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PCB007 MAGAZINE

Sales: From Pitch to PO

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Sales: From Pitch to PO

Though all parts of a company are essential for holistic success, it is a foundational truth that a company lives and dies by its sales. If there are no sales, the company eventually dies. In this month's issue, we're here to help you up your sales game and take your business to the next level.

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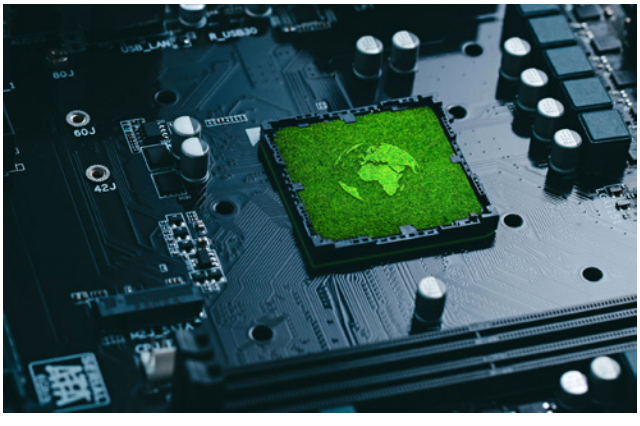

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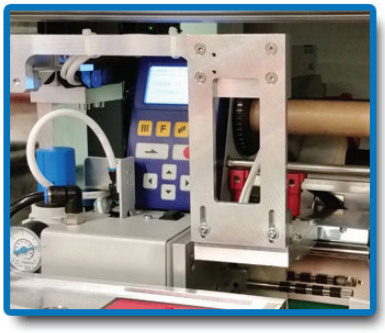

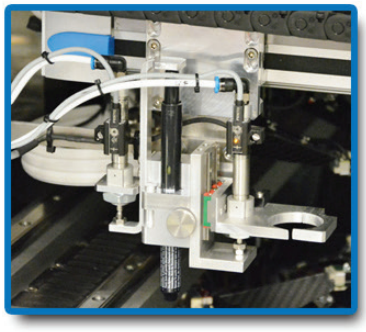

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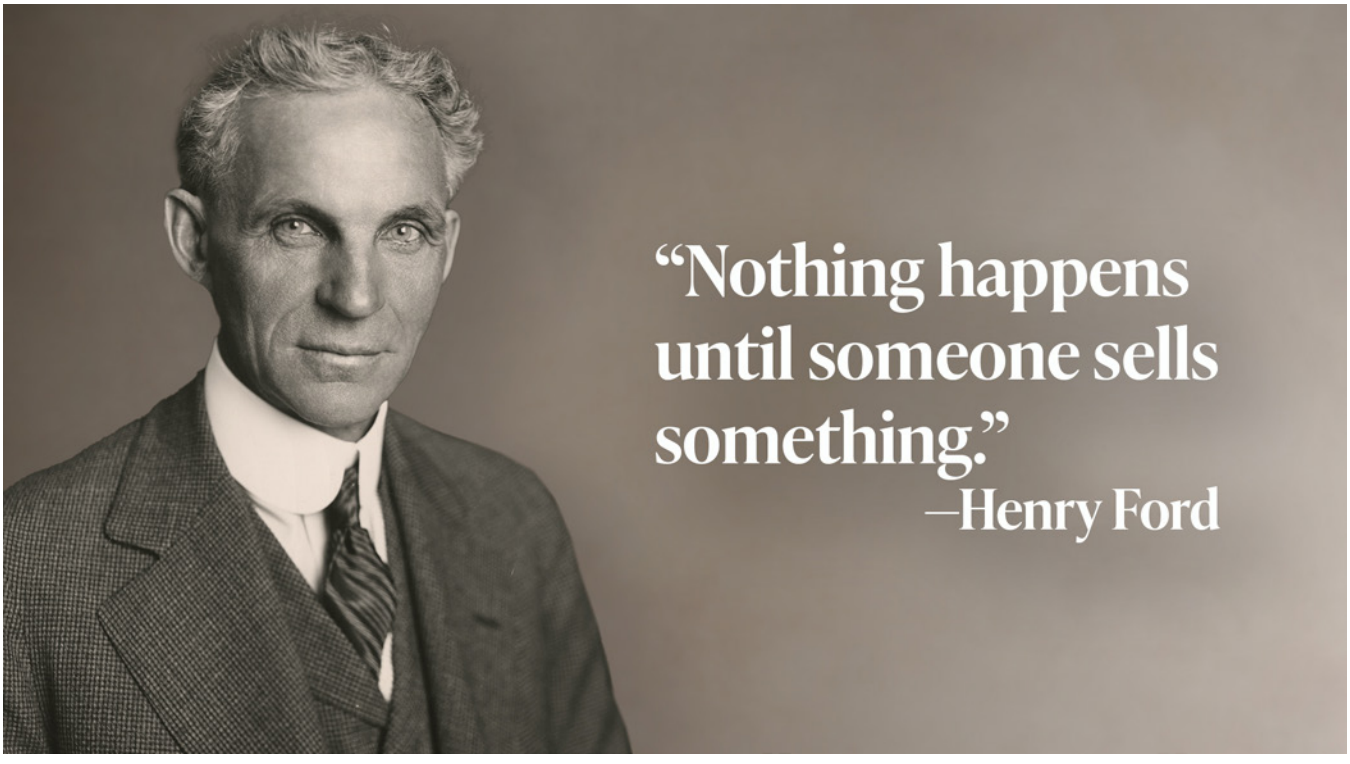
From Pitch to PO: The Sales Stack

by Marcy LaRont, I-Connect007



These days, we talk a lot about "silicon to systems," the incomplete legislation in the U.S. and Europe around chips, and how an end product is useless until it is complete and functional. It speaks to a larger universal truth: There is simply no "whole" without each essential "part" that makes it up. Now, some parts may be weighted more heavily than others, but the interdependency between all the parts is the only way you achieve your endgame.

Having said that, it is also a foundational truth that a company lives and dies by its sales. Receiving that PO or contract starts the operational chain. It is the purest symbol of the machinations of the business process: You are paying me for something I am doing, making, or sourcing for you. Then, every single thing a business does in executing and fulfilling that sales agreement speaks directly to customer experience and whether more POs will follow. You won't keep customers if you don't make a quality product and provide strong customer service. And in manufacturing, we tend to focus on our manufacturing processes, quality, and output, but you must first get the purchase order for any of it to matter.

Speaking from personal experience, sales is a hard job. It doesn't matter if you sell circuit boards, media advertising, or the latest widget that got green-lighted on "Shark Tank." Salespeople must routinely do things that make other people uncomfortable, and they are held accountable for achieving revenue goals that support a whole host of other people's jobs—something which also makes the average employee fidgety.

I believe salespeople and the sales process are among the most misunderstood and maligned parts of almost any business. I wish everyone was

forced to make some cold calls and do a live-in-person customer presentation at least once in their careers to better understand this quirky, unique group of contributors, who, when good at their jobs, give the rest of us job security.

In this month's issue of *PCB007 Magazine*, we explore the nature of the sales process. Before the first PO is ever received, so much preparation, work, and time have already taken place. What should the sales process look like in its best iteration? How can your prowess, your sales team, and your sales process ultimately achieve better results?

I know you'll enjoy a collection of articles included from our resident sales expert and friend Dan Beaulieu, whose 40 years of experience in the field has guided and created strong, effective sales teams. Also included are expert voices from Daniel Beauvois, owner of the component store, and Brittany Martin, the digital marketing manager at I-Connect007. From cold calling, to the importance of having a CRM, to the inextricableand very different roles of marketing and sales, to how to approach a down market, this issue provides PCB sales professionals and business owners with a practical, applicable sales guide to help you gain insight and skill to up your sales game.

Sustainability takes a spotlight in this issue as well. It starts with an interview with Kelly Scanlon and Corey Dehmey, who talk about the partnership between the Global Electronics Association and SERI, and an upcoming summit that focuses on so much more than the traditional mindset of "reduce, reuse, recycle." New contributor, Lynn Bergeson, shares an article covering the need for businesses to better leverage chemical data, and Happy Holden breaks down sustainability in electronics manufacturing based on his attendance at the recent INEMI conference.

MKS' Atotech revisits its IPC APEX EXPO 2025 technical paper on the critical role of vertical plating, MacDermid Alpha discusses direct metallization, and our regular columnists cover a range of topics, including how a sales organization looks when you are an equipment supplier. In a continuation of last month's discussion, Schmoll's Kurt Palmer outlines the various inner layer alignment methods currently used in PCB fabrication, and Shane Whiteside recounts PCBAA's fourth annual meeting in Washington, D.C. and the ongoing work toward achieving acknowledgements for all parts of the manufacturing supply chain and tariff exemptions in the U.S.

Grab a cool lemonade and dive into the July issue of *PCB007 Magazine*. **PCB007**

Marcy LaRont is the managing editor of *PCB007 Magazine* and executive director of IPC Publishing Group. Marcy started her career in PCBs in 1993 and brings a wide array of business experience and perspective to I-Connect007. To contact Marcy, click here.

by Brittany Martin, I-CONNECT007

Attraction to Action: Where Marketing Ends and Sales Begins

Before a PO hits the system, marketing has already done a lot of heavy lifting. In fact, without strategic marketing, the PO might never arrive. At I-Connect007, we have been fortunate to help many companies achieve sales success through marketing. The key to success? Understanding how marketing leads to sales.

Many people think marketing and sales are the same, but while they're closely connected, they play distinct roles: marketing generates demand, and sales converts it. I-Connect007 helps bridge that gap by keeping our customers visible and relevant throughout the buyer's journey. With targeted content, industry reach, and consistent engagement, we make sure your message reaches the right people, so when they're ready to buy, your sales team is closing warm leads, not starting from scratch.

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the sales cycle. It pushes a company's story and solutions into the market, builds awareness, and cuts through the noise to reach the strongest prospects. Done right, marketing creates a runway for sales to take off.


Brittany Martin

Brand awareness takes root through targeted content, industry reach, and consistent engagement that builds visibility and trust over time. Whether it's educational articles, thought leadership, or social campaigns, this marketing does more than inform; it positions your company as a credible, go-to solution. When sales enters the conversation, prospects are already familiar with your brand, people, and value. That familiarity lowers barriers, shortens the sales cycle, and increases the likelihood of conversion.

From the shop floor's perspective, the customer relationship may begin with that first PO and its successful execution. However, seasoned salespeople know that earning a new customer's trust and, eventually, their business, takes time. Customers don't switch vendors lightly, and qualifying a new supplier or process is neither quick nor cheap. That first PO results from the longer, foundational process I've mentioned. It's naïve to think the sales cycle starts with a quote request. If you're serious about sales, the journey begins with marketing through visibility, credibility, and consistent thought leadership.

> "If you're serious about sales, the journey begins with marketing through visibility, credibility, and consistent thought leadership."

Real Case Example 1: Leading With Education

A PCB company wanted to raise awareness and credibility in a competitive market. Experts within the company began contributing short, practical articles to I-Connect007's newsletters and magazines, sharing industry insights and lessons learned. Over time, this steady stream of thought leadership delivered through a trusted industry platform helped position the company as a credible, knowledgeable voice. When customers were ready to explore new vendors, this company was already on their radar. The articles didn't pitch; they educated, which built trust. That trust translated into new inquiries, sales conversations, and ultimately, purchase orders. I-Connect007's platform helped amplify their message to the right audience, laying the groundwork for the sales team to close.

Real Case Example 2: Visibility Through Promotion and People

An equipment company representing multiple machine lines wanted to expand its reach to more decision-makers. To support their sales efforts, they partnered with us to run a series of digital ads across our publications and website. With I-Connect007's broad industry reach and engaged readership, the company consistently stayed top of mind among key buyers. Those repeated, trusted impressions paid off, turning passive interest into demo requests, sales meetings, and ultimately, new deals for their reps to pursue.

In today's competitive landscape, buyers may research for a long time before reaching out for initial contact. Marketing ensures that your company is top of mind when they're ready. Without this important "pre" work—the research, content, lead nurturing, and brand positioning—the rest of the cycle struggles to gain traction. Marketing doesn't just support sales; it sets them in motion and gives sales the best possible chance at success. **PCB007**

Brittany Martin is the digital marketing manager for I-Connect007.

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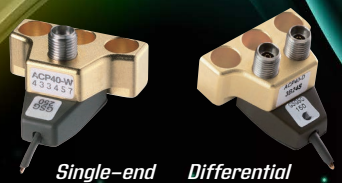

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A Growing Presence in Washington in Turbulent Times

by Shane Whiteside, Summit Interconnect

Last month, PCBAA held its fourth annual meeting in Washington, D.C. It was our largest gathering to date and included speakers from the House and Senate, the Department of Commerce, and OEMs Lockheed Martin, RTX, and Northrop Grumman. We also spent a day on Capitol Hill educating lawmakers and their staff about the importance of a secure domestic microelectronics supply chain.

As I looked around the room, I was struck by the growing depth and breadth of our organization. In less than four years, PCBAA has grown from five PCB manufacturers to nearly 75 members in 34 states, representing raw and refined materials, board shops, assemblers, tooling, training, testing, and most recently, an OEM.

PCBAA staff spend a lot of time in Washington. When it comes to advocacy, there is no substitute for being face to face with the men and women who actually make policy and write legislation. We were fortunate to hear directly from regulators, purchasers, elected officials, and the current administration. Legislators were clear that the current administration will continue to use Executive Orders to take direct action on priority topics. We were advised to work with other like-minded trade groups and the uniformed services' associations to get our mes-

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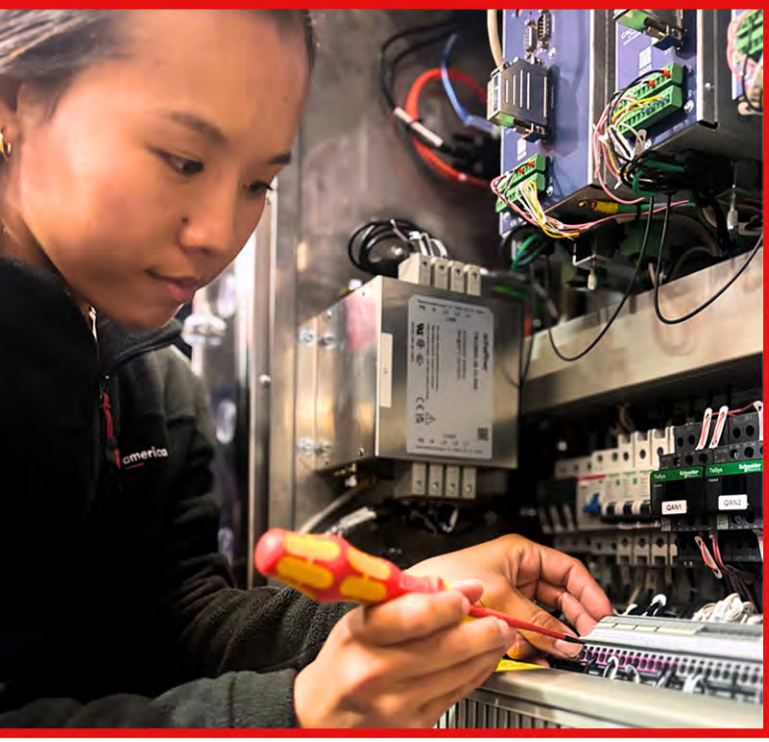

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sages out and drive favorable outcomes for the microelectronics industry.

During the meeting we also took time for open discussion about current dynamics in our industry. Tariffs were a frequent topic of conversation. Companies of all sizes are challenged by the uncertainty caused by frequently changing tariffs. Because we rely on a global supply chain, costs are increasing in unpredictable ways, which makes long-range planning and investment difficult.

We reminded policymakers that the PCB industry represents family businesses and billion-dollar operations alike. At all levels, the ever-changing nature of trade policy is a burden on our industry. This underscores why PCBAA and our partners at organizations like the Global Electronics Association are focused on incentives and policies that will create a demand signal and advance a renaissance of American manufacturing.

As we wrapped up another successful week in Washington, I was left with a few key takeaways:

- Our industry should continue to fight for tariff exemptions for select items in the PCB supply chain. American industry relies on foreign inputs, and our trade policy should reflect that.
- PCB executives need to provide this administration with big ideas for making American companies more competitive on the global stage.
- We must continuously educate legislators, policymakers, and their staff about our industry. PCBs, while essential and ubiquitous, remain largely invisible without our advocacy.
- Our strategy must remain multifaceted. In addition to the PCBS Act, H.R. 3597, we will pursue DoD regulations that secure supply chains and push for domestic sourcing of the microelectronics that power critical infrastructure. We will also work closely with Department of Commerce officials writing the policies and regulations that govern our industry.

We have an opportunity to influence the future of our industry in the year ahead. Now more than ever, we need to work together wherever we operate to educate, advocate, and champion legislation and policies that will revitalize American microelectronics manufacturing. We welcome new members and new voices across our industry to support this very important mission. **PCB007**

Shane Whiteside is president and CEO of Summit Interconnect and current chair of the Printed Circuit Board Association of America. To read past columns, click here.

Copper Price Surge Raises Alarms for Electronics

The copper market is experiencing major turbulence in the wake of U.S. President Donald Trump's announcement of a 50% tariff on imported copper effective Aug. 1. Recent news reports, including from the New York Times, sent U.S. copper futures soaring to record highs, climbing nearly 13% in a single day as manufacturers braced for supply shocks and surging costs.

The problem is that electronics-grade copper, often in the form of rolled or electrodeposited foil, high-purity cathodes, and specialized plating solutions, is not easily substitutable and has few domestic sources. The Global Electronics Association is monitoring the situation closely and urging the administration to exempt electronics-grade copper and associated materials from the tariff list. Meanwhile, manufacturers should assess potential cost impacts and explore supply diversification, recycling strategies, and material substitutions. To learn more, contact Richard Cappetto, richardcappetto@electronics.org.

Read the entire story

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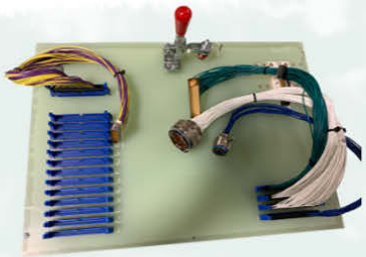

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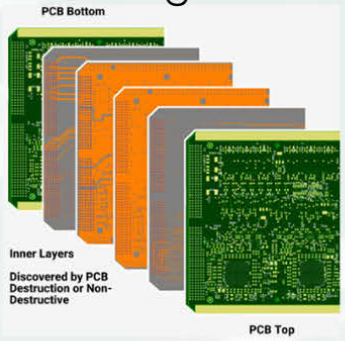

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by Daniel Beauvois, the component store

COVID, Tough Sales, and What Made Me a Better Salesperson

I am the owner and president of the component store, LLC, a PCB rep firm I started 15 years ago, sort of unintentionally. While my business (and my sales prowess) have happily grown, I've witnessed significant changes in the sales process.

Before 2020, we approached sales differently. A persistent, gritty salesperson could approach businesses daily without an appointment. They would often be turned away, but sometimes, they would be given a shot. There are plenty of instances where that one-time unannounced solicitor earned his way onto the AVL and became one of their best suppliers. If you're a purchaser, buyer, or supply chain person, I'm sure you've experienced this—and kudos for doing your job well by continuing to seek out other and better resources and partners for the overall well-being of your company.

Then, in March 2020, after months of chatter and concerning health outcomes from a mysterious and very contagious virus, the COVID-19 pandemic became official, and things started to shut down. As work-from-home mandates became the norm where possible, most folks and businesses abided by shelter-in-

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place protocols set forth by our government. When manufacturing facilities finally came back online, masks, social distancing, regular disinfection, and lots of hand sanitizer became our new normal.

This created a seemingly impenetrable barrier for outside salespeople. Not only did all regular customer visits stop, but so did all forward-moving sales activity, essentially killing those hot pending prospects just one NDA away from submitting their first PO. As an outside sales rep who made his living by creating business inroads and forging new relationships, the COVID-19 period was daunting, and quite honestly, I was not at all prepared.

I was a door-to-door salesman for a time. It's a sales experience I would not trade. In all my years of going door-to-door, I learned some valuable life lessons, met great people, and, most importantly, learned a lot about myself—something which is critically important for anyone who wants to be good at sales. By contrast, encountering the not-so-great people, the slammed doors, and the seemingly endless stream of "no's" helped me develop grit and tenacity.

So, as the global pandemic began rewriting the rules of the modern-day sales interaction, it provided me with a lot of thought time. I sat in my home, day after day, and brainstormed how to engage with new companies differently. Some of those approaches and methods yielded better results than others, but I kept at it. It was challenging to be sure, and every salesperson at every level felt both the awkwardness and the pressure of this new reality. It was and still is much easier to engage with real people face-to-face. At least I could see who was tossing me out of their lobby.


Daniel Beauvois

After some time of bumbling around in the flannel pants I'd worn for several days (can you relate?), it started to come together. I became energized at this new opportunity, forced as it was, to figure out the puzzle of positive and successful sales interaction in the pandemic era. Today, some years post-COVID, what I know for sure is that the truisms around sales and effective communication are always relevant, no matter how you approach the process or what channels (email, phone, traditional snail mail, or in person) you may be limited to at a given time or place. Phone sales will never be my greatest strength area, but I am happy for the opportunity to have developed those muscles all the same.

Beyond COVID

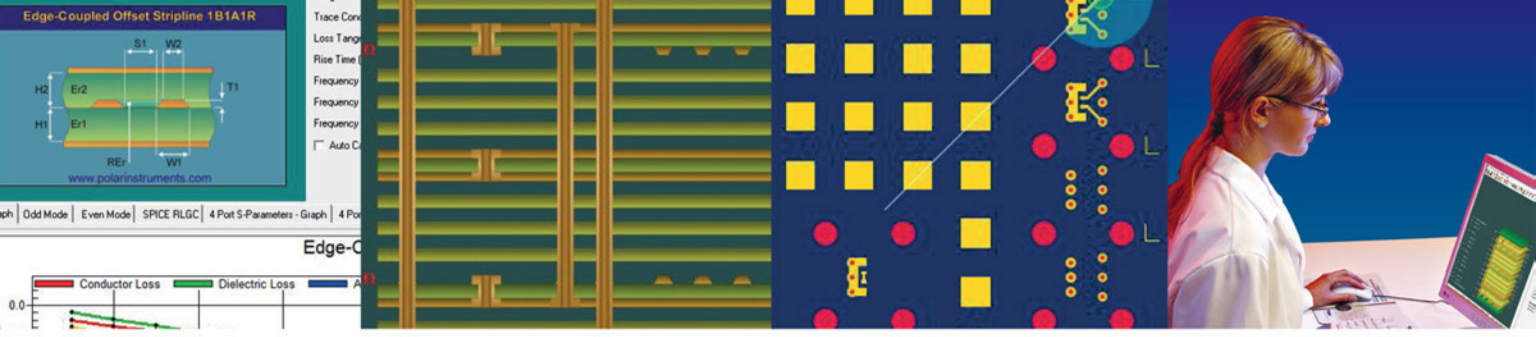
When our society was given the green light to head back to the office and normalcy began to return, the COVID lessons came flooding back to me. What had I learned as a salesperson by living and working through the pandemic? Did any of this learning help me to be a better person or a better sales professional?

Here are some tips that I learned from my COVID-sales era that made me a stronger salesperson:

- Do your homework and research your prospects before engaging them; you'll sound better to them
- Speak on topics other than work, such as your customer's interests and hobbies
- Bring back those thank-you letters. Who doesn't love a letter addressed to their name?
- Try to attend industry-related events. You'll have potential customers there by default

My biggest takeaway, though, was that most working people have many other concerns on a given workday beyond just their work, and those things can't help but follow them into their work encounters. When I approach a potential customer face-to-face and begin speaking to them, I always keep that at the forefront of my mind. This has helped me be both a better person and a better sales professional. **PCB007**

My biggest takeaway, though, was that most working people have many other concerns on a given workday beyond just their work.



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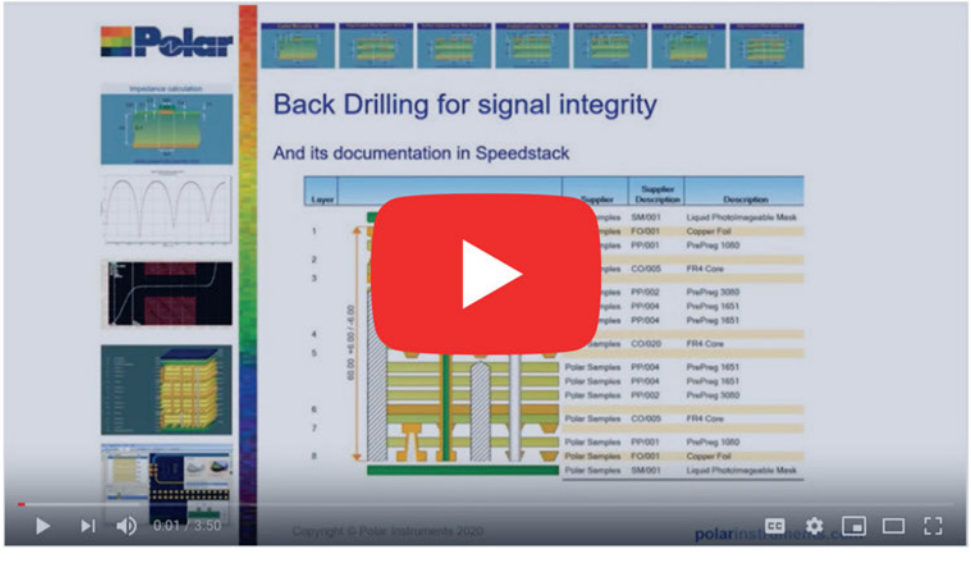

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by Marcy LaRont, I-Connect007

Beyond Recycling: Reshaping Sustainability in Electronics

Corey Dehmey presenting at first eSummit, 2024.

