. They give designers a little different option, but it has its constraints too.

Johnson: Is TUC working in the 3D space?

Korf: There may be development that can't be talked about yet. Most of the materials are based on inks. Laminators are starting to provide solutions in the 3D space.

For a designer, it's the traditional challenge: they must get all the traces in. Signal integrity related budgets are getting tighter. There's always a drive to reduce layer count. You're right that every time you add two layers, you add 20% or more to the cost. That's a consistent and traditional cost bump. The lesson is to keep layer count down. The engineers designing the lower end servers—like you see in server farms—have a maximum layer count because they're trying to keep material costs down. In addition, they don't use the low-loss materials that they'd love to use, simply because they can't afford them. In the high-end servers, cost is not as much a concern as loss. It depends on the application.

I liked your recent *Design007 Magazine* issue on design for manufacturing, especially the sections that discussed the designer's linkage to manufacturers, and just how many steps away from the manufacturers the designers are now. That part really hasn't changed too much over the years. It's getting worse, too, because the buyers make uninformed decisions when they specify the material in a drive to reduce costs vs. optimizing the material properties for the design.

Johnson: Compare that to the 1970s, when everybody in my neighborhood worked at Tektronix and the electro-chem facility was across the street from offices of the teams designing the circuit boards. All you had to do was walk over and talk to techs on the fabrication floor about what they could do, and back-and-forth you go throughout the entire design phase.

Korf: In those days, a lot of the big companies—Tektronix, Digital Equipment, Data General, or IBM—had their own shops where you could tune it to the designer's cost and performance. They could drive technology inside because they had high profit margins. They also spent more time on research; we've lost a lot of that.

Andy Shaughnessy: I'm amazed that so many boards get through. So many designs are successful even though they're not talking to the fabricator until the very last minute.

Korf: I had a conversation with a person in the IC industry last week about how bad our data files are, how we need to improve that with 3D technology, and that we have a chance to start from scratch. He says, "What you mean? They're always good." I said, "No, you came out of the IC fab business where a mistake would cost maybe $100,000. Here we fix it for free."

It was painful to make a mistake and have a bad data file in the IC industry, but not a board fabricator. Unfortunately, that's the core of the problem. From the design side, though, relative to materials, it's a traditional problem. They must get the cost as low as possible vs. a little bit more expensive material to improve circuit performance or reliability. That's what they're driven for.

Strubbe: The challenge continues. It's just more people are getting increasingly higher speeds, so they must worry about more things. In the old days, we had a board designer, the person who laid the board out once we had CAD tools. They came out of the drafting industry. They were primarily drafting people but nowadays they're electrical engineers because there are so many constraints.

Johnson: Right. That's the transition.

Korf: Yes. The trend I'm talking about is not so much from just TUC; it's everyone who is providing materials to this market. The biggest supplier in the world just makes low-end FR-4 and CEM materials because that's their market. It's huge, so there's plenty of customers/volume in that space.

Johnson: I think this is really good. Thank you, Dana and John.

Korf: Always a pleasure. We enjoyed it. **PCB007**

ICT Webinar:
Your Journey to a Smart Factory

Presented by Happy Holden

Happy Holden understands—getting started can be the hardest part. For the past 55 years, he has followed his passion for automation and computers by writing books and white papers, and engineering and managing projects. Each one has always meant one thing: finding the right place to start.

In an upcoming ICT series of eight online sessions, Happy will introduce the topic of "Automation and the Journey to Your Smart Factory," by breaking down the elements this type of journey requires, addressing the five W's, and encouraging study on your own.

Each session is approximately 60 minutes, and is offered at 4:00 p.m. Wednesdays, Sept. 7 to Oct. 26. The webinars are based on Happy's books: *24 Essential Skills for Engineers* and *Automation and Advanced Procedures in PCB Fabrication*. Happy Holden is a retired electronics manufacturing technologist, contributing technical editor for I-Connect007, and a member of ICT.

"The hardest step is getting started," Happy says of his past experiences. "I know; I have done this many times. I have designed and built nearly nine automated PCB factories and a dozen more process factories in my career, all automated by computers and the software that drives them."

What he's learned is that your journey to building a Smart factory must focus on who will design it, what they need to learn, how to analyze and plan the automation, how long it should take, when is the right time, and how much it will cost.

"There are seven major topics to be addressed, with the primary one being to meet your company's business objectives," Happy says, adding that can be achieved by the following:

- Company business objectives
- Zero waste
- Internet of Things sensors
- Predictive analysis
- Zero-defect manufacturing
- Driving zero downtime
- Create solution templates

"Once you have the 'who,' then you need to give them time to learn some of the new tools and skills that will be required," Happy says. This is where he includes the two books he has written, as well as other book titles from I-Connect007, NIST, Siemens, and more.

Once a company has decided to start a Smart factory, Happy says implementing it requires a focus on three things:

1. **Sensing:** Collecting the data in real time
2. **Connecting:** Uniting different and unique data sources
3. **Predicting:** Using models to use the data for predicting the outcome of machine/process events for alerting operators, to predicting machine downtime for maintenance, to improving processes for high controlled impedance performance

The ultimate goal of all this work, Happy says, is customer satisfaction and business success. He suggests first looking at predictive analytics, which will drive you to zero downtime and your quality to zero defects. This can be done by improving overall equipment effectiveness by 5 to 10% gains, and lowering costs through improvement in labor productivity by 10 to 25%.

Traditional methods of statistical process control, process monitoring, and OEE can be replaced with predictive process monitoring and control, providing benefits that improve overall performance and the bottom line, he says.

To view the webinar, sponsored by the Institute of Circuit Technology, contact Bill Wilkie.

This series of webinars is offered at no charge. You can register at any time during the eight weeks, and lectures will be available on-demand after each one is presented, for those who are registered. **PCB007**

How to Automate Your Wet Processes

The Chemical Connection

Feature Column by Christopher Bonsell, CHEMCUT

Considering automating your PCB fabrication line? If you are, then you may have concerns about what it takes to implement new automation technology. The good news is that setting up your processing lines for automation is simpler than you may think. Whether you are obtaining new equipment, or you want to automate a machine that you've been working with for years, automating it can be as simple as tightening a few bolts and wiring a couple connections.

Automating your process lines is now easier than ever thanks to low-cost, user-configurable robot arms. Since most of the processes from the beginning to the end of PCB manufacturing are already automated (at least in wet processing), the only areas left open for automation are the loading and unloading sections. In most cases, people are employed to stand at the ends of the machines loading and unloading material throughout production. As you can imagine, this is not very cost effective because often these people could be performing more important, specialized tasks. By using low-cost, user-configurable robots at the loading and unloading ends of a process (loader bots), you open opportunities for your PCB production to improve. First and foremost, you will reduce the cost per panel thus increasing your profit margins (Table 1 and Figure 1).

Table 1: Cost estimations and parameters for comparison of loader options.

Cost per Employee	Cost per Bot	Shifts	Working Hours per Week
$20 per working hour	$26,000 + ($1.25 per working hour)	2	80

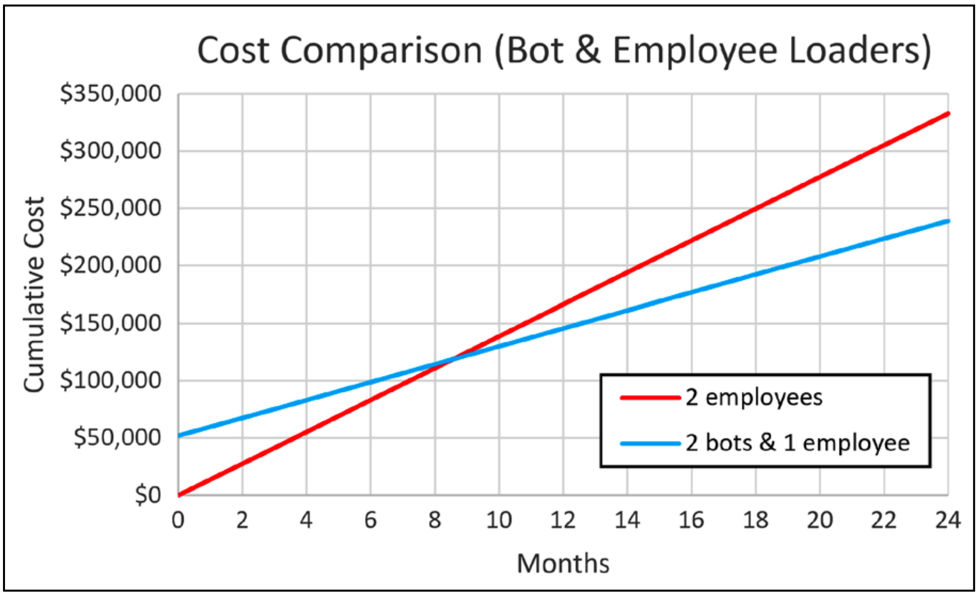


Figure 1: Cost comparison between running a PCB manufacturing process with two employees vs. two bots and one employee (the single employee is for machine maintenance). Data comes from Table 1, with the assumption of equal production volume. Graph shows the long-term cost of loader bots will be less than utilizing employees for loading/unloading purposes.

On top of the cost decrease, you can shift your employees' focus to maintaining the equipment, thus improving machine longevity and efficiency. If this is the direction you wish to take your PCB fabrication line, here are a few considerations you will need to get started.

How Many Loaders Are Necessary?

Before you consider automating your process with a loader bot, you will first want to think about the minimum number of loader bots you'll need to successfully automate your process. This number will depend on your answer to the following questions:

- How many panels do you need to produce per day?
- What is your conveyor speed?
- How large are your panels?
- How many processing lanes are you running (number of panels parallel on the same conveyor)?
- Are there slipsheets that need to be taken off before loading or placed in between panels when coming off the conveyor?

In most cases, you will just need two loader bots to automate your wet process: one for loading and one for unloading.

In most cases, you will just need two loader bots to automate your wet process: one for loading and one for unloading. Although this is the case for most, there are bound to be some exceptions. If you have small panels, high conveyor speeds, multiple processing lanes, or slipsheets involved in your production, you may need more than two loader bots to maintain the maximum production capacity without any errors. This is because to maintain a production level of full efficiency, every movement of the loader bot needs to be purposeful. The loader bot can only move so fast and with each additional task you require the bot to take, the less time it will have to make sure your conveyor space is fully utilized. Even in cases where there are high conveyor speeds and slipsheets, the standard two-loader bots can still get the job done. However, if you find yourself with multiples of these special cases, you should tell your bot provider/representative about the conditions you are trying to obtain. From there, they can run tests and work with you to determine the minimum number of bots to run your desired process. Once you know how many loader bots you will need, then you will know how many resources you will need to spare for them.

Base Necessities for Loader Bots

One of the great things about the loader bots is that they do not require many resources to function. The main resources they need are power, air, and space.

Some loader bots can simply run off a 9V wall outlet. Although they can run off simple outlets, it is wise to plan and provide a source of power that would be close to where the bot will be functioning. For safety reasons, it is best to arrange permanent wiring and avoid extension cords.

Air supply should be a relatively simple resource to provide for the loader bot as well. Since wet processing equipment typically uses compressed air somewhere on the machine, you can feed a line from that source to a regulator valve that would feed into your bot's headframe for suction.

Space is another resource that needs to be allocated to the loader bots. Thankfully, the loader bots themselves can be easily mounted on the side of a machine. Since they will be on the side of a machine, they will likely take up space that will already be available and therefore will not need much planning. However,

Figure 2: Mounted loader bot next to an angled panel tray.

additional space is required to provide trays to hold the panels. This would mean each robot would need a tray within reach. Figure 2 shows an example.

These trays will need to be slightly larger than the panels you are processing, but if you are also working with slipsheets you may need trays for those too. If you plan to reuse the slipsheets or to restack the process boards with slipsheets separating them, you will need extra trays to hold the sheets.

Once you have all these resources prepared, all that's left to do is to install the bot and create the routine that the bot will run through.

Conclusion

Setting up your wet process for automation is quite simple and the most it requires is just a little planning. Once you have all the necessities planned out, it is just plug-and-play from there on. You will get time to work with the program and develop routines for the bot to go through. After that, you have an automated wet processing line that can run for hours without human intervention. **PCB007**

Christopher Bonsell is a chemical process engineer at Chemcut. To read past columns, click here.


Help us finish the fight!

MilAero007 Highlights

IPC Offers First Advanced Packaging Symposium ▶

Registration is now open for the first IPC Advanced Packaging Symposium: Building the IC-Substrate and Package Assembly Ecosystem, to be held October 11-12, 2022, at the Kimpton Hotel Monaco in Washington, D.C.

Ventec Expands Flex-rigid Material Range for Critical Military, Aerospace, and Ultra-high Reliability Applications ▶

Ventec International Group Co., Ltd. has added to its flex-rigid No Flow/Low Flow prepreg range with the introduction of tec-speed 4.0 (VT-462(L) PP NF/LF), a next-generation no & low flow FR 4.0 prepreg material that offers high-Tg, low Dk, low loss, and excellent thermal reliability.

