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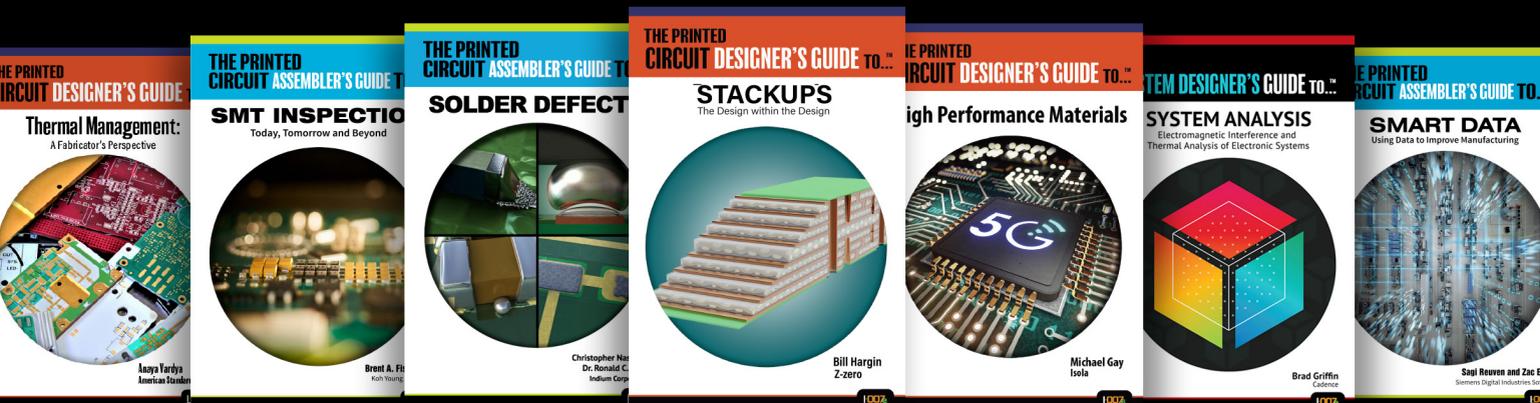
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## Golden ROI Opportunities

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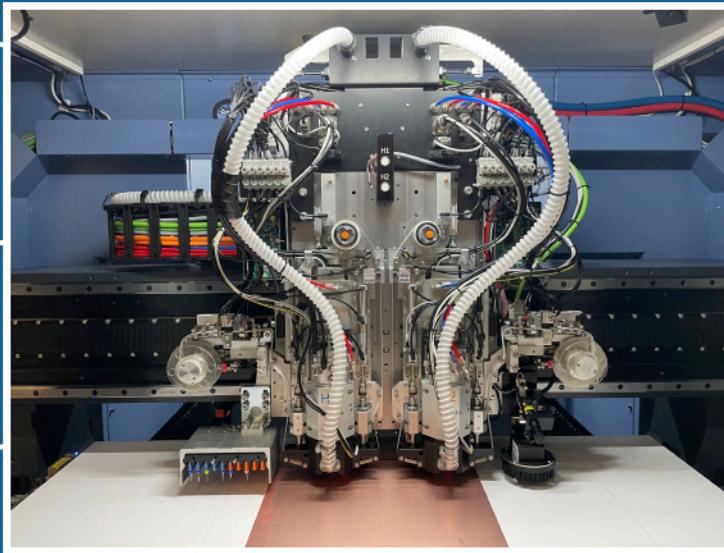
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# Where Are the Golden Eggs?

## Nolan's Notes

by Nolan Johnson, I-CONNECT007

We all went through the simultaneous transitions in our industry in the last three years. To be clear, I'm referring to supply chain issues due to the pandemic, manufacturing channel resiliency, parts shortages, people shortages, governmental investment in infrastructure, and above all, a huge demand for manufacturing capacity. All that demand, all those hurdles, and the all the constraints can leave one a little dizzy.

The reality is that we'll feel both short- and long-term impacts from these trends. Over

the past couple years, the I-Connect007 magazines have covered these topics extensively. I encourage you to go back through our coverage. The U.S. government is following the lead of other nations to fund domestic expansion of semiconductor production, and now printed circuit boards as well. Kudos to IPC and the nascent PCBAA for their work to educate the government agencies on the importance of PCBs in the strategic plan.

It almost goes without saying, but we're all in business to make money, and our industry



is evolving in overdrive right now. The money is coming from new sources; increasingly it's coming back home to Europe and North America. Even if you're not thinking about expanding your capabilities, you're probably thinking about how to expand your capacity, or you're sorting out how to respond to the human capital challenges that came to a near crisis with the pandemic. If your facility is looking to respond to customer demand for new technologies, then you're just adding that to the list, right? A brand-new additive process line, for example, may meet your customer demands, but it doesn't run itself. We simply must look at our business processes and change them to meet the times.

So, what to fund first? Where do I start my investment in my company? Do I fix the staffing issue, so I have all my capacity back? Do I remove process steps with new equipment so that I don't need as much staff, and reclaim valuable floor space I can use later for new capabilities? Perhaps my company needs to follow yet a different path? Where exactly is that golden egg in my facility?

With all these opportunities (demands?) on our investment budget, what provides the greatest return on investment? Where is the hottest area that will maximize the payback to help fund further investment? As is often the case in this complex, constantly-shifting real world, the answer isn't really that simple. As we spoke to the experts, we frequently heard, "Well, it depends." Everyone's mileage will vary, of course. What we determined was that, while there wasn't just one singular hotspot for ROI, there were a few that bubbled up to the surface.

The team at Technica, for example, shared their perspective on the "golden egg" potential they see in the marketplace. That conversation shed light on inkjet printing technology throughout the fabrication process, direct imaging, and robotic automation. Our wide-ranging discussion with all4-PCB's Torsten Reckert also highlighted automation and direct

imaging solutions but added waste management systems as an unexpected ROI hotspot. We went deeper into specifics as well. For example, Sunny Patel detailed Candor's initial experience with its brand new Indubond induction press. I'm also including a discussion with Atlantic Microtool's Neil Robinson and Bruce Siemering, who joined Chemcut's Christopher Bonsell and Jerry Reitz to discuss a highly approachable robotic material handler. Perhaps you saw this unit in action in the Chemcut booth at IPC APEX EXPO 2022? Depending upon your own organization, there ought to be at least one golden egg opportunity for you out of these discussions.

Not to be outdone, of course, our columnists weigh in on ROI-complementary topics. Todd Kolmodin looks into the future of electrical test. Luca Gautero slices his way through PCB cross sections. Our young engineer columnist, Page Fiet, shares simple secrets to make mentorships more effective. Christopher Bonsell examines the interaction between wet processes and Industry 4.0, and Happy Holden's column on copper etchant regeneration reminds us that there is ROI in cost containment as well. Finally, Travis Kelly's PCBAA column details some of the market forces in play now.

There is much to be optimistic about in PCB fabrication right now, and those of us who capitalize on the coming confluence of demand and revitalization support, will thrive in the coming years. So, what is your first golden egg?

You can always contact us with feedback or topic suggestions. Your comments are part of the conversation driving our industry forward. I hope to hear from you. **PCB007**



**Nolan Johnson** is managing editor of *PCB007 Magazine*. Nolan brings 30 years of career experience focused almost entirely on electronics design and manufacturing. To read other columns or to contact Johnson, [click here](#).

# The ROI Hotspots



Feature Interview by the I-Connect007  
Editorial Team

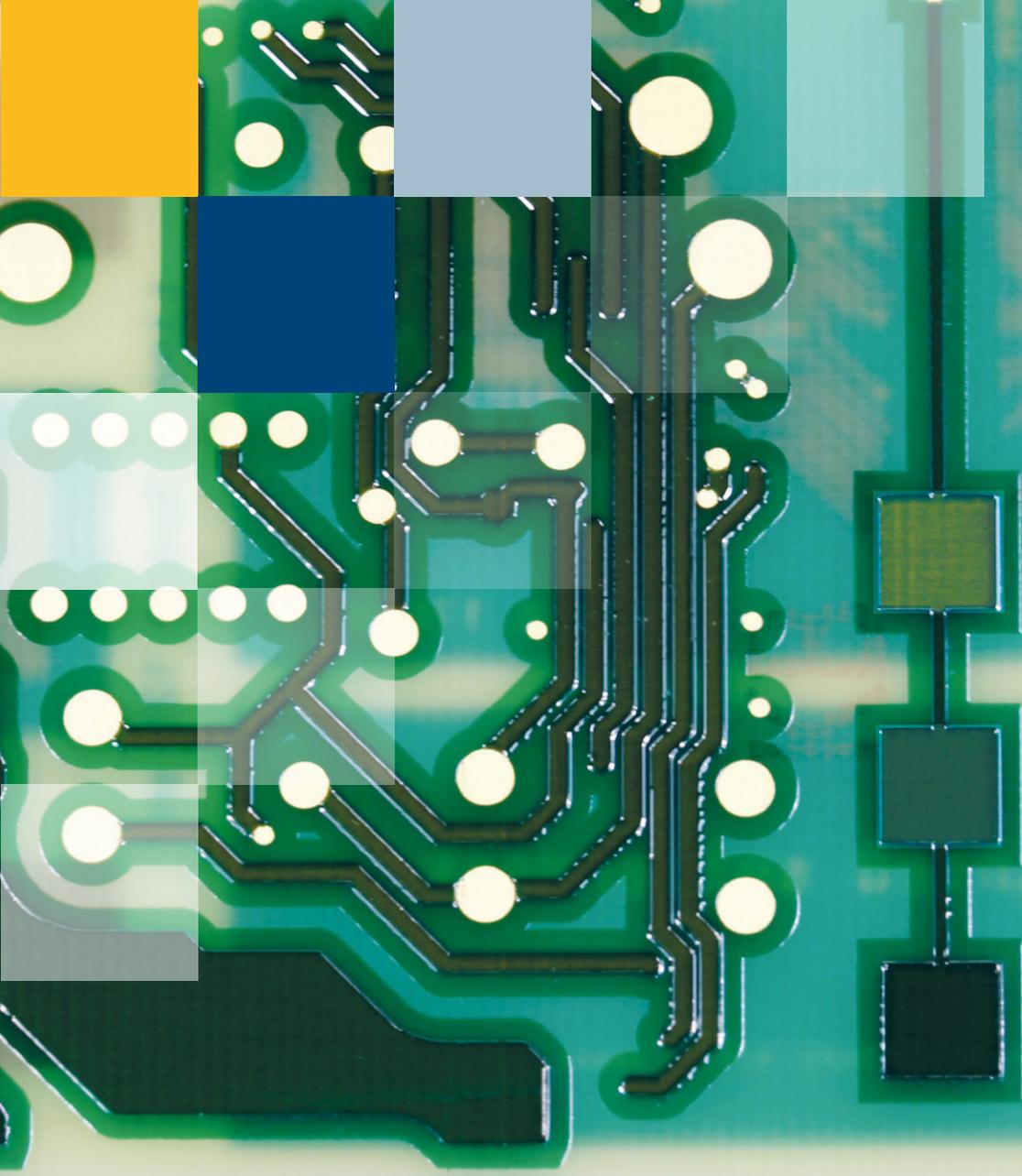
The I-Connect007 Editorial Team discusses with Technica's Frank Medina, Ed Carignan, and Jason Perry about trending hotspots that provide the PCB fabricator a high return on investment (ROI). A theme that carries throughout the conversation is that traditional methods for calculating ROI are being replaced by models that include more qualitative factors.