Environmental sustainability, especially for carbon-intensive industries like electronics manufacturing, means businesses are often plagued with various reporting requirements that don't necessarily address the root problem.

To that end, SERI and the Global Electronics Association are teaming up to reshape sustainability in electronics. In this interview, Kelly Scanlon, lead sustainability strategist for the Association, and Corey Dehmey, CEO of SERI, discuss how their connection at last year's eSummit has evolved into a powerful collaboration focused on circularity—not just reducing waste but rethinking it entirely. With the next eSummit in September 2025, both groups are leading the charge toward a more sustainable, tech-driven future for the industry.

Marcy LaRont: Kelly, let's first talk about Evolve, a new initiative powered by the Global Electronics Association. How does it address sustainability for electronics?

Kelly Scanlon: Evolve is a brand, a resource hub, and even a strategy. The electronics industry is undergoing constant change and continual improvement. We've developed Evolve as the go-to resource for everything related to electron-

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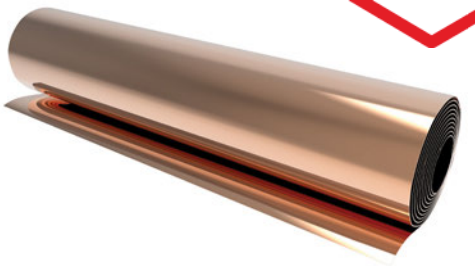

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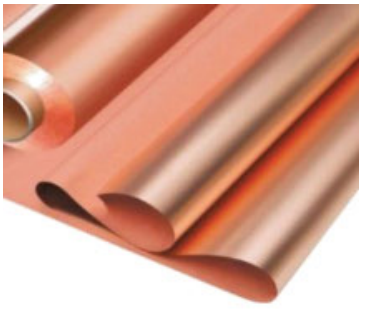

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ics and sustainability. It was launched in March. We also link to what SERI is doing, the upcoming eSummit, and to other organizations working on sustainability for electronics. We want to collaborate with all of them to provide meaningful resources for the industry.


Kelly Scanlon

Tell me about the report you published when you launched Evolve.

Scanlon: The "Wired for Change" report captures the industry's sentiment about sustainability. It highlights survey results indicating that sustainability for electronics is a top priority and that there is momentum toward achieving sustainability goals.

In addition to the recent sentiment report, we've learned from different groups in the electronics supply chain that there are several big, overarching pain points that prevent them from being more ambitious on sustainability—things like supply chain resilience roadblocks, natural resource and waste management hurdles, reporting and disclosure obligations, and workforce development challenges. We are here to help the whole industry with these pain points and high hurdles that prevent our industry from being more ambitious on sustainability.

Can you cite an example of feedback you received and how you addressed it?

Scanlon: In one example, we heard from industry that they need more support identifying safer chemical alternatives. Our industry makes electronics, not chemicals. Consequently, we worked with experts at Clean Electronics Production Network to develop a guide and host a webinar on the resources that may help a company shift to safer alternatives for certain areas of electronics manufacturing.

We're trying to identify the industry's biggest challenges and provide them with resources and information to overcome those challenges.

Does Evolve have a mission or purpose statement?

Scanlon: Yes, the key message is, "Evolve powers industry-wide sustainability." The evolution of sustainability for electronics is what Evolve fuels, leading the way for transformation through collaboration and practical guidance. When sustainability sits at the core of design and manufacturing, electronics are built better.

Corey Dehmey: It's the difference between being linear and reacting to a problem after we've already generated it and being proactive and planning for sustainability throughout that product's lifecycle.

Corey, tell me more about SERI and its role in sustainability for electronics.

Dehmey: SERI, as an organization, focuses on one topic: electronics sustainability. We are a 501(c)(3) charitable nonprofit, so we don't have any members. Our mission is to champion and drive the sustainable use, reuse, and recycling of electronics globally. We focus on electronics from their first use all the way to their end-of-life in the reverse supply chain.

We started 20 years ago, when the U.S. Environmental Protection Agency decided to bring together stakeholders—manufacturers, regulators, professionals, NGOs, and recyclers in the industry—to determine best practices for electronics recycling. After a three-year process, they published Responsible Recycling Practices, known as the R2 guideline. In the early 2000s, the focus was very much on e-waste and its management and on shifting from landfill or dumping to recycling.

The first R2 standard was very focused on recycling. It was developed to measure and recognize those recyclers implementing best practices, environmentally sound management, worker health and safety, and the health of their communities. SERI was started as an organization to house this standard and the certification program. Through the process of creating and releasing the next version of R2 in 2013, the concept of circularity was added to the standard. It wasn't just about recycling or managing waste and keeping it out of landfills. Now it was also about how we implement more reuse and ensure that data is sanitized in that process.

Please explain what circularity means, especially when compared to what is traditionally thought of as recycling.

Dehmey: E-waste management is the result of a linear life supply chain where we take things from the earth, make products, use them, and then we have garbage or waste. Historically, with any product, we must look at how we deal with that waste: collection, landfill, incineration, and/or managing the hazardous things within it. Circularity is building a more regenerative approach. First, how do we recover the materials from those products we've already manufactured and put them back into something new, rather than mining more virgin materials?

It's actually more regenerative than that: How do we maximize the utility of these products? How do we keep them in use longer? That considers the full lifecycle of a product. How long are we building this product to last? How do we service, support, and repair it?

Technology is now integrated into all kinds of things that historically didn't use electronics. With smart technology, you can connect your refrigerator to the internet, start your washing machine from work, or see who's at your door even if you're on the other side of the world. We live in a connected world, so circularity is about encompassing the entire lifecycle of those products.

As this evolves, the R2 standard has been our book of knowledge. It's how we share best practices in electronics reuse and recycling, and how we help to build the knowledge, capabilities, and capacity throughout the world. We don't just say that we want to be sustainable. We've got to build the ability to achieve it. SERI and the R2 certification program are working to build that.

How does eSummit fit into all of this?

Dehmey: The eSummit is the next, logical extension of our programming. We saw the opportunity to bring together the full lifecycle of stakeholders. It's usually one vertical for a conference. We don't get to talk across that lifecycle. The eSummit will take one catwelectronics—look at all the different groups within that entire product lifecycle, and determine how best to bring them together. We will discuss and problem-solve how to make these products last longer, support them, keep them in use, and collect those materials at the end and put them back into new products.

Corey Dehmey

Scanlon: Remember in the 1990s, when computers on your desktop became a reality for businesses, churches, schools, and universities. Those

lasted for a while, but then they stopped working, and they started to pile up. We wondered, "Oh wow, now what do we do with them?"

Dehmey: You know, Kelly, I don't think any of us ever planned to get into this business, me included. I got into this space because I was doing a tech refresh project of 350,000 PCs all over the world, and at that time, nobody thought about what to do with the stuff we were replacing.

This is exactly where eSummit dovetails with Evolve. It's changing the dynamic, the mindset toward looking at the idea of "waste" from the viewpoint of the full product lifestyle. It's planning and being proactive. As electronics keep growing into so many wonderful things, my definition of sustainability is having all this great tech without the harm that we're causing from it. That's the goal.

This may be a slightly contentious point, but it is a business reality that at some point in the economics of manufacturing and consumption, it was decided that it was better for business if products didn't last and we just had to buy new ones. In many cases, it's cheaper to buy a new one than repair the old one. Paper printers come to mind.

Dehmey: Over the years, we have learned that roughly 85% of a product's carbon footprint is generated just in making a new device and bringing it to market. We now understand that it has a huge impact. So, how do we mitigate that? We're not saying we shouldn't make new devices, but how do we get the most use out of them, whether it's better quality, more interoperability, or making sure they get to areas in our communities or the world where they are still useful? These concepts are all part of the conversation. How do you make the model work? How do you make circular supply chains?

The eSummit is trying to achieve a vision of how we can look forward. We always want to be thinking about where technology is headed so that we can plan for it, and how we build with sustainability in mind throughout the whole product lifecycle, and not just react to the problems that are thrown our way at the end.

▲ Panel speakers taking questions at first eSummit, 2024.

Scanlon: Corey already introduced "regenerative." React is also a "re" word, but it isn't as useful as others, like reduce, reuse, and recycle. There are other "re" words as well, like repair, refurbish, remanufacture, repurpose, recover, and redesign. We want to shift away from react.

Dehmey: Kelly and I have talked a lot about recognizing that the procurement of materials for new products and the recovery of those materials at the end aren't connected. The recycling community needs to understand the quality and the types of materials that need to be produced in order to be used in new manufacturing. The manufacturers need to understand what's possible, what is available, and where the opportunities are, and procure

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that to meet their targets for recycled content. Those would be really strong outcomes.

SERI cannot solve the sustainability problem. We're championing the cause, but it will only be solved when everyone add to their part of the puzzle. Together, we can continuously improve. Every year, we want to show that we are getting ahead of the curve and being proactive, rather than reactive, to the problem. That's how we start preventing waste instead of managing it.

Scanlon: Marcy, you asked us about what connects us to SERI. I think the partnership completes us. They allow the Association to be truly circular in our representation of the electronics manufacturing value chain, not just the front end of design and manufacture. Corey and SERI are key because, as experts in circularity, they can reach the other end of the value chain and, together, we close the loop.

Dehmey: The commonality is that we are trying to solve the same problem. I also feel that it's important to mention the power of IPC standards. If it's done properly, a standard can apply anywhere and across boundaries, and can help to harmonize our approach.

That's a good sentiment. Do you have any final thoughts?

Dehmey: We should talk about the term, "waste." If the world is really committed to circularity, a true circular economy doesn't have waste in it. Every waste is food for something else. Let's change our words and start talking about "resources." We need to talk about "waste" as our wasted opportunities within the full product lifecycle. To me, that is the "e-waste." Our ultimate goal should be to eliminate all waste throughout the product lifecycle. That's how we get to circularity, and circularity ends up creating a sustainable future for everyone. From a purely business viewpoint, waste costs money. If we can be more efficient and more resourceful, it makes good economic sense for business.

That's a good note to end on. Thank you, both. PCB007

New Component Reduces Cost, Supply Chain Constraints for Fast-charging EV Batteries

Strengthening the competitiveness of the American transportation industry relies on developing domestically produced electric vehicle batteries that enable rapid charging and long-range performance. The energy density needed to extend driving distance can, however, come at the expense of charging rates and battery life.

By integrating a new type of current collector, a key battery component, researchers at the Department of Energy's Oak Ridge National Laboratory have demonstrated how to manufacture a battery with superior energy density and a lasting ability to handle extreme fast charging. This enables restoring at least 80% of battery energy in 10 minutes. By using less metal, particularly high-demand copper, the technology also relieves strain on U.S. supply chains.

A current collector conducts electricity from the active material within the battery to an external circuit. Current collectors are generally made of metal foil, with one at each pole of the electrode: copper for the anode and aluminum for the cathode. The metals add weight to the battery, increasing the overall weight of the car and the amount of energy required to move it.

The novel current collector, made by industry partner Soteria Battery Innovation Group, is a polymer sandwiched between very thin layers of copper or aluminum. ORNL researchers found that this new component can reduce current collector costs by 85%, pack in 27% more energy for longer trips, and maintain significant energy density after a thousand cycles, even under extreme fast charging conditions that can degrade battery materials more rapidly over time. The new current collector performs as well as its conventional counterpart at about a quarter of the weight, enabling an EV to travel farther on the same charge.

(Source: Oak Ridge National Laboratory)

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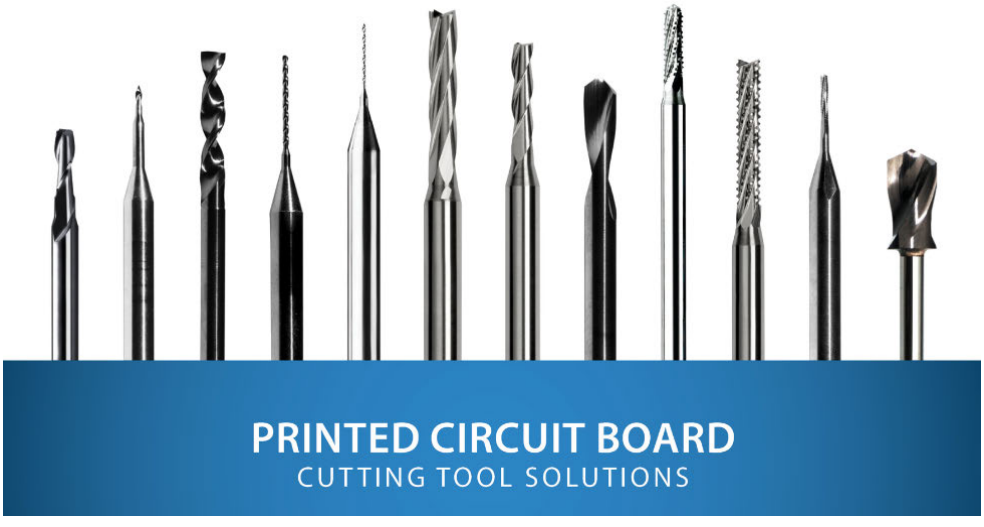

Kyocera designs and manufactures tight tolerance precision carbide cutting tools for PCB applications. Products include drills, routers, end mills, and specialized cutting tools ranging from: 0.05mm to 6.70mm diameters (0.0020" - 0.2638").

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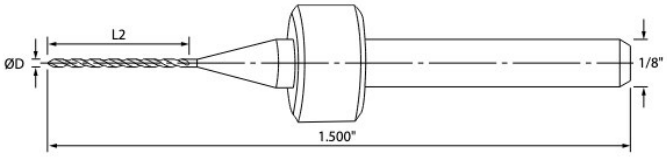

4 Facet Point Geometry

REPOINTING will be a new service offered by Insulectro through Kyocera. The company has recently invested in automated, state-of-the-art equipment and all repointing will be done in Southern California.

Sales Organization from a Capital Equipment Perspective

by Don Ball, Chemcut

The sales organization for a capital equipment supplier to the PCB industry tends to differ slightly from a supplier that manufactures and sells circuit boards to their customers. After all, our sales depend on the printed circuit board manufacturer's sales. If business falls off, you tend to delay or reconsider the need for new or upgraded capital equipment, and then our sales fall off. If your sales go up and you need to increase capacity or replace old equipment, our sales also trend upwards.

Interestingly, all business cycles experience peaks and valleys—peaks as demand rises and sales pick up, and valleys when demand is satisfied and sales decrease. Capital equipment suppliers see the same peaks and valleys but offset by three or more months. So, what is the best sales organization and approach for a capital equipment supplier in which sales depend on their customers' sales?

Over the years, our first contact has cycled among direct sales representatives, employees with responsibilities for assigned territories, and independent sales reps who may represent several suppliers within their territory. There are advantages and disadvantages to each approach, but our experience has shown that we get better coverage with independent sales reps who tend to be in and out of shops more often, representing other suppliers as well as us (chemicals, drills, etch

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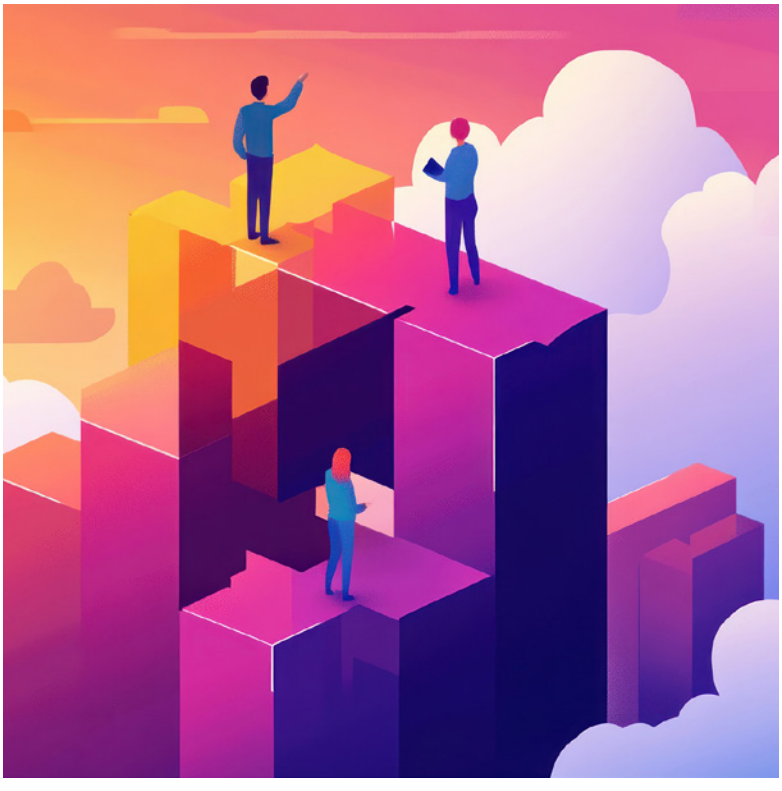
resists, etc.). This gives them a better feel for their (and our) customers' needs. It might be weeks or months between visits for a direct salesperson.

One disadvantage to using independent reps is that they may lack the deep technical knowledge of the equipment that a direct salesperson has, since they may also represent several other product lines, which they must also have some technical proficiency in. To help our independent reps, our technical sales managers (TSMs) can provide direct or indirect support to reps in their territory. Indirect support provides information that the potential customer has asked for, such as technical information and/or test reports, or options to make the customer's job easier or more cost-effective. Direct support includes the TSM getting directly involved in the sales effort with the sales rep. Advances in video conferencing in the last few years have made this easier and more cost-effective, eliminating travel needs while still maintaining close contact.

The sales rep or sales rep/TSM team is responsible for obtaining the information for a realistic quote once the questions of "How fast can you deliver, and what kind of pricing deal can you give me?" are settled. The sales team needs not only the production requirements but also the technical experience of the customer, the technical level of the product being produced, and the kind of competition they are facing. With this information, the sales rep then submits a request for a quote, and the TSM prepares a quote for the equipment that will get the job done for the lowest price, along with a list of possible options to make it easier to complete the job and be more cost-effective. These options may cost a little more now but will save on labor and time in the long run over the life of the equipment.

In normal times, but especially when things start to slow down, a good salesperson will emphasize the intangibles of an equipment purchase, such as installation assistance, start-up help, and process expertise, along with more subtle things that sometimes get lost in detailed discussions.

As business slows down, many customers delay buying new equipment and try to keep their current equipment running longer. Our spare parts and field service business picks up substantially in slow times and takes up some of our sales slack. A good salesperson emphasizes our record in the quick shipment of spare parts and our ability to get field service personnel onsite quickly. This is an invaluable sales tool that is sometimes underutilized.



Our company has always had some form of process lab. This is also a marketing tool, but sometimes we don't emphasize it enough. We have production-sized develop, etch, and strip lines along with several smaller etchers for process development. We invite potential customers to send or bring samples for testing. It is amazing how much more confident people are in purchasing capital equipment when they see their product being run on the equipment they intend to purchase. Our sample and visit workspace increases when the economy slows down, and can sometimes be the clinching argument in a reluctant-to-spend customer pulling the trigger on a purchase order.

And our smaller etchers allow us to test non-traditional processes that come to our attention and lead to sales in unexpected areas. This is a sales tool that has produced results over the years.

For all its faults (spoken from the perspective of an old dinosaur born in the late 1940s), it is essential to have an excellent website. I'm no expert on websites, as you may have gathered, but it has provided many leads we may have otherwise been unaware of, such as etching glass display screens to remove microscopic cracks and scratches from the surface. Inquiries go to the technical sales manager for that territory, who decides whether to contact the potential customer directly or alert the area sales rep for a visit.

Once we send out a quote, the TSM reviews and makes any changes requested by the customer, and, after receiving a purchase order, shepherds the quote through engineering and engineering review with the customer. Once we manufacture the system modules, we assemble the system, wire it, and run it with water on the factory floor test area. The TSM then schedules a Factory Acceptance Test site visit with the customer to confirm the equipment's "as-built" condition matches the quote's specifications. We strongly advise following this step as correcting mistakes is easier in the factory than after delivery.

There may be better ways to organize a sales organization, but some form of the system above has served us well for the last 88 years. Okay, there was no internet in 1957, but you know what I mean. **PCB007**

Don Ball is a process engineer at Chemcut. To read past columns or to contact Ball, click here.

This AI-powered Lab Runs Itself—and Discovers New Materials 10x Faster

Researchers have demonstrated a new technique that allows "self-driving laboratories" to collect at least 10 times more data than previous techniques at record speed. The advance, published in *Nature Chemical Engineering*, dramatically expedites materials discovery research, while slashing costs and environmental impact.

Self-driving laboratories are robotic platforms that combine machine learning and automation with chemical and materials sciences to discover materials more quickly. The automated process allows machine-learning algorithms to use data from each experiment to predict which experiment to conduct next to achieve the goal programmed into the system.

Until now, self-driving labs utilizing continuous flow reactors have relied on steady-state flow experiments. In these experiments, different precursors are mixed together and chemical reactions take place, while continuously flowing in a microchannel. Steady-state flow experiments require the self-driving lab to wait for the chemical reaction before characterizing the resulting material. That means the system sits idle while the reactions occur, which can take up to an hour per experiment.

"We've now created a self-driving lab that makes use of dynamic flow experiments, where chemical mixtures are continuously varied through the system and are monitored in real time," Abolhasani says. "In other words, rather than running separate samples through the system and testing them one at a time after reaching steady-state, we've created a system that essentially never stops running. The sample is moving continuously through the system and, because the system never stops characterizing the sample, we can capture data on what is taking place in the sample every half second.

(Source: North Carolina State University)

by Lynn L. Bergeson, Bergeson & Campbell

Leveraging Chemical Data More Efficiently

Some truths transcend politics, one being that chemical data holds enduring value and is becoming increasingly essential. In the United States, regardless of which party federally controls the levers of power, it's clear that chemical manufacturers and their customers must develop and curate robust data portfolios for their chemical inventories. The commercial imperatives driving this are undeniable and gaining traction.

Data Are Intellectual Property Assets

Data in this context includes health and safety studies, physical property information, environmental fate and transport studies, release and exposure information, and similar information beyond commercial information like financial data, product formulations, and customer lists. A key tenet of the U.S. Environmental Protection Agency's (EPA) regulatory authority under the Toxic Substances Control Act (TSCA) is the principle that manufacturers and processors are responsible for developing adequate information regarding their chemical products. Like any valuable commodity, data needs to be protected from disclosure and managed carefully to retain its value.

The industrial chemical community has not always been as protective of its health and safety chemical data, unlike their

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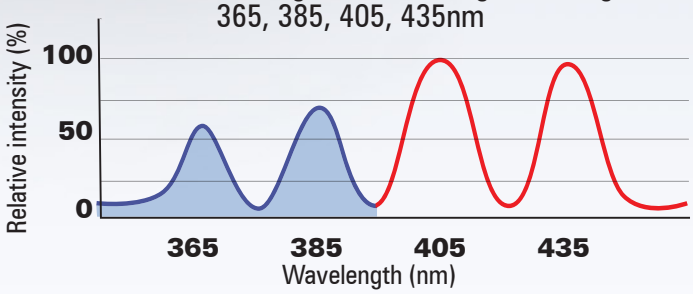

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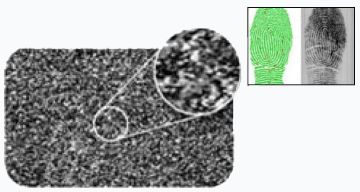

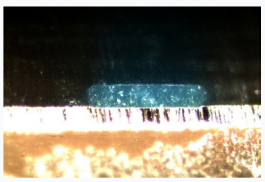

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Lynn Bergeson

FIFRA data, like Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) data, will remain undisclosed unless they satisfy certain conditions, including provisions in FIFRA Section 10(g) that prohibit the release of data to foreign or multinational corporations. Companies cannot claim TSCA health and safety data as confidential. Although TSCA Section 4 includes a data cost reimbursement mechanism, regulators have largely ignored it. REACH helped strengthen the concept of monetizing chemical data, and the recognition of data as a currency in the industrial chemical community is now a more prevailing view.

The Essentiality of Data

A company's freedom to operate is increasingly tied to its ability to prove the safety of its products. Regulatory trends demonstrate this. The EPA's enhanced authority under new TSCA Section 4 to compel chemical data production reflects

Congress's recognition that the public has a right to know more about chemicals in products. The availability of high-quality studies impacts EPA's evaluation of chemical substances under TSCA Section 6 and consequent risk management regulations.