Michigan Tech's Middlebrook Receives Department of Defense Award ▶

The Department of Defense honored Michigan Technological University Professor Dr. Christopher Middlebrook with an award for his innovative efforts to close education gaps and help build tomorrow's electronics manufacturing workforce.

L3Harris, Air Tractor Sky Warden Team Selected for USSOCOM Armed Overwatch Contract ▶

U.S. Special Operations Command (USSOCOM) has selected L3Harris Technologies and Air Tractor Inc.'s AT-802U Sky Warden system for its Armed Overwatch program. Award of the Indefinite Quantity, Indefinite Delivery contract includes a cost ceiling of $3 billion.

Cicor Awarded with a Major Multi-year Aerospace and Defence Business ▶

Cicor Group has been awarded with a major multi-year follow-up business for a total value of around CHF 30 million by a market-leading European manufacturer of specialized aircraft solutions.

MicroFab Acquired by Naprotek, a Portfolio Company of Edgewater Capital Partners ▶

Naprotek, LLC., a leading provider of high-reliability, quick-turn electronics manufacturing, has completed the acquisition of MicroFab, Inc., a privately held company in Manchester, New Hampshire. The business and entire MicroFab team will be integrated into the East Coast operations at SemiGen, a Naprotek Company.

FTG Awarded Multiple Simulator Products Purchase Orders ▶

Firan Technology Group Corporation has been awarded a total of $7.5M in new purchase orders from its two largest simulator customers. FTG will supply multiple complete sets of cockpit assemblies for military and commercial simulators for different aircraft including refueling fixed wing aircraft, helicopters, and jets.

NASA Space Robotics Dive into Deep-Sea Work ▶

What's the difference between deep space and the deep sea? For a robot, the answer is: not much. Both environments are harsh and demanding, and, more importantly, both are far removed from the machine's operator.

Microvias Can Be Stacked in Certain Packages

Interview by the I-Connect007 Editorial Team

Summit Interconnect's Gerry Partida recently spoke with the I-Connect007 Editorial Team about his research into root causes of weak microvias. Rather than a single manufacturing process cause, Gerry suggests that microvia reliability is the culmination of several material interactions and that contrary to popular belief, microvias can still be stacked in small, tight packaging densities. He highlights the need for simulation, as well as some of his findings that he plans to publish in a paper at IPC APEX EXPO 2023.

Nolan Johnson: Gerry, I understand your team has been doing some research into microvia stacking and will have a paper at the upcoming IPC APEX EXPO on this topic. What have you been learning?

Gerry Partida: Remember back in the early days of HDI, we would stack microvias as deep and plentiful as we wanted to? Then people started experiencing intermittent failures. Boards got hot, the components would fail, and it went back and forth. Manufacturing did something wrong, the assembler overbaked the boards, and it would go back and forth again. A lot of designs started to suffer, especially certain military products that would stack microvias. We would ask, "Why isn't it working? Why does it work when it does work?" Most of the microvias that were stacked originally were small BGA packages. They were 0.4 mm or 0.5 mm, and those densities drove you to stack. These designs often were for the commercial OEMs, but if something failed, the commercial guys didn't come back to discuss the issues.

Gerry Partida

But for the military guys who have ASICS that cost hundreds of thousands of dollars each, the stakes are much higher. If it is for space, then it can only be assembled once for flight; it cannot be taken off and reused. The military packaging then was a much wider pitch than the commercial guys who were stacking microvias initially.

When we looked at where the failures were happening, they were still happening with the commercial guys who were going three or four deep stacking microvias. They weren't trying to make short, squatty, wide-diameter microvias because they were using thicker dielectrics to get wider lines for impedance. Consequently, we went for a time where there really didn't seem to be a problem. Then it became, "We see a fracture at the target pad on the stack of the microvias," and everybody thought there was a weakness in the electroless copper.

We all came up with these rules of thumb: Don't stack more than two. A lot of DOEs were done, and they almost always concluded, "Do two stacks and then stagger off." That seemed to work. Even fabricators we would work with had rules like, "Keep your aspect ratio for a single microvia at 0.75 to one. If you're stacking them, keep them at 0.6 to one." That seemed to work; we got good results.

Now, during this time we employed reflow resistance testing to monitor the strength of connections in the finished product. We started learning more about what works, and what doesn't work. Some designs would slip through, where they do a three-stack on tight pitch, and they were passing. We were asking that if our rule of thumb was only two, then why is it working at three? When you look at the design, it's a 0.4 mm pitch.

Last year, you interviewed me about the ability to simulate microvia reliability. As more material got into the simulation software, and as we had more experience with it, it became evident that the simulation was showing us that the tighter pitch devices could handle more stacked microvias and even smaller diameters. The simulation showed that it could survive reflow.

IPC accepted my paper for 2023, so my presentation will show that it is possible to stack deeper in certain package densities, but elsewhere on the board, you would need to stagger because of the material expansion of microvias stacked in the middle of nowhere. The via is fighting against the expansion of the material itself at 360°F. But in a BGA, it is supported by the other microvias around it, like rivets holding the material together. That's why they survived.

That's why the commercial boards in the past had survived—because they used smaller packages. That's what I want to share, in simulation as well as in D coupons. I want to put a tight, dense, 0.4-mm pitch and do a three stack. On the second one, put it on 1 millimeter pitch on the same coupon to demonstrate that there's a population difference between three stack and a tight pitch passing six reflows. Then when they're a 100-mil pitch, you will see more failures when they're wider spaced.

Now I have proof to give designers that, yes, you have these three levels of connections, these three microvias and connections. In these smaller packages of 0.4 mm, 0.5 mm, it's beneficial because it's a tight density. But don't take that same three-stack configuration outside of those type packages. You must stagger. You have room. If you have a discreet component or something that's big, there's room to stagger, and those can be reliably staggered by themselves.

I want to share with the design community that there's a rule that is dependent on density. What's illuminating is there's a deeper understanding of the reliability of the interconnect of microvias and where they fail.

What breaks the microvia is material expansion. So, when you stack them, it's the material expansion of the entire stack from top to bottom and how much strain is created during reflow. Do you have enough surface area to hold on for the expansion expected? That's what the simulation software does. It looks at the prepreg, how much is retained copper, total distance, and says, "There's this much force. You have this much surface area. It's not enough to hold on. It will fail at this reflow."

That's what I hope to present at IPC APEX EXPO so that it's helpful to the designers to understand, "Okay, I can do this safely in a very tight pitch device because the microvias support each other in an area. But in my design, I make sure I had different rules outside of those packages." For the most part, they use the same rule everywhere.

Shaughnessy: What was your process to get here? Was it just trial and error?

Partida: Luckily, we've had a D coupon tester in-house for years, so I had all the cross-section data for all the jobs that went through D coupon testing. With the ones that were weaker, I could go back and cross-section them. I could see how thick it was, and I could check the laser. I had access to the CAM data, so I knew what the laser drill size was. I knew what we were projecting for the dielectric. I could look at the cross-sections to see if we got there or not.

In early 2021, when I started using the simulation software, I had all this data. I wanted to plug it in backward from what's already tested and see how closely they match. For the most part, they matched. I had this one weird outlier, it wasn't matching, and I was looking for something else. But then we worked with our suppliers, and they said, "Look at your laser via. It's too smooth at the bottom. You didn't prepare this correctly." And then we said, "You know what, that's right." Once we did that, then the simulation software was in line with what was going on. It helps us make sure our processes are set right. Make sure that we are going with the right starting point of building a board. But the guidance is to have the customers design and use stacking where they can for their benefit, but not to put it where it's going to make the reflow in danger by stacking too much in the middle of nowhere. And that's really my mantra for this year in sharing with the customers or the design community.

It helps us make sure our processes are set right. Make sure that we are going with the right starting point of building a board.

Shaughnessy: Don't stack out in the middle of nowhere. That's good.

Partida: About six months after playing around with the simulation software, I changed the pitch from a real tight pitch, and I got a lot of reflows. I said, "Oh, wait a minute. This customer uses a 1-millimeter pitch," and I switched it. It was like four reflow cycles to failure. I thought, "Something is wrong with this software. The bigger, the better. It should have been better." So, I called the software guy, and he explained how the microvias, as they are densely packed, will support each other. He simulated and looked for that. As he explained it to me, I realized that every time I had a triple stack or four stacked microvia failure, they were widely pitched or in the middle of nowhere.

It was this realization: That's what happened all the time. It wasn't the BGA packages. It was always like some SMA that somebody hand-soldered and they didn't re-stack or in the middle of nowhere there was a resistance that kept on changing the component, taking it off and on. That material was expanding so much around that single location and kept on breaking the microvia. I said, "That's really what's causing this thing. We've got to let the designers know that you can't do that in discrete components. Just do it in your tiny pitch device."

And even one millimeter is too widely spread out. My friend refers to "mechanical crosstalk," where all the microvias in close proximity help to support each other. I couldn't find mechanical crosstalk as any term online, but it was brilliant. I like the way he said it.

My friend refers to "mechanical crosstalk," where all the microvias in closely proximity help to support each other.

Johnson: Gerry, you really have my interest piqued with that little story. You're talking to the engineers who created the simulation tool, and they've got this figured out—the fact that they have simulated this, and they know these effects. They also understand at this point how they interrelate. They have the most reliable microvia solutions figured out thanks to what they know in the simulator, because you can't simulate what you don't know.

Partida: That's what our industry has done. We've stacked microvias without knowing what the reliability would be or the cause and effect by the selection of prepreg material. We were blind and did things because we could. Honestly, it does all the impedance calculation. I don't bother at all. I let my guys do the stack-ups. I just plug it in to check the reliability. In my APEX EXPO presentation last year, I said this that is the ability to simulate what happens before we start fabricating. We should be doing it at the design stage. This is as revolutionary in what we do to fabricate circuit boards as it was to do net compare to the Gerber data back in the '90s. It's that much of a game-changer.

Shaughnessy: So, how does the simulation tool work?

Partida: You just type in whatever pitch you want. A lot of times I don't know from the customers what it is. I'll do a 1 millimeter, 0.8 or 0.65, and you just change the pitch. You change that number. Re-simulate, then okay, it's 10 reflow cycles to failure at 0.5; change it to 0.65. It's still 10. Good. Then switch it to 1 millimeter and it's 8, it's still safe. I'm okay with it. Or you run it at 1 millimeter and it's four reflow cycles. You run it at 0.5. It's 8. You say, "I've got to call them back. What is the pitch in your design that you have eight stacked microvias?" We must ask more questions. You can't just look at a print and know what it is because you don't know if they use a rule everywhere in the design or just use it in the tight devices.

They must do the simulation at the beginning of the design when they make the rules for the stack and the type of pitch devices and elsewhere. They really need to do it up front. That's a big paradigm shift for them. You're telling designers who many times don't hear about or deal with the reliability fallout at assembly, especially if they outsource the design. They're not intimately aware of what is going on with failures, low yields, or D coupon testing.

Shaughnessy: One of the crazy things about this was that a lot of these vias were failing during reflow, but then the open was closing back up. It would come out as a pass and then it would get into the field and fail. Is that still happening?

Partida: We affectionately call that self-healing. During reflow, usually an open on a microvia will happen as we approach the very peak of the reflow temperature. Therefore reflow testing and resistance monitoring is so critical and important. The event of the open is very short and it's wide open. It's not like a resist. It's open, but it's only at 10 or 15 degrees of the peak reflow that this happens. It goes open and then it re-connects. What happens is that the material compresses back down and just reconnects. Once it's gone open, a separation exists. It is so small you can't see it at 500x sometimes. So, when it cools down, it just compresses and makes contact at room temperature. But once the component comes up to the temperature, it can create a slight gap in resistance and if you're doing super high-speed digital, it's really an RF carrier and signal. If you have a gap, it's just going to ruin the signal.

Shaughnessy: This is pretty huge news. I know a lot of really smart people have been looking at this issue over the past few years.

Partida: I just want to share what we've learned. It is possible to stack microvias, sometimes. You have to simulate, though.

Johnson: Thank you, Gerry. We appreciate this.

Partida: Thank you for the opportunity. PCB007

WHITE PAPER EXCERPT:

Next Progression in Microvia Reliability Validation—Reflow Simulation of PCB Design Attributes and Material Structural Properties During the PCB Design Process

Gerry Partida, SUMMIT INTERCONNECT

Editor's note: This paper was presented and published for the 2022 IPC APEX EXPO Technical Conference in San Diego, California, and is reprinted with permission from the author.

To understand how best to address the failures of microvias, it's useful to go back into history. And, in particular, to start with the test method process.