**Nolan Johnson:** Frank and Jason, Where do you see the ROI hotspots in manufacturing right now?

**Frank Medina:** One is solder mask equipment; another area is automation and material handling.

**Jason Perry:** I think there are several more areas. A lot of effort has been put into the inner layer and outer layer departments. People are moving toward upgrading the back end of the process. We're seeing more demand for solder mask improvement and technology, direct write type of technology, and inkjet applications.

Reducing process steps, improving throughput, and improving time to market—getting product through the shop faster always equals higher dollars and lower costs. There's a drive toward that on the back end, including automation to reduce labor costs as those costs continue to increase. We're seeing demand to automate repetitive tasks the operators would normally be doing. The goal is to repurpose



inkjet

printed

soldermask

1,0 kV

2,5 kV

3,5 kV



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operators to more important areas, instead of just feeding lines or moving product, and let automation fill the void.

## Inkjet Solder Mask

**Johnson:** It looks like the technology on inkjet solder mask is emerging into its own. Would you detail the steps that get removed from the process when you move to inkjet solder mask?

**Perry:** You will still do a direct write like you would with a direct imaging machine. The advantage now is you have no coating process.

The first step that's removed is the coating of the solder mask application: any equipment or manual operation that is used to screen print, flood coat panels, or even spray coat panels. That process is quite inefficient because there's a lot of process steps involved and wasted solder mask. With inkjet applications, we're printing everything that we're using, so there's little to no waste. You can print the mask where you want, and not have to flood coat an entire panel.

That would be the first advantage. Another is reduction of VOCs because you have a lot of them in the conventional solder mask process, during the coating application; with inkjet, we're eliminating that element of the process. It's a big advantage as the industry moves toward being as green as possible, in specified regions.

## Direct Imaging

**Barry Matties:** Direct imaging is one technology that always seemed to offer a great ROI, but with a heavy investment. Is that a good ROI? What are the trends? Are more people looking for it, or is the market where it needs to be?

**Perry:** There's been a definite industry shift toward direct imaging. Most of the shops now

have some form of direct imaging machinery and there are more players in the market. There are still a small handful of shops who don't have it, though.

The drive for direct imaging (DI) has now shifted into the solder mask area for improved throughput and quality. The initial effort was for fabricators to use DI in the inner layer area because that is where they could realize the most cost savings impact, and then the technology was adopted in the outer layer imaging area. Now with the introduction of high-powered LEDs to image the solder mask, the new DI machines are delivering improved throughput, along with high resolution. As the equipment matures, I think the move to inkjet solder mask will be a market shift in the near future.



Jason Perry

**Medina:** The DI primary imaging equipment being purchased today isn't as much about ROI as it is about the capability of the equipment to image finer and finer lines. The mSAP and other semi-additive processes are driving this need. We're seeing more customers trying to image 0.001" and less.

But in regard to the evolution of this technology, as customers with DI start to upgrade to the new technology, the older models will become available and that will allow the smaller shops to get into DI at a much lower price through the used equipment market.

There is no doubt the market continues to grow the use of DI equipment, but the next step is where inkjet comes in. As that technology evolves, it creates other opportunities for that type of technology to direct write, basically putting the resist just where you want it—rather than coat an entire panel and then remove what we don't want. That's a huge cost savings.

**Matties:** When someone is making a purchase decision, where does the ROI become a factor in the decision process? Is that a driving factor?

**Medina:** On the business side, some of the conversations I've had are about labor, which is becoming scarce, and wages are going up; people don't want to work in the plating shops of a PCB fab house.

Management is asking, "How do I function with fewer people in those areas where people don't want to work?" Some don't mind working in AOI; the conditions are clean. But surely in the wet process areas is where we're seeing a good amount of interest in how to reduce labor.

**Matties:** Are there solutions available? In a brownfield site, obviously, space and flow are the factors, right?

**Medina:** That's the challenge for board shops. They can only do so much, right? But inkjet printing is a place where you can take out process steps, which should free up space for other use.

**Johnson:** Earlier, you linked direct imaging to inkjet solder mask and additive processes. Why are those two increasingly going hand in hand?

**Perry:** It's the paradigm shift to additive technology, where the DI has replaced the conventional exposure process and has made dramatic strides to improve quality—not just for registration, and performance, which was huge, but across the board for imaging quality. It didn't replace anything, though. It replaced your phototool process, but it's still coating the entire panel with dry film or solder mask, exposing it, and then developing it all off. The next evolution step is additive technology.



WonderWise atmospheric cleaning equipment.

## Automation and Going Green

**Johnson:** One of the things that I've been picking up about our conversation so far is a one-two punch of removing process steps and incorporating automation. Those two things seem to amplify each other.

**Medina:** Yes. There are opportunities for customers in labor cost reduction and environmental chemical consumption. With inkjet printing, you're removing chemical processes, developing and cleaning screens, and all the things that you do in the process to flood print the boards. Then you have the atmospheric plasma cleaning equipment (WonderWise) that we featured at the IPC APEX EXPO this past January, placing chemical clean prior to dry film, or inner layers and outer layers. We now have that installed in our demo center and are scheduling running samples for customers who want to bring boards in to test it out.

**Johnson:** How does that work?

**Medina:** It's a guided atmospheric plasma machine and it has two advantages. One, it

replaces chemical processes. It makes it easy to automate the dry film process because it can be installed in the yellow room, gaining the space where the chemical clean process was installed. Secondly, it's really good, we believe, for HVLP copper, because you're not changing the surface or removing copper at all. We believe that PCB designers will like it because they will gain more consistency with their signal integrity.

**Johnson:** Usually when fabricators are making changes to processes, there's a compelling advantage, something has pushed them. Is it staffing shortages and the resultant need for automation, which triggers equipment upgrades, or is it capabilities and processes, with automation as a tag-along?

**Ed Carignan:** I've been in this industry for over 30 years and over just the last five years people are very focused on moving toward a zero discharge, very green, zero waste deposit. This is driven by a lot of things, including ROI and clients. You see technology like the Wonderwise equipment using a plasma cleaning that's non-chemical based. It is extremely attractive for green processes.

It's also true that when you get into additive manufacturing there are fewer materials that go down the drain and must be treated before they're discharged. There's a lot of focus in that one area and you could argue that it doesn't always have perfect ROI in the traditional way where you calculate labor and material costs. There is, however, an impact on how you market your company as a green source of printed circuit boards. A lot of people are jumping into that, making commitments to their communities, and marketing the idea that they're increasingly a greener industry and less of a messy industry.



Ed Carignan

**Medina:** When you talk about marketing your company, green initiative is one benefit, but also everything we're discussing also reduces the cycle time. Most U.S. business is in the high-mix, low-volume NPI arena; it's all about how fast they turn that job, how fast they deliver. That is where they make their money.

When you cut out all those steps and you're able to process a circuit board in a shorter time frame, there is a gain to the business. But how do you measure that in ROI? It's a little more difficult, as now the benefits aren't as tangible. But they do bring benefits to the company.

**Matties:** Right, just like adding capacity, it's an incredible ROI.

**Medina:** Exactly. If you get a board through the facility faster with less processing, now you can take on more work, right?

**Matties:** When brownfield sites are looking at zero waste, are they opting for a complete refurb of their system with new technology, or are they bringing it in piece-meal as the opportunity presents itself?

**Carignan:** The existing brownfield sites have the opportunity to bring in a variety of packages, allowing them to get closer to zero discharge. Fortunately, many upgrades can be incremental. In other words, you can handle different waste streams and implement different technologies without overhauling your whole waste treatment area, which, of course, would be difficult to do. Fortunately, most of the zero-waste technology that people are moving toward can be implemented in situ.

**Matties:** Is the ROI on incremental upgrades high enough to reconsider your investment strategy?

**Medina:** The industry hasn't invested because it brings any value or cost savings. Instead, they've put in waste treatment to comply

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with regulations and requirements. Waste treatment is operating overhead. They're looking for incremental cost savings from waste treatment.

With less effluent going out, there's less treatment and use of chemicals. The point is, they're only doing it because of compliance issues, or because their equipment is ready to be replaced and they might need to replace old equipment with something more efficient. But they don't do that to reduce costs. They need to look at Wonderwise to reduce chemical usage, look at inkjet technology and other technologies as possible ways of reducing chemical consumption and disposal.

**Carignan:** In some of the cases, the customers of the fabricator want this. There's a customer demand saying, "We really would like to find partners in the fabrication industry as a whole, who are green, because the products derived from that channel are what we want to carry in our branding."

**Matties:** It's more about reducing the load on your waste treatment, which saves you money, not only on input costs, but also in having to manage that waste.

**Medina:** Yeah, and that's true when you talk about existing facilities. Now, if you've got a greenfield, that's the opportunity to take advantage of all the ways you can reduce waste, as Ed said, and become a green operation. If you look at GreenSource Fabrication on the East Coast, that was their whole strategy. Then you've got Schweitzer building a facility in Idaho, and their intention is to follow the GreenSource example. OEMs are increasingly sensitive to zero waste and being green; we'll continue to see more board shops being more willing to do the same.



Frank Medina

## Inkjet Printed Resists

**Happy Holden:** You mentioned inkjet. I wonder about the progress on etching or plating resists that are inkjet-printed and bypassing the entire photoresist direct imaging develop/etch/strip strategy.

**Carignan:** In the first wave, there are several manufacturers. The hot market for inkjet is clearly solder masks because solder mask is such a lengthy—and not a very clean—process, with a lot of process steps and a lot of labor costs. The focus from any of the manufacturers is to promote solder mask because the ROI is more apparent. You can feel it in labor costs. You can feel it in everything.

However, there are people today who are using plating resist. Etch resist and legend printing has been around for quite a long time now; the viscosities have been worked out; it is a jettable material. I would agree with you, Happy, that jettable plating resist is probably the next frontier. What makes it more attractive is that there are many manufacturers who already have those chemistries. It's logical to think that would be the next frontier.

Now, most of the manufacturers are focusing on solder masks because it is such a labor-intensive, capital equipment-intensive and wasteful process. That's really why it has the first application, if you will.