Innovators seeking to commercialize new chemicals under TSCA Section 5 are at a severe disadvantage if they lack chemical and exposure data. The absence of these data results in the imposition of conservative risk assumptions and multiple safety factors during new chemical review that make operating conditions less competitive.

REACH is premised on similar principles. Under REACH, the greater the production volume, the greater the data burden as a regulatory predicate to marketing the chemical. REACH-like laws around the globe are premised on the same principles, creating a regulatory imperative to know more about a chemical's hazard and risk profile as a prerequisite to commercialization. Generating new data is not always necessary, as it's possible to leverage read-across and chemical analogue analysis to fill data gaps. What is no longer acceptable is the adage "What you don't know can't hurt you."

Emerging product stewardship principles require manufacturers of industrial chemicals and articles alike to understand the toxicological, environmental fate, and exposure implications of their products. Incomplete product profiles translate into product liability, commercially adverse inferences regarding risk potential, and mistrust in commercially significant constituencies like customers, workers, regulators, and neighbors.

Savvy companies are conducting data gap analyses for critical products and key chemical components in them and voluntarily generating defensive data. The availability of these data fortifies advocacy opportunities in product liability disputes, fulfills product stewardship commitments, and holds entities accountable to answer questions key stakeholders are likely to ask if things go south. This is smart. While facts and science may not always win over juries, defendants have a much stronger case when they support their arguments with data.

What to Do Now

Smart businesspeople are taking stock of their chemical product inventories and critically assessing their options. Here are a few to consider:

Conduct a data call-in: Companies need to know what data they own or have access to through data sharing agreements. Trade associations can assist by managing these efforts to ensure they efficiently identify unpublished studies to present a comprehensive composite overview of a chemical's data, use, and exposure information unique to a commercial sector. Use a lawyer in this exercise to carefully navigate confidentiality claims, competition issues, and related legal sensitivities.

Curate data prudently: Companies and trade associations must carefully curate existing data to preserve confidentiality and maximize value. Develop standard operating procedures to routinize these protections and observe them.

Prepare data sharing agreements to leverage data: To monetize data effectively, entities that need to rely on it must be able to access the data and pay fair data compensation. Data sharing agreements should spell out the rights, duties, and obligations of the contracting parties. Compensation mechanisms need to be standardized.

Develop data smartly and carefully: There are many reasons to generate chemical data. It is critical that a decision to do so, whether by a company or jointly by a consortium, is based on a review of global regulatory and testing protocol requirements. Satisfying Good Laboratory Practice (GLP), Organization for Economic Co-operation and Development (OECD), and other testing requirements is challenging but essential.

It is a brave new world, fueled increasingly by chemical data. Like any asset, it's essential to manage these data smartly and generate new data carefully. These politically agnostic facts are true globally. Start now to embrace them and plan accordingly. **PCB007**

Lynn L. Bergerson is the owner and managing partner of Bergeson & Campbell, P.C., president at The Acta Group, and B&C Consortia Management.

Inner Layer Alignment Methods in PCB Production

by Kurt Palmer, Schmoll America

In PCB manufacturing, precision is a fundamental requirement. Among many complex processes, the accurate registration of inner layers before lamination is one of the most critical. Much like a child's game where rings must be perfectly stacked onto a single pin, PCB manufacturers align multiple conductive and insulating layers to form a cohesive, functional board. This alignment directly affects PCB precision; tighter layer alignment results in smaller "annular rings," superior performance, and higher yields.

People commonly use these three methodologies to align inner layers before the lamination process, each with distinct operational characteristics and implications for production:

1. Pin-lam: This traditional method involves placing physical pins within the lamination press tools (Figure 1).
2. Mass-lam: Unlike pin-lam, mass-lam does not use pins within the lamination press. Instead, precise alignment and pre-fixing of the multilayer stack are done before the stack enters the press (Figure 2).
3. Two methods exist for implementing mass-lam:
   - Automated lay-up machine.
   - Two-step lay-up process

Different manufacturers use these methods, yielding varied results depending on their spe-

▲ Figure 1: Press tool for pin-lam. (Source: C.A. PICARD)

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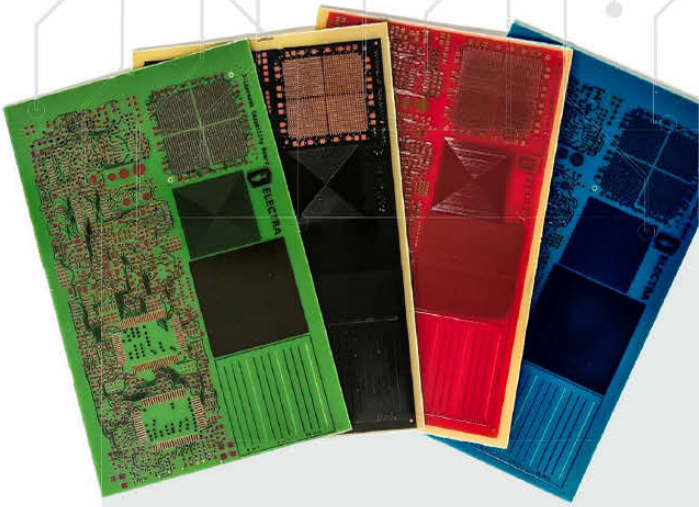

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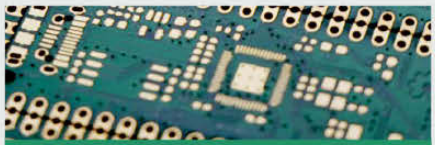

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▼ Figure 2: Press tool for the mass-lam.

cific equipment, process control, and production requirements. Understanding the nuances of each is essential for making informed decisions.

Pin-lam: Pin-lam technology begins by creating precise tooling holes in the inner layers. The process carefully inserts these layers and prepreg sheets onto the fixed pins within the press tool. This mechanical locking ensures that all layers remain accurately registered during the high-temperature and high-pressure lamination cycle. While various techniques exist for creating these initial tooling holes, the most common and efficient method is punching the inner layer using a specialized post-etch punch machine.

This method offers several advantages:

- **High productivity**
- **Material flexibility:** Pin-lam allows users to work with all PCB substrate materials, from standard FR-4 and rigid-flex boards to more exotic combinations of materials.
- **Extreme accuracy:** When combined with optimal positions of pins and holes and a precision-engineered punching machine, pin-lam can be extremely accurate, allowing material to flow predictably, thereby ensuring high-level process control.

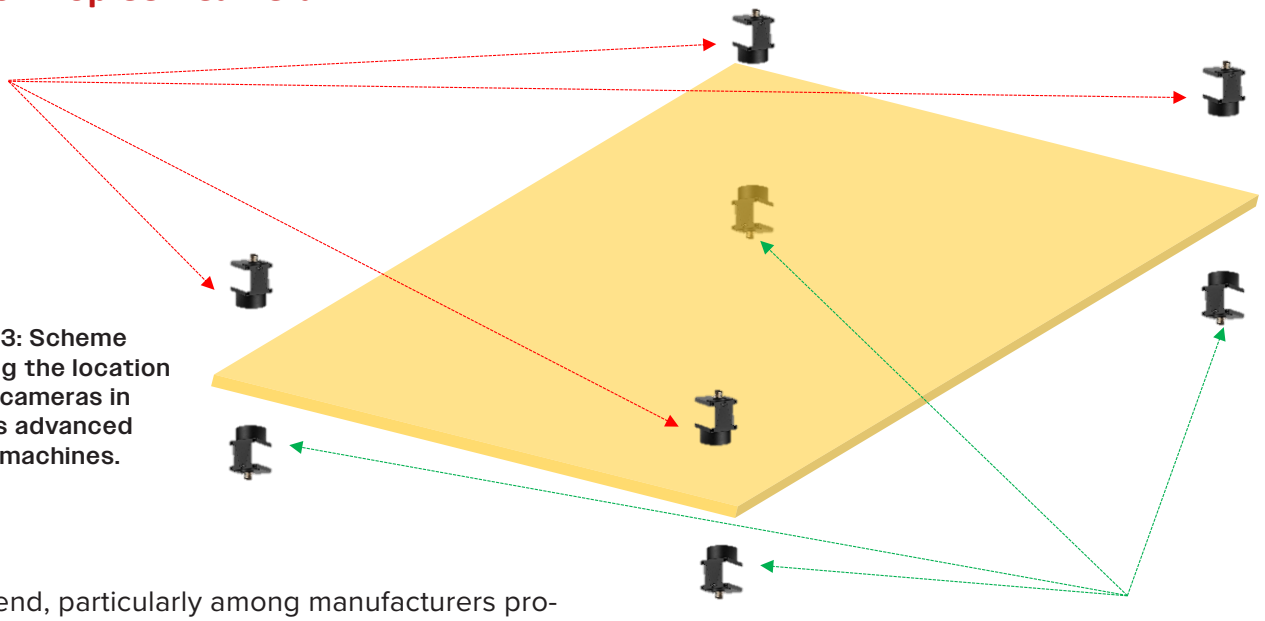
Mass-lam: Mass-lam methods aim to reduce or eliminate the need for pins during the final lamination by focusing on pre-fixing the inner layers before pressing.

Mass-lam with two machines: This technique, based on initial pin alignment, involves two distinct stages. After the first stage, where it's often a punch machine that prepares the inner layers with holes, operators place these layers, along with prepreg sheets, onto pins on a specialized "pre-fixing" machine. This machine then performs a preliminary bond or rivet to hold the stack together. Following this initial fixation, the operator removes the pins and transfers the pre-fixed stack to the lay-up zone of a pin-less press tool for final lamination.

Mass-lam with one machine (automated lay-up): The most automated variant of mass-lam involves machines that automatically load inner layers and prepreg, align them without physical pins, and perform pre-fixation via bonding or riveting. These systems typically do not measure individual layers before lay-up, but instead, align them relative to the position of the first layer loaded. While this method offers automation benefits, it relies heavily on the consistency of incoming material and stability of alignment to the first layer. Despite some automation, an operator is still required to feed the machine with raw layers and prepreg.

Improving Accuracy and Quality

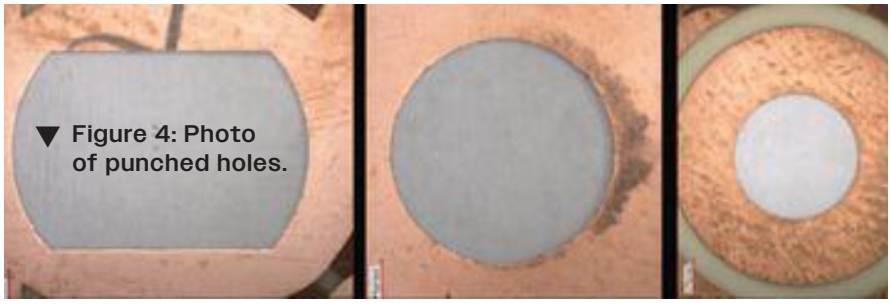
The introduction of mass-lam initially led many factories to consider it the future of inner layer alignment because of its automation potential, and several manufacturers adopted the technology. However, there is now a shift away from



▶ Figure 3: Scheme showing the location of the cameras in today's advanced punch machines.

this trend, particularly among manufacturers producing high-end, high-density, or large-format PCBs. These manufacturers are now investing in advanced post-etch punch technology as an inner layer alignment solution. This change is driven by the precision capabilities that modern post-etch punch machines offer:

- **Top and bottom cameras for alignment:** Modern post-etch punch machines feature high-precision cameras positioned on the top and bottom of the panel (Figure 3). These systems compensate for any potential misalignments between the top and bottom sides of an etched inner layer. By individually measuring and compensating for each side, these machines ensure optimal alignment and compensation of internal layer shifts.
- **Integrated measurement system as a critical control point:** The integrated measurement system within a modern post-etch punch machine transforms it into a vital control point for the entire PCB fabrication process. Beyond punching holes, the machine accurately measures the dimensions and fiducial locations of each inner layer before it proceeds to lamination. This provides invaluable feedback, allowing manufacturers to:
  - » **Validate each layer:** Identify and, if necessary, discard inner layers that are out of tolerance before consuming additional valuable resources in subsequent, more costly, production steps.
  - » **Process monitoring:** Collect data on layer distortion or etching consistency, which can be used to fine-tune upstream processes and improve overall yield, significantly reducing scrap and rework costs.
- **Perfect tools and special double tooling systems:** Achieving perfectly consistent holes on panels of varying thicknesses is paramount. High-end post-etch punch machines utilize robust, precision-engineered tools and often incorporate specialized double tooling systems. These systems ensure clean, consistent hole quality regardless of the material thickness (Figure 4).



▼ Figure 4: Photo of punched holes.

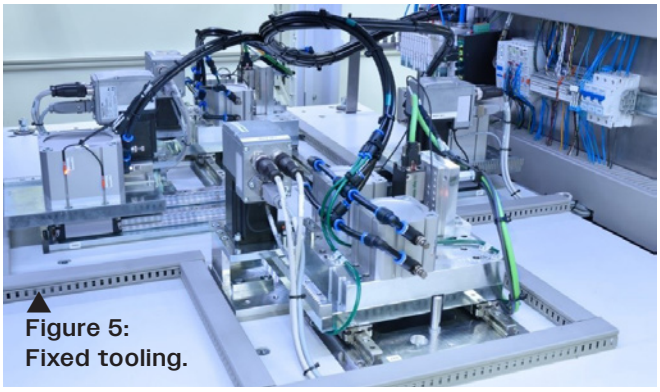


Figure 5: Fixed tooling.

- **Fixed position of punching tools:** The design of advanced post-etch punch machines features a fixed position for the punching tools. This mechanical rigidity and absence of moving tool parts contribute significantly to the exceptional positional accuracy of the punched holes and consequently the alignment of inner layers. By eliminating variables associated with tool movement or indexing, the system ensures highly repeatable and reliable hole placement, which is critical for precise layer-to-layer registration (Figure 5).

These sophisticated capabilities allow manufacturers to achieve outstanding results, even on complicated boards, such as those with high layer counts, fine-pitch features, or mixed material stackups. The ability to precisely control and compensate for minute shifts translates into superior final product quality, as evidenced by cross-sections demonstrating minimal shifts between copper layers (Figure 6).

Summary

The journey to multilayer PCBs begins with precise inner layer alignment. While each method—pin-lam, mass-lam with two machines, and mass-lam with one automated machine—remains viable, the optimal choice hinges on a careful evaluation of several critical factors:

- Accuracy requirements
- Capability to measure inner layers before lay-up
- Required productivity levels
- Pre- and post-processing needs
- Panel sizes
- Predictability
- Maintenance requirements
- Compatibility with different materials

Ultimately, the best inner layer alignment method is a strategic choice for each manufacturer, tailored to their production goals, technology roadmap, and board designs. This stage is a critical control point that directly affects overall factory efficiency, waste reduction, and final product quality. **PCB007**

Kurt Palmer is president of Schmoll America. To read past columns, click here.

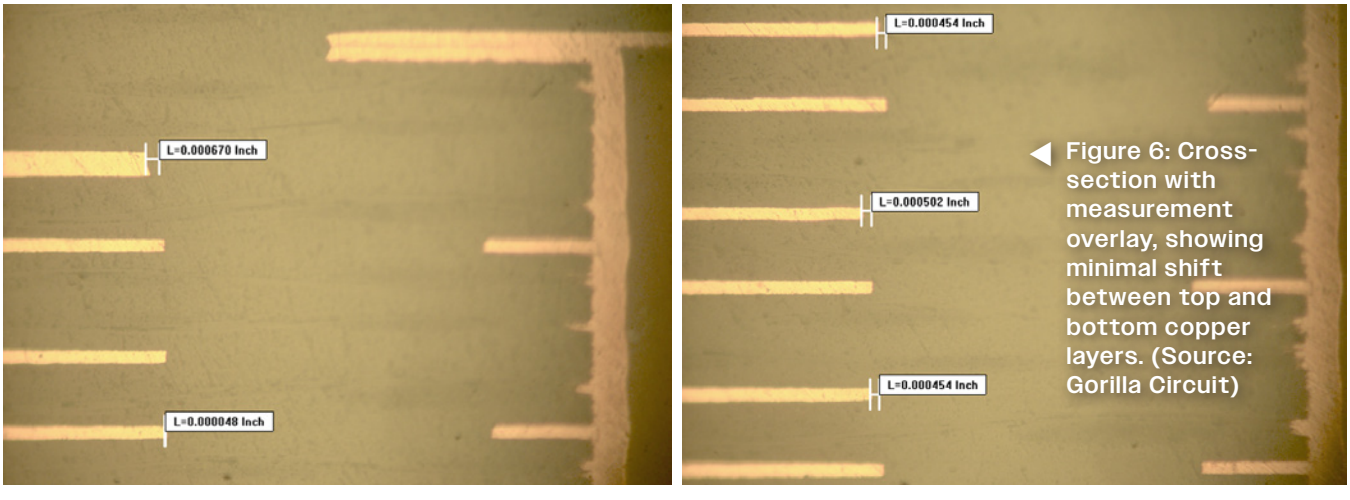


Figure 6: Cross-section with measurement overlay, showing minimal shift between top and bottom copper layers. (Source: Gorilla Circuit)

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EU Defence Electronics Ecosystem Highlighted in Brussels ▶

With the geopolitical landscape shifting, the need for Europe to strengthen its autonomous defence capabilities has never been more urgent. In this interview, Alison James, senior director of Global Electronics Association—Europe (formerly IPC), discusses the European Defence & Security Summit in Brussels, June 9–13, as well as the first IPC–ASD Europe Defense Electronics Summit, June 10, which brought together 70 leaders from across the electronics manufacturing supply chain.

The Knowledge Base: A Conference for Cleaning and Coating of Mission-critical Electronics ▶

In electronics manufacturing, there's a dangerous misconception that cleaning and coating are standalone options, that they operate in different lanes, and that one can compensate for the other. Let's clear that up now. Cleaning and conformal coating are not separate decisions. They are two chapters in the same story—the story of reliability.

Bell to Build X-Plane for Phase 2 of DARPA Speed and Runway Independent Technologies (SPRINT) X-Plane Program ▶

Bell Textron Inc., a Textron Inc. company, has been down-selected for Phase 2 of Defense Advanced Research Projects Agency (DARPA) Speed and Runway Independent Technologies (SPRINT) X-Plane program with the objective to complete design, construction, ground testing and certification of an X-plane demonstrator.

Moog Announces Acquisition of COTSWORKS ▶

Moog Inc., a worldwide designer, manufacturer and systems integrator of high-performance precision motion and fluid controls and control systems, announced the acquisition of COTSWORKS Inc., an aerospace and defense fiber optics transceiver component manufacturer, for a purchase price of $63 million. The transaction is subject to customary purchase price adjustments and was paid using a combination of cash and shares of the Company's Class A common stock.

OSI Systems Lands $17 Million Order for Cargo and Vehicle Inspection Systems ▶

OSI Systems, Inc. announced that its Security division received an order valued at approximately $17 million from an international customer for cargo and vehicle inspection systems. The order includes the Eagle® P60 high-energy, drive-through inspection system and the Eagle T60 high-energy trailer-mounted vehicle scanning solution. The Company will also provide installation, training, and multi-year maintenance and support services.

Northrop Grumman to Offer Advanced Ground-based Radars to Romania with ROMARM ▶

Northrop Grumman Corporation has signed a Memorandum of Understanding with ROMARM, a Romanian state-owned leader in defense, to collaborate in offering a ground-based radar solution to the Romanian Air Force. The radar will deliver advanced capabilities and performance against today's most sophisticated threats while also providing interoperability with command-and-control systems employed by NATO countries, including the United States.

RTX's Raytheon Awarded $74M U.S. Navy Contract for RAM Guided Missile Launching System ▶

Raytheon, an RTX business, was awarded a $74 million contract to produce RAM Guided Missile Launching Systems (GMLS) for the U.S. Navy. "This contract marks the largest single order of U.S. RAM launchers in over two decades and will ensure our naval assets remain well-protected against anti-ship threats," said Barbara Borgonovi, president of Naval Power at Raytheon. "Our continued investment in modernizing production capacity enables us to meet the growing global demand for the world's most modern short range ship self-defense weapon system."

DAN'S SALES GUIDE

Master your sales game in 2025 and beyond

DIVE IN!

Dan Beaulieu is president of D.B. Management Group, and an I-Connect007 columnist. Click here to visit his column page.

Mastering the Hunter-Farmer Sales Model

Would your sales manager know the answer if I handed a sales manager a list of their top 100 customers and asked, "Which salespeople acquired the accounts, and who kept them?"

Your sales team should have the right balance of who finds the business (your hunters) and who keeps it alive, growing, and thriving (your farmers). If you don't have both, you're leaving a lot of money—and market share—on the table. Unfortunately, too many sales teams are lop-sided, and if you're running the sales team, it's your job to fix that imbalance.

First, Understand the Difference

"Hunters" and "farmers" aren't titles, but rather instincts, personas, and ways of being. It's how a salesperson operates.

- Hunters are business developers with bold, aggressive, and curious personalities. They love the chase, and are at their best when walking into a room full of strangers or opening a cold lead list with a pen and a plan.
- Farmers are nurturers who love stability, routine, and predictability. They shine in account management, checking in regularly, solving problems, upselling without pressure, and keeping clients happy for the long haul.

You need both, and to know which is which.

Step One: Evaluate the Mix

Start by taking inventory of your team. You don't need a personality test—you need a behavior test. Look at what they do, not what they say.

- Who on the team brings in new business consistently?
- Who is best at growing existing accounts?
- Who avoids cold calling like it's radioactive?
- Who lights up when a lead needs to be chased down, but vanishes after the PO?
- Who gets invited to customer weddings, and who can barely remember the buyer's name?

Now, map it out by drawing a two-column chart with hunters on one side, and farmers on

the other. Put your team members where they "lean." Some folks are hybrids, and that's fine, but the "leaning" matters. Salespeople almost always gravitate toward one or the other as their comfort zone. It's your job to recognize that pattern and align it accordingly.

Step Two: Evaluate the Business

Now, when looking at your business, consider:

- How much of my revenue comes from new accounts vs. existing ones?
- Is my growth flat because no one is prospecting?
- Am I churning clients because they're not being taken care of?
- Do my hunters keep closing business that my team can't support?
- Are farmers spending all their time doing customer service instead of growing accounts?

This is where most companies get tripped up. They assume they're covered because they have "sales reps." But if all your reps are the same type—or doing the wrong role for their strengths—your growth will stall or slump.

Step Three: Plug the Gaps

Once you've mapped your team's mix and your business's needs, the answer usually becomes obvious. You'll see where the imbalance is. Let's walk through a few examples.

SCENARIO A: TOO MANY FARMERS, NOT ENOUGH HUNTERS

Your sales are stagnating. Although you have great relationships with current customers, not enough new accounts are coming in.

Diagnosis: You're over-farmed and under-hunted.

Fix: It's time to add or activate hunters. That might mean hiring a business development rep or repositioning someone with the right personality to focus 80% on new logos.

Real-world example: A few years ago, I worked with a PCB shop that had four account managers, all wonderful at retention but terrified of cold outreach. We added one rep whose only job was to book new meetings, and within six months, new business was up 35%.

SCENARIO B: TOO MANY HUNTERS, NOT ENOUGH FARMERS

You're landing new business left and right, but six months later, half of it's gone. Customer complaints are rising, and repeat orders are rare.

Diagnosis: You've built a revolving door. Hunters open it, but no one is holding it open and making sure customers stay.

Fix: Assign clear account managers, or create a handoff process where every new client is transitioned to a farmer. In some cases, this means hiring a dedicated client success manager.

Real-world example: A manufacturer I advised had two superstar hunters who closed $4 million in business in a year, but nearly half those accounts walked because no one followed up. We restructured the team to assign every new account a designated farmer within 48 hours of close. Retention skyrocketed.

SCENARIO C: YOU HAVE HYBRIDS, BUT NO DIRECTION

You've got a few reps who do a little of everything, but inconsistently. One month, they hunt, and the next month, they farm. There's no structure.

Diagnosis: Undefined roles means unpredictable results.

Fix: Clarify your expectations. Even if someone is wearing both hats, make sure they split their time. Monday–Wednesday: new business. Thursday–Friday: existing accounts, or assign by territory or account tier.

Real-world example: One sales rep I coached was constantly overwhelmed. After we split his week into two focused days on outreach and three on retention, his revenue doubled in 90 days. Clarity creates consistency.

Step Four: Compensation Matters

Compensation drives behavior. Once you've set the roles, reinforce them with your culture and your compensation plan. If you pay hunters and farmers the same way, they'll all drift toward what pays the easiest. That's usually farming. It feels safer.

- For hunters: Reward activity and early wins, such as meetings booked, demos held, first POs
- For farmers: Reward growth and longevity, such as upsells, retention, NPS scores
- Celebrate both roles equally: Sales managers love the thrill of the hunt. But if all your praise is for "big new wins," don't be surprised when no one wants to stay back and nurture.

Step Five: Revisit and Adapt

This isn't a one-and-done exercise. Sales evolve and markets shift, and so should your mix. Each quarter, ask your team:

- Are we growing the pipeline?
- Are we keeping what we land?
- Who needs support or realignment?
- Where are we (still) leaking revenue?