Historically, PCB fabrication and delivery of finished products preceded test methods to validate the finished PCB. In the 1970s, PCBs were fabricated and shipped without electrical test (ET) validation. At the beginning of the 1980s, electrical testing became standard and a requirement for all but the simplest products. For the next decade, PCBs were built by using a "Golden" board programming. The Golden board method used a finished PCB from a finished lot of boards, and it was placed on a test fixture by an operator who would then initiate a self-learned shorts and opens program from the board. If the second PCB matched the first, a Golden board was established. One of the shortcomings of the Golden board testing was that it was susceptible to missing the errors in the fabrication data that had been supplied. This method would also allow for CAM errors to go undetected up to assembly. A solution finally came about when CAM and net list compare was made available in the late 1980s. In this process, software was used to validate the received data before fabrication started and then the same software was used to generate an ET program to validate the finished PCB. This method saved product cycle time, prevented the loss of material, and saved manufacturing time at both the PCB fabrication and assembly levels.

Today the industry is facing a similar challenge with microvia reliability especially after reflow of the PCB at assembly, during rework, or operating in the field. As with the shortcomings of electrical testing in the past, the industry designed PCBs with microvias without evaluating the thermal properties of the material or the geometries in the design. Fabricators produced the finished goods and evaluated the finished PCB to established performance standards such as IPC-6012. When difficult-to-detect failures occurred post assembly, a test method IPC-TM-650 2.6.27 was established and a caution was added to the IPC- 6012 rev E in section 3.6, Structural Integrity. The testing of a D coupon via IPC-TM-650 2.6.27 did validate that the finished PCBs were safe for assembly, but it did not stop a fabricator from building a bad design. Until now, there was not a method to simulate a PCB design that validated that the material selection, dielectric thickness, microvia size, and configuration (single, stacked, or staggered microvias) could survive 6X reflows. As with the evolution of electrical test and the use of the software to validate the design and the final test, we now have software that will validate the structural integrity of a microvia in a design during PCB stackup, before a design has been approved and placed into the fabrication process. This new software provides the industry a way to validate the design, fabricate a microvia design with confidence, and validate that the PCB has met the structural requirements by testing to IPC-TM-650 2.6.27. This paper will demonstrate real cases where validation software has identified structural issues with a microvia design and how this software can provide modification of the PCB design geometries that will result in a working stackup.

This method saved product cycle time, prevented the loss of material, and saved manufacturing time at both the PCB fabrication and assembly levels.

Microvia Failure Location: In the Target Pad and Plated Microvia Interface

There have been many studies regarding microvia failures. In this document, the focus is not on the location of the failure but instead elaborating on the mechanics that initiate microvia failures. The goal is to show how our industry can now plan and prevent microvia failures in a finished PCB by planning and validating a stackup at the layup stage and then simulating how that PCB can survive 6X reflow cycles when the fabrication process has been completed.

To date, many different studies have identified that microvias are weakest at the electroless copper interface. Electroless is deposited over the microvia and lies between the target pad and the electroplated microvia. In most cases, the failed microvia is found in the electroless at the bottom of the single microvia and almost always at the bottom of stacked microvias.

Improvements in electroless copper have been made and they have improved microvia reliability. The new advanced electroless chemistry can demonstrate that epitaxy and bottom-up recrystallization can occur between the target pad and the electroplated microvia. Studies have shown that direct metallization, which does not use electroless, also achieves epitaxy and bottom-up recrystallization. In both cases, reflow testing demonstrates improved microvia reliability, but these structures can still fail and not meet 6X reflows with resistance changes less than 5%.

The question arises as to why microvias are weak. They are not but simply put, microvias are butt joints and, as such, are inherently weak. Buried or epoxy filled vias require wrap plating for these types of interconnections per IPC-6012 Table 3-4 and 3-6. It is not possible to have wrap plating at the microvia target pad, and the best that can be done is to improve the interface with epitaxy and bottom-up recrystallization. However, it should be noted that even with these improvements and with direct metallization that has no electroless, we can still create microvia failures during reflow and D coupon testing.

What Causes the Microvia to Fail?

During reflow there is temperature cycle material expansion of the laminate that creates stress on the microvia butt joint. When the stress created by the expansion exceeds the strain limit of the target pad and electroplated microvia interface, plastic deformation occurs, and non-conformance exists.

Many studies have tested microvias before reflow and after reflow and have concluded that microvias are fine. However, microvias typically fail during reflow and the resistance change can only be detected during the peak reflow temperature cycle. A microvia failure at peak temperature will cause an open, and plastic deformation in the microvia will create permanent damage at the target land microvia interface. What makes this type of failure so frustrating is that the open does not exist at ambient room temperature so chasing down the type and cause of the failure is a lengthy process that can impact both engineering cycle time and overall product development costs.

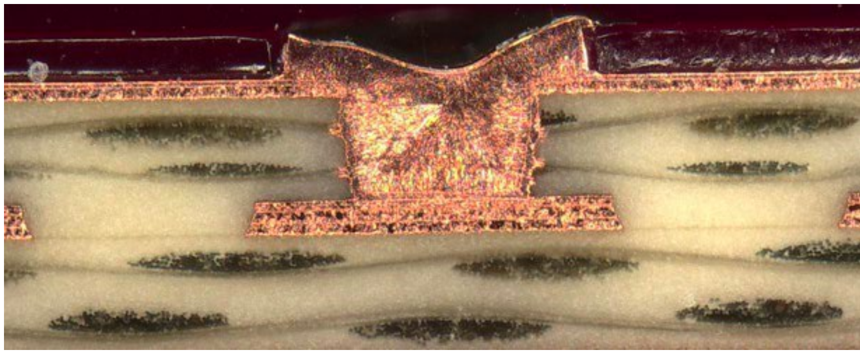


Figure 1: This depicts the image of a resin-rich spread glass material. In this image, the white portion is resin and the woven glass is gray.

Actions taken to reduce the microvia failures have included increasing the microvia diameter and reducing the aspect ratio. These actions and the new rules resulting from them haveing reduced failures. The benefits of these rules are described below.

- Increasing the microvia diameter increased the interface area.
  - A small increase of a microvia from 0.1 mm to 0.127 mm increases the surface area by 56%.
  - A wider surface area increased the survivability of a microvia if the same material expansion was exerted on the larger target pad interface.
  - Reducing the aspect ratio typically reduced the overall dielectric thickness.
    - This thickness reduction decreased the material expansion potential which improved the microvia survivability.
  - Stacked microvias required a lower aspect ratio than a single microvia for consistent 6X reflow passes.

While these new rules have worked for most builds, failures have still occurred. Most of the failures occurred with dielectrics that exceeded 0.15 mm/.006" or if high resin content prepreg was used. When failures did occur, the typical solution was to try and increase the microvia diameter, reduce the dielectric and rebuild the parts with the hope that the rebuild would pass.

The Traditional Stackup and Material Selection Processes and How They Affect Microvia Reliability

During the traditional stackup and material selection processes, the importance of microvia reliability is often not considered. This is due, in part, to not clearly understanding the stackup and material selection process in general and, specifically, how microvia reliability factors into these processes and why it needs to be addressed so early on.

Material selection for a stackup may be specifically defined by the PCB designer. In this case, each ply of prepreg and each core construction is defined and a stackup is provided to a PCB fabricator. When a stackup is not provided by the PCB designer, the fabricator is allowed to make the material selection. In many cases, the fabrication drawing can simply state that lead-free FR-4 material is to be used by specifying IPC-4101/126. The simplest instructions are that there are no dielectric callouts on the fabrication print and a PCB fabricator can select any core thickness or prepreg glass style that will accommodate the required overall thickness and, if required, impedance requirements. These basic generic instructions open the door to infinite stackup variations. A PCB designer or the electrical engineer could make all the stackup decisions by specifying the resin system brand; the core and prepreg openings, and the core constructions and prepreg types. But these practices are standardized within the industry and are dependent upon the company's design practices as well as the experience level of the designer or engineer.

PCB planners will select dielectric woven glass styles that are compatible with laser drilling. Another consideration for planners is to select resin rich prepreg to fill internal plated layers that are found in HDI designs. Electrical engineers will select low loss and spread glass weave to improve the electrical performance of high-speed designs. Stackups will favor a high resin content and spread glass combination to meet fabrication and electrical performance needs. PCB007

To read the rest of this white paper, click here.

Nano-Cu Paste for Microvias

Happy's Tech Talk #12

by Happy Holden, I-CONNECT007

Complex build-up HDI technologies continue to expand in applications. Copper electroplating of vias has been perfected but the process is yet another electroplating solution to maintain and can sometimes be a lengthy process. Current conductive paste fills are not as conductive as solid copper but provide reduced cycle time, are still highly conductive, and are cost effective.

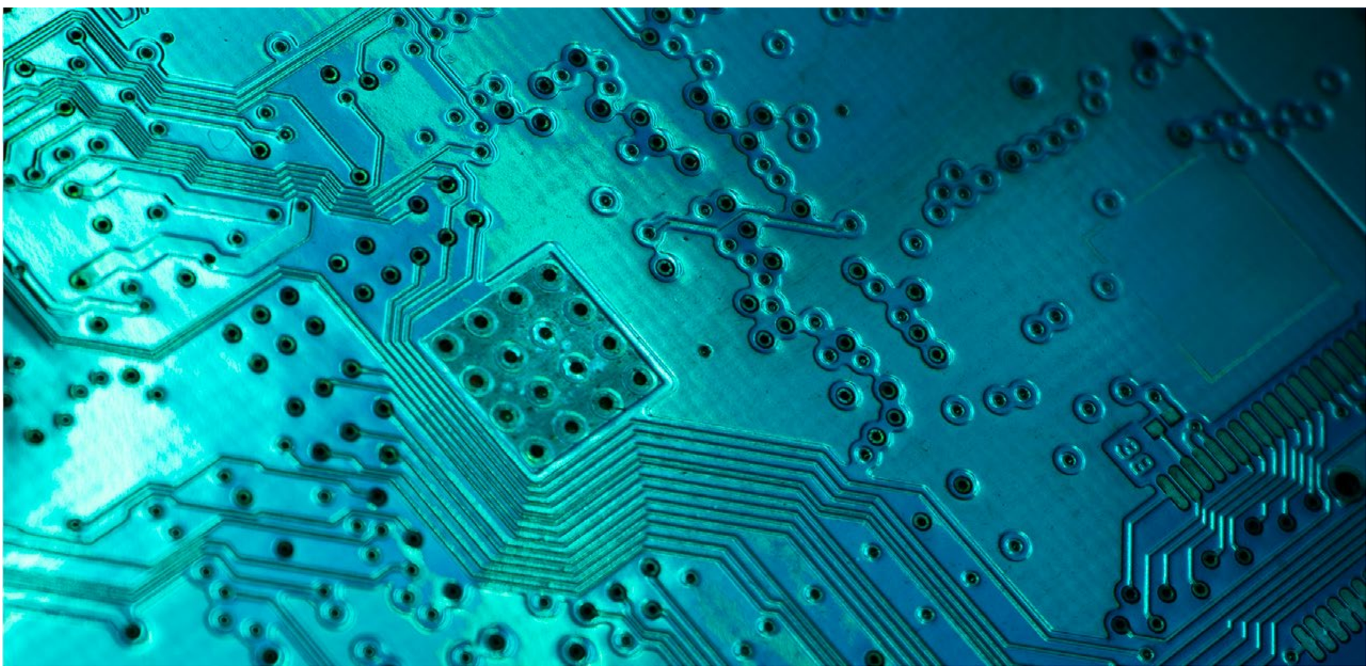
Introduction

Karl Dietz wrote on this topic several times in his Tech Talk series. No less than five separate columns were devoted to nanotechnology and conductive via-fill. The via-fill Tech Talk columns are titled:

- "The Dilemma of Innovation" (*CircuiTree,* October 2000)
- "Processes For HDI" (*CircuiTree,* December 2000)
- "Via Fill" (*CircuiTree,* July 2006)
- "Nano-particles in Electronics" (*CircuiTree,* October 2008)
- "Conductive Pastes and Inks" (*The PCB Magazine,* September 2011)

Metallizing Pastes

The metal-filled pastes have been around a long time. First used in the early 1960s for conductive jumpers and to connect double-sided non-plated through-hole (PTH) printed circuit boards with silver inks, their use has



expanded over the years. An innovation came about in the mid-1980s with ORMET's development of the transient liquid phase sintering (TLPS) conductive pastes that would sinter into a solid metal structure. This was used for conductive traces, board-to-board multilayering, and inner layer fabrication, as seen in Figure 1.

Many of the metallized pastes were originally used as via connections in the Japanese HDI process created in the early 2000s, such as ALIVH (any layer internal via hole), B^2IT, or PALUP. These pastes used conductive particles and were different from nano-technology pastes or TLPS pastes.

The advantages of these newer pastes were:

- Improved reliability (avoidance of trapped air or liquids)
- Improved planarity of multilayer structures (for more reliable surface mount or improved photolithography)
- Higher interconnect density (e.g., via in pad vs. dog bone designs)
- Better thermal management
- Enable stacked microvia structures

Fabrication Process

The via filling process (Figure 2) is quite common today. Automatic equipment is available as well as simple prototyping apparatus.