## Engineering Expertise and Industry 4.0

**Holden:** Maybe their bandwidth of investment and implementation has to be narrowly focused, because of their resources. They can't afford or don't have the manpower to do too many things in parallel or nothing's going to get done.

Labor automation is a 1980s strategy, which, rightly so, the printed circuit people are just catching up to the big OEMs who did it in the '80s and '90s. But I wonder how long before they get into the 2020 smart factory, which is data driven. The whole realm of the smart fac-

tory and Industry 4.0 is really focused around sensors and data. Are any of them beginning to look at sensors and data?

**Medina:** I think that's a very good question, Happy. Industry 4.0 for SMT is much more prevalent than the PCB side; there are already SMT facilities in the United States which are Industry 4.0 smart factory designs. It's easier to implement because the process steps are much less than in a PCB shop. I always say, from my experience in all three (semiconductor, PCB, and SMT), that the PCB fab guys don't get paid enough. That's because their processes are so custom, whereas in SMT and semiconductors, it's very repetitive.

So, we see Industry 4.0 on the SMT side. Right now, I think there's more of a drive in Europe by the PCB fab manufacturers to pursue the Industry 4.0 objective than in the U.S. Although, we have just started this initiative with one of the major PCB fab companies in the U.S.

The larger PCB facilities are more inclined to implement Industry 4.0, but in general, when you talk to some of the smaller operations, not so much. They're just not there yet.

**Matties:** All this is coming down to the decision of the fabricator. I think we're going to see a more piece-meal strategy on the bare board side. They'll make sure it has the features, but it's going to be an isolated install.

**Medina:** I also think that the process steps in building a fabricated board are so much more complex. It's not as streamlined as an SMT facility, or even an EMS facility. That's the challenge. But it's not insurmountable.

But the fact is that we don't promote it too much to the fab guys because they're just try-



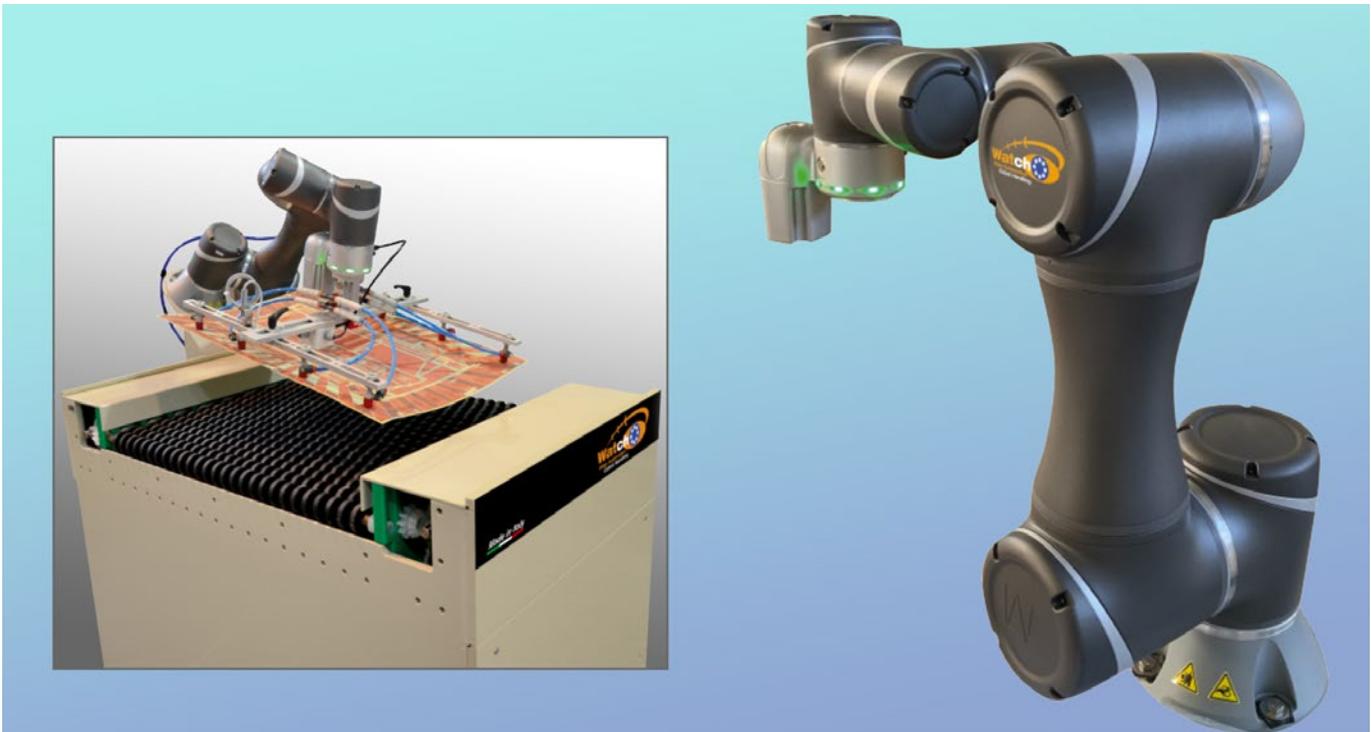
SÜSS JETx-M.

ing to figure out how to get the boards out the door. They don't have the resources to do it, but there is value in continuing to promote it to the fab guys by giving them examples of what others are doing in that area.

**Matties:** Their resources are limited, so even if we continue to talk about the benefits ad nauseam, in the end, they have to be able to commit to it and then fund it. Those are two tough decisions to make.

**Medina:** In 2000 or 2001, just as things started to shift to Asia, we had volume plants in North America running large programs. We could go in and show them how much benefit our materials delivered in cleaning, for example, because the numbers were based on reality. You could measure the yield improvement, because they had repetitive product running down the line in volume. If a product was running low yields and they switched to a different machine with a different cleaning setup, you could see the difference.

Now, you can't measure the improvement as easily because it's five panels of this, 15 panels of that, 10 panels of this. You don't have that



Technica Watch Wise automation.

same product running repeatedly in order to baseline your quality system.

**Matties:** Any final thoughts on this hot ROI topic?

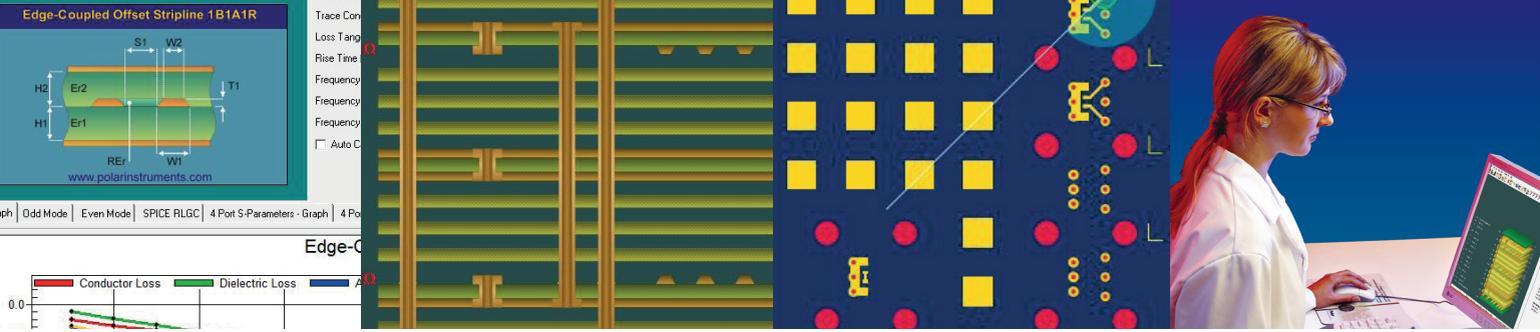
**Perry:** With respect to ROI, I liken it back to the days of the early legend inkjet printers. That was a difficult adoption to our industry because there was an art to screen printing legend. It was difficult to convince customers to look at an inkjet legend printer. We had to do tons of ROI justifications; it was always about the ROI. Even after showing the ROI, customers still wouldn't make the change. It took a long time until the industry adopted it. Now, I don't think anybody calculates the ROI to buy an inkjet legend printer. They purchase it because they know it's the right thing to do. When you move that forward to direct imaging, the same thing happened. I think we'll see the same type of movement with inkjet printing, including resist, etch resist, and solder mask.

These three processes are going to make sense with direct application, but people still want to run the ROIs today. That ROI can be

difficult, because you must include the speed of the process improvement, and the elimination of multiple process steps. That's very difficult to do in this environment; all the work that we process is in departmental batches. All these fabricators have been looking for space around the shop to add another process, increase the process flow, or add a new equipment. That makes it difficult.

**Carignan:** The traditional view of ROI is vanishing. Customers are demanding different forms. They want cleaner factories, higher technologies, and information—back to the discussion of Industry 4.0. They want information and they expect you to have it. If they want to quarantine a lot, or if they want finite traceability, it's going to be hard to do an ROI on that. Except, of course, to say, "We won't be selling to a lot of customers, because we don't have these capabilities." It's a lot like IT equipment.

It's hard to do an ROI, if you have something that's working. How do you quantify the risk of losing data, or having a security breach? It's hard to justify spending that kind of money. But

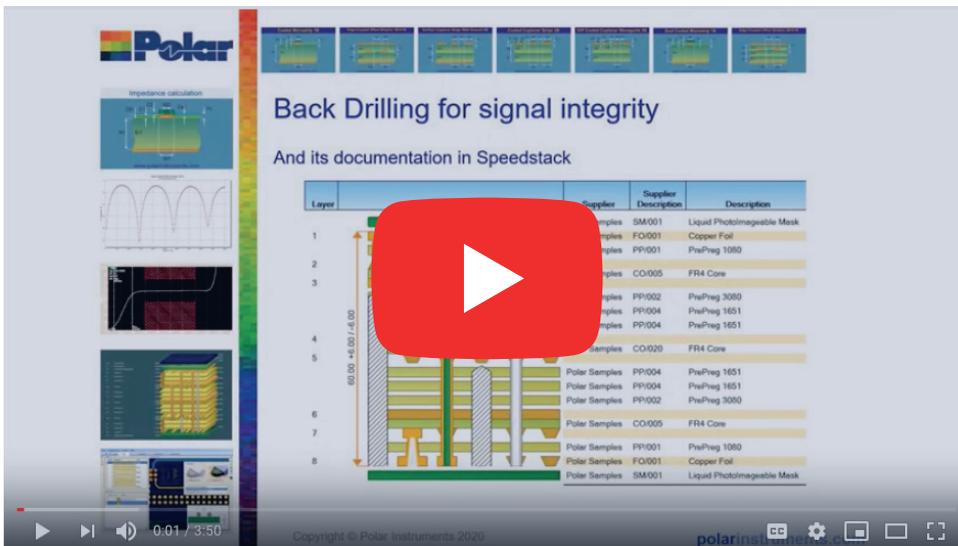


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people do it every day because it's important. You won't be doing business with many customers unless you have these things in place. We're finding justifications for ROI evolving. Now, ROI might just be that our cycle time is faster. And if our cycle time is faster, then I know that there's money in this and I know I can compete with somebody who previously was faster than me.