Most companies don't fail because of bad salespeople. They fail because of mismatched roles. You wouldn't send your best hunter to babysit a long-time account, and you wouldn't ask your warmest, most patient farmer to cold-call 50 leads a day. Yet I see it all the time. The best sales organizations are like well-run farms: They plant, tend, and harvest. So, don't just chase rain clouds. Fix your mix.

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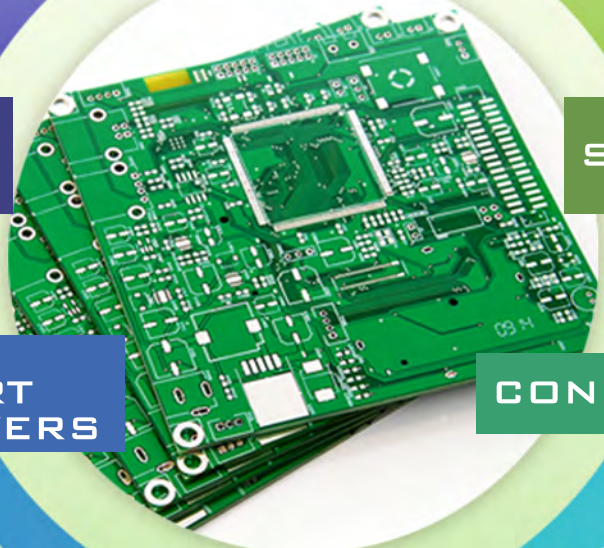

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What Sales Organization Is Right for Your Business?

There's no one-size-fits-all sales model, no silver bullet, no plug-and-play team that magically delivers results. But when business owners, presidents, and sales VPs stare at stagnant numbers or missed targets, they frequently ask me, "Dan, should we go with reps or a direct sales team?"

This is the wrong question. Instead, ask, "What structure gives us the best shot at profitable, predictable, scalable growth, for our business, in our market, and with our strengths?"

The Myth of 'Either-Or'

Sales structure isn't about preference; it's about performance, market fit, and execution. The best model for you is the one that consistently gets you in front of the right customers, at the right time, with the right solution. Instead of making it a philosophical debate, treat it like a strategic decision.

What Are You Selling—and to Whom?

If you're selling complex, high-ticket solutions with long sales cycles—products that require trust, education, and hand-holding—a direct sales force may make the most sense. Your product and sales cycle benefit from full-time folks who live and breathe your value proposition.

But if you're selling commodity, catalog, or spec-in items and need coverage across dozens of OEMs and contract manufacturers, outside sales reps are likely a better option, especially if they carry complementary lines, have deep contact lists, and are already walking the halls of your dream customers.

If you're in a niche industry—defense, aerospace, or semiconductors—where credibility, compliance, or existing contracts are critical, know who your buyer is and how they buy before deciding who should talk to them.

The Truth About Reps

Remember, manufacturer's reps are not mercenaries; they are entrepreneurs, business owners, and risk-takers. They are also not magicians, miracle workers, or babysitters for a broken product or a

half-baked marketing plan. Remember, they're certainly not your punching bag when sales are down and you haven't picked up the phone to check in or offer help in months.

Don't Outsource Accountability

Too many companies treat reps like vendors instead of partners and then wonder when they don't perform. They outsource accountability and call it "strategy."

It's not difficult to work with reps: Show up, train them, pay them fairly, and don't change the rules (or comp plans) midstream. Give them the tools to make your product easy to sell. Check in, ask questions, field challenges, and solve problems with them. Becoming a real partner with your rep will lead to positive sales results.

When Direct Makes Sense

If your product requires deep technical expertise that you just can't teach fast enough, your market is consolidated and strategic (with a few big accounts that need handholding and quarterly business reviews), or maybe the reps are tapped out with too many lines, you aren't likely to be a priority. That's when it's smart to bring in a full-time, dedicated sales team that is soley focused on your business.

Still, don't assume direct means "better." It may be a better organizational decision for your needs, but it is also typically more expensive than a rep model, requiring more infrastructure, overhead, and management. Getting clarity on the how, what, and why of it is essential for business success.

The Hybrid Approach

Most great companies do both. They think like a coach building a team: Who covers what, and why? Where do we need offense and coverage, who's our closer, and who sets the play?

They build a core direct team for strategic accounts, product launches, or new verticals, and partner with reps to cover the rest of the field. They use inside sales to support both. They segment accounts by value, complexity, and stage, not by dated territory maps. Your model must be flexible and forward looking.

Metrics Over Models

If you're still not sure which direction to go, start with the numbers by tracking:

- Revenue per rep vs. direct salesperson
- Cost of sale per model
- Customer acquisition time
- Close rates by sales channel
- Customer retention by sales model

Before you change your sales model, fix your measurement system. Let the data guide you. If you're not tracking this information, stop. Changing models without measuring outcomes is like switching seats on the Titanic: You're still sinking, but you're just doing it with a different view.

Common Mistakes That Kill Sales Models

If your sales model—rep, direct, or hybrid—isn't working, chances are you're making one of these mistakes:

1. **No clear expectations:** Reps and direct teams alike need scorecards, territories, goals, and KPIs. If you're not providing that with clarity, you're losing.
2. **Lack of training:** "Just go sell" is not a strategy. Whether they're W-2 or 1099, your salespeople need playbooks, messaging, and support.
3. **Territory cannibalization:** Nothing kills morale faster than fighting over who owns the deal. Define lines, respect them, and compensate fairly.
4. **Poor follow-up:** Whether it's a lead from a show or a rep's hot account, if you don't follow up with urgency, you deserve to lose.
5. **No accountability:** Everyone needs feedback, so check in with your reps and coach your direct teams. Set clear expectations and demonstrate consistent accountability across your team.

Conclusion

You can win with reps, a direct sales team, or both. However, you cannot win with confusion, complacency, or politics. Strategy trumps all. The best sales model is the one that brings in revenue predictably, profitably, and repeatedly.

How Top Salespeople Navigate Slow Times

Anyone can look like a hero when the economy's booming, the factory's full, and customers are flush. But what kind of salesperson are you (or your staff) when the phones go quiet, your inbox is full of nothing but spam, your top account hasn't placed an order in weeks, and everyone starts tightening their belts? That is when real salespeople stand up.

The amateurs and the unskilled blame the market. They sulk, slow down, and sit around, waiting for the storm to pass. They might even start polishing their resumés. But sales professionals lean in and work harder. They see a slow period as an opportunity.

1. Plan, Don't Panic

Great salespeople don't let emotions steer the wheel, or panic when the pipeline dries up for a month or two. Instead, they go into diagnostic mode.

- **They ask smart questions.** Is this a seasonal dip or something more? Which industries are being hit hard and which ones aren't? What have I done in the past during slow spells that worked?
- **They build a plan.** It's not a wish or a hope that things pick up, but a plan that is thought through and executable.

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- **They look at their numbers.** They audit their pipeline, review stalled quotes, and evaluate their territory. They go back through old notes, contacts, and RFQs. They check in with lost accounts and become intentional about everything.

2. Go Back to the Basics

When things are slow, you get the invaluable gift of time. Use that time to sharpen your tools by:

- Reviewing your messaging and value proposition
- Relearning the company's (new) capabilities or services
- Updating your CRM notes
- Writing follow-up emails that you didn't have time for before
- Reconnecting with dormant customers
- Cleaning up your prospect lists
- Digging into competitor updates and market trends

3. Dial Hard

In a booming market, you might get one meeting for every 10 emails or calls. In a slowdown, it might be one out of 30 or even 50. While the amateurs slow down their outreach when response rates drop, the pros ramp up. This isn't the time to go quiet, but to go louder. Be smart, helpful, and relevant—but louder.

The pros also check in with empathy. Instead of asking for business right away, ask how the customer is doing, what's changed, and what's shifted? Listening is a sales superpower.

4. Build Relationships Beyond Just Quotes

In slow periods, don't just give another sales pitch. People want a partner who understands what they're going through.

The pros use this time to:

- Offer value without expecting a sale
- Send industry insights, articles, or benchmarking reports
- Introduce useful connections or vendors
- Help the customer make smarter decisions, even if it doesn't lead to a PO right now

They know that sales are built on trust, and slow periods are a prime time to build that trust.

When business picks back up (and it always does), the customer remembers who cared, helped, and stuck around without pushing. That's the person they want to work with when the money's flowing again.

5. Get Creative

A great salesperson doesn't wait for the company to give them a promotion or for the marketing department to save the day. They develop new offers, bundles, or service packages that address their customers' new needs. They make their own luck.

They examine and explore:

- Can I offer a phased delivery plan?
- Could I position this as a cost-saver, not a CapEx expense?
- Can we help them consolidate vendors and save time?
- Do we offer something they don't even realize we can do?

Great salespeople know that recessions are a time when smart companies take market share; they don't lose it.

6. Don't Disappear

One of the worst things you can do during a slow period is disappear from your customers' radar. This is exactly the time they need to know you're still there. Even if they're not buying right now, they still have problems, need insight, and want to feel connected. Stay present by sending useful updates. Check in regularly with your customers and prospects, and share success stories. Invisibility is sales suicide.

7. Professional and Personal Development

Sales downtime is self-improvement time. Slow periods are training camps for future top performers. The best sales reps use this time to:

- Learn more about their industry
- Read the business book they've been meaning to read
- Watch webinars on objection-handling
- Practice presenting
- Study the competition
- Upgrade their soft skills

The one thing no market can take away from you is your skill set.

8. Lead from the Front

If you're a sales leader reading this, your team is watching how you behave when things get tight. Don't freeze up, complain about management, or hide in your home office. Instead of letting morale slip, roll up your sleeves and get to work.

The best sales leaders keep the energy high and stay optimistic. They get in the trenches, lead call blitzes, and coach one-on-one. They share stories of grit and hustle. Remind your team: We've been here before, and we'll get through it again.

9. Plant Seeds

A down market is like winter: Nothing seems to be growing, but the soil is resting and getting ready.

Smart salespeople plants seeds by:

- Building a pipeline for the next quarter
- Getting on RFP lists
- Positioning for long-term contracts
- Starting conversations that may take months to mature

Smart, skilled salespeople know that some of the best opportunities don't start with an immediate yes—they start with a consistent presence. When the thaw comes, they're the first to harvest.

Final Thought: Your Actions Define You

As historian and philosopher Will Durant said (summarizing Aristotle), "We are what we repeatedly do. Excellence, then, is not an act, but a habit."

Slow periods come for every industry, company, and salesperson. It's how you respond that defines your career. Anyone can ride the wave when it's high, but when the tide pulls back, only the strongest swimmers keep moving. So, the next time things get quiet, speed up. Pick up the phone, sharpen your pitch, help your customer, and learn something new. Make it a habit to keep showing up with excellence.

21 TIMELESS Sales Truths

Sales is about people buying from people. Tools evolve, but human connection remains key. If you're struggling to close or connect, don't overcomplicate. Go back to basics to move forward.

1. **People buy from people they like**
   Customers don't care how great your tech is—if they don't like you, they're not buying. Relationships still matter more than algorithms.

2. **No one wants to be sold; they want to be helped**
   Stop pitching and start solving. Listen more than you talk. Ask better questions and diagnose before prescribing. It's about their needs, not just what you do.

3. **The fortune is in the follow-up**
   Amateurs quit early. Pros follow up relentlessly with tact, respect, and persistence. Most sales happen sometime after the fifth touch, not the first.

4. **Know your customer better than they know themselves**
   Great salespeople do their homework. They know the customer's goals, pressures, competitors, and even pet peeves.

5. **Time kills all deals**
   If they're interested today, close the deal today, not next week. Urgency isn't pressure, it's momentum. The longer a deal sits, the colder it gets.

6. **People buy outcomes, not products**
   People don't buy drills; they buy holes. Stop selling features and start selling results. What does your solution change for them? What problem does it solve or prevent?

7. **You can't help everyone**
   Every "yes" to the wrong client is a "no" to a better one. Selling isn't begging, it's matchmaking. Walk away from the bad fits.

8. **Referrals: The easiest sale you'll make**
   Happy clients are your best sales force. Do great work, ask for their reference, and make it easy for them to spread the word.

9. **Price only matters when the value isn't clear**
   Don't race to the bottom! If they say you're too expensive, you didn't show enough value. Build the value first, then justify the price.

10. You're always selling, even when you're not
You're never off the clock or record—your actions, online and off, reflect your brand. From posts to how you treat people, it all matters.

11. The second sale is more important than the first
Anyone can close a one-time deal. Real pros get reorders. Repeat business is the truest measure of trust and success.

12. If you don't believe in it, neither will they
What sells? Conviction, enthusiasm, and belief. If you're not excited about what you offer, find something else to sell.

13. Sales is a transfer of confidence
It's your job to make the buyer feel 100% confident. That comes from clarity, consistency, and calm. How you show up matters, always.

14. The best salespeople are also the best listeners
Who's in control? The one asking the questions. Listening is your sharpest weapon, so use it.

15. The customer isn't always right, but they always matter
Yes, you'll deal with irrational requests, but don't be a jerk about it. Grace under pressure wins more than ego ever will.

16. Your CRM doesn't close deals, you do
Don't hide behind software. Use it to support your relationships, not replace them. A well-timed phone call beats a perfectly tagged contact record every time.

17. Rejection isn't personal—it's proof you're working
If you're not getting "no's," you're not doing enough. Rejection builds resilience. Embrace it, learn from it, and move on.

18. Activity drives results
You can't predict every sale, but you can control your calls, emails, visits, and outreach. Inputs matter. Sales is a numbers game (with heart).

19. You never know who's listening
Be kind to the intern. Be sharp on every call. Today's silence could be tomorrow's biggest client. Your reputation spreads faster than you think.

20. Every salesperson needs a system
Winging it isn't a strategy. Use scripts, checklists, and habits. Systems drive consistency—and consistency closes deals.

21. Be the one who calls back
Seriously, just call people back. Answer emails. Show up. That alone puts you ahead of most salespeople these days. Reliability beats charisma.

Companies With a CRM Are Serious About Sales

I've been in this business for over 40 years, and I've seen companies spend hundreds of thousands of dollars on equipment, expand factories, rebrand multiple times, and hire consultants until the parking lot is full. But when it comes time to invest in something that will actually grow revenue—like using a customer relationship management (CRM) system—they suddenly get frugal.

In today's competitive sales environment, if you still think a CRM system is a "nice-to-have" or just a fancy piece of software for big companies with beanbag chairs and kombucha taps, you're already behind. Companies with a real CRM system—from the No. 1-rated Salesforce down to Zoho—are serious about sales. (No, an Excel spreadsheet does not count.) A well-chosen and properly utilized CRM keeps customers returning, brings in new ones, and makes your salespeople accountable. That's real return on investment.

What is a CRM Anyway?

At its core, it's just a system—a tool—to help you track every interaction you've had, are having, or should be having with your customers and prospects.

It is a database, to-do list, and calendar. It's your follow-up conscience—your sales team's external brain. It's the one place where, if used properly, all the moving parts of your sales engine come together in sync.

In short, it's how grown-up companies manage relationships.

Now, if you're one of those guys still saying, "But Dan, my guys know all their accounts," let me ask you a question: What happens if one of your top salespeople leaves tomorrow? Do you have a record of every quote, email thread, or follow-up date? Do you have all current customers' and prospects' contact names, titles, and pricing

history? Or will you be trying to find the password to Steve's Excel file named "Customers and Prospects" that you hope he put in the cloud?

Why You Need a CRM

Here are some reasons to stop dragging your feet and implement a great CRM system now.

1. Accountability

A CRM shines a bright light on what's being done—and what's not. Who followed up? Who dropped the ball? What stage is that big quote in? It brings visibility, and puts performance in the spotlight where it belongs. Salespeople who are doing the work will love it. ...

2. Follow-up that doesn't fail

The biggest sales killer is a lack of follow-up. A sales manager should worry when they hear statements such as, "I meant to call them," "They said to reach out in April," and "I think they were interested." Sales is not a memory contest. Your CRM can do the work for you with reminders, alerts, timelines, and tasks, telling you exactly who to call, when, and why.

3. Pipeline management

Stop guessing and forecast better. A good CRM provides visibility into your entire sales pipeline: All stages of the quoting process, accounts won, where you need to follow up, and what's stuck. You can sort by rep, product, and region, giving you a whole list of variables to get the information you need, the way you need it. It removes your blindness and gives the gift of sight.

4. Improved collaboration

Sales isn't a solo sport. With a CRM, your team can share notes, tag teammates, assign follow-ups, and work together on accounts. If someone's out sick, the handoff is seamless. If a customer calls in, anyone can pull up the history. A CRM system elevates your service game 100% of the time.

5. Customer retention

The money is in repeat customers. The best companies open relationships, and a CRM helps you keep those relationships warm. A CRM keeps those relationships alive by providing reminders for service calls, thank-you notes, warranty check-ins, and reorders.

6. Data-driven decisions

W. Edwards Deming said, "In God we trust, all others bring data." With a CRM, you can pull reports on how long your sales cycle is, which reps are crushing it, what industries respond best, which sources bring the most leads, and where deals are dying. You stop guessing what's working, and start knowing.

7. Onboarding new reps

Hiring and onboarding new salespeople is much easier with a CRM. Because all accounts, contacts, and conversations are already in the system, a new salesperson doesn't have to start from zero. They can pick up where the last person left off and hit the ground running. That is solid gold, both for that new employee and their employer.

8. Marketing and sales alignment

A CRM helps the sales and marketing teams together by tracking which leads came from which campaigns. It lets marketing see what kind of leads turn into deals. It lets sales request specific content for specific customers.

9. "But my team won't use it."
A good CRM should be easy to use, mobile-friendly, and part of the daily workflow. If your team refuses to use the tool you've invested in to help them do their jobs better (and help the company gain more revenue), then you don't have a sales team, but rather a group of cowboys riding in different directions. It may be time to make some changes.

Of course, getting any team to use new tools requires leadership. You have to train and support them, and then hold them accountable. You can't simply throw software at them and hope it sticks. It takes some work, but the payoff is enormous.

Companies that think they're "too small" for a CRM are the ones who need it the most. When you're small, every relationship counts. You can't afford to let one opportunity slip through the cracks.

Choosing the Right CRM

There is no one-size-fits-all CRM. Some companies do well with simpler CRM tools like HubSpot or Zoho, while others need something more robust like Salesforce or Pipedrive. There are plenty of industry-specific CRMs to choose from.

Start simple. These are some things you'll need:

- Contact tracking
- Task reminders
- Sales pipeline management
- Email integration
- Reporting and dashboards
- User buy-in

Don't let the perfect CRM become the enemy of the good CRM. Pick something, start using it, and build from there.

CRM = Commitment

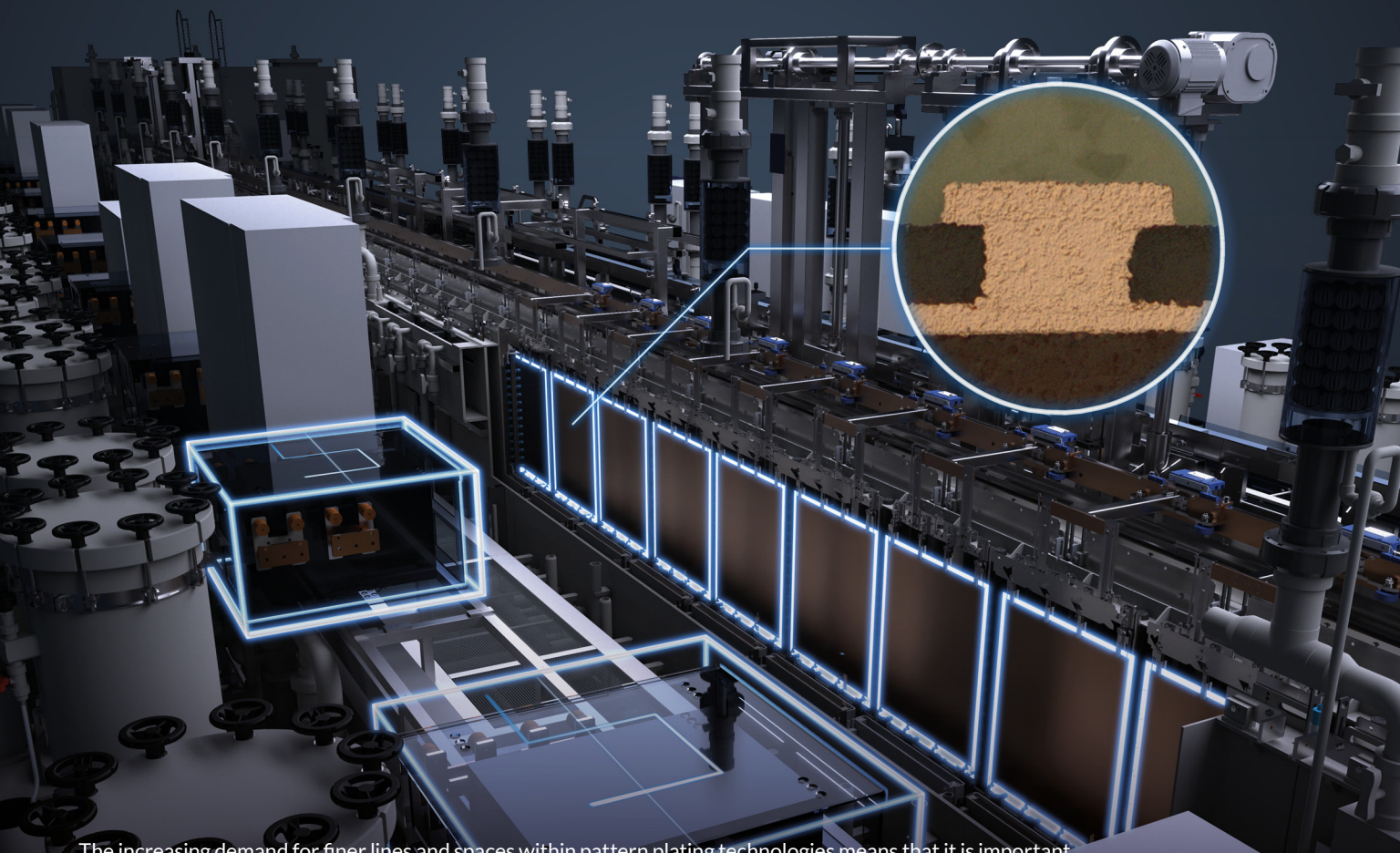
Sales is the lifeblood of your company, so managing your customer relationships with excellence isn't optional. It's your edge, strategy, and survival. In 2025 and beyond, companies that track, measure, and follow up will beat those that just "try harder."

The companies that win are the ones that remember every conversation, follow every lead, and never let an opportunity die quietly in an inbox. That's not software. That's people using the right software.

PCB007

mks
Atotech

vPlate® – Vertical systems solution for advanced HDI PCBs and IC substrates



The increasing demand for finer lines and spaces within pattern plating technologies means that it is important to greatly reduce the touching of the panel surface in order to avoid damages to the dry film. MKS' Atotech vPlate equipment is specifically designed for the touchless transportation of PCB panels for advanced manufacturing technologies such as SAP and (a)mSAP. It can be applied to various PCB types, ranging from standard multilayer and HDI to advanced HDI, rigid-flex, and IC substrates, with fine lines and spaces down to 8/8 µm.

The vertical continuous copper plating equipment is fully automated and compatible with our InPro® chemical process series for TH and BMV filling for advanced HDI, mSAP, and IC substrates, as well as our conformal plating processes such as InPro® VLF and InPro® Flex 2. For HAR and HHD applications we provide a combination of our Cuprapulse® IN process with vPlate's pulse plating capability. With vPlate, we provides a one-stop-shop solution for effective equipment, software and process solutions.

To find out more about vPlate, scan the QR Code to the right.

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by Dirk Ruess and Mustafa Oezkoek, MKS' Atotech

Advancing Electrolytic Copper Plating for AI-driven Package Substrates

Editor's note: The following technical paper, originally titled "Cutting-Edge Pulse Plating Solutions for Uniform Deposition of Copper with Enhanced Reliability in State-of-the-Art Server Technology," was first presented at IPC APEX EXPO 2025's Technical Conference, with original work published within the conference proceedings.