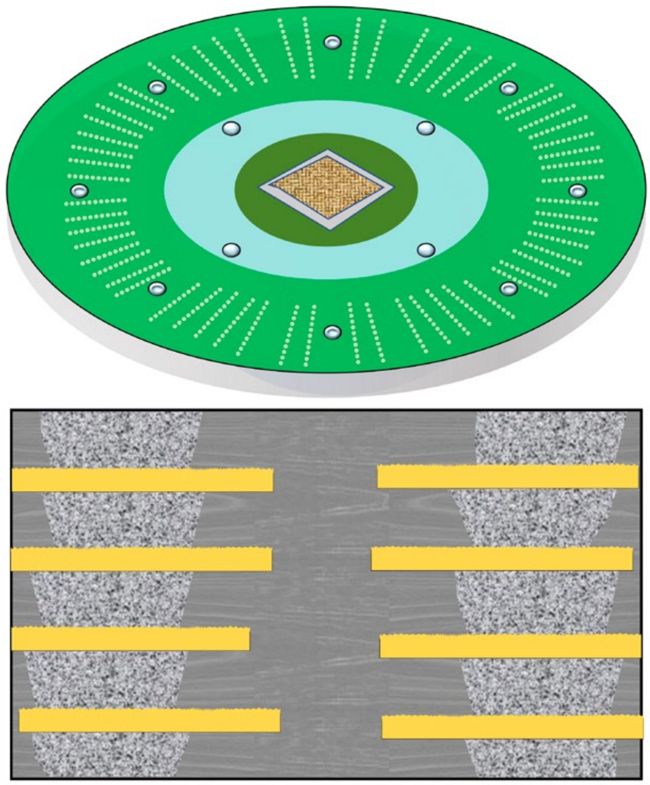


Figure 1: Typical applications of conductive pastes board-to-board or inner layer interconnects using the TLPS series[1].

Screen printing or inkjet is now the most common method.

Material Properties

The silver-laden conductive pastes have been around since the early 1960s. The introduction of nanotechnologies has revolutionized these

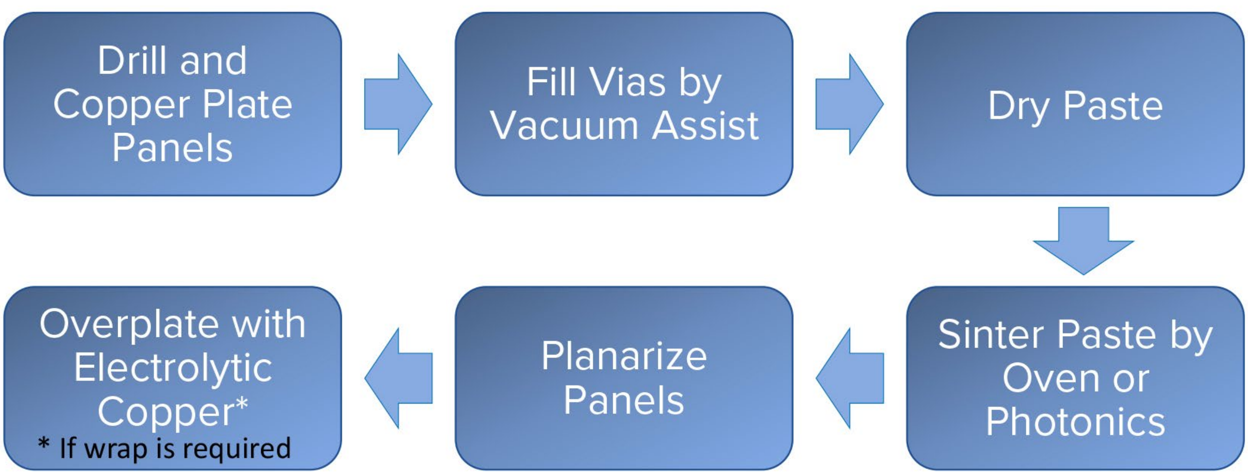


Figure 2: Via fill process flow[2].

conductive pastes. The Holy Grail of conductive pastes has been copper-based or carbon-nanotube based. But even the best nanoparticle pastes exhibit a bulk resistivity more than 20 times that of bulk plated copper. The latest to be developed is a nano-copper particle that is coated to prevent oxidation, allowing air handling of the paste. By mixing the nanoparticles with micron-sized copper particles, resistivities of only six times that of bulk copper have been achieved[2].

Transient Liquid Phase Sintering Pastes

The most electrically and thermally conductive metallic pastes are those that are TLPS. These are metallic pastes that combine small particles of solder materials (many nanoparticles) with small particles of solderable metals in a fluxing polymer binder. After sintering and during lamination of the subassembly cores or blind vias into a single PCB, the solder particles melt, wet the solderable particles, and form an interconnected metallic mesh. The metallic mesh formed has a melting point higher than the original solder alloys and is therefore stable through subsequent thermal excursions such as lead-free assembly operations. The solder particles also wet to the copper caps on the PTHs, the caps become permanently metallurgically bonded to the metal mesh of the sintered paste interconnect, and deliver a continuous and robust thermal and electrical conduction through sintered metal joints. Table 1 shows the testing of this type of paste.

Via Filling Experiments

Even though the resistivity of these nanopastes is higher than bulk plated copper, the ideal application is for filling blind vias, as they are small and less sensitive to the resistivity. Table 2 shows the results of tests conducted on 125 um (0.005") diameter blind vias of various depths drilled into different substrates and subsequently filled with the nano-copper conductive pates and sintered. The samples were both etched into pads and left as copper-clad panel-plated specimens. Sintering was conducted either by an 808 nm diode laser, photonic flash tube (BB flash) or baked at a reduced temperature in a reducing environment.

Table 1: Reliability analysis of PCB with sintered paste interconnects.[3]

TEST	TEST CONDITIONS	RESULTS
Thermal shock	-55°C – 125°C, 500 cycles	Pass, Max resistance change 7.5%
Temp Cycling	0-100°C, 1000 cycles	Pass
Humidity + bias testing	85°C, 85RH%, 50V bias, hold 240 hrs.	Pass
Humidity + Thermal Aging	85°C, 85RH%,hold 1000 hrs.	Pass, Max resistance change 4.0%
High temp storage	150°C, hold 1000 hrs.	Pass, Max resistance change 7.0%
Solder reflow test	Reflow @ 260°C, 5 cycles	No delamination
Electrical test	No shorts or opens	Pass

Table 2: Summary of results of experiments with nano-copper paste filled blind vias on FR-4 and glass.[2]

Substrate	Conductivity	Sintering Method	Adhesion	Additives
	X Bulk Copper		*Tape Test*	
Etched FR-4	12X	Laser	Pass	
	100X	BB Flash	Fail	
	>100X	Oven 250°C	Fail	
	8X	Oven 225°C	Pass	Nano
Clad FR-4		Laser	Fail	
		BB Flash	Fail	
	6X	Oven 250°C	Pass	Substrate Fail
	6X	Oven 225°C	Pass	Nano
Glass	8X	Oven 225°C	Pass	Nano

Table 3: Process and examination items. [4]

No.	Substrate	Type of Via	Via Size (μmφ)	Via Depth (μm)	Aspect Ratio	Via Filling Method	Sintering Condition
1	Si (TSV)	Non-Through Hole	10	90	9	Printing	Formic Acid 220°C (1 h)
			20	120	6		
			50	150	3		
2	Si (TSV)	Through Hole	30	300	10	Press	Formic Acid 220°C (1 h)
3	Glass (TGV)	Through Hole	30	300	10	Press	Formic Acid 220°C (1 h)
4	Organic Substrate	Non-Through Hole	90-180	160	0.9-1.8	Press	Formic Acid 150°C (1 h)
			180	300	1.7		
5	Organic Substrate	Through Hole	140	3000	21	Press	H_2 220°C (1h)

In other studies, copper paste was used as a filling material for through-silicon vias (TSV), through-glass vias (TGV), and organic substrates. Non-through-holes with diameters of 10-60 mm and depths of 90-150 mm formed in the substrate surface layer were filled with the Cu paste, as well as through-holes with diameters of 30-300 mm for Si and glass, and 140-3000 mm for the organic substrates. All the pastes were sintered, and the results are seen in Table 3[4]. The process is seen in Figure 3 using a vacuum frame and press plate to fill the vias.

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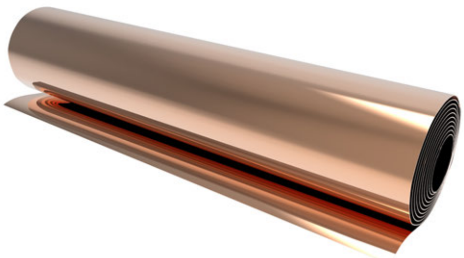

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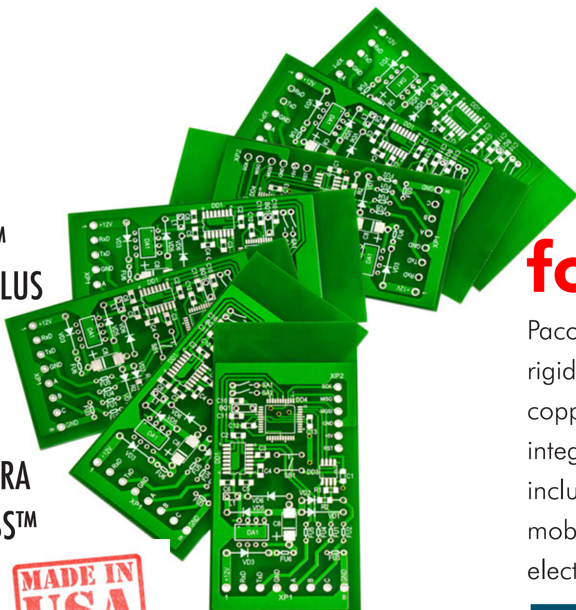

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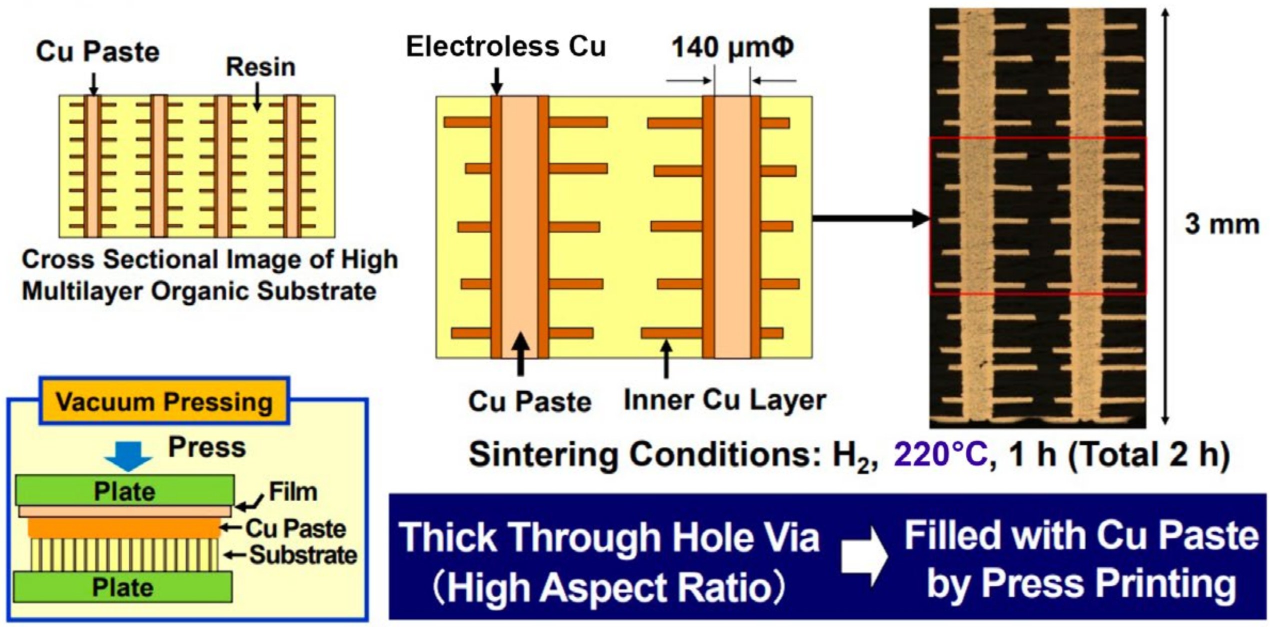

Figure 3: A TLPS Cu paste is pressed into various substrates and sintered. Results show both blind vias and through-hole vias passed all reliability tests[4].

Sintering

Sintering refers to a process where a mixture of particles is fused together, usually thermally. Sintering mixtures can be used as structures, dielectrics, and conductors. Conductive sintering products have been used in electronics for some time with ceramic thick-film technology (cermet). Cermets require high temperatures (>800°C) for sintering while conductive pastes based on polymers sinter at much lower temperatures (<220°C). These polymer thick films (PTFs) are typically uncured liquid polymers, usually epoxy or acrylic based, filler with conductive particles. As the polymer cures and shrinks, the particles encounter each other and the substrates, making the connection. Fortunately, we now have technology such as photonic sintering[5] that will sinter the conductors without heating the substrate.