I don't know if all those traditional add-ups and subtractions, like labor cost and such, are as influential. People aren't saying, "It needs to pay for itself in a year or I don't want it." People are looking at that, but I don't think that's the over-arching reason for ROIs now. They're

looking at an overall strategy that includes security, safety, environmental concerns, and continuing to work with the clients who are expecting those things.

**Matties:** How would you rank the importance of that decision tree or process? What are the factors? You're saying they're looking at ROI differently.

**Carignan:** In my day, when I was running a lot of plants, ROI was probably the single most important factor. What's the payback period? I want to know that number; it's what's ranking capital requirements from all the plants I'm

## Discovering the Advantages of Inkjet Printing for Solder Mask

The team at Technica supplied this analysis of the ROI contributions of inkjet solder mask to help quantify the statements made in the interview.

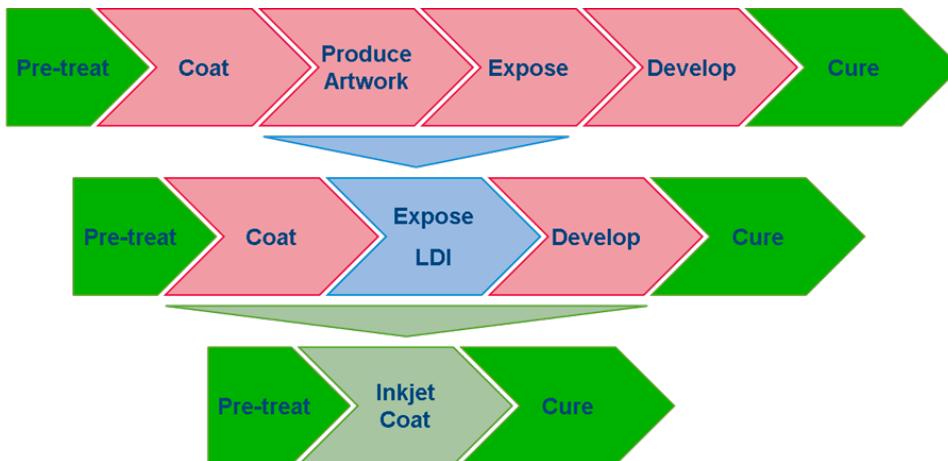
### Savings on Operational Costs

A reduction in process steps is achieved by direct patterning of the solder mask. The cost drivers in

Figure 1 are removed or minimized, thanks to inkjet printing.

The single standard inkjet solder mask tool is a drop-in replacement for the traditional full surface coating (exposure) developing process and their respective tools.

Inkjet printing is convenient thanks to:



- A significant reduction on running cost, such as material and electrical energy bill
- A greater efficiency of the solder mask material
- An auxiliary chemistry, like flushing liquid for maintenance, has less volume and cost impact compared to traditional chemistry

The latter point ensures the environmentally friendly aspect of the inkjet technology by avoiding continuous refresh of large quantities of developing chemistry.

Figure 1: Qualitative comparison between existing technology for traditional solder mask processing (red), an LDI alternative (blue) and additive route (green). (Source: SÜSS)

overseeing. The natural choice is to start with the ones that pay back the fastest.

But that school of thought is very much going away. Customers want to know what the payback is, but what are the other factors to consider? When the answer is no longer being accessible to these customers, we may have to make these investments.

**Johnson:** What I'm hearing is that the traditional ROI model was built on the foundation of primary factors and, increasingly, your customers are thinking in terms of secondary and tertiary factors, about whether that investment brings them more business, improves their effi-

ciencies, or gives them something else to market that's an intangible but which can contribute to the return on investment.

**Medina:** Exactly. If you think about things like measuring labor when it's not just the hourly wage, but it's the cost of benefits. Also, how do you run your line with chronic absenteeism?

**Matties:** We certainly appreciate all your expertise, time, and attention today.

**Johnson:** Yes, good conversation. Thanks, guys.

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

## Roadmap of the Return on Investment

Tools in the field, despite the novelty of this approach, have already demonstrated savings of 10% during the first year of introduction. Several factors will contribute to a continuous savings increase:

- Healthy material suppliers' competition to increase sources and quality
- Material demand increase leading to economy of scale on material production
- Customer's learning curve to maximize the digital aspect of inkjet technology in combination with the handler system
- Availability of upgrades and options, both software and hardware, to improve throughput

The target saving, per year, on operational expenditure is above 30% when compared to curtain coating and optical exposure.

## Additive Deposition, Selective Thickness

Solder mask is applied only in areas where it is needed. Total material savings can exceed 80% compared to traditional processes. Solder mask is not deposited in drill holes. This is an advantage compared to present technologies, for which, after development, hardened solder mask (almost unremovable by requirement) needs to be mechanically reworked or removed. In addition, to selectively place the solder mask on the required areas only, its deposited layer thickness can be tightly con-

trolled. Functionalities that depend on the deposited amount of solder mask material can be matched by design for each location.

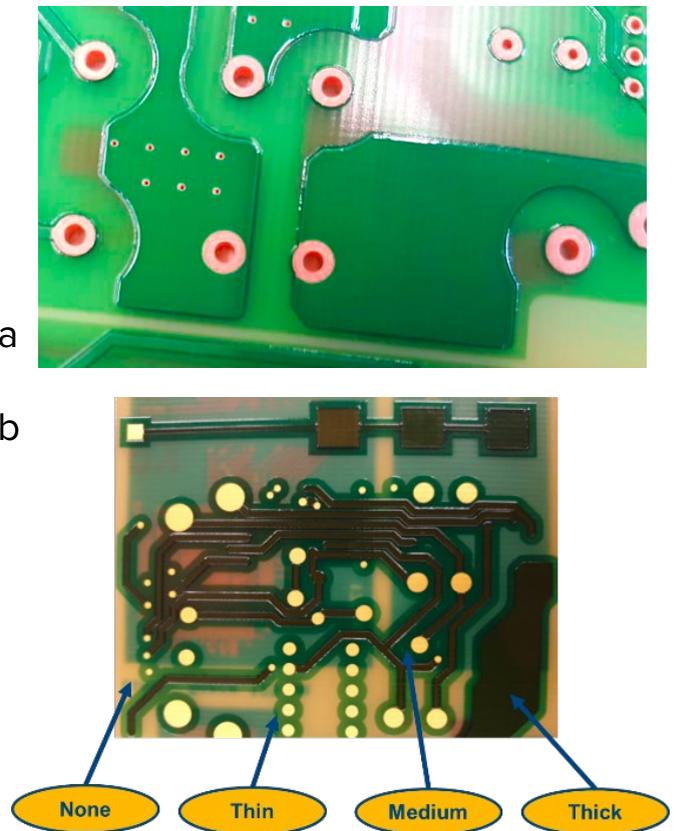


Figure 2: Thin/thick solder mask layer application. Both (a) and (b) illustrate the versatility of this additional feature. (Source: SÜSS)

# How Industry 4.0 Shapes PCB Wet Processes

## The Chemical Connection

by Christopher Bonsell, CHEMCUT

Earlier this year, I had the opportunity to attend IPC APEX EXPO 2022 where I was able to network with many great people in the electronics industry and see how other businesses are connected to the work we do at Chemcut. Although that might have been my main take-away, there was another trend that I couldn't ignore: the fourth generation of the industrial revolution is alive and well in the industry. After witnessing the many technologies that can be leveraged to boost automation, I couldn't help but consider how they may impact the wet processing side of PCB manufacturing. I also wonder about other forms of

automation we may soon see and what those developments could mean for the industry.

### Material Handling

One of the main areas where we see an impact is material handling. The newest development is the implementation of robotics alongside PCB equipment to load or unload material into/from processing machines (Figure 1). PCB manufacturers have long-awaited this technology due to its many benefits.

Certainly, with the introduction of robotics to wet processing equipment, a boost in production rate is to be expected, but there

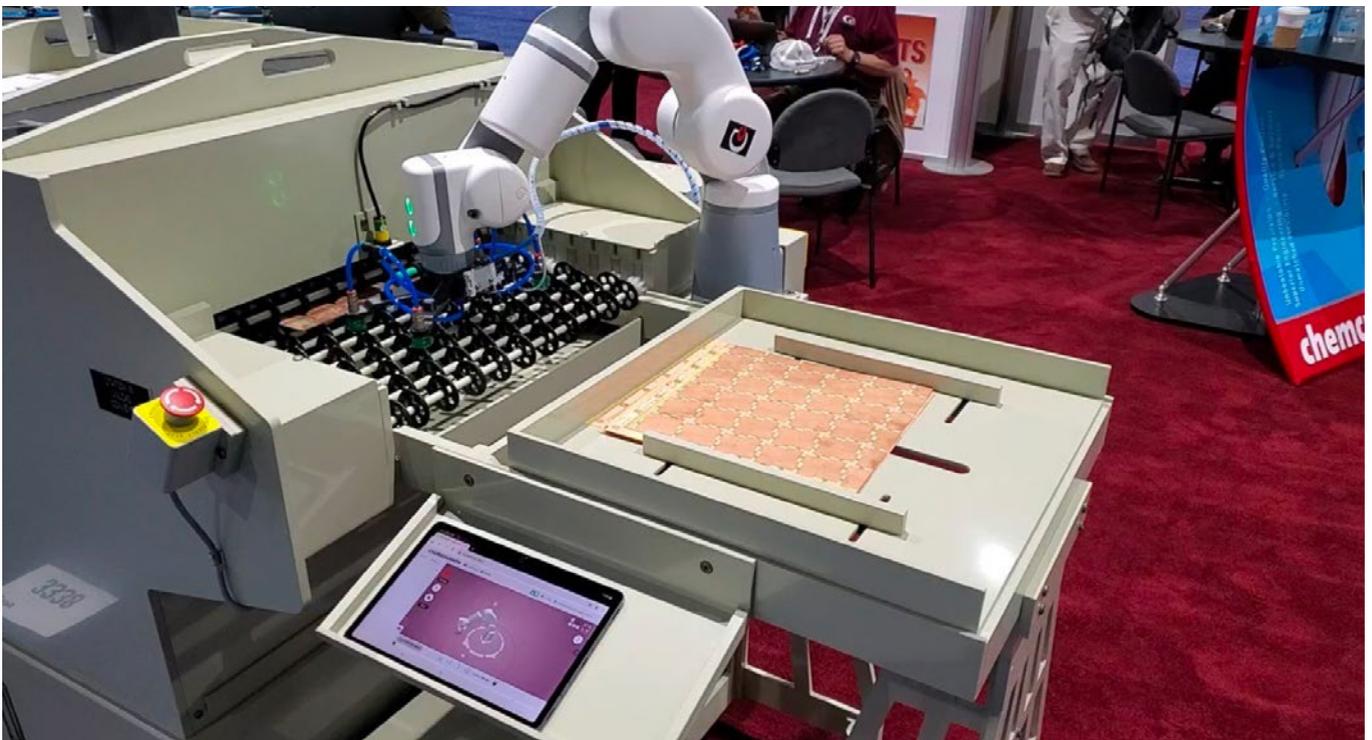


Figure 1: A low-cost, user-configurable robot arm unloading PCBs.