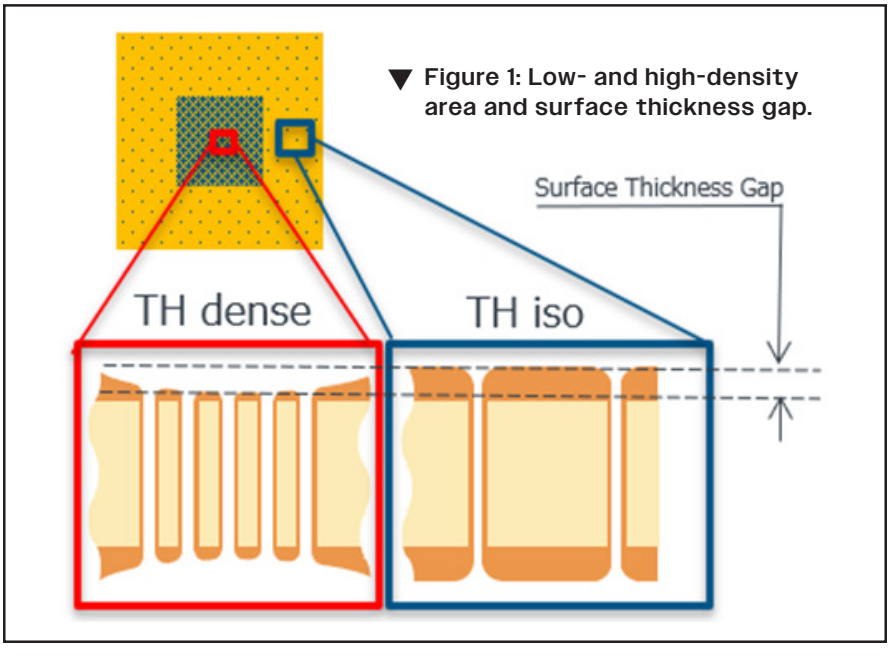
The rise of artificial intelligence (AI) applications has become a pivotal force driving growth in the server industry. Its challenging requirements for high-frequency and high-density computing are leading to an increasing demand for development of advanced manufacturing methods of package substrates with finer features, higher hole densities, and denser interconnects. These requirements are essential for modern multilayer board (MLB) designs, which play a critical role in AI hardware. However, these intricate designs introduce considerable manufacturing complexities.

The Critical Role of Electrolytic Copper Plating

Electrolytic copper plating is a key process in package substrate manufacturing, significantly impacting subsequent stages such as etching. A major challenge in electrolytic plating is ensuring uniform copper distribution across the entire panel, whether in areas with a high density of holes or more isolated sections. Such high hole-density regions are integral to modern multilayer board (MLB) designs, despite introducing several manufacturing complexities. Traditional plating methods often result in inconsistent copper thickness across regions with varying hole densities, leading to discrepancies known as the "surface thickness gap." This can lead to inconsistencies in etching and overall circuit performance. Moreover, achieving high throwing power is crucial to ensure sufficient copper is deposited within through-holes without excessive surface copper.

Breakthroughs With Pulse Plating Technology

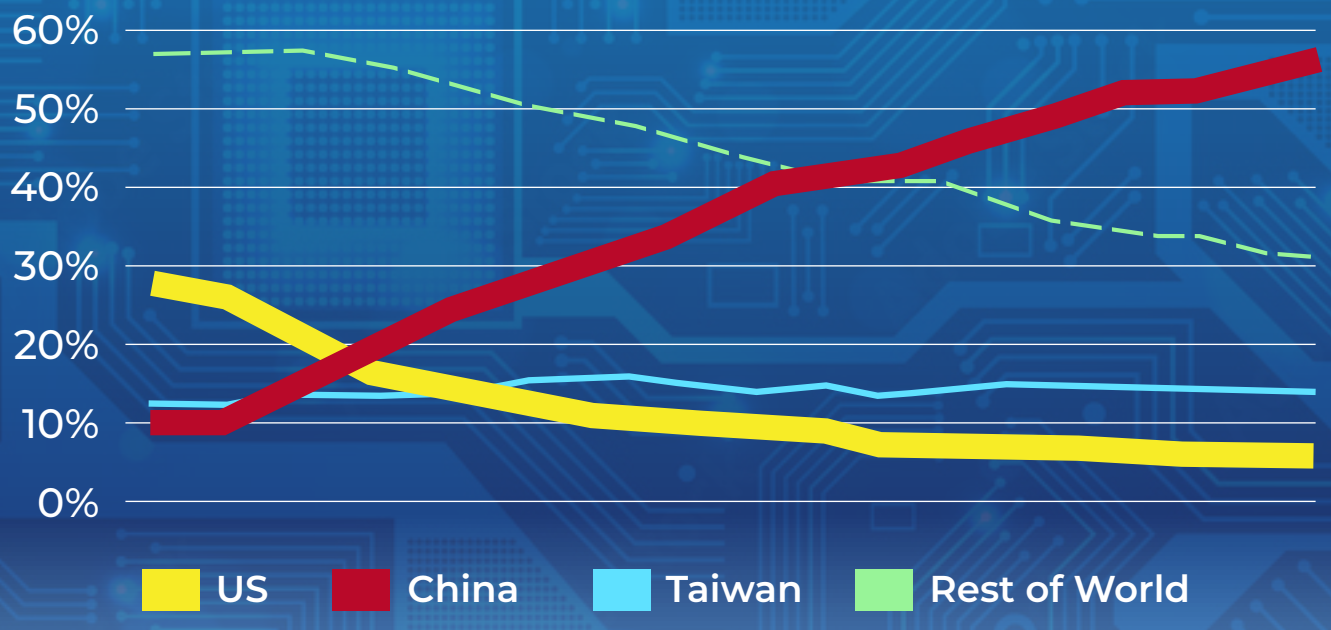
Recent innovations in pulse plating technology, particularly when integrated into vertical conveyorized plating systems, are transforming the way copper is deposited in high-density package substrates. Pulse plating enables more consistent copper distribution, significantly improving surface uniformity and throwing power—even in panels with a high concentration of through-holes. This technique is especially valuable in AI-focused applications, where hundreds of



▼ **Figure 1: Low- and high-density area and surface thickness gap.**

CONGRESS MUST ACT TO RESTORE AMERICAN LEADERSHIP

Global Production of PCBs



Over the past three decades American-made PCBs shrunk from 30 percent to 4 percent of the world's supply

Congress must act by:

- Passing the PCBS Act (H.R. 3249)
- Investing in American companies
- Providing tax incentives for OEMs to buy American
- Accelerating efforts to secure critical supply chains

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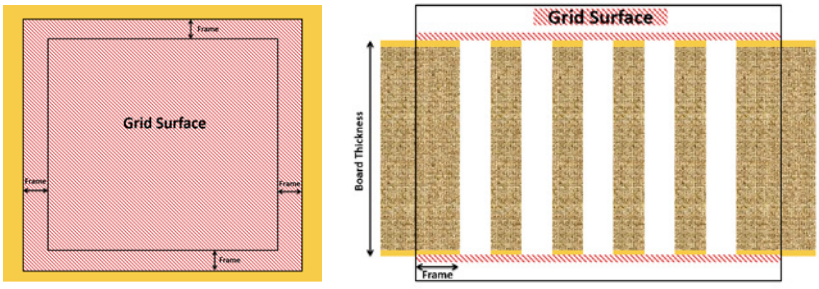
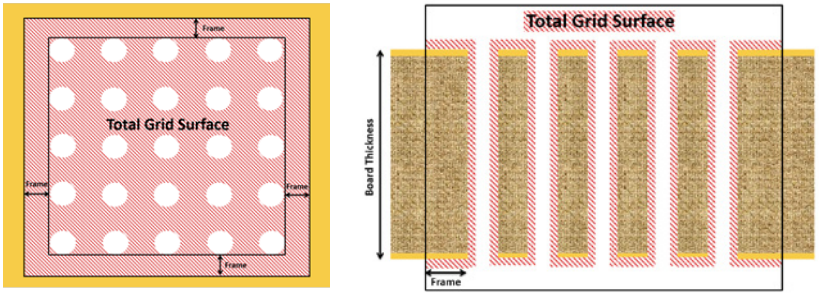


▲ Figure 2: Definition of grid surface at high hole density areas.



▲ Figure 3: Definition of total grid surface at high hole density areas.

thousands of through-holes are needed to meet the escalating I/O requirements of GPUs and other high-performance processors. Pulse plating ensures reliable performance across both densely clustered and isolated areas, reducing process variation and enhancing downstream reliability.

Meeting the Demands of AI Substrate Designs

Traditional package substrates feature fewer than 300,000 through-holes on a 510 mm × 515 mm panel. In contrast, substrates engineered for AI applications often exceed 350,000 through-holes—reflecting the need for far greater I/O interconnectivity. These complex panels include regions of both high and low hole density, posing serious challenges for uniform copper deposition. MKS' Atotech's recent evaluations of three such AI-specific panel designs demonstrate the superior performance of pulse plating in addressing these challenges. The tests highlight the technology's ability to ensure consistent copper thickness, reduce surface thickness gaps, and maintain high plating quality across complex geometries—fulfilling the stringent requirements of today's AI and HPC applications.

High Hole-density Surface Factor (HHD-SF): A Key Metric for Copper Plating Performance

One of the major advancements in the evaluation of copper plating technology is the introduction of the high hole-density surface factor (HHD-SF). This metric quantifies the complexity of plating designs with varying hole densities and the challenges they present for uniform copper deposition. A higher HHD-SF value indicates a more challenging plating process, with clustered through-holes and narrower pitch distances making it more difficult to achieve uniform copper distribution. Understanding and managing HHD-SF is critical for optimizing plating processes and ensuring consistent performance in advanced package substrates.

Optimized Plating Electrolyte and Equipment

Meeting the rigorous demands of AI-driven applications requires a holistic planning approach—one that tightly integrates specialized electrolytic chemistry with advanced equipment platforms.

Example for Calculating the High Hole-density Surface Factor (HHD-SF)

Grid	5 x 5 holes
Board thickness	1.5 mm
Hole diameter	0.2 mm
Hole pitch	0.4 mm
Wall to wall	0.2 mm
Frame	1.0 mm

Grid Surface	28.9 mm²
Total Grid Surface	50.9 mm²
HHD-SF	1.76

	Temp. °C	Time (mins)	Components
Acid Cleaner	< 35	3	Cleaner
Rinse	RT	2	3 stage water rinse
Etch Cleaner	25	1	Microetch
Rinse	RT	5	3 stage rinse
Acid Dip	RT	1	Sulphuric acid (10% by vol.)
Copper Plate	22	As required	Copper Process

▲ **Figure 4: Process flow of pulse copper plating electrolyte.**

In this study, the Cuprapulse® pulse plating electrolyte was specifically engineered to deliver exceptional performance on high-density IC substrates with strict uniformity requirements. Its formulation supports precise control over copper deposition, even in panels with complex geometries and variable hole densities.

Uniform copper thickness across the substrate surface is a critical parameter in advanced packaging, particularly for high-frequency and high-I/O-density circuits commonly found in AI and HPC hardware. Inconsistent plating can compromise signal integrity, reliability, and yield.

By combining this chemistry with vertical conveyorized pulse plating systems, this approach ensures:

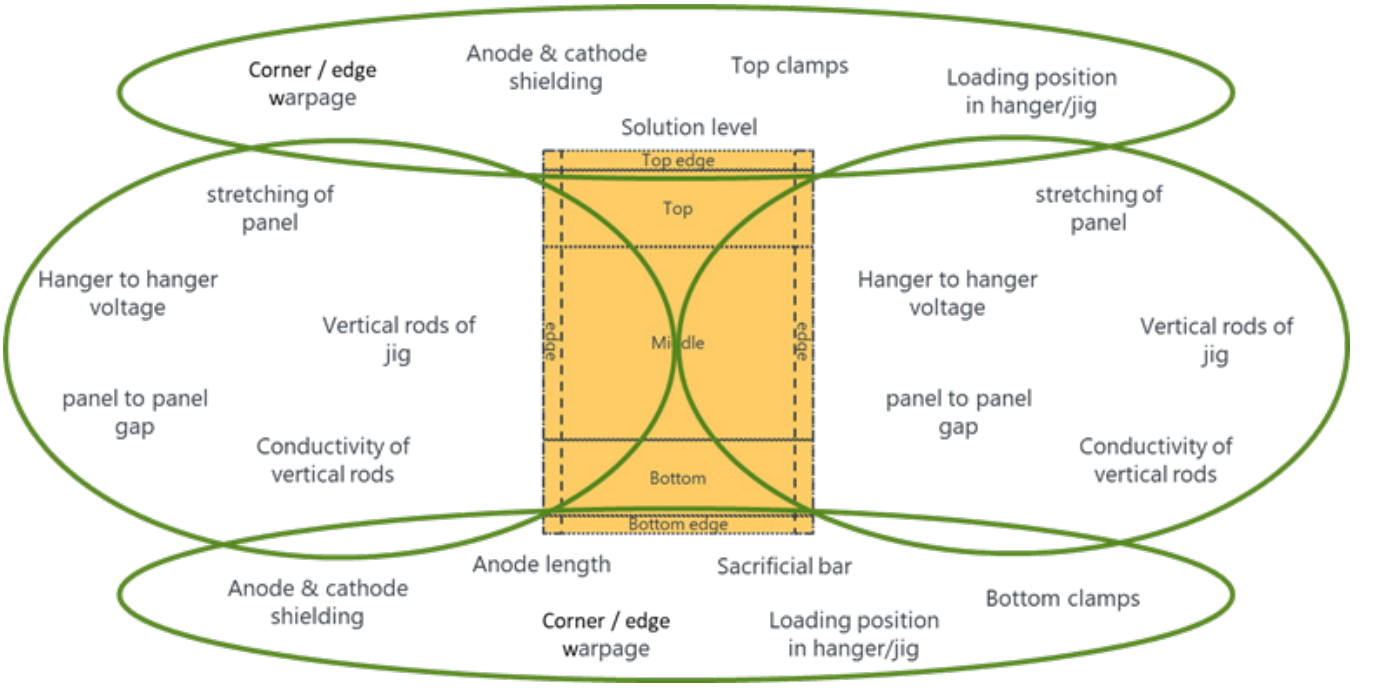
- Superior throwing power in dense and isolated through-hole areas
- Minimized surface thickness variation
- Enhanced overall circuit performance

This synergy between chemistry and equipment is essential to enabling next-generation AI substrates that meet the highest standards of electrical functionality and manufacturing precision.

Key Factors Influencing Uniformity

Achieving uniform copper deposition across package substrates is a critical performance requirement, especially in high-density applications such as AI and HPC hardware. While chemical formulation plays an important role, panel-level copper uniformity is primarily governed by the design and configuration of the plating equipment.

Modern vertical continuous plating (VCP) systems, such as those used in package substrate manufacturing, incorporate advanced features like customizable shielding, precision anode architecture, and automated loading systems to meet stringent quality standards.



▲ **Figure 5: Equipment factors influencing uniformity and affected panel areas.**

Optimizing Top and Bottom Uniformity

To maintain uniform plating, specific mechanical and process controls are essential:

- Top-side uniformity depends on maintaining consistent solution levels, properly adjusted shielding, and stable clamping, assuming correct operation of the automatic loading system
- Bottom-side uniformity requires an optimized anode configuration, with sacrificial burning bars providing additional control over deposition in lower panel regions
- Independently adjustable shielding at the anode and cathode enables fine-tuning across varying panel designs and dimensions, ensuring uniform coverage from top to bottom

Addressing Leading and Trailing Edge Issues

While global parameters like anode shielding and level settings help control top and bottom uniformity, they apply uniformly to all panels. In contrast, leading and trailing edge effects—where electrical current concentrates at panel edges—require individualized solutions.

As panels travel through the VCP system, current crowding at the front and back edges can cause over-plating. This effect is exacerbated when panel spacing or alignment is inconsistent, even in continuous production.

Importance of Jig Design

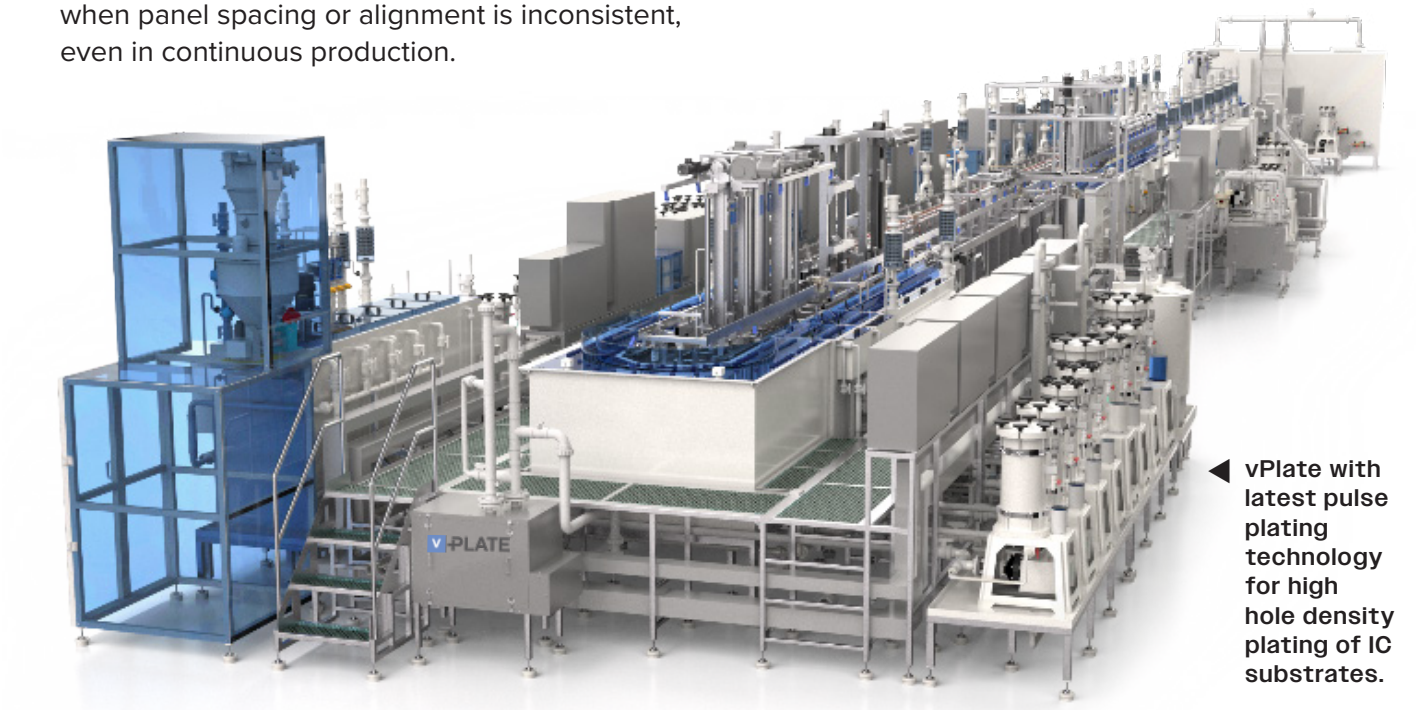
This challenge highlights the critical role of jig design between panels. Specially designed jigs collect excess current and prevent over-plating at the panel edges. They are tailored to the specific design of each panel, ensuring that the current is evenly distributed across the entire panel. However, traditional jig solutions come with economic and environmental drawbacks, such as increased current usage and the need to manage excess plating material after processing.

vPlate®: A Smarter VCP System

To address these limitations, the vPlate vertical continuous plating system integrates specially designed jigs and high-precision panel alignment within the copper plating module. This advanced system ensures:

- A consistent and adjustable inter-panel gap
- Enhanced edge uniformity without excessive plating
- Greater overall process efficiency with reduced material waste

By combining smart jig technology with refined equipment architecture, this plating system represents a next-generation approach to uniform copper deposition in complex package substrate manufacturing.



◀ vPlate with latest pulse plating technology for high hole density plating of IC substrates.

DESIGN TIPS #124:

ETCH COMPENSATION

What is minimum space and trace? The answer depends on the starting copper weight.

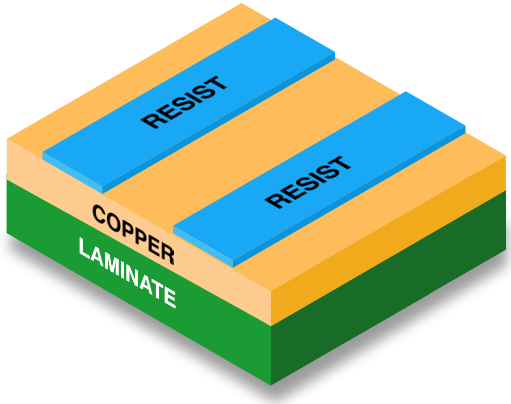
This is because we must do an etch comp on the traces in CAM to compensate for known etch loss. The space between traces after compensation will play a role in whether a board can be manufactured.

The lower the spacing width, the higher the cost. Designers don't always account for the proper starting copper weight after edge compensation.

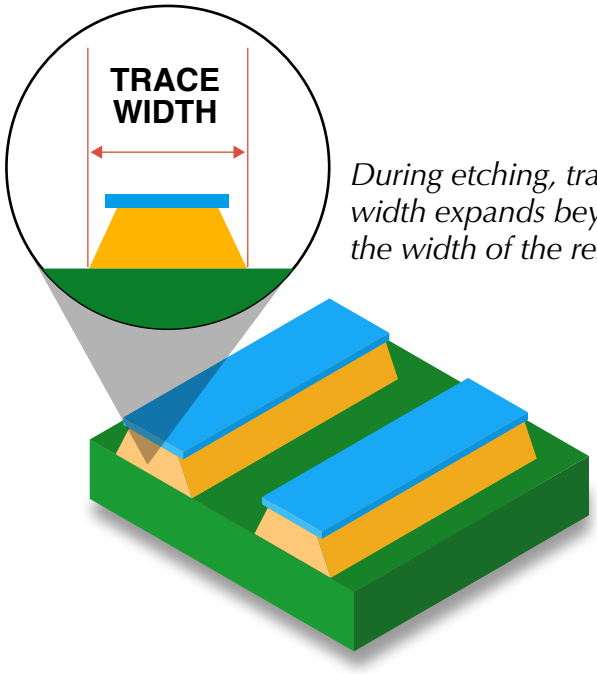
Design tips:

- For accurate starting copper weight, **add a half mil (.0005″) to all copper features**.
- **Start with 3/8 or 1/4 oz. foil**, reducing etch comp and less likely to cause a spacing issue.
- **Boards that call for full body electrolytic gold are not comped** to avoid gold slivers occurring during the etching process.

Before etching



After etching



During etching, trace width expands beyond the width of the resist.

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Innovative Jig Design and Implementation of a Jig Tester

Jigs play a crucial role in maintaining the precise distance between the cathode (substrate panel) and the anode during the copper plating process. This spacing is critical for preventing panel warpage, ensuring consistent copper thickness; furthermore,this plating system comes along with a jig tester for continuous monitoring of jig conditions, ensuring that clamp conductivity, force, and deformation are kept within optimal parameters, improving overall plating uniformity, improving yield, and alleviating the workload for operators.

Improving High Hole-density Capabilities

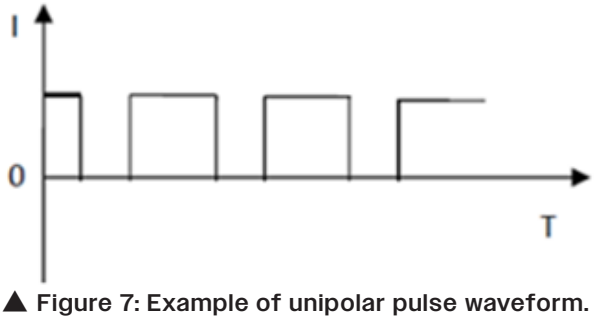
As PCB and package substrate technologies evolve, next-generation designs demand increased through-hole densities, which in turn require greater copper deposition within holes as compared to surface areas. Traditional fluid agitation systems are no longer sufficient. Sparger systems equipped with eductor nozzles are essential for effective wetting and chemical treatment processes; offset eductor nozzles on both sides facilitate optimal mass transport of copper into through-holes. Frequency-controlled pumps with high-flow capabilities offer flexibility for varying product specifications.

While direct current (DC) plating remains efficient and cost-effective for most applications, pulse plating is increasingly preferred for substrates featuring:

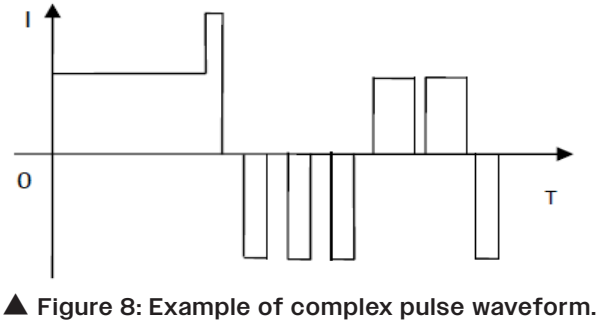
- High through-hole counts
- Tighter pitch spacing
- Greater aspect ratios

In this study, the plating line utilized rectifiers from multiple suppliers, supporting a range of configurations from cost-effective to high-end systems. These were paired with advanced process control software, enabling precise pulse waveform and profile customization based on specific board designs.

This level of control ensures that copper distribution remains uniform—even in the most demanding applications—thereby supporting the reliability and performance expectations of AI, HPC, and next-gen computing platforms.



▲ Figure 7: Example of unipolar pulse waveform.



▲ Figure 8: Example of complex pulse waveform.