Conclusion

When considering the process of filling blind-vias or through-hole vias with plating, the new conductive copper-based TLPS pastes are faster, nearly as conductive, and possibly lower in cost than the plating process. In addition, the use of photonic soldering/sintering makes these conductive pastes practical on lower cost substrates such as paper, plastic films, or other organic materials not suitable for immersion in acid plating baths. **PCB007**

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Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa Westwood, Merix, Foxconn, and Gentex. He is currently a contributing technical editor with I-Connect007, and the author of *Automation and Advanced Procedures in PCB Fabrication*, and *24 Essential Skills for Engineers*. To read past columns, click here.

Electrodeposition of Copper, Part 3

Plating Distribution and Throwing Power

Trouble in Your Tank

by Michael Carano, AVERATEK

Introduction

Success in the plating room rests largely on the understanding and the application of those critical principles that govern the process of electrodeposition (often referred to as electroplating). This month, I look at the fundamentals of plating distribution and throwing power, and what that means for the circuit board fabricator.

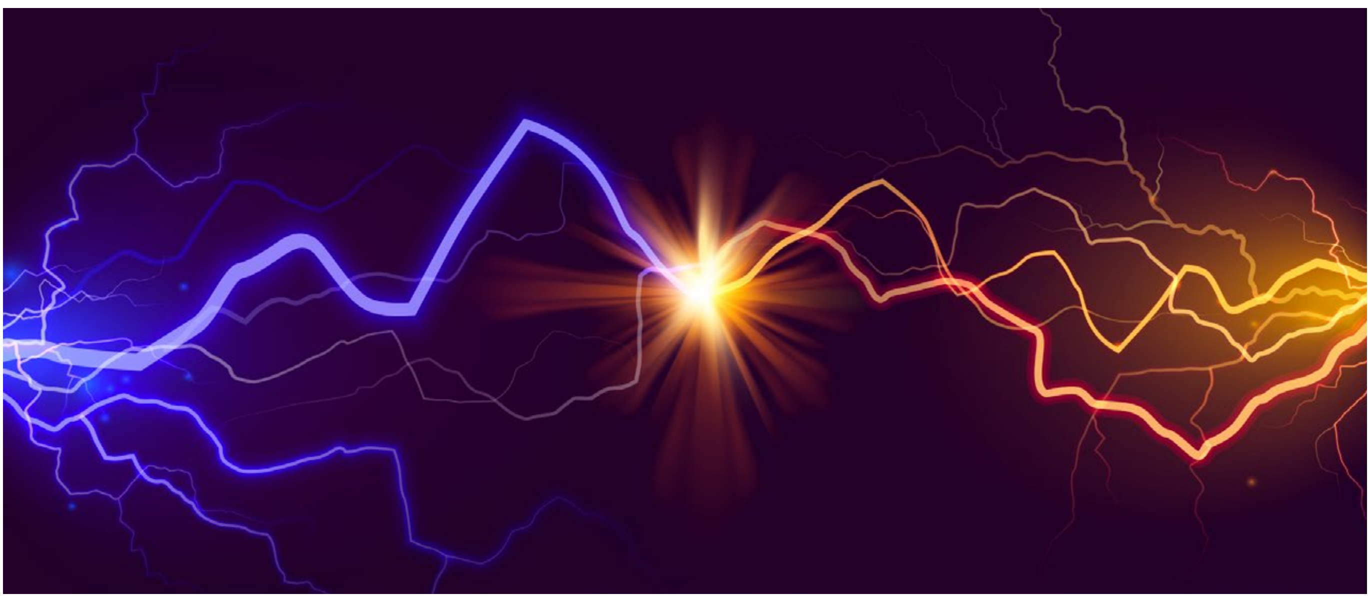
Current Distribution

There are many factors that influence the flow of current in the electroplating cell and, ultimately, the distribution of the metal across the part, along with the concept of throwing power. These are:

- Overall composition of the electrolyte
- Polarization influence
- Conductivity of the electrolyte
- Cathode efficiency/current density curves
- Geometry of plating system/plating cell design
- Other factors such as use of organic addition agents
- Substrate composition and structure
- Surface preparation and pre-treatment

When studying electrodeposition, one needs to understand that current distribution has two components:

- Primary current distribution
- Secondary current distribution



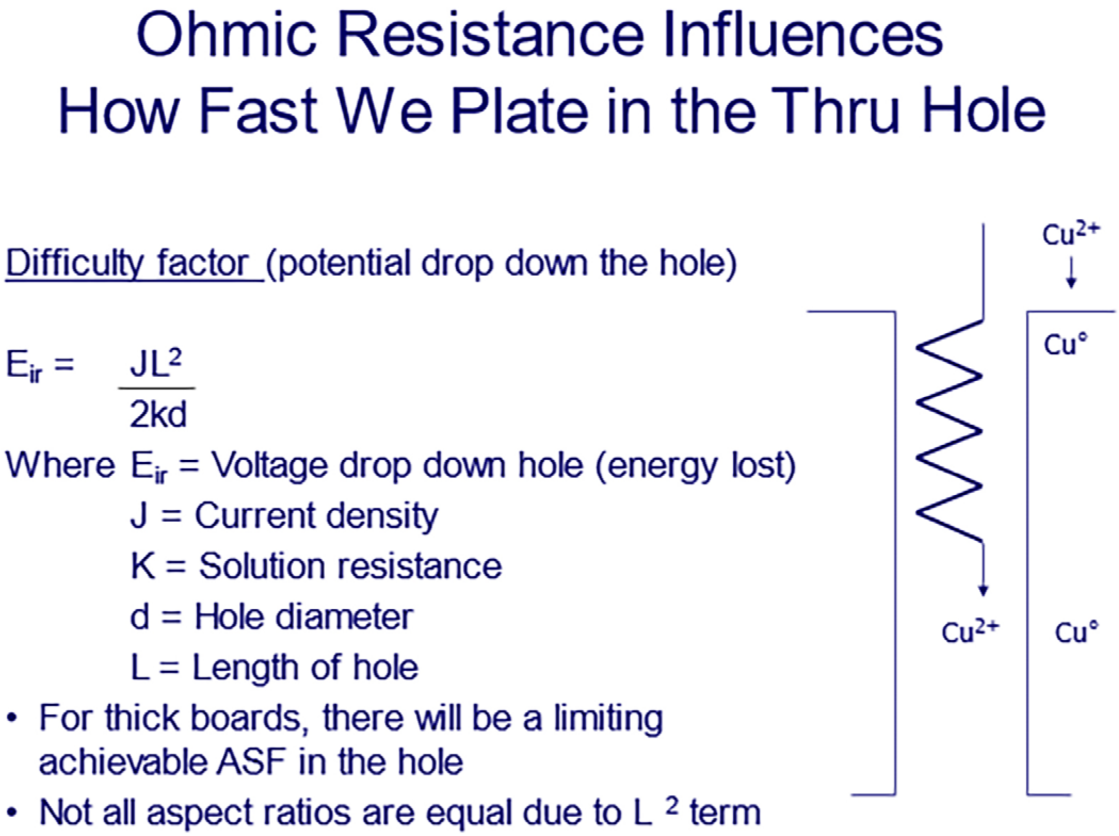


Figure 1: Key factors influencing the plating distribution.

One can easily apply these two entities to develop a model for the electroplating process. Primary current distribution is determined by voltage drop inside the cell and electrode shape and position. Basically, this is governed by the electrical field within the cell itself.

Fortunately for the electrodeposition process, other factors come into play. If only primary current distribution were present, relatively uniform plating distribution and good throwing power in high aspect ratio through-holes would be challenging if not nearly unattainable. Now, secondary current distribution is influenced by ohmic resistance in the plating cell along with the kinetics of the electrodes.

More specifically, organic addition agents and other additives act as high current density inhibitors—suppressing plating in the high current density areas of the board. This allows for improved micro throwing power in the lower current density areas, i.e., areas of higher ohmic resistance. This can be better explained below in Figure 1.

Again, if the cell resistance is low, then primary current distribution would dominate. In other words, portions of the part or PC board closest to the anode would receive the most current. Thus there would be overall poor distribution of plating thickness across the part and in the through-holes (Figure 2).

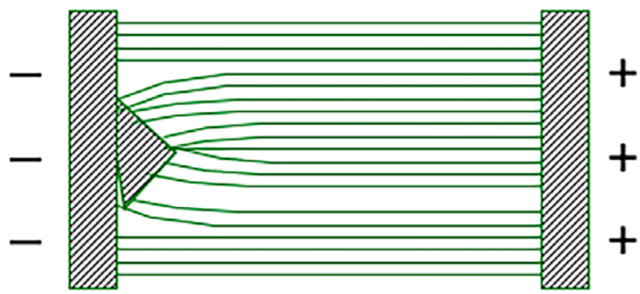


Figure 2: Primary current distribution. Low resistance in the cell favors thicker deposits in those areas considered as higher current density areas.

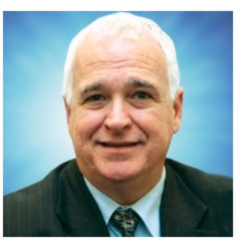
Fortunately for the process engineer, other factors come into play in the form of secondary current distribution. The difference between primary and secondary current distribution lies in understanding electrode kinetics in addition to solution resistance. Secondary current distribution allows for a more uniform current distribution across the cathode surface. This is primarily because of electrode kinetics by means of an activation overpotential. This overpotential tends to make the current distribution more uniform.

Compared to the primary current distribution, the secondary current distribution is smoother, with a smaller difference between the minimum and maximum values. When the activation overpotential is included, a high local current density would introduce a high local activation overpotential at the electrode surface, which causes the current to naturally take a different path—essentially finding its way to the lower current density areas. Therefore, one can improve through-hole plating distribution.

The engineer can improve plating distribution and throwing power by manipulating the following:

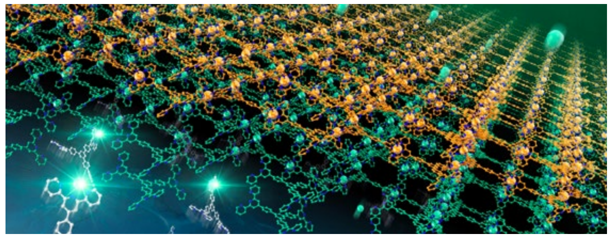
- Reduce cathode current density
- Increase conductivity of the electrolyte—higher acid concentration
- Ensure uniform solution agitation across the panels, but not excessive
- Monitor contamination and organic build-up in the plating electrolyte
- Increase anode-to-cathode distance—10 inches improves throwing power vs. 6 to 8 inches

Remember this is a process and needs to be controlled. **PCB007**



Michael Carano is VP of quality at Averatek. To read past columns, click here.

At the Water's Edge: Self-assembling 2D Materials at a Liquid-Liquid Interface



Molecular 2D materials find immense applications in materials science, owing to their wide structural variety and easy controllability. Establishing a simple and efficient method for their synthesis is, therefore, important. Now, scientists from Japan present a simple method for synthesizing heterolayer coordination nanosheets, a promising 2D material, shedding light on how certain chemical coordination reactions occur at liquid-liquid interfaces. Their method could help develop novel 2D materials with applications in optoelectronic devices.

Coordination nanosheets are one particularly interesting type of 2D material. The "coordination" refers to the effect of metallic ions in these molecules, which act as coordination centers. These centers can spontaneously create organized molecular dispositions that span multiple layers in 2D materials. This has attracted the attention of materials scientists due to their favorable properties. In fact, we have only begun to scratch the surface regarding what heterolayer coordination nanosheets - coordination nanosheets whose layers have different atomic composition - can offer.

A team of scientists from Tokyo University of Science (TUS) and The University of Tokyo in Japan reported a remarkably simple way to synthesize heterolayer coordination nanosheets. Composed of the organic ligand, terpyridine, coordinating iron and cobalt, these nanosheets assemble themselves at the interface between two immiscible liquids in a peculiar way. The study, led by Prof. Hiroshi Nishihara from TUS, also included contributions from Mr. Joe Komeda, Dr. Kenji Takada, Dr. Hiroaki Maeda, and Dr. Naoya Fukui from TUS.

(Source: Tokyo University of Science)

The New World Order of JIC

Article by Dan Beaulieu
D.B. MANAGEMENT GROUP

The great business thought leader Margaret Heffernan commented that we are changing from just-in-time (JIT) to just-in-case (JIC). As we've worked our way through the issues of the past two years, the world is changing from a complicated to a complex system, and we must be prepared to face the challenges it brings.

During the past 10 to 20 years—and especially the past 20 months—we have learned how unpredictable and volatile the world has become. Not only the business world, but everywhere.

Who ever thought there would be a shortage of anything? Could we have imagined an epidemic that literally brought us to our knees? Who thought that Russia would start another 1940s-style war? We thought we were done with that, didn't we? Who could predict what would happen next? Think of owning a factory that produces plastic straws and bottles, one day your products are deemed a serious threat to the environment, and your company looked at as a pariah?