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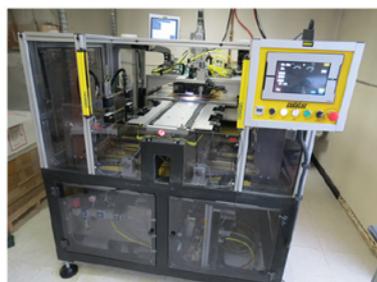
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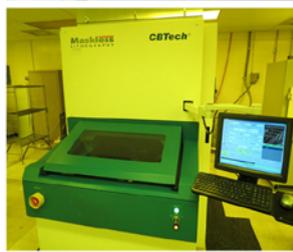
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are other benefits. With a loader like the one shown in Figure 1, panels are also less likely to become damaged. Although loading a panel into a machine may sound like a simple task, it is highly susceptible to error. If the person loading the panel is not careful enough, the corners and edges of the panel can easily be damaged. Even if the operator only slightly damage the edges of the panel, it could result in a much larger problem down the line. The initial damage can become exaggerated and effectively ruin the product even more. It could even cause the panel to create a jam inside the machine and halt production.

It should also be noted that this problem becomes an even greater concern as you try to obtain thinner PCB layers. Since the thin materials are more easily damaged, they often need to be handled with extra care. For some PCB manufacturers, the layers being manufactured are so thin that people loading the material must be specially trained on how to handle panels without causing damage. By introducing robotics into this section of the PCB manufacturing process, so many variables are removed, thus keeping production consistent in a simple and effortless process—even for ultra-thin materials.

---

**Since the thin materials are more easily damaged, they often need to be handled with extra care.**

---

## Smart Connections

Another development in automation is the ability to operate them from our smart devices. Loaders like the one shown in Figure 1 can be conveniently operated from a laptop or any touch screen device. Smart connections are not limited just to loading robot-

ics either. Recently, we have started to see implementations of smart device interaction with your wet processing equipment, effectively allowing you to make process changes anywhere.

Having this new freedom to effectively run your entire process from a smart device creates some new opportunities. Without requiring someone to continuously monitor and operate the machine now, these workers can then shift their focus to specialized tasks such as checking etchant conditions, calibrating probes, or performing maintenance checks. This will grant PCB manufacturers more time and resources to take care of matters that are important yet often overlooked. For instance, the person who would typically load panels all day could implement a cohesive preventive maintenance program like I discussed in my previous column, “[The Case for Preventive Maintenance](#).” Reallocating time and resources to matters like this would be a great way to keep your PCB manufacturing process moving at a steady pace with a reduced number of sudden complications.

## Where It All Comes Together

With this further push for automation, there will be plenty more extraordinary developments ahead. Now that robotics and smart devices are becoming more integrated into PCB processing equipment, I think the future certainly holds promise in making these seamlessly interconnected. I think it is likely that this technology will become fully integrated with wet processing equipment. Perhaps it may even get to the point where processing lines can become autonomous. To achieve this, however, there seems to be one more area that will need further development: where data science meets wet processing.

If you look at the technology available today, you can see that the infrastructure for creating autonomous wet process lines is nearly complete. Let’s look at the technology we have at our disposal in wet processing equipment:



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- **Robotics:** To take care of loading and material handling typically required by manual labor
- **Smart connections:** To control your equipment or receive updates anytime and anywhere
- **Real time data logging:** To observe the dynamics of each system in relation to the final product (data collected from equipment controls and quality checks)

To obtain an autonomous process, it seems that all these items just need to be brought together to form one united system that follows the PCB from start to finish. The only thing left to do is to utilize data logging to provide feedback into the system, perhaps with

the smart connects as a universal controller. From there, it is possible that some form of machine learning could be implemented to dynamically interact with the system and make necessary process changes or decisions without requiring someone’s input. With autonomous wet processing lines, we would certainly see major growth in the PCB industry as they became more accessible. If technology continues its current trend, we may see this become a reality sooner than we would expect. **PCB007**



**Christopher Bonsell** is a chemical process engineer at Chemcut. To read past columns or contact Bonsell, [click here](#).

## Lasers Trigger Magnetism in Atomically Thin Quantum Materials

Researchers have discovered that light—in the form of a laser—can trigger a form of magnetism in a normally nonmagnetic material. This magnetism centers on the behavior of electrons. These subatomic particles have an electronic property called “spin,” which has a potential application in quantum computing. The researchers found that electrons within the material became oriented in the same direction when illuminated by photons from a laser.

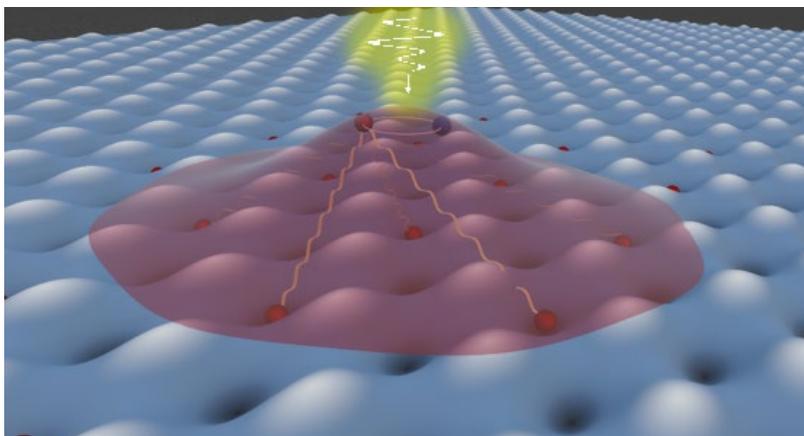
The experiment, led by scientists at the University of Washington, the University of Hong Kong and the Pacific Northwest National Laboratory, was published April 20 in *Nature*.

By controlling and aligning electron spins at this level of detail and accuracy, this platform could

have applications in the field of quantum simulation, according to co-senior author Xiaodong Xu, a Boeing Distinguished Professor at the UW in the Department of Physics and the Department of Materials Science and Engineering, and scientist at the Pacific Northwest National Laboratory.

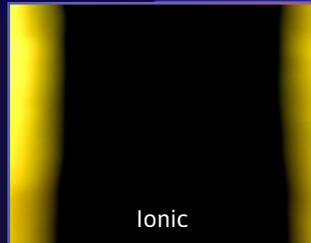
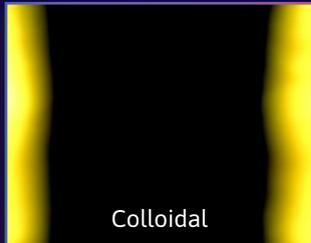
“In this system, we can use photons essentially to control the ‘ground state’ properties—such as magnetism—of charges trapped within the semiconductor material,” said Xu, who is also a faculty researcher with the UW’s Clean Energy Institute, the Molecular Engineering & Sciences Institute, and the Institute for Nano-engineered Systems. “This is a necessary level of control for developing certain types of qubits—or ‘quantum bits’—for quantum computing and other applications.”

The team worked with ultrathin sheets—each just three layers of atoms thick—of tungsten diselenide and tungsten disulfide. Both are semiconductor materials, so named because electrons move through them at a rate between that of a fully conducting metal and an insulator, with potential uses in photonics and solar cells. Researchers stacked the two sheets to form a “moiré superlattice,” a stacked structure made up of repeating units. (Source: University of Washington)



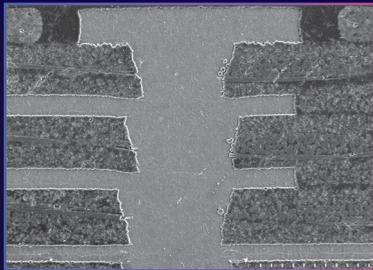
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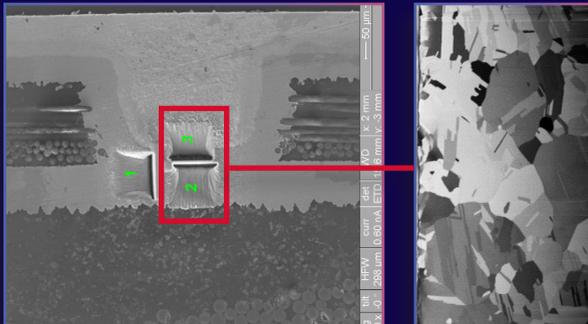
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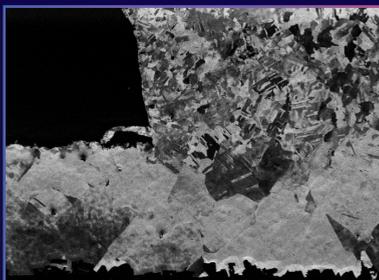
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# Surveying the Fab Landscape: Where to Find ROI



Feature interview by I-Connect007  
Editorial Team

Torsten Reckert and the team at all4-PCB have a uniquely broad view of what's happening in the industry. When we asked Reckert about the hottest areas for return on investment, he shared answers that were insightful and sometimes surprising. Readers will note that this conversation includes multiple references to Alex Stepinski and his approach to developing paradigm-shifting processes at GreenSource Fabrication LLC. Reckert worked closely with Stepinski during his time at GreenSource, and just as Reckert is an expert on the current market, Stepinski is a thought leader on how to optimize processes, making his mention in a return-on-investment conversation particularly valuable.

**Nolan Johnson:** From your perspective at all4-PCB, what are your pain points?

**Torsten Reckert:** The biggest pain point is automation, since the market has very high employment currently and PCB companies don't have access to people to operate their machines. If it's work process equipment, loading a machine, unloading a machine, any kind of process tool, the availability of personnel is very difficult in most parts of North America. Chicago is a significant example. For years, little investment took place to address automation and now the situation is urgent, since finding and retaining labor has become very challenging.

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Integrated automation V-score from Shoda.

It's not necessarily always individual loading/unloading machines that you attach to a piece of equipment, it's potentially pieces of equipment with automation already integrated. We've sold several V-scores with automatic load and unload, where the customer can put a stack of circuit boards on the front of the machine, walk away, and have the job (or jobs) processed, then come back and just pick up the panels on the other side of the machine. This frees up resources that can focus on other issues as the panels are being processed.