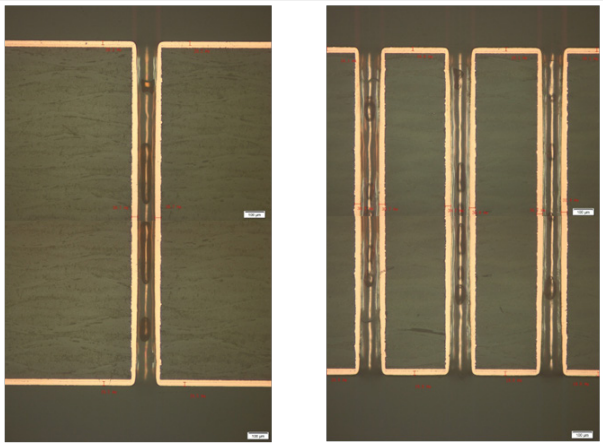
Automation and Integration of Industry 4.0

The equipment operates with an advanced automation platform developed through extensive expertise, integrating control software along with SCADA (supervisory control and data acquisition) capabilities while supporting concurrent batch processing and vertical integration protocols such as SECS/GEM and OPC-UA. The system software aligns with Industry 4.0 principles and is fully compatible with the Digital Factory Suite (DFS), which has been designed and developed by MKS' Atotech, for incorporating remote service capabilities alongside system integration features including Industrial Internet of Things (IIoT) functionalities and edge computing solutions. This promotes factory digitalization while optimizing production, process maintenance, control measures, and visualization.

The DFS includes key features such as:

- Remote equipment monitoring: A comprehensive dashboard provides a complete overview of all tools, enabling monitoring and decision-making without leaving the office or interrupting operations.
- Traceability: All data from various sources is combined into a single interface, offering detailed traceability down to each batch and individual PCB for efficient root cause analysis and actionable insights.

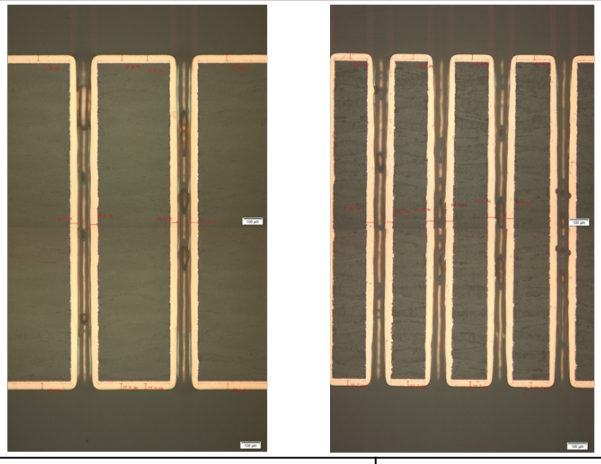
Board 1: HHD-SF >1.6 (over 350k holes/panel)



Surface thickness gap [µm]	0.99
Min. Cu in hole [µm]	30
Avg. Cu in hole [µm]	30
TP at HHD [%]	164
TP at isolated holes [%]	155

▲ **Figure 9: Plating result of board 1 with HHD-SF >1.6 and over 350,000 holes per panel.**

Board 2: HHD-SF >1.7 (over 850k holes/panel)



Surface thickness gap [µm]	3.73
Min. Cu in hole [µm]	39.7
Avg. Cu in hole [µm]	40.1
TP at HHD [%]	172
TP at isolated holes [%]	144

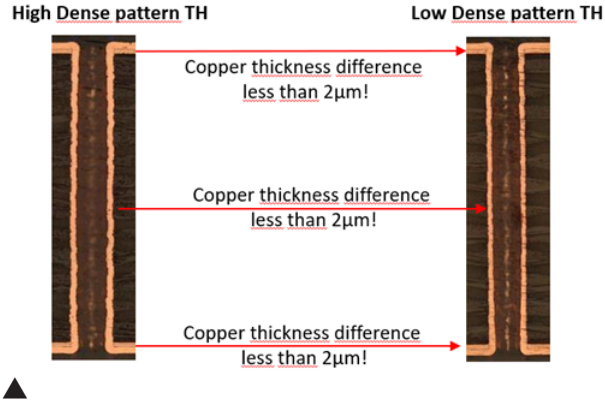
▲ **Figure 10: Plating result of board 2 with HHD-SF >1.7 and over 850,000 holes per panel.**

- Prompt alerting: Real-time, user-configurable notifications for relevant tool events are sent, ensuring the right users receive prompt alerts via PC or mobile devices tailored to their priorities, thereby enabling faster decision-making and issue resolution.
- Advanced troubleshooting: Scalable dashboards and alerts, combined with traceability, provide quick access to relevant data, helping teams diagnose and resolve problems more efficiently.
- Preventive maintenance: Real-time hardware health monitoring is assured to detect early wear and tear, schedule maintenance, and manage spare parts effectively.
- Control over chemistry consumption: Comprehensive information about the consumption of each chemistry is created without a need to generate and export reports at each single tool and compute consumption manually.
- Control over utilities consumption: Precise measurement, monitoring, and reporting on utility usage, giving customers full control over consumables and enabling precise cost planning.

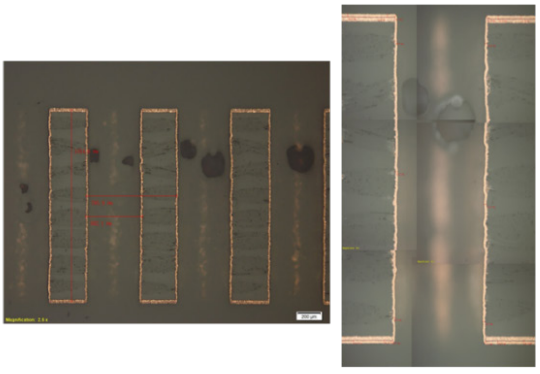
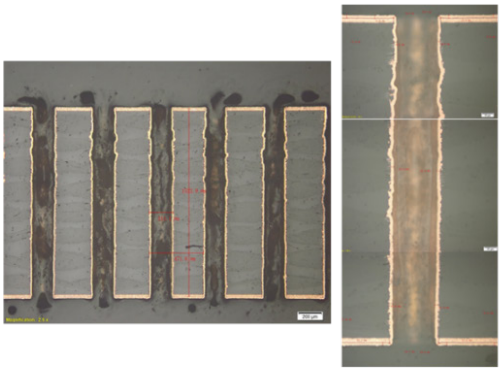
Results

In the evaluation of pulse plating technology, a design of experiments (DOE) approach was employed to optimize process parameters. The results demonstrated significant improvements in plating uniformity and throwing power. For a challenging board design with over 350,000 through-holes and an HHD-SF of 1.63, a surface thickness gap of just 0.99 µm was achieved, with throwing power reaching 164% in dense hole areas and 155% in the isolated hole area.

In another design with over 850,000 holes and an HHD-SF of 1.7, a surface thickness gap of 3.73 µm was achieved, with throwing power reaching 172% in high-density areas and 144% in the isolated hole area.



▲ **Figure 11: Comparison of copper distribution of high dense pattern (left) and low dense pattern (right) with just a surface Cu thickness gap of < 2 µm on a panel (510 mm × 515 mm).**

Board 3: mixed HHD-SF (over 23k holes/panel)		
▶ **Figure 12: Plating result of board 3 with mixed HHD-SF up to 2.6 and plain areas on board.**		
	HHD area 1	HHD area 2
HHD-Surface Factor	2.5	2.6
Panel thickness [mm]	1,6	1.6
Through hole diameter [mm]	0.5	0.2
Min. Cu in hole [µm]	10.6	10.6
TP at HHD [%]	100	95

The most challenging board design focused on enhancing throwing power into holes featuring various high-hole-density grids alongside differing hole diameters, resulting in HHD-SF values reaching up to 2.6.

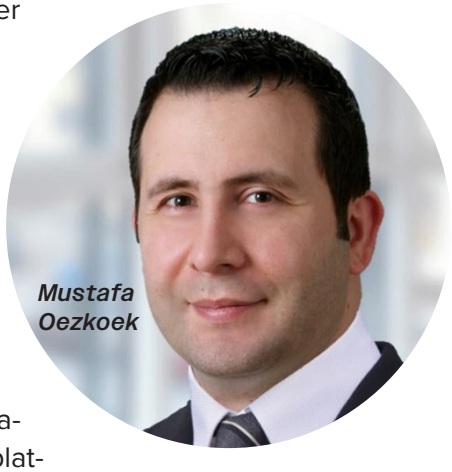
Conclusions

This study demonstrates that the combination of advanced equipment—such as MKS' Atotech vPlate system—and specialized electrolytic chemistries like Cuprapulse IN delivers superior performance in achieving the stringent requirements of high-density IC substrates. In contrast, conventional vertical plating systems using basic direct current (DC) processes and standard electrolytes consistently fall short in delivering the uniformity and reliability demanded by today's high-performance applications.

Dirk Ruess

A key contribution of this research is the introduction of the high-hole-density surface factor (HHD-SF), a novel metric that quantifies plating complexity based on hole density and design characteristics. HHD-SF offers a standardized framework for classifying the technical demands of PCBs and IC substrates, enabling more consistent evaluation and benchmarking of copper plating performance across manufacturing environments.

While the study is rooted in the needs of AI server applications, its implications extend far beyond. Industries such as telecommunications, data storage, automotive electronics, and advanced computing all increasingly rely on substrates with dense interconnect architectures and highly uniform copper deposition. These requirements are critical to ensuring signal integrity, thermal performance, and long-term reliability.



Mustafa Oezkoek

As the electronics industry pushes the limits of miniaturization and integration, innovations in plating chemistry, equipment, and process control—like those demonstrated in this study—are setting new standards for IC substrate manufacturing across a wide spectrum of high-tech sectors. **PCB007**

Dirk Ruess is global product manager—equipment, **Mustafa Oezkoek** is global product manager—panel and pattern plating at MKS' Atotech.

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Metallizing Flexible Circuit Materials: Mitigating Deposit Stress

by Michael Carano, Consultant, Global Electronics Association

Metallizing materials, such as polyimide used for flexible circuitry and high-reliability multilayer printed wiring boards, provides a significant challenge for process engineers. Conventional electroless copper systems often require pre-treatments with hazardous chemicals or have a small process window to achieve uniform coverage without blistering. It all boils down to enhancing the adhesion of the thin film of electroless copper to these smooth surfaces.

Internal stress in the copper deposit is a significant factor with respect to adhesion of the plated metal to the substrate. This process of plating on polyimide flexible materials is very much plating on plastics (POP). Electroless copper has been adapted for metallization of difficult-to-plate substrates and materials such as polyimide, POP, and molded interconnect devices (MID). As the technology advances toward higher frequencies and faster data transfer rates, highly engineered materials further complicate the plating process.

The Challenge of Metallizing Smooth Surfaces

One significant concern with metallizing thin films over substrates is the concept of deposit stress. Hydrogen gas is a by-product of the electroless copper deposition process. Consequently, hydro-

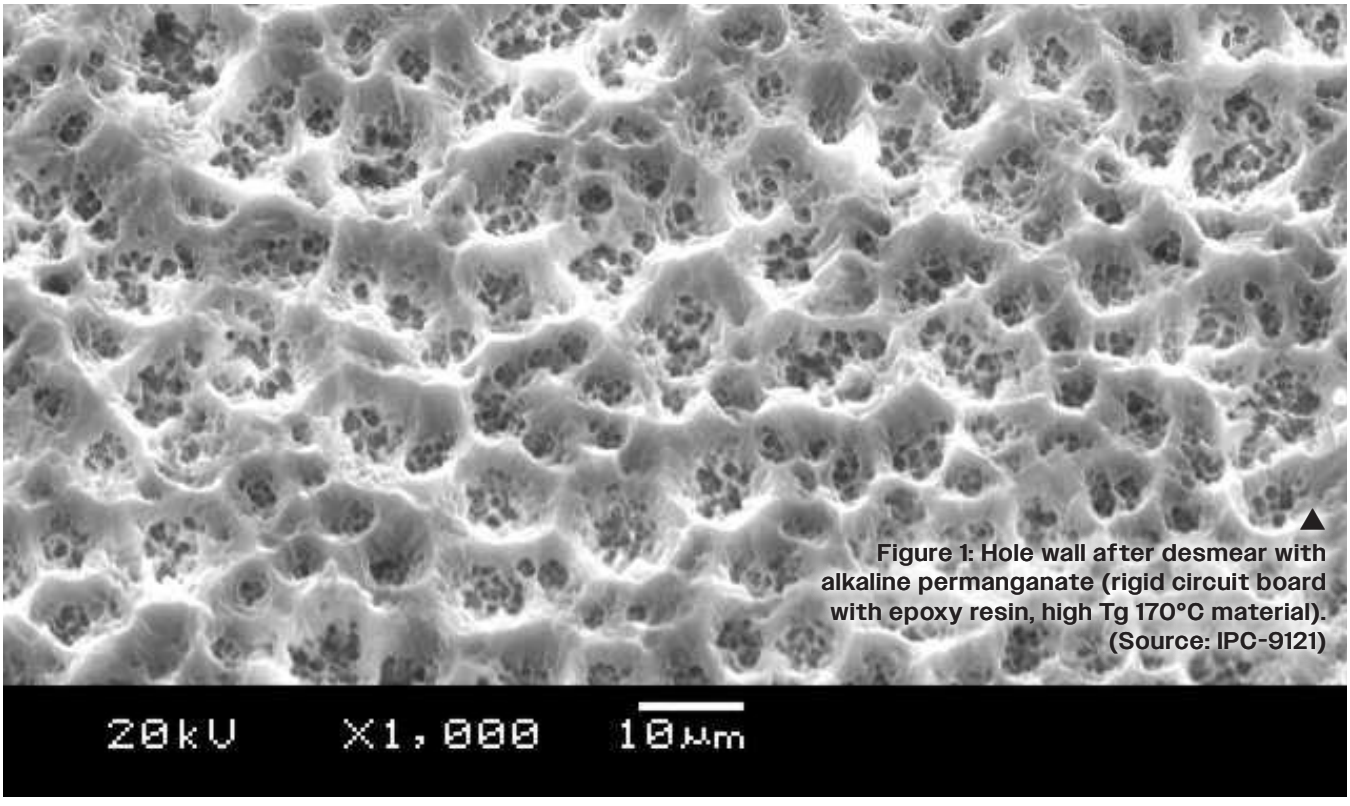

Figure 1: Hole wall after desmear with alkaline permanganate (rigid circuit board with epoxy resin, high Tg 170°C material). (Source: IPC-9121)

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gen may be incorporated into the thin deposit, which may have a negative influence on internal stress. The hydrogen gas issue has been attributed to blister formation in the copper deposit. A challenge typically encountered on smooth surfaces, such as polyimide-based flexible circuit materials, is ensuring good adhesion of the electroless copper to the substrate. Adhesion of a thin film deposit to a substrate that lacks sufficient microroughness is compromised. To mitigate this issue, one solution is to reduce the internal stress of the copper deposit as much as possible.

Now, one remedy to minimize hydrogen gas effects on the deposit is to lower the surface tension of the electroless copper electrolyte. By lowering surface tension through the use of specific wetting agents, the hydrogen gas bubbles are less likely to remain on the plated surface. The hydrogen gas issue notwithstanding, there is a concern with electroless copper deposit stress. Excessive deposit stress will cause the copper-plated deposit to blister or pull away from the substrate. This is, essentially, a stress relief phenomenon.

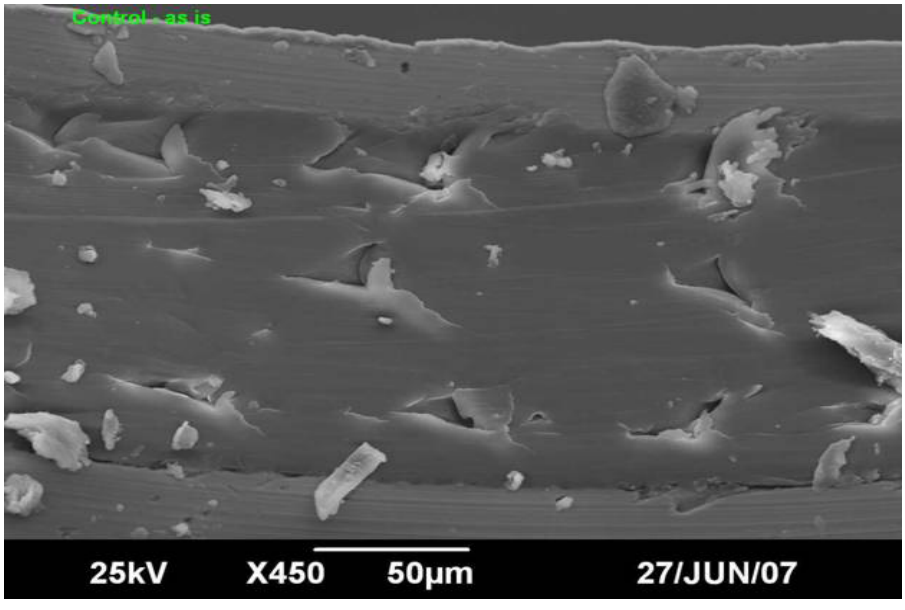
It is well known that polyimide materials for flexible circuit fabrication have a rather smooth texture even after plasma desmear. Unlike most epoxy-based resin systems, polyimide for flex does not have the micro-roughened surface texture generally experienced with alkaline permanganate chemical desmear. With these "anchoring sites (Figure 1), there is ample surface area for the thin film of electroless copper to adhere to epoxy-based resin systems.

Another limiting factor with respect to adhesion of copper to flexible polyimide is the low surface energy of polyimide films. Surfaces with low surface energy tend to repel chemical interactions, making it more difficult for process chemistry to effect good adhesion properties. In addition, flexible circuits are, by design, flexed and bent during their useful service life. Thus, creating excellent adhesion of the plated copper to the substrate is critical to the life function of the circuit. Certainly, plasma treatment of the polyimide material provides an improvement to the low surface energy of polyimide. However, such treatments often don't go far enough to ensure long-term adhesion by relieving internal stress.

The Influence of Stress

Stress in the electroless copper deposit can be either compressive or tensile. The copper deposit can be thought of as a spring that is either under tension (stretched) which is tensile stress or compressed which is compressive stress. Compressively stressed copper deposits lift or blister off smooth surfaces that lack anchoring sites such as adhesive-less polyimide flexible materials.

The spiral contractometer (Figure 3) utilizes a strip of metal wound into a coil or helix. The unit is attached to the plating cell and the metal is then deposited on one side of the coil only. Depending on the type and extent of the internal stress, the coil will either expand or contract. If the deposit is compressively stressed, the coil will tighten. If the stress is tensile, the coil will expand. The contractometer is equipped



◀ **Figure 2: Polyimide flexible circuit after plasma desmear (note the smooth topography). (Source: IPC9121, *Process Effects Handbook*)**

▲ Figure 3: Spiral contractometer for measuring internal stress in the plated deposit.

with a gauge to measure quantitatively whether the stress is compressive or tensile.

It is somewhat obvious that for a circuit experiencing the potential for many flexures throughout its life, excellent plating adhesion to the substrate is necessary. Low to no stress in the copper deposit is preferred. It is important to remember that adhesion of a thin film to a substrate is a complex mechanism. Internal deposit stress is just one factor. Additional factors affecting adhesion are:

- Ionic bonding between two surfaces
- Adsorption: Adhesion is based on interatomic and intermolecular interactions such as van der Waals and perhaps Lewis Acid interactions
- Mechanical interlocking

Mechanical interlocking depends on the contribution from a roughened surface. In the case of flexible polyimide, a roughened topography is not achievable.

With respect to flexible polyimide, optimum adhesion of the electroless copper deposit is heavily dependent on internal deposit stress and adsorption of the palladium catalyst to a plasma desmear treated surface. Please keep these factors in mind when troubleshooting an adhesion issue.

You might consider using a direct metallization process for flexible circuity and difficult to metallize substrate materials. **PCB007**

Michael Carano brings over 40 years of electronics industry experience with special expertise in manufacturing, performance chemicals, metals, semiconductors, medical devices, and advanced packaging. To read past columns, click here.

by Jim Watkowski, Harry Yang, and Mark Edwards
MacDermid Alpha Electronics Solutions

Figure 1: Electronics companies are increasing their sustainability efforts.

Direct Metallization: A Sustainable Shift in PCB Fabrication

The global electronics industry is undergoing a significant transformation, driven by the need for more resilient supply chains and environmentally sustainable manufacturing practices. Printed circuit boards, the backbone of interconnection for electronic devices, are at the center of this shift.

Traditionally, PCB fabrication has relied heavily on electroless copper, a process that, while effective, is resource-intensive and environmentally hazardous. In response, many manufacturers are turning to direct metallization technologies as a cleaner, more efficient alternative.

Supply Chain Pressures and the Need for Diversification

According to Evergreen Analytics, tech giants are actively transitioning their supply chains to new locations across Asia[1], adopting multi-country strategies to better balance cost, risk, and operational efficiency. Additionally, the Global Electronics Association[2] reports that 59% of companies plan to increase their sustainability efforts in 2025, with printed circuit board and contract manufacturers leading the charge[3].

These shifts, while strategically necessary, intro-

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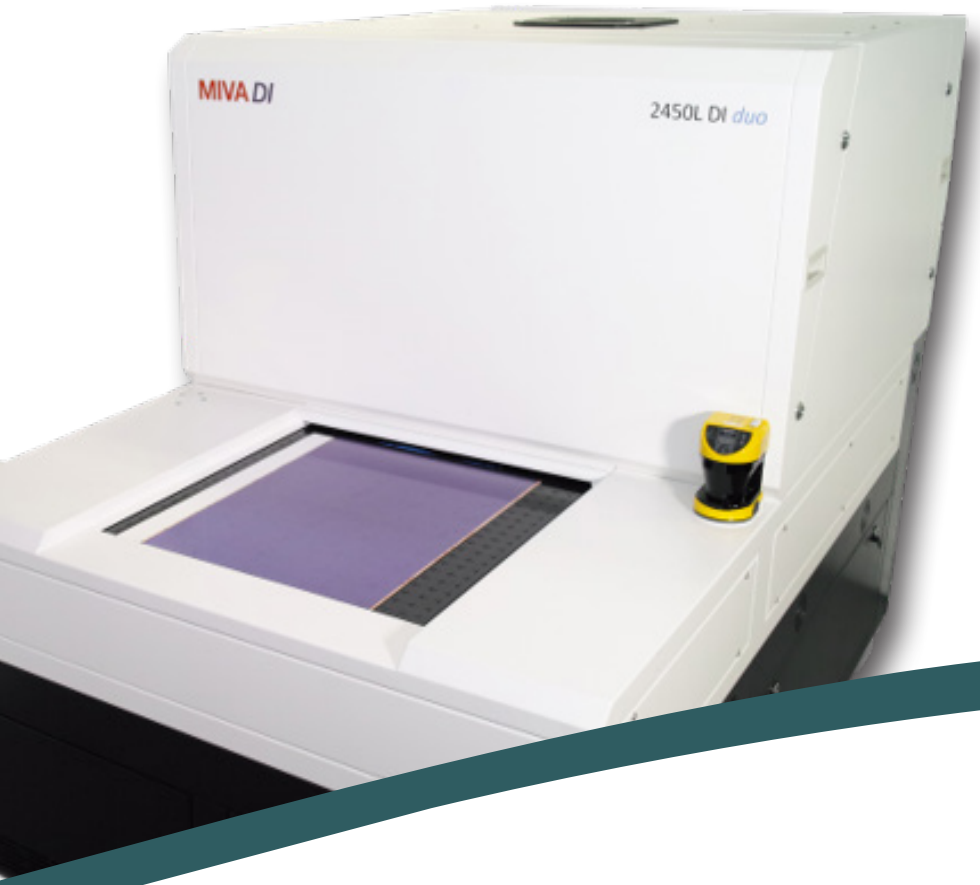

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Figure 2: Direct metallization eliminates formaldehyde, EDTA, and precious metals.

duce significant challenges, particularly in terms of cost, lead time, and accurately measuring environmental impact. One of the most pressing concerns for supply chain managers is how to relocate production without compromising efficiency or sustainability. For instance, the traditional electroless copper process, reliant on multiple chemical baths and high water and energy consumption, is increasingly at odds with the industry's push toward more sustainable and efficient manufacturing practices[4].

The Environmental Toll of Electroless Copper

Fabricators use electroless copper to create conductive pathways in PCBs by chemically depositing copper and palladium into drilled holes. This process forms vias, connections between different layers of a circuit board. However, it requires hazardous chemicals such as formaldehyde and EDTA and generates toxic waste that is difficult to treat. The environmental and health risks associated with these substances are prompting regulatory scrutiny and industry re-evaluation.

Despite its widespread use, electroless copper is energy-intensive and contributes to greenhouse gas emissions. It also poses occupational hazards and increases operational costs due to the need for extensive wastewater treatment and chemical handling.

Direct Metallization: A Greener Alternative

Direct metallization offers a compelling solution to these challenges. Unlike electroless copper, it eliminates the need for formaldehyde, EDTA, and precious metals like palladium. The process enables direct copper-to-copper bonding, reduces the number of manufacturing steps, and significantly lowers water and energy usage.