To survive today, we need the JIC mentality. We must be prepared for the unexpected. No longer can we rely on cycles and patterns to predict the future, or what we might be able to handle based on what that future brings. Now we must prepare for the unexpected. We must be flexible and able to adapt to whatever comes our way.

It means we must prepare ourselves for any change. Not only must you have more than one solution, supplier, or partner, you need many of each. For example, many of us depended on China for almost everything, and now we must diversify our supply chain for those same things.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FIND LOCATIONS
SELECT CALIBRATION
CHOOSE COLLIMATOR
GET YOUR DATA
72% of XRF testing time is lost on setup.
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See how you can break free with the FT230.
Our unique Find My Part™ technology and intelligent user interface eliminate setup steps, speeding up analysis and reducing costly errors.
The all new FT230 XRF coatings analyzer takes down the hurdles between you and your data.
Make sure your quality control keeps pace. Choose the FT230.
Hitachi FT230 Simply Smarter

We have certainly felt the bitter sting of dependency on a country that is now, at best, a frenemy. That may be as good as it gets, especially considering recent news headlines demonstrating that simply visiting an ally is looked upon as an act of aggression by our sworn frenemy and sorrowful supplier of everything.

We have certainly felt the bitter sting of dependency on a country that is now, at best, a frenemy.

But there is hope in embracing change and, for lack of a better expression, embracing one another.

The biggest single strategy for surviving this new world (dis)order is to work with each other. We need partnerships and trusted relationships with many more people at many more companies.

- Instead of having one single supplier we need to develop relationships with many suppliers—just in case.
- Instead of having only one strategic partnership, we need to develop many strategic partnerships—just in case.
- Instead of having only one friend in our local governments, we need to have many friendships—just in case.

Can we learn to trust one another? If not, we're playing a dangerous game when we see ourselves on an island rather than part of a community. This is part of the just-in-case mentality.

Of course, our businesses must function, yet we must develop new and innovative ways to handle whatever comes our way, no matter how challenging that may be.

For example, we can be like two PCB shops that are eight miles apart and amicably share processes with one another in a "mi PCB casa es tu PCB casa" type of cooperative trusting partnership. Maybe we can emulate the quick-turn PCB shop that is sending orders and customers to their friends who have a production shop, which in turn does the same thing back to them. It works. They win and the customer wins.

I know of a laminate company that is encouraging the OEMs to allow their PCB suppliers to substitute similar laminates to handle shortage issues. I also know of design, fab, and assembly companies that are now working in harmonious, trusting partnerships to provide their customers with that critical, complete, synergistic solution they need today rather than tomorrow.

These trusted cooperative partnerships are happening right now. No longer can we afford to reside in competitive silos, playing a zero-sum game with winners and losers, because the result in a win-lose situation is we all lose.

The best way to handle the challenges we face today, the challenges of a changing and unpredictable world, is to have many good and trusted friends, people who will have each other's backs.

I see this happening on our continent and in other regions around the globe, but it's not enough. This spirit of trusting cooperation must be completely global. We must find good partnerships with people and companies around the world, just like the network of scientists did when rushing to develop the COVID vaccines. We need to behave like they did: working in an open and honest forum, sharing experiences, challenges, and discoveries to develop a vaccine that literally saved mankind.

Let's take a page from their playbook. We can find ways to work with our corporate partners in cooperative and trusting ways to handle the unpredictability of our new world disorder. **PCB007**

Dan Beaulieu is president of D.B. Management Group, and an I-Connect007 columnist. To read past columns, click here.

Supplier Highlights

Rogers Corporation Reports Second Quarter 2022 Results ▶

Net sales of $252 million increased 1.5% versus the prior quarter resulting from commercial actions and higher demand in the EV/HEV, portable electronics and defense markets.

The Chemical Connection: Don't Sludge-Out—A Guide for Alkaline Etching ▶

In my last column, I compared cupric chloride and alkaline cupric chloride, mentioning that alkaline etchant is the most used etchant for PCB fabrication. It is used because it provides a high etch rate, improved etch factor, and compatibility with metallic resists. Although it has some great benefits, it has the drawback of being difficult to control.

The Shaughnessy Report: Tune Up Your Pricing Strategies ▶

If you're a fabricator, these are challenging days. But there are also plenty of opportunities available—if you know when to embrace them. Your suppliers have sent you an email explaining why their prices are going up—everything is—and now you feel like you're stuck between a rock and a hard place.

Dale Baker Joins Nano Dimension's Senior Management as President of the Americas ▶

Nano Dimension Ltd. announced that Dale Baker will join the company as president of Nano Dimension–Americas, where he will head the expansion of Nano Dimension's U.S. operations, worldwide sales activity and will execute the company's current organic and M&A growth strategy.

Nortech Systems Announces Patent for Flexible Faraday Cage PCB and Cable ▶

This work is based on the important work of Michael Faraday in the 1830s that contributed to our current understanding of shielding effects of what we now call a Faraday Cage.

MKS Instruments Announces Closing of Atotech Acquisition ▶

MKS Instruments, Inc., a global provider of technologies that enable advanced processes and improve productivity, announced the completion of the previously announced acquisition of Atotech Limited for approximately $4.4 billion in cash and MKS common stock.

Minister President Weil Visits LPKF's Garbsen Site ▶

As part of a visit, Minister President Stephan Weil visited laser specialist LPKF at its headquarters in Garbsen. LPKF has been developing and producing innovative solutions for the technology industry since 1976.

KLA's 2021 Global Impact Report Highlights New Climate Goals ▶

KLA Corporation released its 2021 Global Impact Report, highlighting its most recent environmental, social and governance (ESG) progress and goals.

Møn Print Joins ICAPE Group ▶

From the 29th of August, Møn Print A/S joins ICAPE Group's worldwide organization to become ICAPE Denmark.

Lessons Learned: Communication Still the Key

Interview by Nolan Johnson
I-CONNECT007

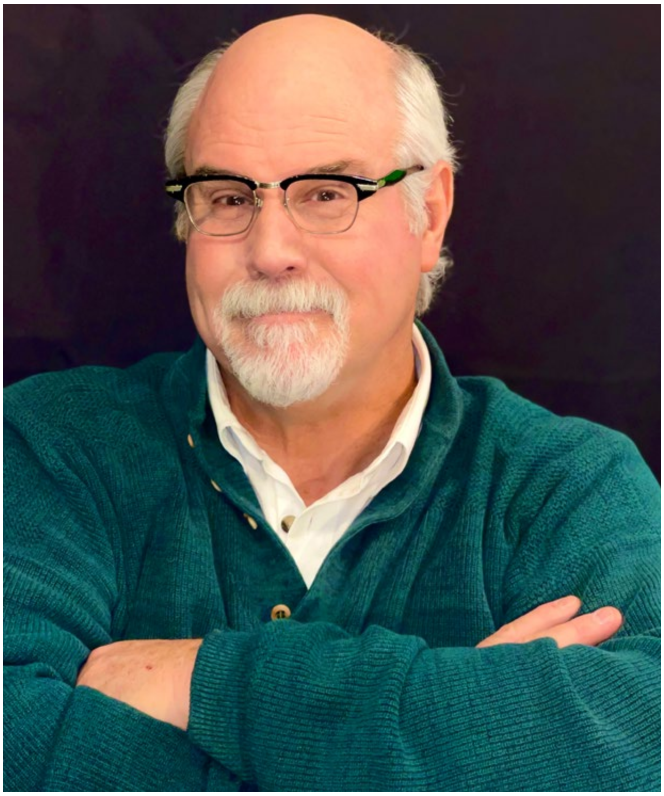
Kelly Dack and Nolan Johnson explore the silver linings from the past two years, especially the importance of good communication. These skills are—as they have always been—key to the success of the project. But how do you define the best methods for communication? Kelly breaks down four personality types and why it's important to recognize how one person differs from another. When you better understand how a person thinks, your level of effective communication increases exponentially.

Nolan Johnson: Kelly, as an industry veteran with a great deal of experience in OEM design and expertise in the early stages of specifying a design for manufacturing and production, what are some of the lessons learned for working with your EMS provider that you and your coworkers have developed over the past two years?

Kelly Dack: I talk often about the stakeholders involved in creating printed circuits or electronics for the world. It involves communication which, just like in any relationship, is probably the foremost attribute to establish. We need good communication, or systems, processes, and people do not work. In our industry, we have relationships with suppliers, customers, and coworkers, and we need to recognize the importance of how we communicate with them.

When I look at suppliers in the electronics industry, for example, something that's worked for me is to get out and meet them. I like to shake their hands and make eye contact. Most designers are very tactile. We like to touch and feel the materials. We like the smells of the assembly and fabrication lines.

At Prototron, part of my role was to reach out and shake the hands of their



Kelly Dack

customers, to help them understand design for manufacturability, and how to design so that their products would flow through the manufacturing floors of the prototype fabrication supplier. I was in an office that was right down the hall from those who were doing the work—the sales, the lamination, and selecting materials. It gave me a holistic overview of everyone involved in the PCB fabrication industry. I made dozens of lasting relationships and widened my network. I know I can call on any of them for reference or to have a question answered.

Then I worked for an EMS provider and that opened my eyes to everything required for design for manufacturability and design for assembly. As a designer, I was able to see not only how my designs—which were sent to this company—were being assembled, but also to see hundreds of other customers' designs and how they were (or not) being assembled by this provider. The designs being sent to our suppliers are not often able to be produced because of certain DFM, DFA, or DFX reasons.

They say the best way to learn is to teach. Now that I have the knowledge of what can and will go wrong, I can communicate back to our customers. We've created specifications and documentations so our customers can produce data and documentation that will help their products flow through our lines. It's another opportunity to communicate.

Right now, I do work for EPTAC Corporation, a company in New Hampshire that supplies IPC standards knowledge to our industry. They train and teach design, soldering, manufacturing, assembly—all the specifications that make our industry run. That has given me the opportunity to meet hundreds of designers, software engineers, and all walks of life in the electronics engineering industry. I've built many relationships in helping them to learn IPC and design standards. From a supplier standpoint, building closer relationships has to do with communication, the ability to share knowledge, and to recognize what needs to be shared.

Johnson: Right. Obbviously you have customers who are specifying to performance. One of the highest visibility areas of struggle in the past couple years has been component supply chain and availability. What are some of the ways that you and your team are finding to work with your OEM type of customers more effectively? What has changed there?

Dack: A lot has changed, but when we talk about building relationships, who are our customers? Our sales team has customers; our interoffice groups often have customers. I like to say that anyone who relies on the deliverables that we provide are our customers. We need to make sure that we're communicating and receiving the right information to provide the appropriate communication. To do a better job, I've learned that, first, we must recognize our customers. Reach out, shake a hand, make eye contact, and introduce yourself so that your customers understand exactly what

you do, what you can provide to them, and the expectations of the deliverables.

The best way to help you is to communicate. So, let's sit down, talk, and define a working relationship, whether that's the CEO of a company, a supplier in Shenzhen, or your coworker in the next cubicle. We must define our expectations.

Johnson: We talk a lot about communication. How have the past two years affected our ability to communicate effectively? Are people more willing, able, and interested in communicating more closely, or is this still evading us?

Dack: The last two years have shown us a lot about the need to communicate effectively. We all experienced the pros and cons of using online meeting software, which has been either highly successful or marginally successful. It's relevant to the expectations.

> The last two years have shown us a lot about the need to communicate effectively.

Johnson: Are you seeing behavior changes with the customers you interact with? Are you feeling like the expectations for how we communicate are changing? Many of us are much more familiar with working in a video teleconferencing environment. We don't need travel for at least an approximation of face to face. Is that changing how the communication happens?

Dack: It's a great question. We're seeing more data trying to take the place of our eye-to-eye physical human contact. We're relying on data. We must recognize this and realize that data can have pitfalls. If it's not rich data, it's not helpful. The expectations need to be set and met. Just today, I'm dealing with a company that has sent us data, but they haven't sent us a fabrication drawing specification. There are no acceptability specifications. They've sent data with a PCB outline and some holes, but we don't know what the expectations are for the tolerances. Can we V-score the sides or do they need to be routed? Can we tab route the sides? If we do these manufacturing operations, will the expectations be met? So, data alone isn't cutting it without understanding the relationship between the stakeholders.

Johnson: Do you feel like the ability to have a dialogue has gotten better?

Dack: I think it's the same as ever. We need to understand personality types in order to shift to their communication preferences. Here are examples. There's a type A, the "director type" who's goal-oriented, risk-taking, and great under stress. We shift into a certain communication style when we communicate with a type A. Their expectations are that we're short, concise, and we have the answers.

There's a type B, the socializer (and I could be accused of being this). We're relationship oriented, outgoing, and enthusiastic, but in being such, we might not meet the expectations of the type A personality. We may give you way too much information, but you may not need it.

Then there's a type C, the thinker, the analytical. They're detail-oriented, logical, and prepared. This could describe an engineering personality. They deal with facts and numbers, and they may be accused of not necessarily being social.