**Barry Matties:** Torsten, when you say automation, is it merely to the extent of loaders and unloaders or are they looking for a digital factory as well?

**Reckert:** With existing PCB factories, it's primarily about adding a loader and an unloader to an existing piece of equipment that is already on the manufacturing floor. Alternatively, replacing certain pieces of equipment with automation integrated, like the V-score example, various machine manufacturers are offering new equipment with an integrated loader and unloader. This is much more important than the overall plant automation at present. I think full plant automation is much simpler to implement in the case of a greenfield facility where

you have the space to design everything. Taking an existing factory and automating it, from a product tracking and overall automation standpoint—similar to what Alex Stepinski did at GreenSource—is very challenging in existing circuit board facilities.

**Matties:** You're thinking that to achieve the level of Alex Stepinski is hard to do in an existing facility?

**Reckert:** You need plenty of space. San Jose is a fantastic example. You have quite a few sophisticated facilities

with incredible revenue-per-square-foot but if you want to add loading and unloading automation to their machines, including docking transport carts, buffer stations or connecting conveyors, especially in their wet process areas, there's hardly any space. In many cases, the maximum level of automation that is possible is to add small footprint, custom robot arm solutions to load from tray to machine entrance conveyor and from exit conveyor to a tray or rack. Transport of the tray or rack between machines would be done manually.

Another hurdle is that people still struggle to justify spending a lot of money on automation. There's still a mindset to ask, "Why spend a lot of money on automation when we can have someone load the machine?"

**Matties:** What about batch processing? Is there an automation push on the chemistry side? That was something Stepinski did at GreenSource, and it seemed like it was pretty attainable for any fabricator.

**Reckert:** It's interesting that you bring it up. I spent quite a bit of time talking to Alex [Stepinski]. We were very involved in the GreenSource facility with several equipment vendors.

When it comes to taking individual wet process machines and incorporating more proac-

tive process controls so that you don't need to do as much manual monitoring of the process, most just don't share his vision yet.

**Matties:** You've been visiting the factories and talking to the industry for years. Why do you think that mentality exists?

**Reckert:** The more isolated the circuit board facility is, the more open-minded they are to automating, to having more process controls in place on the wet process machines to do things more proactively. Quite honestly, at least in my personal assessment, which a lot of people agree with, if the vendors are close to the actual customer base, like in California or Chicago, then the customers are accustomed to getting daily visits from the chemical vendors.

Some chemical vendors have staff based in the circuit board shops and they do the work for the customer controlling the processes. It's the same thing with servicing machinery. If a machine is down in Southern California, then we need to jump, whereas if the facility is more remote, they know they have to do first tier



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Small footprint robot arm automation.

service themselves. They have no other choice basically if they want to get the issue rapidly addressed. So, you've got a regionality there when it comes to this topic.

**Matties:** Is there an ROI factor that some of these companies wouldn't see or necessarily be able to reconcile?

**Happy Holden:** You have to separate the system information and data from the automation. A loader/unloader is a very simple form of mechanization, but there are eight to 10 levels of investment before you get to Alex's vision at GreenSource. People need to assess where their need is. If they can't get people, is the need for somebody to load a machine and then unload it? Or do they need experienced people who are going to look at blueprints with years of experience?

**Johnson:** Torsten, am I hearing that the technical aspect—increased capabilities or smaller feature sizes—is taking a backseat to getting the work through the shop because you don't have the staff you need?

**Reckert:** In some cases, for sure.

**Johnson:** Step through some of the manufacturing processes and talk about where automation is reducing the labor requirement? What should a fabrication facility be researching?

**Reckert:** In our experience, the pressure is usually highest in the inner layer processing area because of the quantity of materials that must be handled, and the attention that is required in handling the material to avoid defects.

Key process steps are: the develop/etch/strip line, the post etch punch line, and the oxide line prior to lamination. People want to automate these horizontal conveyerized machines first, if they can. Next steps would be automating direct imaging and possibly AOI.

**Matties:** Are you seeing a lot of interest in the additive market? When you add it all up, it seems a reasonable investment to bring additive as a capability into a facility.

**Reckert:** There's a lot of discussion, and some people are trying it. But this is something people must be very careful about. I'm sure Happy



Enclosed automation with transport cart.

remembers, but in the 1990s, HDI technology with resin copper foil and other methodologies was coming to the U.S. It was in demand for consumer electronic type products, like cell-phone boards. It needed tight geometries even by today's standards. In the U.S. market, almost nobody was willing to invest in the equipment, the clean room areas, and everything that you needed. As a result, it didn't happen. The Asians addressed that need very rapidly and consumer electronics shifted to Asia. Virtually nothing got built in North America. The Asians would just build greenfield plants with all the necessary equipment to do it right in a very clean environment. It's a question of real commitment to the objective of being able to do real additive technology production.



Torsten Reckert

**Matties:** Your example from 20 years ago—do you bring that up because you have some doubt that additive will land here?

**Reckert:** I think it's actually going to happen now because current geopolitics point to the need in North America to become independent of Asia. If the U.S. strategically wants to be independent from a supply chain standpoint for very critical product, then the capability has to be here in North America.

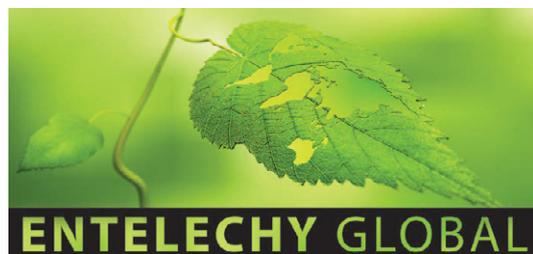
Instead of supporting a country like Russia to develop their circuit board manufacturing capabilities for military purposes by selling a lot of sophisticated capital equipment into that market during recent years, focus should be on developing more advanced technology facilities in the West. Everybody's seeing that now with the Ukraine situation and China. There could be a lot of tension in the future. So yeah, the U.S. has to get involved in this high-density interconnect technology, which I know, Happy, you've been preaching for 30 years.

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**Holden:** With semiconductor down to a couple of nanometers for the transistor, we're now talking about 114 billion transistors for the new Apple M1 super chip. Those chips require 3,000 IO pins and a circuit board with 3,000 pads at a very fine pitch. It's what the semiconductor guys drive us to.

**Reckert:** And now they need to be built in the U.S. vs. in South Korea, Taiwan, or Japan. Additive technology for outer layer fine lines and spaces is definitely here to stay, but there's still a lot to learn to make it successful; there's hardly any experience in North America.

**Matties:** What's the most important advice you give a fabricator regarding equipment?

**Reckert:** The service level is really important, of course. We at all4-PCB support a lot of different machines. Equipment suppliers and customers should work closely together to identify the most crucial spare parts that should be kept by the customers.

When a customer is bringing in a new machine for a certain process step, we advise strongly that they invest in the additional spare parts. One customer in Idaho, for example, has been purchasing a set of spare parts for every machine they're installing.

**Matties:** They're doing it right then.

**Reckert:** They're doing it absolutely right. GreenSource was doing the same thing as well.

**Matties:** Well, it's unplanned downtime otherwise.

**Reckert:** Absolutely.

**Matties:** When you look at the industry over the past few years, what innovation strikes you as being the most amazing or most important in your estimation?

**Reckert:** The big idea everybody wants to see happen is inkjet solder mask. That would, as

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you know, remove quite a few process steps in a smaller footprint.

**Matties:** Is zero waste an issue out there for people? Is this a driving topic for people?

**Reckert:** Not yet. Not for the existing facilities that already have a process in place for dealing with the wastewater. It's not their priority. But for a green-field plant, it's a very sexy proposition.

**Matties:** When someone says automation, there's this image of this lights-out factory.

**Reckert:** I think there's resistance to really investing in automation. Over the past couple decades, people have thought automation was just a necessary evil; what does it really add to the value of the circuit board that we're selling to the customer? But that resistance is weakening.

The first step of automation is to put on a loader/unloader; this is typically how people have thought. To be honest, it's not just about putting a loader/unloader in front of a piece of equipment. But again, in the Bay Area you'll see firms where they put in these wet process machines and never even considered budgeting space for automation. This was the mentality until not too long ago.

**Johnson:** Are they willing to retrofit if it's possible?

**Reckert:** That interest is coming up now. That's why I brought up the topic initially because there is that interest. How do we take the small footprint that we have in front of our developer



Automatic mylar peeler is needed prior to DES (from Sowotech).

or etcher before let's say the develop edge strip line? How do we automate loading in layers and unloading from our wet process equipment, with the small footprint that we have available?

**Johnson:** The major theme here is automation and WIP handling are the big issues, to the point that pursuing additional competitive capabilities takes a back seat to actually getting work out the door, period.

**Reckert:** I agree.

**Johnson:** Torsten, I think this has been eye-opening. There are some different perspectives to look at here than I would've anticipated.

**Matties:** We appreciate you, Torsten, very much. Thank you so much.

**Reckert:** Have a good day. PCB007



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# Chemcut's Robotic Solution

Feature Interview by the  
I-Connect007 Editorial Team

The I-Connect007 Editorial Staff spoke with Chemcut's Jerry Reitz, and Atlantic Microtool's Bruce Siemering and Neil Robinson about recent robotic automation advances, a specific robotic solution from Automata, and the changing factors tipping toward robotic automation in the current market.

**Nolan Johnson:** While robotics in the PCB fab area have been on the cusp for quite some time, it seems they haven't taken off. Chemcut has been working with Atlantic Microtool and Automata on a possible solution. What motivated you to partner on robotic handlers now?

**Jerry Reitz:** By no means is this a large, industrialized robot. We believe that it is a fit for most of our customer's applications, from small shops with smaller budgets and limited space to large facilities looking for a plug and play solution for large volume production.

**Andy Shaughnessy:** Who's the manufacturer?



**Bruce Siemering:** The robot arm is manufactured for Chemcut by a robotics company out of the United Kingdom. Atlantic Microtool, which is owned by me and Neil Robinson, made the initial contact and introduction to Chemcut.

We wanted to solve this problem where somebody is running a conveyorized line, and they're loading a metal panel or a circuit board every 30 seconds, and they're just standing there, or they're running around to the other side to unload. It's a mundane job that would be a perfect fit for this robot.

As we were looking for a robot, we noticed the ones we found were a little more difficult to program because the software was intimidating. One of the attractive features of this

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BY TAIYO



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robotic handler we offer is that the software works on top of Python, which is a common software that runs automation.

It's very easy to use and it's not intimidating. When we first sent a robot to Chemcut one of their engineers, Dan Dietz, had it up and running in an hour or two. You can pull it out of the box, follow the instructions, and program it pretty rapidly to pick something up and move it to a conveyor. There's not a very complex tool path with it.