Companies that have implemented direct metallization report numerous benefits, including:

- Lower environmental impact
- Enhanced occupational safety
- Improved reliability and fewer defects
- Reduced chemical and maintenance costs
- Shorter cycle times and faster job turnaround

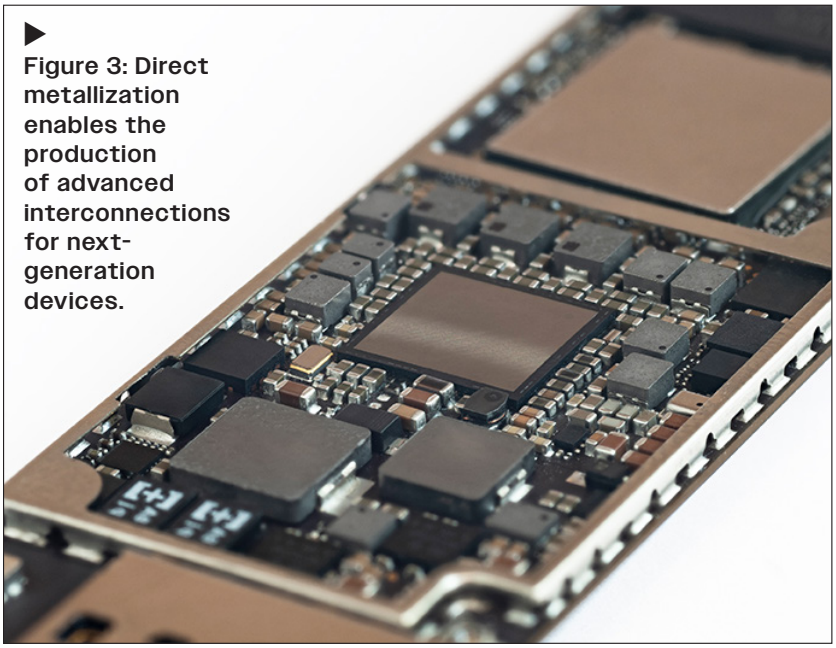

Figure 3: Direct metallization enables the production of advanced interconnections for next-generation devices.

These advantages attract companies aiming to establish new production facilities or upgrade existing ones in line with their sustainability goals.

Supporting Innovation and Profitability

The shift to direct metallization is not just about environmental responsibility; it also supports innovation and profitability. As the electronics industry evolves, there is growing demand for high density interconnect (HDI) PCBs, which require finer lines and tighter spacing. Direct metallization technologies are well-suited to meet these demands, enabling the production of advanced interconnections on circuit boards for next-generation devices.

MacDermid Alpha, a leader in this specialist area, has helped hundreds of companies adopt direct metallization. Our technologies support a wide range of PCB types and interconnect architectures, including flexible, rigid-flex, and hybrid constructions. By reducing production costs and improving quality, direct metallization helps manufacturers remain competitive in a rapidly changing market.

Environmental Stewardship and Industry Leadership

The environmental benefits of direct metallization are substantial. By eliminating hazardous chemicals and reducing resource consumption, the process aligns with global efforts to combat climate change and protect ecosystems. It also helps companies meet regulatory requirements and corporate sustainability objectives.

MacDermid Alpha's commitment to environmental stewardship[5] is reflected in its development of advanced chemistries and processes that support green manufacturing. Our portfolio includes carbon, graphite, and conductive polymer options tailored for HDI and mSAP (modified semi-additive process) technologies. These innovations enable higher interconnect densities, lower costs, and reduced environmental footprint.

Real-world Impact and Industry Validation

Real-world performance data validates the effectiveness of direct metallization, including stud-

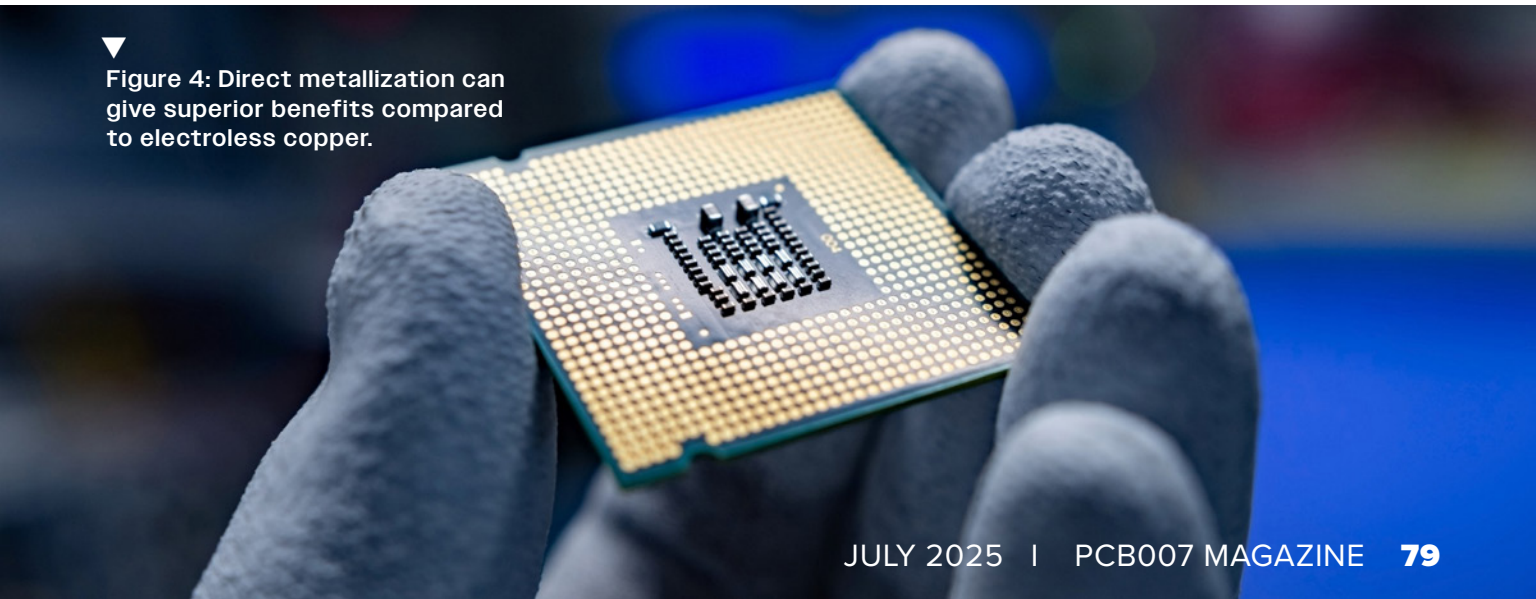

Figure 4: Direct metallization can give superior benefits compared to electroless copper.

▼ Figure 5: Global electronics needs to meet modern environmental standards while maintaining high yield production.

ies conducted under the U.S. Environmental Protection Agency's Design for the Environment Program. Manufacturers that implemented the technology report:

- Enhanced hole wall reliability
- Lower wastewater treatment expenses
- Automated features for greater efficiency
- Improved quality and reduced need for inspections

These outcomes demonstrate that direct metallization is not only a viable alternative to electroless copper but a superior one in many respects.

Navigating the Transition

Transitioning to an alternative technology may seem daunting, but the right expertise and support make it manageable. MacDermid Alpha offers over four decades of experience in direct metallization and provides comprehensive assistance to companies making the switch. Their solutions help companies transition to direct metallization while maximizing the benefits of greener, more efficient manufacturing.

Summary

The global electronics industry is undergoing a significant transformation, driven by the need to meet modern environmental standards while maintaining production efficiency. Traditional PCB fabrication methods, such as electroless copper, are increasingly out of step with these goals due to their high water and energy consumption and hazardous chemical use. In response, a shift toward direct metallization would enable a cleaner, more efficient alternative.

Direct metallization eliminates the need for harmful chemicals and significantly reduces resource consumption while maintaining or improving product quality and reliability.

MacDermid Alpha is at the forefront and leading with advanced direct metallization solutions, suitable for a wide range of PCB types, including high-density interconnect (HDI) and flexible circuits. Their technologies support the industry's shift toward miniaturization and higher performance while aligning with global sustainability initiatives.

As interconnect densities increase, manufacturers must adopt cleaner, more scalable metallization processes to meet performance and sustainability goals. As environmental regulations tighten and global supply chains evolve, the adoption of direct metallization technologies is not just a technical upgrade; it is a strategic imperative. This shift offers manufacturers a unique opportunity to align operational efficiency with environmental responsibility. By embracing cleaner, more sustainable processes, companies can future-proof their operations and position themselves as leaders in a rapidly transforming global market. **PCB007**

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Jim Watkowski is VP Circuitry Solutions, **Harry Yang** is VP Commercial Asia, and **Mark Edwards** is Strategy Account Director, Circuitry, all at MacDermid Alpha Electronics Solutions.

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Sustainability and Circularity for Electronics Manufacturing

by Happy Holden, I-Connect007

I attended INEMI's June 12 online seminar, "Sustainable Electronics Tech Topic Series: PCBs and Sustainability." Dr. Maarten Cauwe of imec spoke on "Life Cycle Inventory (LCI) Models for Assessing and Improving the Environmental Impact of PCB Assemblies," and Jack Herring of Jiva Materials Ltd. spoke on "Transforming Electronics with Recyclable PCB Technology." This column will review information and provide analysis from both presentations.

Life Cycle Inventory Models

Dr. Cauwe noted that over the past several years, there has been rapid growth in technologies designed to mitigate the effects of climate change. We have made great strides in broader sustainability targets, particularly in recycling, use of renewable chemicals, and overall process efficiency, resulting in energy savings.

PwC's recent report on sustainability[1] shows that companies find sustainability valuable to their businesses. Rising energy demands, evolving customer (OEM) expectations, and a perceived long-term competitive advantage are factors that keep companies focused on sustainability and circularity, including decarbonization, waste, and obsolescence.

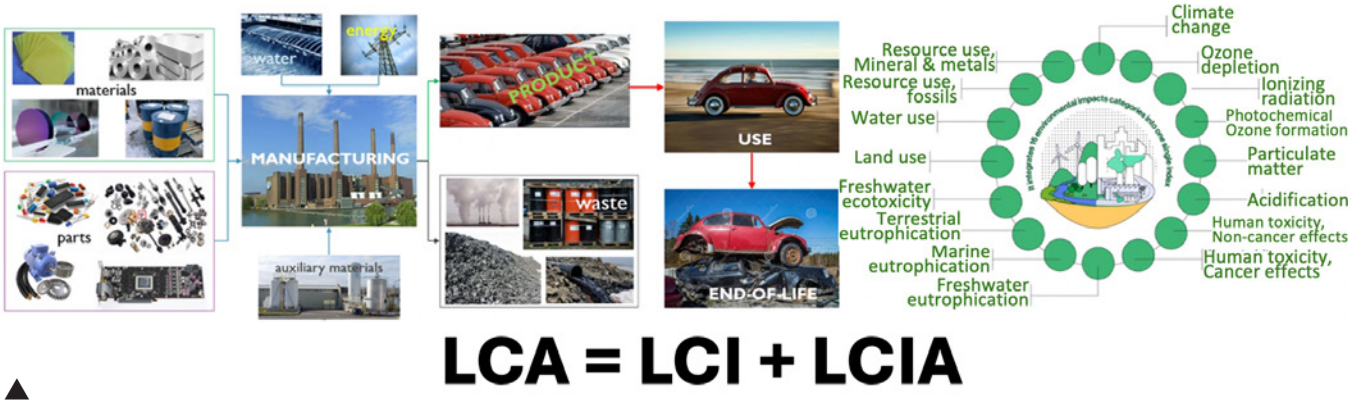
Life Cycle Assessment (LCA)

Europeans have always taken the lead on environmental concerns. The PEP ecopassport program for electronics manufacturing is a framework for creating and publishing environmental declarations (PEP) with a database that assesses the environmental impact contributed by electronic assemblies. It is based on LCA and contains detailed data on materials, energy, water usage, and waste generation for various components (Figure 1).

We perform this using the LCA, a combination of LCI and LCIA. LCI quantifies products' inputs and outputs, while LCIA assesses the environmental impacts.

Life Cycle Impact (LCI): Assembles data on all materials entering and leaving (a so-called materials balance) the fabrication or assembly process at an electronics product facility (ISO) to create a parametric LCIA model.

Life Cycle Impact Assessment (LCIA): Engineers design LCIA models for use in a range of manufacturing processes and product designs. Inputs include design data, energy, water, and waste for PCB manufacturing processes.



▲ **Figure 1: Life Cycle Assessment (LCA), composed of the Life Cycle Inventory and Life Cycle Impact Assessment. (Source: imec and iNEMI)**

The Sustainability Impact of Using Direct Metallization

Can PCB Fabrication Be Green?

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WATER
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DISCOVER THE TRANSFORMATIVE BENEFITS OF SWITCHING TO DIRECT METALLIZATION

Current processes within PCB fabrication can be energy intensive, use hazardous chemicals, and consume substantial amounts of water, but greener alternatives exist and are gaining traction in the PCB industry.

Direct Metallization

Adopt a Greener, More Efficient Primary Metallization Process

REDUCE RESOURCE CONSUMPTION

- Reduced temperatures, fewer steps, equals 50% less power and 75% less water use
- Stable chemistry with low chemical usage - over 90% reduction in chemical consumption

ELIMINATE HAZARDOUS SUBSTANCES

- Delivers high reliability without using any precious metals such as palladium
- Eliminates hazardous substances such as formaldehyde and EDTA

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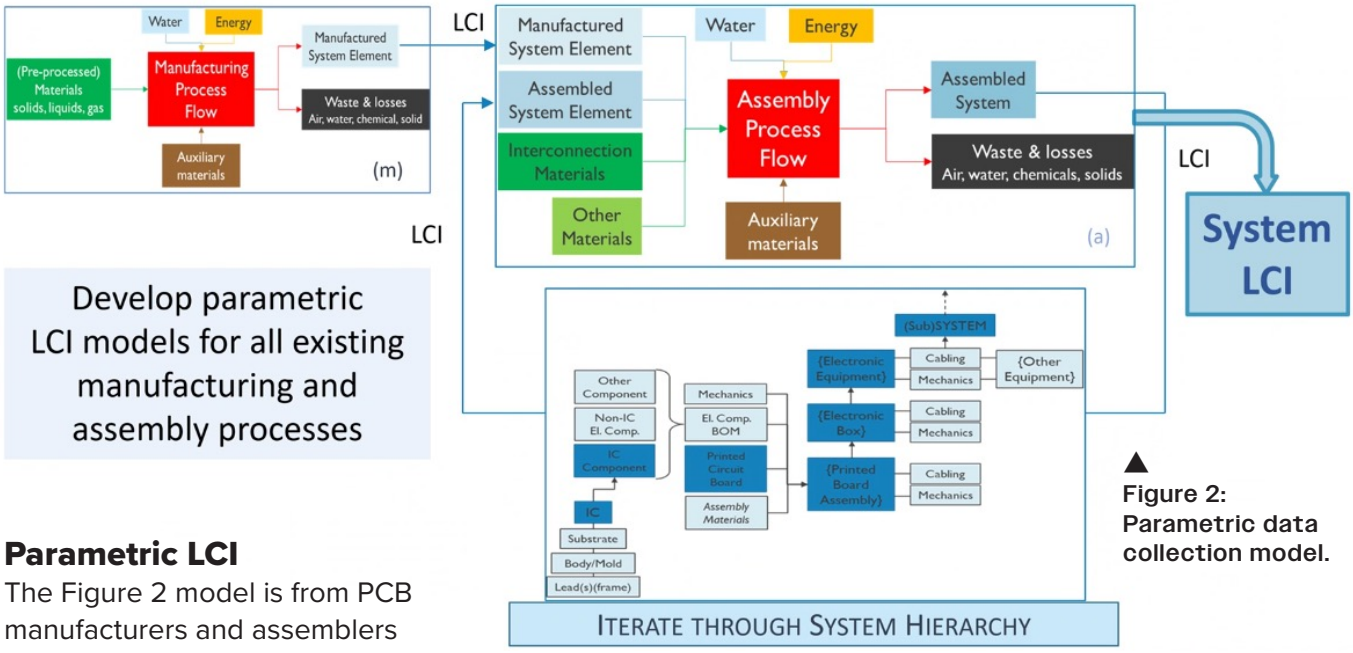


▲ **Figure 2: Parametric data collection model.**

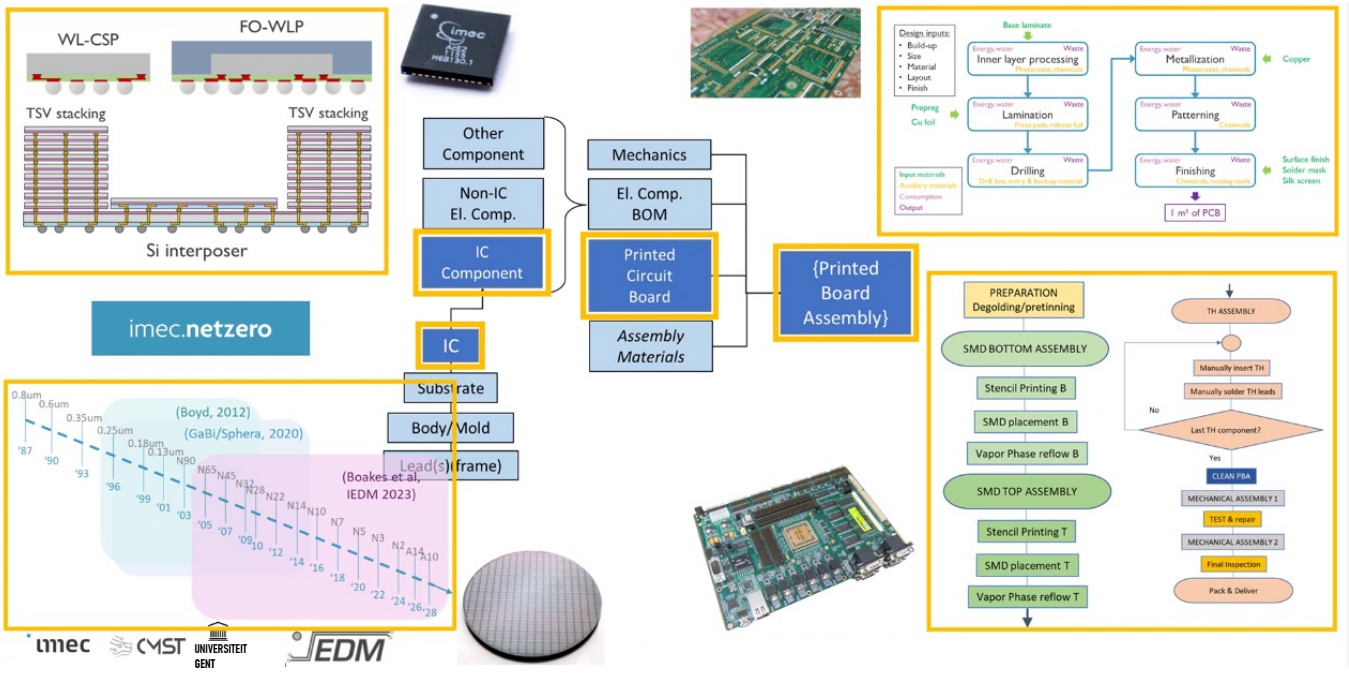
Parametric LCI

The Figure 2 model is from PCB manufacturers and assemblers and includes product volumes, line capacity, and generated waste. Unfortunately, the model assumes 100% production yields for simplification, which affects accuracy. The program also has no way of verifying the accuracy of the reported data. Static and aggregated datasets to create design-dependent production LCI models should require some ISO standard for validation.

The PCB Manufacturing LCI Model

The parametric PCB model in Figure 3 is designed to facilitate material sourcing, electronics manufacturing, product use, and end-of-life considerations in the design phase. This is an ambitious mission meant to help OEMs reach their environmental sustainability targets.

The detailed PCB LCI model is



▲ **Figure 3: The manufacturing model, including components, PCB, and assembly.**

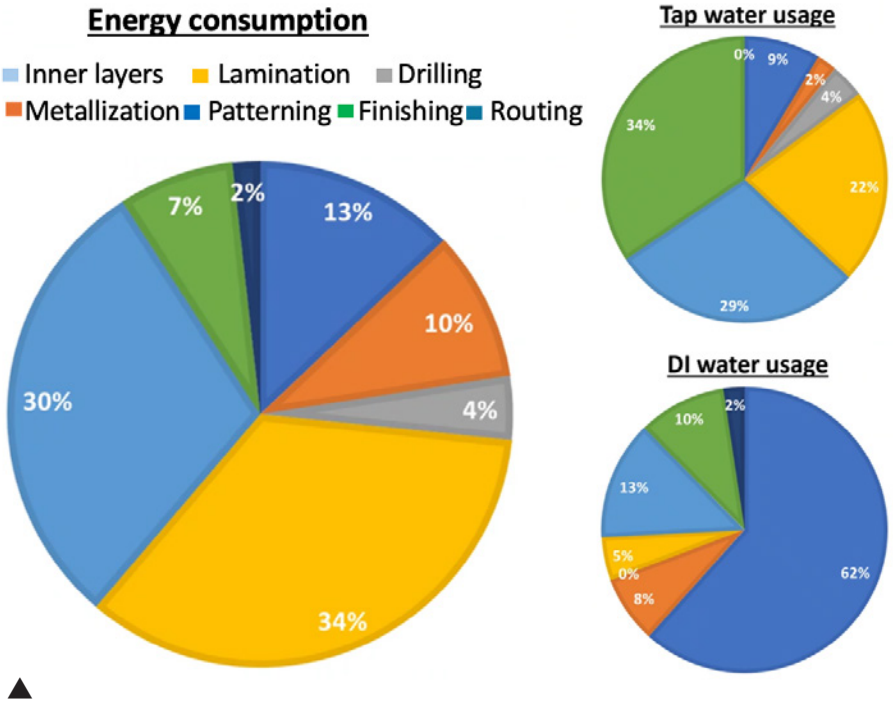


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Figure 4: The PCB manufacturing LCI model illustrates the environmental impact of energy, water usage, chemical consumption, and waste generated just for the substrate part of electronics manufacturing.[1]

based on a standard four-layer multilayer, with inputs and outputs normalized for 1 m2 of output. The panel occupation (number up on a panel represented as a percentage) is an important parameter in the model calculating energy, water, chemicals and generated waste.

Twelve-layer Board Example

A 12-layer FR-4 board was 156 mm x 140 mm and 1.8 mm thick, using ENIG with solder mask. Figure 4 shows the model results, summarizing energy, treated water, and DI water usage in graph form.

The high energy usage of 2.49 kWh/m^2 stems from using gold in ENIG because gold and other noble metals require high energy consumption in refining and processing. The lowest are immersion silver, tin, and OSP.

Summary

I have previously collaborated with Cauwe on UHDI reliability with the IPC UHDI Standards Committee (D33-AP). This is a new role for him at imec in Europe, but his prior work in the EU Space Agency on advanced UHDI is notable.

There was a clear model correlation with eco design specifications based on:

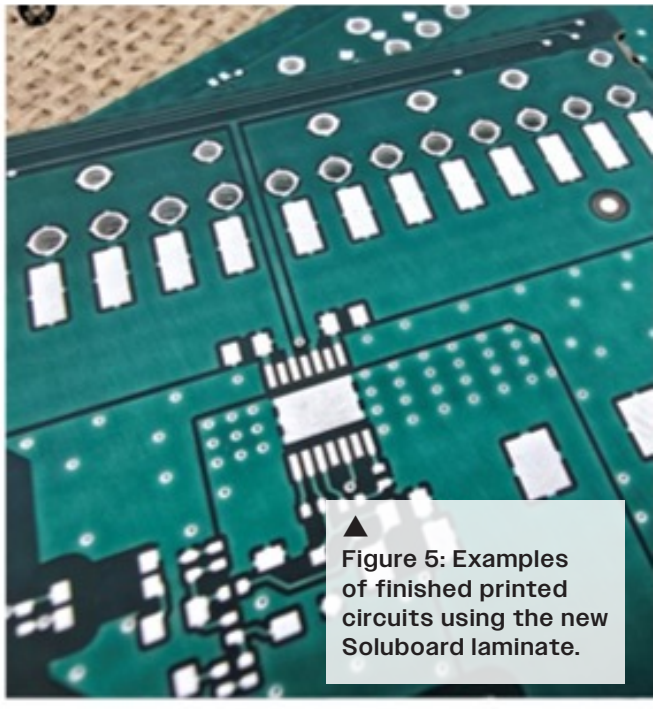
- Base material types
- Panel utilization (panel occupation)
- Total layer count
- Yields

Over the years, I developed my own PCB panel model in conjunction with the MCC program, which focuses on semiconductor technology, circuit schematics, and component packaging (I/Os and pitch) to provide costs, density requirements, design rules (layers), electrical performance and estimated first-pass-yields, but not eco elements. As this EU LCI model develops, I may add these to my modeling software.

What appears to be driving this work is:

- Eco-design: Regulation (EU) 2024/1781 of the European Parliament and of the Council, establishing a framework for the setting of eco-design requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repealing Directive 2009/125/EC (OJ L, 2024/1781, 28.6. 2024)
- Creation of the LCA database and manufacturing models to collect data from suppliers and fabricators
- Eco-reporting: To amend the corporate sustainability reporting Directive (EU) 2022/2464 of the European Parliament and of the Council (Dec. 14, 2022)
- Create eco-improvement targets for water, materials, energy, and waste

Let's hope these regulations are well-researched and well thought out (unlike the lead-free solder regulations). There is likely to be an impact on the U.S. as China seems involved and interested. My models indicate that HDI and UHDI technologies significantly impact boards in terms of materials, size, yields, and layer count reduction.