Finally, I describe a type D, the supporter type. While they're task-oriented, they tend to stabilize a group because they're supportive; they're the cheerleaders. They show cautious optimism.

My point is that it takes a village to create a team of communicators. When we recognize the personality types of our stakeholders, we can communicate effectively. That challenge has been and still exists. I'm not sure if it's gotten better or worse.

Johnson: What you're describing is easier done when you're working with a coworker and have plenty of time to get data points with them, even if it's remote. It's a little bit more challenging when you're working with a customer or in a more transactional relationship, but it can be done. It's good to be mindful of that and to approach those conversations, trying to figure that out about each person.

Dack: I've learned that building closer working relationships has to do with communication, the ability to communicate, and the ability to altruistically give of yourself to plant seeds that can grow into beneficial relationships for not only yourself and your coworker, but your team, your company, and for the industry. That's a neat little package.

Johnson: Well put. I think that's a perfect place to end it. Thank you, Kelly. **PCB007**

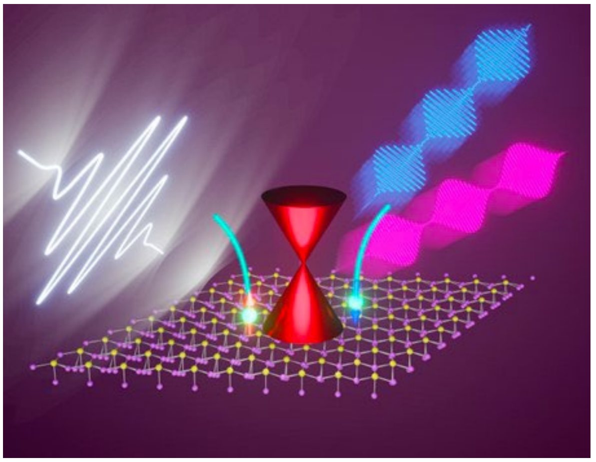
Kelly Dack, CIT, CID+, provides DFx centered PCB design and manufacturing liaison expertise for a dynamic EMS provider in the Pacific Northwest while also serving as an IPC design certification instructor (CID) for EPTAC. He is an I-Connect007 columnist. To read past columns, click here.

When Light and Electrons Spin Together

Theoreticians at the MPSD have demonstrated how the coupling between intense lasers, the motion of electrons, and their spin influences the emission of light on the ultrafast timescale. Their work has been published in npj computational materials.

Electrons, present in all kinds of matter, are charged particles and therefore they react to the application of light. When an intense light field hits a solid, these particles experience a force, called the Lorentz force, that induces some exquisite dynamics reflecting the properties of the material. This results in the emission of light by the electrons at various colors, a well-known phenomenon called high-harmonic generation.

The MPSD team undertook the task of understanding how the light and the spin of the electron can interact in Na_3Bi, a topological material known as a Dirac semimetal (the three-dimensional analogue of graphene), via an effect known as spin-orbit coupling. Understanding better how spin-orbit coupling influences the electron dynamics on these timescales is an important step towards understanding the electron dynamics in complex quantum materials; it is the spin-orbit coupling that makes quantum materials interesting for future technological applications. It is expected to lead to the next generation of electronic devices, namely topological electronic systems.



The authors show how spin-orbit coupling affects the velocity of the electrons within the electron bands of solids, effectively acting like a magnetic field which depends on the electrons' spin. Changes in the electron velocity can affect the electron dynamics in Na_3Bi and that this effect can sometimes be detrimental to the generation of high-order harmonics. While this material is non-magnetic, the team has shown that the spin of the electrons is important for the dynamics, as it couples to the potential felt by the electrons, which is modified by the intense applied light-field.

(Source: MPSD)

Leadership 101: The Law of Timing

The Right Approach

by **Steve Williams,** THE RIGHT APPROACH CONSULTING

Introduction

Good leadership always makes a difference; unfortunately, so does bad leadership. This leadership truth continues as we will be talking about law 19 of the 21 Irrefutable Laws of Leadership.

"The Law of Timing: When to lead is as important as what to do and where to go."
—John Maxwell

Timing is Everything

How often have we heard this throughout our lives? Too often to count I would suggest. We don't have to look very far to find examples of both good and bad timing. In the context of leadership, there are really only four outcomes for any decision and the first three are a result of poor timing:

1. Wrong action at the wrong time = disaster.

This is the worst-case scenario of the first three outcomes that will result in nothing good: missed goals, cost increases, and the perception of your leadership skills will suffer. It doesn't matter whether the timing was too early or too late you can't expect a great result.

2. Right action at the wrong time = resistance.

Taking the right action at the wrong time may be unsuccessful because the people you

lead can become resistant. Taking the right action at the wrong time will undermine a leader's relationship and trust with their team.

3. Wrong action at the right time = mistake.

Natural entrepreneurs tend to have a strong sense of timing, intuitively knowing when to seize an opportunity. They also have a propensity for risk, which sometimes results in mistakes in their actions. However, great leaders know when to cut their losses. Timing is everything, but the right actions are equally important.

Poor Timing Example: Nintendo Virtual Boy

In 1995, 20 years before virtual reality (VR) became mainstream and a must-have technology for gamers, Nintendo launched the first VR headset for the consumer market. Nintendo had done their research and went into this venture with eyes wide open. Their previous attempt at VR was the Private Eye, a 3D, stereoscopic, head-tracking prototype whose technology would eventually be employed in the Virtual Boy. But limitations in existing technology resulted in an awkward looking stationary device, which kind of defeats the purpose of VR. Given its limitations and the $179.95 price tag (1995 dollars) the device was a total flop; a case of a poor timing with a technology ahead of its time. Technology has caught up with the concept and companies like Oculus have propelled VR into an affordable experience and standard technology of gamers.

The fourth outcome is the only one that results in a win:

4. Right action at the right time leads to success.

Great things happen when the right action and the right timing come together. Goals are achieved, profits increase, and growth is sustained. Great leaders have a track record of transforming organizations by taking the right action at the right time during critical situations.

Good Timing Example: iPod and iTunes

Do the names "Rio" or "MPMan" sound familiar? Probably not, unless you owned one (I owned a Rio). Prior to 2001, they were part of the first MP3 players to hit the market. Back then you either had to rip a CD or download bootlegged music files to get them on the player, and capacity was only about 20 songs. Where others may have seen a crowded market, Apple realized this as a market opportunity and introduced the iPod in 2001 with Steve Job's jaw-dropping statement at the product launch: "1,000 songs in your pocket." The other genius timing move was iTunes; the first "legit" service to seamlessly purchase, download, and load music on the iPod. At a time when space was at a premium, the iPod simplified access to music and data storage and truly revolutionized how we purchase and listen to music.

As it turns out, timing *is* everything.

Follow these guidelines and The Law of Timing and you will truly be surprised at the results. Focus on enhancing your leadership skills to lead by example and the results will be epic. **PCB007**

Steve Williams is president of The Right Approach Consulting. He is also an independent certified coach, trainer, and speaker with the John Maxwell team. To read past columns, click here.

TOP TEN
EDITOR'S PICKS

Q4 Concerns: Hold on to Your Hats

IPC Chief Economist Shawn DuBravac has plenty to share about the state of the U.S. economy and how the electronics manufacturing industry might weather the storms of high inflation, rising interest rates, and low unemployment. It's an interesting situation to find ourselves in as the flurry of opinion on a 2023 recession starts to take shape. Does it make sense to invest in PCB fab now?

What's Going On in Congress? Your Handy Guide to PCB Legislation Headlines

We know you have so many questions about what the legislation means for you. Will there be funds to expand or upgrade my facilities? What about tax breaks? How will my specific needs be known? What will the current legislation mean for U.S. vs. China relations?

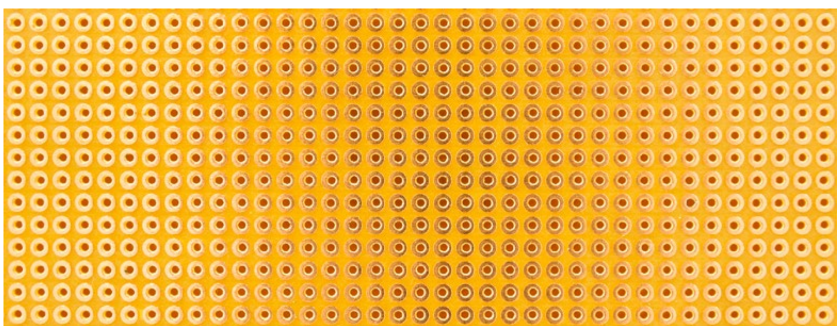
IPC Lauds Passage of 'CHIPS and Science' Act; Electronics Industry Calls for a Holistic Approach to Reviving Domestic Electronics Capabilities

IPC's John Mitchell issues a statement to comment on President Biden's signature on the "CHIPS and Science Act" in Washington, D.C.


John Mitchell

Trouble in Your Tank: Electrodeposition of Copper, Part 2

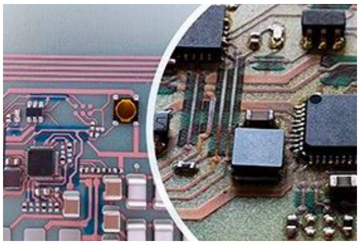
In this next series of columns, the intricacies of electrodeposition technology and its function of building up the thickness of copper in the holes and on the surface will be presented in detail.



Happy's Tech Talk #10: Optical Alignment/Coupon Welding for Stackups

In this month's column, I will discuss optical alignment for pinless lamination stackup, a topic that complements the induction lamination in my November 2021 column. Pin tooling plates have been used for lamination since it first started sometime in the 1960s. I first encountered multilayer stackup when I was assigned to increase capacity for our multilayer output in 1972. This was to accommodate the growth of our computer business.

InnovationLab Demonstrates Breakthrough PCB Production Method Based on Additive Manufacturing



InnovationLab, the expert in printed electronics "from lab to fab," announces it has achieved a breakthrough in additive manufacturing of printed circuit boards, helping to meet higher environmental standards for electronics production while also reducing costs.

Schweizer Announces Preliminary Results for 1H2022

According to preliminary figures, the SCHWEIZER Group achieved consolidated sales of EUR 64.6 million in the first half of 2022 (first half of 2021: EUR 59.4 million).

Challenges of the 2022 PCB Market: The Party's Over

With his knowledgeable insight into the business and technology of the printed circuit industry, Dr. Shiuh-Kao Chiang, managing partner at Prismark Partners, has put a global perspective on the challenges of the 2022 PCB market. His presentation at the EIPC Summer Conference in Orebro, Sweden, on June 14 was eagerly awaited by an attentive audience, keen to share his vision.

Graphic PLC Secures Nadcap and AS9100 Rev D Approval

Graphic PLC, one of Europe's leading manufacturers of advanced PCBs is delighted to announce that it has successfully passed its Nadcap reassessment and has been awarded Nadcap accreditation with merit.

KLA Reports Fiscal 2022 Q4, Full Year Results

KLA Corporation announced operating results for its fourth quarter and fiscal year ended June 30, 2022. KLA reported GAAP net income attributable to KLA of $805.4 million and GAAP diluted earnings per share (EPS) attributable to KLA of $5.40 on total revenues of $2.49 billion for the fourth quarter of fiscal year 2022.

For the latest news and information, visit **PCB007.com**

Career Opportunities

CHEMCUT

Electrical Engineer

Located in State College, Pennsylvania, Chemcut, a world leader in wet processing equipment for the manufacture of printed circuit boards and chemical etching of various metals, is seeking an electrical engineer.

Objectives:
The electrical/controls engineer will not only work with other engineers, but interface with all departments (manufacturing, sales, service, process, and purchasing). The engineer will design customer systems, creating electrical and control packages, while focusing on customer requirements.

Responsibilities:
- Process customer orders (create schematics, BOMs, PLC programs, relay logic controls, etc.)
- Startup and debug customer equipment on production floor
- Interface with engineering colleagues and other departments, providing input & direction
- Provide electrical/control support to customer service
- May require occasional travel and overtime

Qualifications:
- Bachelor's degree in electrical engineering or an EMET degree
- Machine control design experience a plus
- Good communication skills working in a team environment
- Strong ability to work independently with minimal supervision
- PLC and HMI experience a plus (ex. Studio 5000 Logix Designer, Factory Talk)
- Experience with AutoCAD, Microsoft Word, and Excel

Chemcut benefits include: Medical, dental and vision Insurance, life and disability insurance, paid vacation and holidays, sick leave accrual, and 401K with company match.

To apply, please submit a cover letter and resume to hr@chemcut.net.

apply now

EMA Design Automation®

Technical Marketing Engineer

EMA Design Automation, a leader in product development solutions, is in search of a detail-oriented individual who can apply their knowledge of electrical design and CAD software to assist marketing in the creation of videos, training materials, blog posts, and more. This Technical Marketing Engineer role is ideal for analytical problem-solvers who enjoy educating and teaching others.