**Neil Robinson:** When we've done demonstrations in the field, we show up at a customer site and within 45 minutes, we are actively loading product onto any conveyORIZED line. Not only is the setup simple, but it's very simple to operate. Anybody who works in a manufacturing facility could be taught to program this robot within a couple of hours, unlike other industrial robots that have equally sophisticated software that require certain expertise to program. As Bruce pointed out, the software used to program this robot is a very user-friendly shell that sits on top of Python. Through graphics on the screen, two buttons that reside on the robot, and a mouse, you can create pretty sophisticated programs to load and unload equipment. The robot also has several digital inputs and outputs for sending and receiving commands from other equipment and devices.

**Johnson:** Is the handler so specialized that it only works well in a board fab application, or can it be used for other purposes?

**Robinson:** This robot wasn't originally designed for the chemical milling or PCB industries. Actually, most of the early applications were in laboratory automation. We've taken that robot



Bruce Siemering

and adapted it to chemical milling and the printed circuit board industries with the use of specialized suction grippers. The robot can also be equipped with other tooling to handle many different applications, but primarily we are focused on the conveyORIZED equipment that Chemcut offers.

**Johnson:** With such an easy setup and operation, are your customers buying into the idea?

**Robinson:** Yes, overall, there are 300 to 400 units in the field with the first chemical milling installation in the United Kingdom. That unit has been in operation for a couple of years and the robot is holding up very well to that chemical environment.

**Siemering:** That was one of the initial questions and concerns when we brought this to Chemcut. They said, "Is this going to hold up in this chemical environment, which tends to eat the rafters out of the ceiling?" A typical chemical milling shop is an even harsher environment, sometimes, than a PCB environment. The robot has been in place for two years now and we have had no issues. The exterior is all plastic and sealed up very well. There's not a separate electrical box that has to hang somewhere. Everything, including the software, is inside the base of the robot. It's compact and affordable. Someone can get started with some common tasks around a PCB or chemical milling facility and put the person that was running that machine to better use, or they can operate two or three machines.

**Johnson:** Jerry, what is the value proposition that you see at Chemcut when attaching this handler to your equipment?

**Reitz:** We see a great value-add to it. One of the things that we've always struggled with is finding automation equipment that will stay affordable and offer a small footprint. We've demonstrated this to several customers and at the IPC APEX EXPO show, it seems to be a very high interest offering from us. There are a lot of great third-party material handlers out there. The biggest problems, though, are they are high cost, very difficult, and typically very large. So, for us at Chemcut, this is a perfect fit.



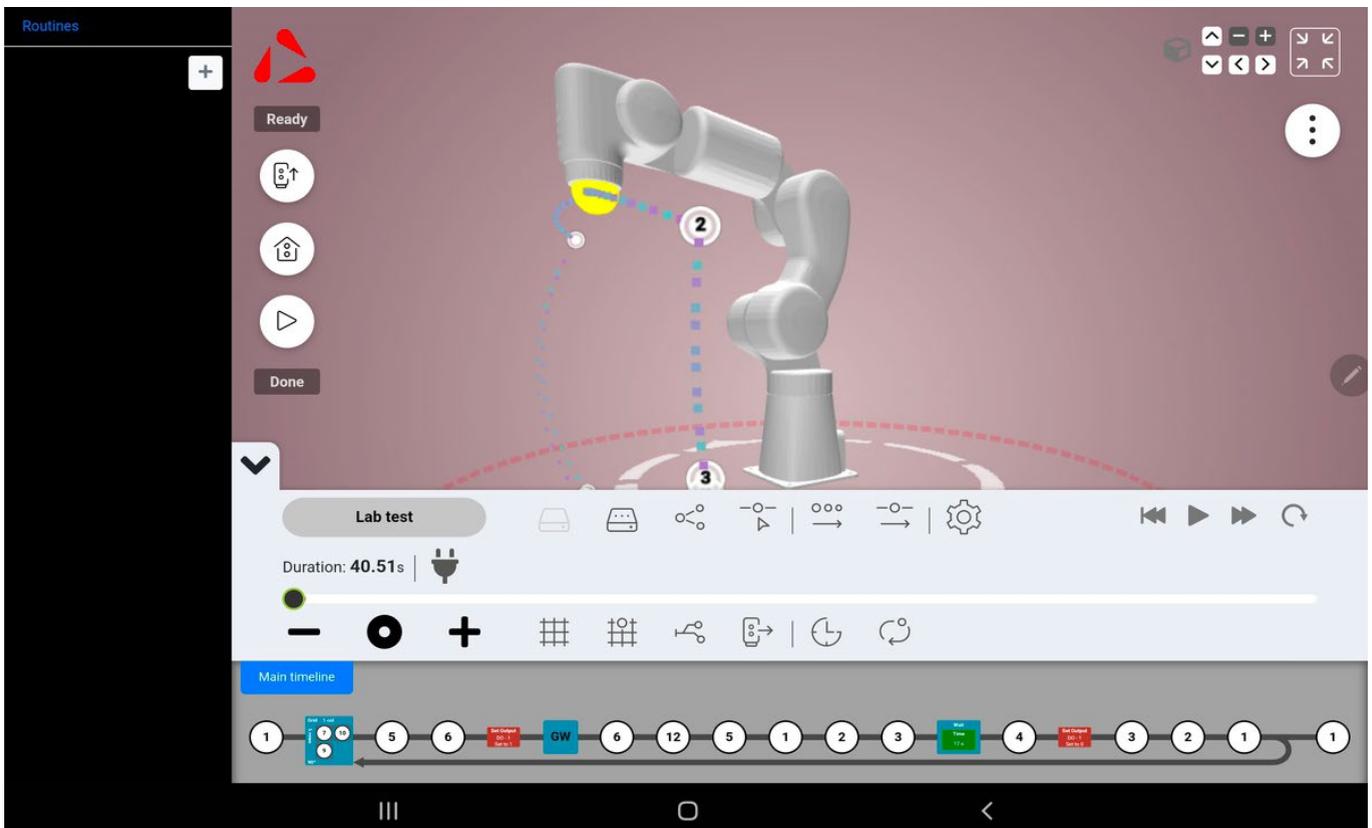
Jerry Reitz

**Shaughnessy:** What is the situation for your end customer? What are the pain points that they're talking to you about which make this automation so much more valuable to them?

**Siemering:** The people we talk to, be it chemical milling or PCB, are having a hard time finding people to come in, apply for the job, and stay in the job. This job can be mundane, standing there, loading panels. Sometimes one person is running a machine, loading their five or six panels, and they run to the other end of the machine to unload. If the line is going into a cleanroom, they have to load the machine, suit up and run in the cleanroom and grab the

five panels that come off; it's just not efficient.

We just have one chemical clean install where the robot can load 20, 50, or however many panels, while the operator unloads in the cleanroom, and moves the panels to the next process. As far as an ROI, it is less than six months,



Close up view of the robotic arm's user interface.



so it is a no brainer. As soon as they looked at it, they said, “We’ll just take it.” It won’t necessarily eliminate jobs, but rather that person operating the line will be working more efficiently. Sometimes there’s a fear that people will lose their job to a robot, but if somebody’s running one machine, that same person can probably have an easier day running two machines with the help of a robot.

**Johnson:** Is that how customers realize increased capacity, throughput, and top line sales?

**Siemering:** Yes. The installation Neil referenced in the UK was initially on a chemical clean line. They doubled the throughput of the line, with just the same person running it. For them, the purchase was an easy decision to make.

**Johnson:** In the spirit of doing return on investment calculations, what’s the asking price right now for the Automata robot?

**Reitz:** For the robot itself, it’s \$21,000, without

any heads. A fully functional robot right out of the box is around \$25,000 to \$26,000.

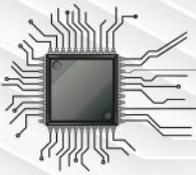
**Johnson:** One half of a full-time employee over six months is going to deliver that return, isn’t it?

**Siemering:** Yes, plus the increase in throughput.

**Robinson:** Regarding ROI, keep in mind that while it does replace a half of an employee, that’s also over multiple shifts. The robot can work three shifts a day, which improves ROI significantly.

**Johnson:** Not to mention the programming complexity that goes along with the other sort of robots you’re mentioning is extremely high—they’re usually optimized for doing a few highly intricate jobs such as welding or material management at a larger scale than PCBs.

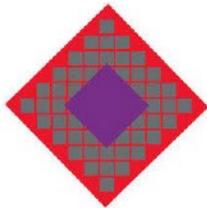
**Siemering:** We feel this robot is a really good fit for the PCB facility. Initially, we’re saying that the chem clean line is the simplest thing to set it



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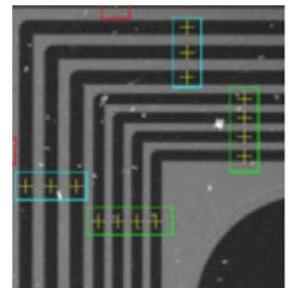
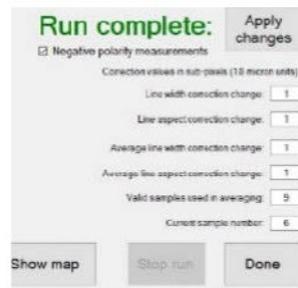
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up on. Once they learn and understand it, and are a little more comfortable with what they can program on it, they'll find other applications within the facility.

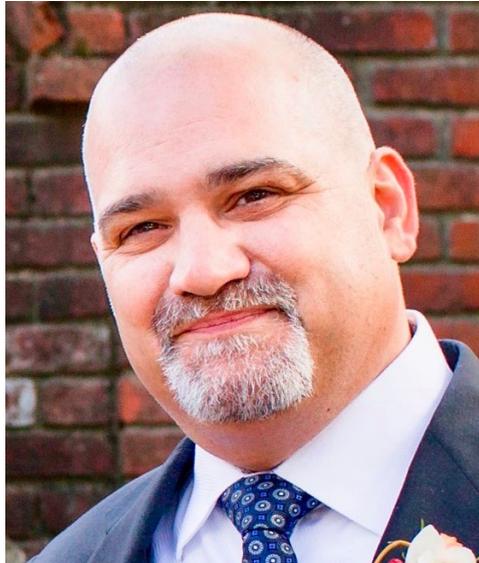
For example, last month I was visiting a customer. As we walked through the plant, he was pointing out areas he would like to automate. Many of them were a perfect fit for this robot while others needed another solution.

We partnered with Chemcut because we wanted their assistance with the add-on integration, making it easy for an existing customer to add automation into their process. Regarding the setup that you saw at the IPC show, Chemcut designed the bracket and the rack. It's adjustable and can handle different size panels making it easy for customers to transition from one job to another.

**Robinson:** Both pieces of equipment work in concert with one another, so if the Chemcut machine stops, the robot will wait for the machine to be ready for the next panel.