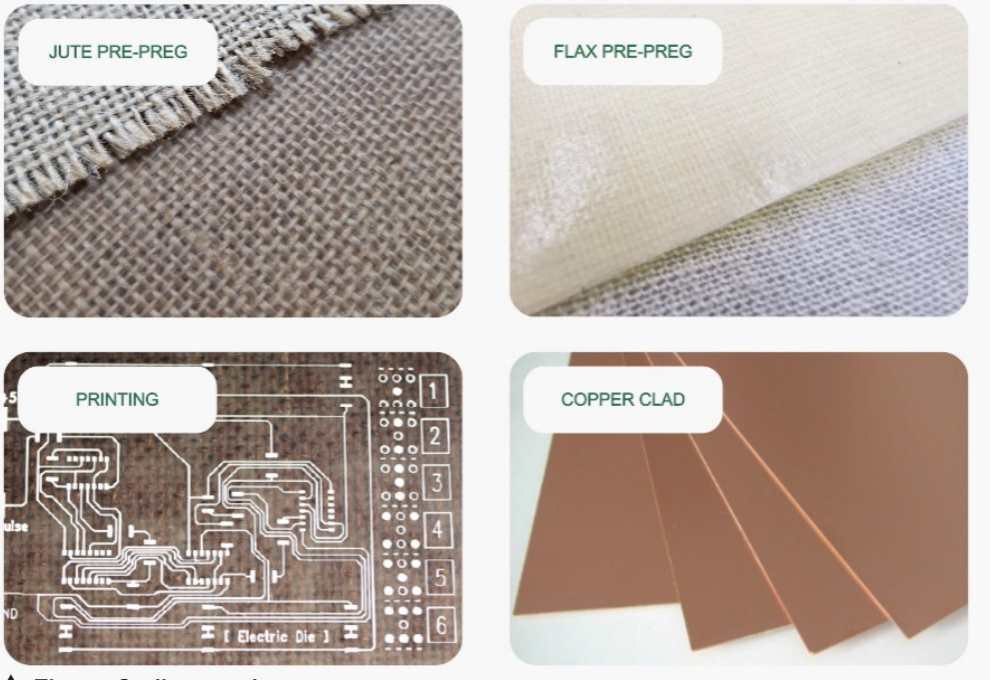
▲ Figure 5: Examples of finished printed circuits using the new Soluboard laminate.

Transforming Electronics with Recyclable PCB Technology

Jack Herring discussed his UK company's efforts to develop a biodegradable laminate suitable for electronics. This new copper-clad laminate is called Soluboard. While traditional FR-4 uses glass cloth and complex thermoset resins, Soluboard uses natural fibers coated with biodegradable materials, allowing the laminate to be broken down at end-of-life. This enables the recovery of metals that would otherwise be lost and offers a 68% lower carbon footprint compared to standard FR-4 (Figure 5).

There are several large corporations concerned with obsolescence and end-of-life. Experts estimate that by 2030, more than 6.5 million tons of waste PCBs will be produced and end up in landfills. The Soluboard represents a way to manufacture rigid PCBs with a laminate that can be a drop-in replacement for double-sided FR-4 in standard PCB fabrication, which can then be recycled at end-of-life with a certified non-hazardous hot water-based process.

Jiva has been working on a suitable FR-4 replacement since its founding in 2017 (Figure 6).



▲ Figure 6: Jiva products.

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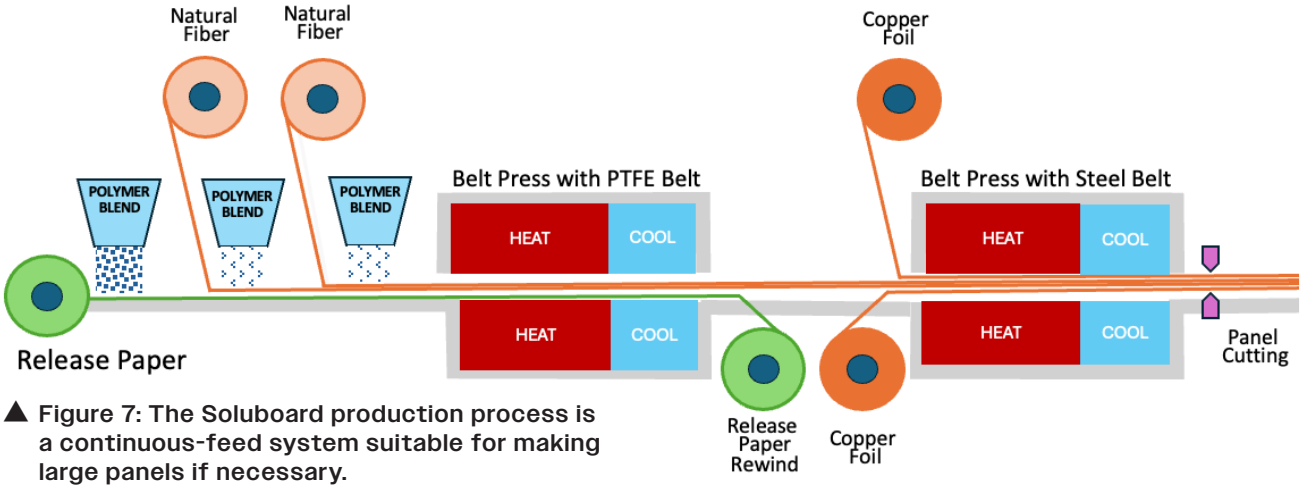

▲ Figure 7: The Soluboard production process is a continuous-feed system suitable for making large panels if necessary.

Products now include:

- Jute prepreg
- Flax prepreg
- Additive manufacturing of printed electronics substrates
- The new rigid copper-clad FR-4 replacement

Manufacturing Process

The production process is continuous, allowing for a lower carbon footprint. We have not seen this used for rigid laminates since the discontinuation of Glasteel Industrial Laminates (GIL-1000) in 2003 (Figure 7).

The current Soluboard product for a 1.6 mm laminate has a 68.38% lower CO2 footprint than standard FR-4, derived from lowering the kg/m2 generated in manufacturing materials-processing and transportation. If assembly switches to low-temperature solder (LTS) to reduce the reflow oven energy (by 40%), then a savings of 11.7 kWh is achievable annually, as well as a CO2 drop in emissions of 1.11 tons per week per oven or 57.2 tons per year.

The biodegradable composite materials include hydrophobically modified polyvinyl alcohol (PVA) with a halogen-free flame retardant (organic phosphonate).

Soluboard ® Technical Datasheet		Value	Unit	Method
General	Laminate Thickness	0.4-3.2 (+/- 15%)	mm	--
	Copper Thickness	9 - 140	Microns	--
Mechanical	Tensile Strength	40.65	MPa	ASTM D638
	Flexural Strength	84.22	MPa	ASTM D790
	Peel Strength	0.85	N/mm	IPC-TM-650 5.2.1
Thermal	Decomposition Temperature (Td)	285	^{O}C	IPC 2.4.24.6
	Glass Transition Temperature (Tg)	85	^{O}C	IPC 2.4.25
	CTE (Ambient to Tg)	37	ppm/^{O}C	IPC 2.4.24
	Thermal Conductivity	0.24	W/mk	ISO 8894-1:2010
	Flammability (UL File #E539951)	V1	--	UL 94
Electrical	Dielectric Constant (10 MHz)	3.5 – 4.1	--	ASTM D159-18
	Dissipation Factor $ (50 MHz)	0.094	--	ASTM D159-18
	Surface Resistivity	8.07 x 10^{6}	M-ohm	ASTM D257
	Volume Resistivity	5.55 x 10^{7}	M-ohm-cm	ASTM D257

Jute, flax, or hemp fabrics are impregnated with a PVA-FR mixture using a belt press. The entire procedure takes about five minutes, including heating and cooling the composites.

Development

In developing these products over time, Jiva has worked with 50 OEM customers focused on board processing and performance for:

- Notebook computing
- Domestic appliances
- Kitchen appliances
- White goods
- LED lighting
- FR-4 process compatibility
- Disposable electronics
- Additive manufacturing

The presentation highlighted four OEM product case studies using two suppliers of Soluboard laminates to three PCB fabricators.

Summary

Eventually, we will always need a suitable biodegradable copper-clad laminate. I am particularly concerned about the trend of disposable electronics, especially in the growing market of medical sensors and advertising. Much work is being done to make paper more suitable for these applications but if rigidity is required, then we only have paper-phenolic, CEM-1, CEM-3 and FR-2. Disposable electronics are not segregated and enter normal trash bins. I do not know the costs of this laminate, but volume will lower the cost over time, and copper will become the dominating factor. My bet is on additive manufacturing and the development of carbon-nanotube metallization.

The fact that the material's manufacturing is continuous-conveyor and not batch-panel provides opportunities for high-frequency application, coupled with its lower dielectric constant, CTE, and that it is 37% lighter than FR-4. It has a lower Tg and Td, but newer plasma conformal coatings may nullify that feature.

More details of the performance, reliability, and decomposition kinetics can be found in a presentation from the 2025 EIPC Summer Conference in Scotland. Jiva had a booth at IPC APEX EXPO 2025, and should be returning in 2026. **PCB007**

References

1. PwC's Second Annual State of Decarbonization—Sector Insights, May 20, 2025.

Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa Westwood, Merix, Foxconn, and Gentex. He is 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.

Highlighting Jerry Siegmund

Editor's note: Dan Feinberg continues his series on the Hall of Fame for the Global Electronics Association, spotlighting the achievements of past Hall of Fame members.

The Raymond E. Pritchard Hall of Fame (HOF) Award has been awarded to those who have contributed significantly to the Global Electronics Association (formerly known as IPC) and our industry. Though many early HOF members have passed away and are unknown to today's membership, their contributions still resonate. This special series on Hall of Fame members provides a reminder of who was honored and why.

This Hall of Fame spotlight features Jerry Siegmund, a visionary leader and supporter of fabricators and suppliers. He was inducted into the Hall of Fame in 1997 and passed away in 2018. Jerry's influence is deeply woven into the fabric of the Association's history. From the early days of his initial involvement to his leadership roles, Jerry's influence on IPC standards and practices provides insight into the qualities and achievements that garner such a prestigious honor.

Jerry joined the Global Electronics Association when his company (MacDermid) was navigating challenges and exploring new opportunities. His background in technology and management made him a valuable asset, not only to his company but also to the Global Electronics Association, bringing fresh perspectives and strategic insights. His early work in the industry showed his dedication and innovative approach to addressing issues. He played a vital role in advancing manufacturing techniques and improving quality standards.

In his earliest years at the Association, Jerry served in various capacities, ranging from project management to overseeing critical technological developments. His ability to manage complex projects and drive them to successful completion quickly garnered the attention of senior leadership. One of Jerry's most significant contributions was developing and refining IPC standards. He was instrumental in creating guidelines that improved the consistency and quality of electronics manufacturing. His work ensured that manufacturers adhered to stringent criteria, which elevated the industry's overall performance.

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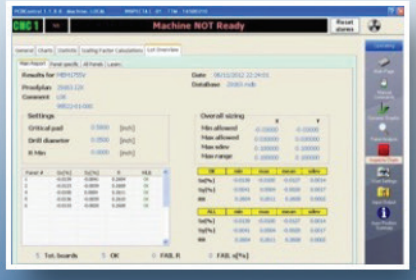

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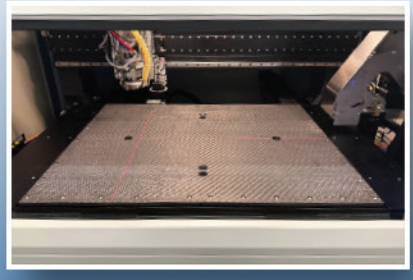

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Ribbon cutting at the first IPC Printed Circuits Expo, which opened to rousing reviews. Front row, from left to right: Jerry Siegmund, Siegmund & Associates; Peter Sarmanian, Printed Circuits Corportation; Sam Altschuler, Altron Incorporated; and Dan Feinberg. Morton Electronics Materials

One of Jerry's notable early projects was developing a new software platform that enhanced the Association's operational efficiency, revolutionizing the management of internal processes. This led to increased productivity and streamlined workflows. Jerry's innovative approach and technical acumen were instrumental in the project's success.

He was promoted to several leadership positions at the Association, each of which allowed him to further his impact, including as a founding member of the Technology Market Research Council. When I became involved in setting up the supplier's council and getting suppliers to become a more integral sector of the Association, he was extremely supportive. He was also quite supportive when we approached the Board of Directors with the idea of starting an annual trade show (which became APEX EXPO).

Suppliers to the industry often came to him to try out their new products and processes, such as advanced aqueous dry film resists that he tested at his facility. This supported the Global Electronics Association and his industry colleagues. His keen understanding of market trends and customer needs allowed members to develop products that met and exceeded market expectations. His opinions and recommendations often played a significant role in their broad adoption. Under Jerry's leadership, the Global Electronics Association embarked on several expansion efforts, both domestically and internationally, and he was instrumental in identifying new markets and forging new strategic partnerships.

Even after transitioning from day-to-day operations, Jerry continued his influence through his advisory roles and mentorship. His wealth of knowledge and experience was a valuable asset to the ongoing success of the Association and to the industry suppliers who developed and supplied new products and processes to the industry.

Throughout his long career, he received wide recognition for his accomplishments through numerous awards and accolades, solidifying his reputation as a visionary leader and highlighting the vast resumé that enabled his Hall of Fame induction.

Jerry's transformative leadership, innovation, support, and dedication inspire and guide the Global Electronics Association toward a future of growth and enduring success. His legacy is characterized by his unwavering commitment to excellence and profound impact on the organization's evolution. His leadership left an indelible mark, shaping the Association's culture, operations, and market positioning. **PCB007**

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July 31, 2025

TECHNICAL PAPER ABSTRACT:
September 12, 2025

POSTER ABSTRACT:
December 1, 2025

PROFESSIONAL DEVELOPMENT COURSE ABSTRACT:
September 19, 2025

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PCB007 TOP 10

Check out these highlights from PCB007.com

Seeing a Future in Mexico

Alejandro Hernández, the undersecretary for investment promotion in Guanajuato, is inviting electronics-related companies seeking long-term investment in a centrally located area with access to highways, railways, and ports. Guanajuato has the sixth-largest GDP in Mexico and is the country's fastest-growing manufacturing state. The state is home to manufacturing plants for five of the world's top automakers, three tire plants, a recent $12 million investment from a PCBA provider, and an $18 million expansion by a global automotive electronics supplier.

Tariffs: Hope for the Best, Plan for the Worst

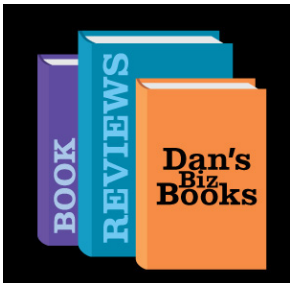
Paul Krugman received the Nobel Prize for Economics in 2008 for his work in economic geography and identifying international trade patterns. In April, he told the *Goldman Sachs Exchanges* podcast[1], "The secret sauce of the Trump tariffs is that they are extremely uncertain. Nobody knows what they will be. Nobody knows what comes next. Now, if you're a business trying to make plans, would you want to invest under those conditions?"

Webinar Review: A Global Trade and Economy in Flux

In a July 8 webinar, Global Electronics Association Chief Economist Shawn DuBravac provided a comprehensive analysis of the evolving international trade environment, its implications for inflation, monetary policy, and labor dynamics, and a sober assessment of market valuations. In "Navigating a Shifting Landscape," DuBravac painted a picture of a global economy in flux, where shifting trade alliances and tariff structures are redrawing the supply chain map and influencing the broader economic landscape, while also conveying an overall bullish market outlook.

Dan's Biz Bookshelf: 'Dream First, Details Later'

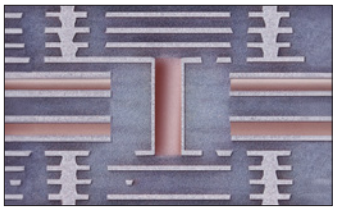
If you have brilliant ideas but get stuck overthinking, then Dream First, Details Later: How to Quit Overthinking & Make it Happen! by Ellen Marie Bennett is the book for you. This high-energy, no-nonsense guide is what entrepreneurs, creatives, and go-getters need to break free from analysis paralysis. Bennett, the founder of the culinary workwear brand Hedley & Bennett, shares her compelling journey from a scrappy, idea-filled dreamer to a thriving business owner.



The Big Picture: Our Big 'Why' in the Age of AI

With advanced technology, Tesla, Google, Microsoft, and OpenAI can quickly transform life as we know it. Several notable artificial intelligence (AI) studies, including the 2024 McKinsey Global Survey on AI, have offered insights into AI's adoption, impact, and trajectory. The McKinsey study revealed that AI adoption continues to grow, with 50% of respondents reporting using AI in at least one business area. Other key findings were: The average number of AI capabilities used by organizations doubled from 1.9 in 2018 to 3.8 in 2024.

The Death of the Microsection



I got my start out of college grinding and polishing PCB microsections. Back then, via structures were rather large, and getting to the center in six steps of grinding and polishing was easy compared to what my team has been doing recently at the lab. HDI, ultra HDI, substrates, embedded components, and the plethora of (tiny) via structures (micro, stacked, buried, staggered, etc.) that connect everything in today's "boards" make arriving at a via structure's center using a microsection a true nightmare—and a miracle for the lab technician if attained.

The Evolution of Picosecond Laser Drilling

Is it hard to imagine a single laser pulse reduced not only from nanoseconds (0.000000001 s) to picoseconds (0.000000000001 s) in its pulse duration, but even to femtoseconds (0.000000000000001 s)? Well, buckle up because it seems we are there. In this interview, Dr. Stefan Rung, technical director of laser machines at Schmoll

Maschinen GmbH, traces the technology trajectory of the laser drill from the CO2 laser to cutting-edge picosecond and hybrid laser drilling systems, highlighting the benefits and limitations of each method, and demonstrating how laser innovations are shaping the future of PCB fabrication.

Smarter Machines Use AOI to Transform PCB Inspections

As automated optical inspection (AOI) evolves from traditional end-of-process inspections to proactive, in-line solutions, the integration of AI and machine learning is revolutionizing defect reduction and enhancing yields, marking a pivotal shift in how quality is managed in manufacturing. Giovanni Obino, senior director of industrial digital solutions at MKS' Atotech, discusses the remarkable advancements in AOI technology over the past decade and the imperative for PCB manufacturers to embrace digital transformation.

Takeaways from the Keynotes at the Edinburgh EIPC Summer Conference

In Edinburgh, Scotland, June 3-4, delegates from 17 countries convened for the 2025 EIPC Summer Conference and enjoyed a superlative program of 18 technical presentations over two days. EIPC President Alun Morgan welcomed everyone to the Delta Hotel, reminding us that in its previous iteration, it was the Royal Scot, traditionally the annual venue of the Institute of Circuit Technology Northern Symposium. To my delight, he produced a copy of the 1982 proceedings, where I gave a presentation on outgassing.

China Plus One, Part 3: Inorsen Group, a Vietnam Success Story

In recent years, Western OEMs have continued to push for China Plus One factories and the advancement of China's Belt and Road Initiative (BRI). At present, there are two main modes for PCB companies to go global: building greenfield factories or through mergers and acquisitions (M&A). Thailand is currently the primary geographic choice to build greenfield factories, whereas, increasingly, mergers and acquisitions in Vietnam and Malaysia provide opportunities for companies to expand markets and acquire resources.

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Required Skills:

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atg is seeking an Applications Engineer located in the Chicago area to join their U.S. team to support system installations, customer demos, and ongoing technical service. This role provides pre- and post-sales support, oversees machine setup and calibration, and troubleshoots on-site and remote issues. You'll work closely with customers, engineering teams, and product developers to deliver innovative solutions and influence future system enhancements.

Key Responsibilities:

- Perform software installs, machine setup, and calibrations
- Conduct demos, training, and system buyoffs
- Develop and optimize customer assembly processes
- Troubleshoot and resolve technical issues
- Document procedures and contribute to manuals
- Collaborate cross-functionally to improve products

Qualifications:

- Associate's degree in electrical engineering or related field
- 2–3 years in applications or field service engineering
- Experience in PCB testing or circuit board assembly preferred
- Strong knowledge of electronics, networking, and documentation
- Excellent communication and customer service skills
- Ability to travel up to 50%, domestic and international

Work is hybrid/home-based with travel. Must have valid passport.

Contact Klaus Koziol at Klaus.Koziol@mycronic.com to apply.

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- **Procedure Optimization:** Analyze quality trends and RMA data to update processes, inspection checklists, and control plans

Qualifications:

- Associate degree or equivalent experience in electronics manufacturing
- 3+ years in bare board PCB QA, with IPCA600/CIS and IPC6012 certification
- Strong auditing, training, documentation, and cross-functional collaboration skills
- Proficient in rootcause failure analysis

Join us to ensure rigorous compliance, elevate fabrication quality, and continuously improve manufacturing standards.

Contact brandon@ace-pcb.com and James@ace-pcb.com to apply.

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- Strong candidates will have more than five years of experience with in-circuit test equipment. Some experience with flying probe test equipment is preferred. A candidate would develop, and debug on our test systems and install in-circuit test sets remotely online or at customer's manufacturing locations nationwide.
- Proficient working knowledge of Flash/ISP programming, MAC Address and Boundary Scan required. The candidate would also help support production testing implementing Engineering Change Orders and program enhancements, library model generation, perform testing and failure analysis of assembled boards, and other related tasks. An understanding of stand-alone boundary scan and flying probe desired.
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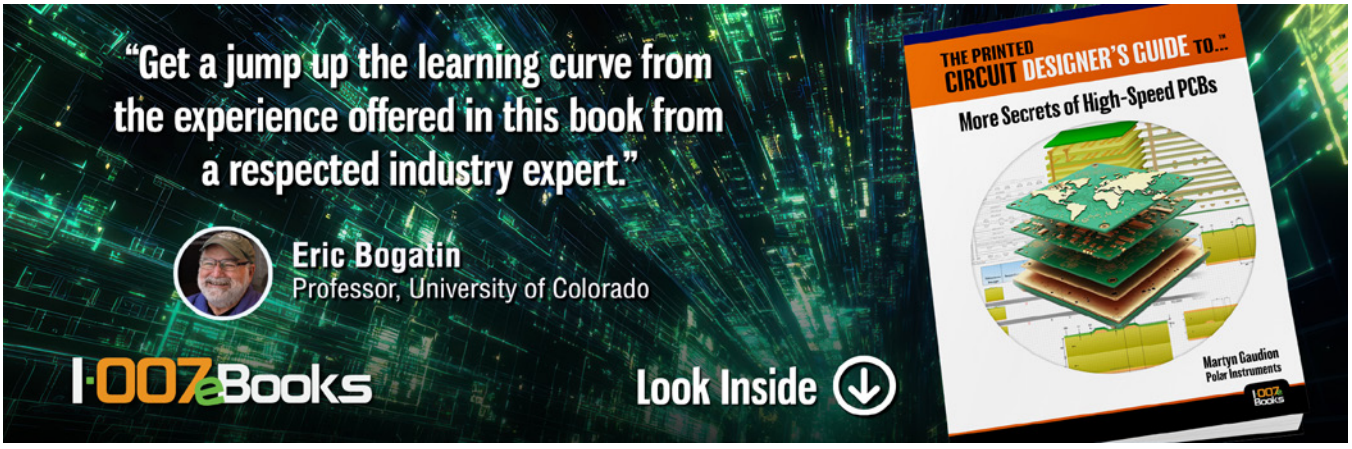
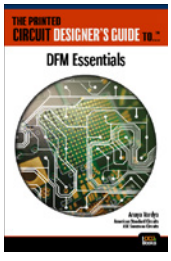


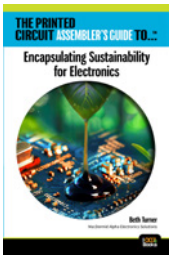
I-007eBooks The Printed Circuit Designer's Guide to...



DFM Essentials

by Anaya Vardya, American Standard Circuits, ASC Sunstone Circuits

One of the biggest challenges facing printed circuit board designers is not understanding the cost drivers in the PCB manufacturing process, particularly the manufacturing of advanced technology PCBs. The guidelines offered in this book are based on both ASC recommendations and IPC standards. **Download your copy today.**



Encapsulating Sustainability for Electronics

by Beth Turner, MacDermid Alpha Electronics Solutions

This book discusses the growing demand for sustainable solutions in the market and highlights examples of bio-based resins and the demand from emerging technologies. **Read it now!**

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PCB007 MAGAZINE

PCB007 MAGAZINE®
is published by IPC Publishing Group, Inc.
3000 Lakeside Dr., Suite 105N, Bannockburn, IL 60015

July 2025, Volume 14, Number 7
PCB007 MAGAZINE is published monthly
by IPC Publishing Group, Inc., dba I-Connect007

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