Requirements:
- Bachelor's degree in electrical engineering or related field with a basic understanding of engineering theories and terminology required
- Basic knowledge of schematic design, PCB design, and simulation with experience in OrCAD or Allegro preferred
- Candidates must possess excellent writing skills with an understanding of sentence structure and grammar
- Basic knowledge of video editing and experience using Camtasia or Adobe Premiere Pro is preferred but not required
- Must be able to collaborate well with others and have excellent written and verbal communication skills for this remote position

EMA Design Automation is a small, family-owned company that fosters a flexible, collaborative environment and promotes professional growth.

Send Resumes to: resumes@ema-eda.com

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Career Opportunities

Career Opportunities

INDIUM CORPORATION®

Supplier Quality Manager

Headquarters, New Hartford, NY

JOB SUMMARY:
The Supplier Quality Manager is responsible for maintaining and improving the quality of Indium Corporation's supplier base as well as compliance with identified quality standards and risk mitigation. This position will work cross-functionally with Supply Chain, Operations, and our suppliers. The role will ensure that the quality levels of all Indium Corporation suppliers and products meet customer requirements while supporting the company's growth, vision, and values.

REQUIREMENTS:

- Bachelor's degree in business, supply chain or a science-based discipline
- Minimum 3 years in a supply chain role supporting or leading supplier quality
- Obtain and/or maintain International Automotive Task Force (IATF) auditor certification within first 3 months of employment
- Able to work independently or lead a team, as needed, to meet goals
- Excellent oral and written communication skills
- Knowledge of quality standards
- Proficiency in MS Office

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Koh Young America

Technical Service & Applications Engineer

Full-Time — Midwest (WI, IL, MI)

Koh Young Technology, founded in 2002 in Seoul, South Korea, is the world leader in 3D measurement-based inspection technology for electronics manufacturing. Located in Duluth, GA, Koh Young America has been serving its partners since 2010 and is expanding the team with an Applications Engineer to provide helpdesk support by delivering guidance on operation, maintenance, and programming remotely or on-site.

Responsibilities

- Provide support, preventive and corrective maintenance, process audits, and related services
- Train users on proper operation, maintenance, programming, and best practices
- Recommend and oversee operational, process, or other performance improvements
- Effectively troubleshoot and resolve machine, system, and process issues

Skills and Qualifications

- Bachelor's in a technical discipline, relevant Associate's, or equivalent vocational or military training
- Knowledge of electronics manufacturing, robotics, PCB assembly, and/or AI; 2-4 years of experience
- SPI/AOI programming, operation, and maintenance experience preferred
- 75% domestic and international travel (valid U.S. or Canadian passport, required)
- Able to work effectively and independently with minimal supervision
- Able to readily understand and interpret detailed documents, drawings, and specifications

Benefits

- Health/Dental/Vision/Life Insurance with no employee premium (including dependent coverage)
- 401K retirement plan
- Generous PTO and paid holidays

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Career Opportunities

Electrical Engineer/PCB/CAD Design, BOM/Component & Quality Support

Flexible Circuit Technologies (FCT) is a premier global provider of flex, rigid flex, flex heaters, EMS assembly and product box builds.

Responsibilities:

- Learn the properties, applications, advantages/disadvantages of flex circuits
- Learn the intricacies of flex circuit layout best practices
- Learn IPC guidelines: flex circuits/assemblies
- Create flexible printed circuit board designs/files to meet customer requirements
- Review customer prints and Gerber files to ensure they meet manufacturing and IPC requirements
- Review mechanical designs, circuit requirements, assembly requirements, BOM/component needs/ and help to identify alternates, if needed
- Prepare and document changes to customer prints/ files.
- Work with application engineers, customers, and manufacturing engineers to finalize and optimize designs for manufacturing
- Work with quality manager to learn quality systems, requirements, and support manager with assistance

Qualifications:

- Electrical Engineering Degree with 2+ years of CAD/PCB design experience
- IPC CID or CID+ certification or desire to obtain
- Knowledge of flexible PCB materials, properties, or willingness to learn
- Experience with CAD software: Altium, or other
- Knowledge of IPC standards for PCB industry, or willingness to learn
- Microsoft Office products

FCT offers competitive salary, bonus program, benefits package, and an outstanding long-term opportunity. Location: Minneapolis, Minn., area.

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KYZEN
Where Science and Care Converge.

Regional Manager

Midwest Region

General Summary: Manages sales of the company's products and services, Electronics and Industrial, within the States of KS, MO, NE, and AR. Reports directly to Americas Manager. Collaborates with the Americas Manager to ensure consistent, profitable growth in sales revenues through positive planning, deployment and management of sales reps. Identifies objectives, strategies and action plans to improve short- and long-term sales and earnings for all product lines.

DETAILS OF FUNCTION:

- Develops and maintains strategic partner relationships
- Manages and develops sales reps:
  - Reviews progress of sales performance
  - Provides quarterly results assessments of sales reps' performance
  - Works with sales reps to identify and contact decision-makers
  - Setting growth targets for sales reps
  - Educates sales reps by conducting programs/ seminars in the needed areas of knowledge
- Collects customer feedback and market research (products and competitors)
- Coordinates with other company departments to provide superior customer service

QUALIFICATIONS:

- 5-7+ years of related experience in the manufacturing sector or equivalent combination of formal education and experience
- Excellent oral and written communication skills
- Business-to-business sales experience a plus
- Good working knowledge of Microsoft Office Suite and common smart phone apps
- Valid driver's license
- 75-80% regional travel required

To apply, please submit a COVER LETTER and RESUME to: Fernando Rueda, Americas Manager

fernando_rueda@kyzen.com

apply now

Career Opportunities

pluritec®
MACHINES FOR PRINTED CIRCUIT BOARDS

Field Service Engineer

Location: West Coast, Midwest

Pluritec North America, ltd., an innovative leader in drilling, routing, and automated inspection in the printed circuit board industry, is seeking a full-time field service engineer.

This individual will support service for North America in printed circuit board drill/routing and X-ray inspection equipment.

Duties included: Installation, training, maintenance, and repair. Must be able to troubleshoot electrical and mechanical issues in the field as well as calibrate products, perform modifications and retrofits. Diagnose effectively with customer via telephone support. Assist in optimization of machine operations.

A technical degree is preferred, along with strong verbal and written communication skills. Read and interpret schematics, collect data, write technical reports.

Valid driver's license is required, as well as a passport, and major credit card for travel.

Must be able to travel extensively.

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Manncorp™

SMT Field Technician

Hatboro, 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

apply now

Career Opportunities

ventec INTERNATIONAL GROUP 騰輝電子

European Product Manager
Taiyo Inks, Germany

We are looking for a European product manager to serve as the primary point of contact for product technical sales activities specifically for Taiyo Inks in Europe.

Duties include:

- Business development & sales growth in Europe
- Subject matter expert for Taiyo ink solutions
- Frequent travel to targeted strategic customers/ OEMs in Europe
- Technical support to customers to solve application issues
- Liaising with operational and supply chain teams to support customer service

Skills and abilities required:

- Extensive sales, product management, product application experience
- European citizenship (or authorization to work in Europe/Germany)
- Fluency in English language (spoken & written)
- Good written & verbal communications skills
- Printed circuit board industry experience an advantage
- Ability to work well both independently and as part of a team
- Good user knowledge of common Microsoft Office programs
- Full driving license essential

What's on offer:

- Salary & sales commission--competitive and commensurate with experience
- Pension and health insurance following satisfactory probation
- Company car or car allowance

This is a fantastic opportunity to become part of a successful brand and leading team with excellent benefits. Please forward your resume to **jobs@ventec-europe.com.**

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MivaTek Global

Field Service Technician

MivaTek Global is focused on providing a quality customer service experience to our current and future customers in the printed circuit board and microelectronic industries. We are looking for bright and talented people who share that mindset and are energized by hard work who are looking to be part of our continued growth.

Do you enjoy diagnosing machines and processes to determine how to solve our customers' challenges? Your 5 years working with direct imaging machinery, capital equipment, or PCBs will be leveraged as you support our customers in the field and from your home office. Each day is different, you may be:

- Installing a direct imaging machine
- Diagnosing customer issues from both your home office and customer site
- Upgrading a used machine
- Performing preventive maintenance
- Providing virtual and on-site training
- Updating documentation

Do you have 3 years' experience working with direct imaging or capital equipment? Enjoy travel? Want to make a difference to our customers? Send your resume to N.Hogan@MivaTek.Global for consideration.

More About Us

MivaTek Global is a distributor of Miva Technologies' imaging systems. We currently have 55 installations in the Americas and have machine installations in China, Singapore, Korea, and India.

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Career Opportunities

INSULECTRO

Are You Our Next Superstar?!

Insulectro, the largest national distributor of printed circuit board materials, is looking to add superstars to our dynamic technical and sales teams. We are always looking for good talent to enhance our service level to our customers and drive our purpose to enable our customers to build better boards faster. Our nationwide network provides many opportunities for a rewarding career within our company.

We are looking for talent with solid background in the PCB or PE industry and proven sales experience with a drive and attitude that match our company culture. This is a great opportunity to join an industry leader in the PCB and PE world and work with a terrific team driven to be vital in the design and manufacture of future circuits.

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Prototron Circuits

Sales Representatives

Prototron Circuits, a market-leading, quick-turn PCB manufacturer located in Tucson, AZ, is looking for sales representatives for the New England and Northern California territories. With 35+ years of experience, our PCB manufacturing capabilities reach far beyond that of your typical fabricator.

Reasons you should work with Prototron:

- Solid reputation for on-time delivery (98+% on-time)
- Capacity for growth
- Excellent quality
- Production quality quick-turn services in as little as 24 hours
- 5-day standard lead time
- RF/microwave and special materials
- AS9100D
- MIL-PRF- 31032
- ITAR
- Global sourcing option (Taiwan)
- Engineering consultation, impedance modeling
- Completely customer focused team

Interested? Please contact Russ Adams at (206) 351-0281 or russa@prototron.com.

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Career Opportunities

Career Opportunities

Career Opportunities

BLACKFOX
Premier Training & Certification

IPC Instructor

Longmont, CO; Phoenix, AZ; U.S.-based remote

Independent contractor, possible full-time employment

Job Description

This position is responsible for delivering effective electronics manufacturing training, including IPC Certification, to students from the electronics manufacturing industry. IPC instructors primarily train and certify operators, inspectors, engineers, and other trainers to one of six IPC Certification Programs: IPC-A-600, IPC-A-610, IPC/WHMA-A-620, IPC J-STD-001, IPC 7711/7721, and IPC-6012.

IPC instructors will conduct training at one of our public training centers or will travel directly to the customer's facility. A candidate's close proximity to Longmont, CO, or Phoenix, AZ, is a plus. Several IPC Certification Courses can be taught remotely and require no travel.

Qualifications

Candidates must have a minimum of five years of electronics manufacturing experience. This experience can include printed circuit board fabrication, circuit board assembly, and/or wire and cable harness assembly. Soldering experience of through-hole and/or surface-mount components is highly preferred.

Candidate must have IPC training experience, either currently or in the past. A current and valid certified IPC trainer certificate holder is highly preferred.

Applicants must have the ability to work with little to no supervision and make appropriate and professional decisions.

Send resumes to Sharon Montana-Beard at sharonm@blackfox.com.

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American Standard Circuits
Creative Innovations In Flex, Digital & Microwave Circuits

CAD/CAM Engineer

The CAD/CAM Engineer is responsible for reviewing customer supplied data and drawings, performing design rule checks and creation of manufacturing data, programs and tools required for the manufacture of PCB.

ESSENTIAL DUTIES AND RESPONSIBILITIES

- Import Customer data into various CAM systems.
- Perform design rule checks and edit data to comply with manufacturing guidelines.
- Create array configurations, route, and test programs, penalization and output data for production use.
- Work with process engineers to evaluate and provide strategy for advanced processing as needed.
- Itemize and correspond to design Issues with customers.
- Other duties as assigned

ORGANIZATIONAL RELATIONSHIP

Reports to the engineering manager. Coordinates activities with all departments, especially manufacturing.

QUALIFICATIONS

- A college degree or 5 years' experience is required. Good communication skills and the ability to work well with people is essential.
- Printed circuit board manufacturing knowledge
- Experience using Orbotech/Genflex CAM tooling software

PHYSICAL DEMANDS

Ability to communicate orally with management and other co-workers is crucial. Regular use of the phone and e-mail for communication is essential. Sitting for extended periods is common. Hearing and vision within normal ranges is helpful for normal conversations, to receive ordinary information and to prepare documents.

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Career Opportunities

U.S. CIRCUIT

Plating Supervisor

Escondido, California-based PCB fabricator U.S. Circuit is now hiring for the position of plating supervisor. Candidate must have a minimum of five years' experience working in a wet process environment. Must have good communication skills, bilingual is a plus. Must have working knowledge of a plating lab and hands-on experience running an electrolytic plating line. Responsibilities include, but are not limited to, scheduling work, enforcing safety rules, scheduling/maintaining equipment and maintenance of records.

Competitive benefits package.
Pay will be commensurate
with experience.

Mail to:
mfariba@uscircuit.com

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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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