**Johnson:** We're starting to talk about including material automation into an existing factory. Much of the conversation is that you can bring that process automation into your factory when you're building a greenfield, but upgrading an existing facility is something that a lot of people shake their heads at. They say it's just too much work, not worth tackling. It seems like this application is proving them wrong.

**Reitz:** I agree. All the Chemcut customers we've shown are very excited about it. They want us to demonstrate the unit and they are already sending samples into our lab. We have



Neil Robinson

a full-scale R&D lab where we're going to demonstrate using their parts and panels for proof of concept for them. It's getting more interesting by the day.

**Shaughnessy:** In the spirit of talking about the good, the bad, and the ugly, what can't this robot do? Are there material types that just don't seem to work, based on the current experience?

**Robinson:** There is a payload limit, which is just under three pounds so certain panels—like large backplanes—might be beyond the payload of the robot. But it will handle the majority of most customers' workloads.

**Johnson:** What happens in a high-mix situation where they may be running jobs that the handler can't handle? What do they do?

**Robinson:** With the small percentage of product that exceeds the payload the robot would remain parked off to the side and it would be business as usual. They would just run the machine the way they have been for years.

**Johnson:** It's not in a situation where they actually lose old school functionality by integrating the robotic handler?

**Reitz:** Not at all. The base of the robot is only six inches by six inches, so it does not take up a lot of space.

**Siemering:** With the bracket that Chemcut designed and demonstrated at the IPC show, the material is always picked up in the same spot—the center—therefore, the dimension of the panel doesn't really matter.

**Johnson:** It sounds like the key data point, then, for teaching a panel to handle it, is to simply identify the center.

**Siemering:** Yes, and the end of arm tooling can be configured to pick up any size panel. One of the applications we were working on was 12 by 24 inches, but it was stainless steel that was 0.003” thick.

**Robinson:** The thin stainless steel would have the tendency to sag in the middle, which could cause handling issues in the form of dents and creases. In that application, we just added extra suction grippers in the middle; instead of having a standard four suction grippers it has increased to eight to keep the material from any sag in the center.

**Johnson:** I presume those extra four suction cups didn’t hurt the application on more rigid materials either?

**Robinson:** It certainly wouldn’t, and it certainly wouldn’t hurt to have more suction cups.

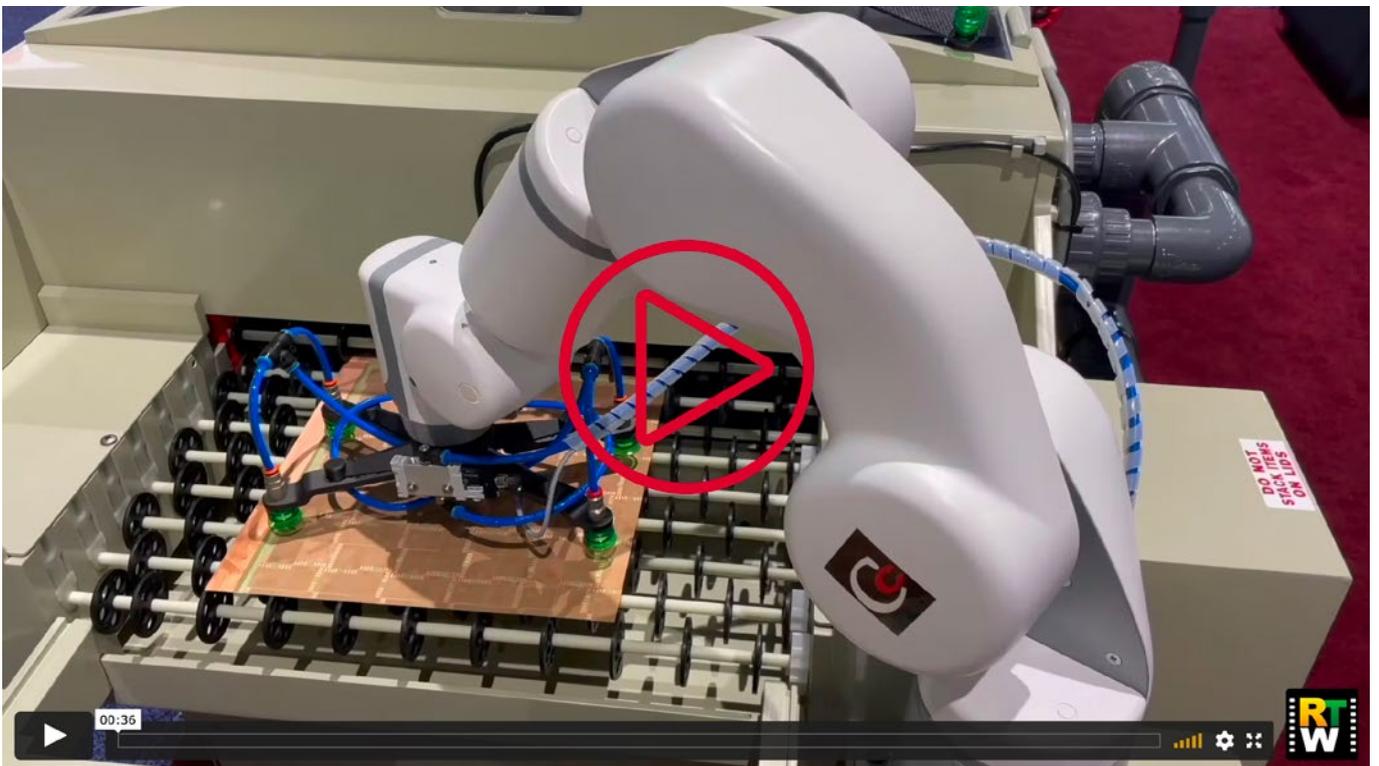
It’s just a matter of whether it is needed or it’s overkill.

**Shaughnessy:** How does service and support fit into this equation?

**Siemering:** That’s one reason we wanted to partner with Chemcut, because they already have an established global service network. If you’re in Washington or California, you buy a robot from us in New Hampshire and you can’t figure something out, Chemcut’s service team is all over the place. They’ll be able to help resolve the issue.

Plus, this robot is small enough that if the problem just can’t be rectified onsite, or there’s a mechanical defect, we would just box up another robot, exchange them, and we figure out the issue back in our facility. Customers are more comfortable, though, when there’s support close by.

**Shaughnessy:** Gentlemen, thanks for your time and insight. PCB007



# Candor Nails the ROI With InduBond



## Feature Interview by Nolan Johnson

I-CONNECT007

Nolan Johnson follows up on his original interview with Sunny Patel, engineering manager at Candor Industries, about the economics of this new InduBond® X-Press 360 lamination press. It sounds like Patel has hit the “easy” button with the installation of this machine.

**Nolan Johnson:** You recently installed the InduBond X-Press 360 lamination press. There’s a lot of hype and promise around this particular technology regarding energy savings and versatility. What are your impressions in using this press?

**Sunny Patel:** Well, the hype is real. It’s such a great machine. Because of its simplicity and the flexibility of use, I find it a lot easier to work with than our previous press. The energy

savings speak for themselves; the capabilities of going up to 375°C and 65 kg/cm<sup>2</sup> pressure allows us to do pretty much any kind of pressing. The name of the game right now is to try to increase your available capabilities; the press does that without many difficulties. You don’t need a PhD on the machine and it’s very easy to use. We’re very happy with it.



Sunny Patel

**Johnson:** That’s great to hear. Capabilities and energy use are two of the things that are significantly better. Is there a positive impact on throughput?

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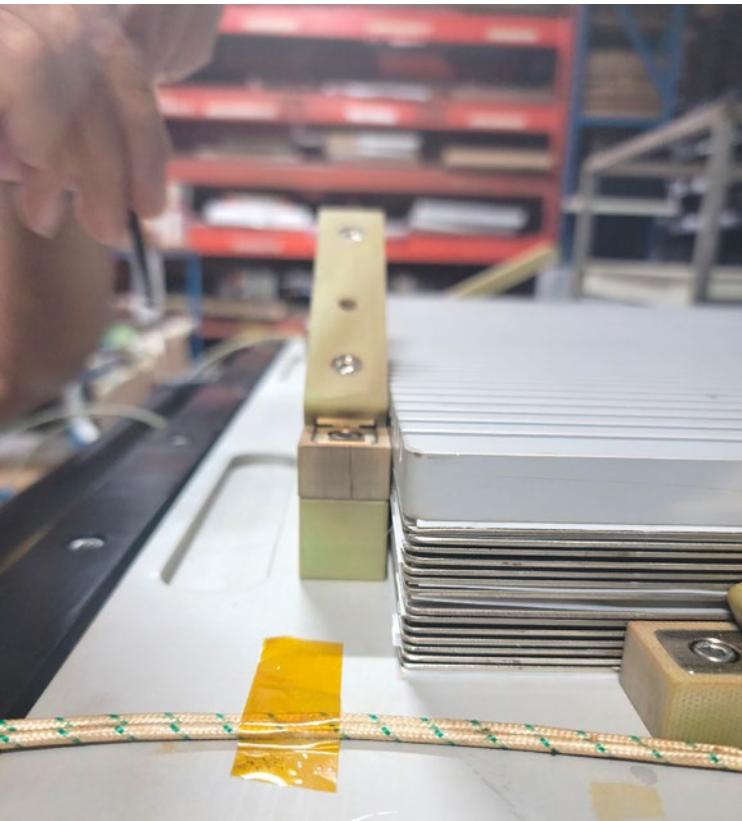


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Close up view of the Indubond press in action.

**Patel:** Yes. The system that we used before was a good system. But the nice thing about the InduBond is you can control both the heating and the cooling. Because everything is so dialed in, the time we used to take to wait for the cooling has dramatically decreased. There's a lot of throughput increase as well, not only on that side, but also the layout process, because previously we had use a continuous copper foil lamination system. Other people may not have the same problem; they would have problems with pinning. Our headache may not have been pinning, but other board shops may find this a lot easier because it's a pinless system.

You don't have to move around bulky press plates. Just build your book, put in your stainless steel, and just keep stacking; it's simple to do. I can do it and I never ran a press before this one. Overall, throughput has increased, just because of the capability. The smaller your press stack is, the faster you can heat up because there's less load. You can even do the small quick-turns pretty fast.

**Johnson:** Have you had a chance to put together some numbers on how the operating costs have changed? For example, you said that the energy savings are dramatic. What are the numbers?

**Patel:** I don't have the numbers in front of me, but I believe I calculated one press before to be \$40 or \$50 a lamination press cycle. Now it's around \$5. If you add up all the presses, it's quite a significant savings. Not only that, but we're using less copper. And because the layout is easier, we're saving on time.

**Johnson:** I know it's a relatively new machine to you, but regarding calibration and preventative maintenance, does that look like that's better than the old press or the same?

**Patel:** The press plates are easy to maintain. The only thing we have to do is add oil and clean filters. There aren't many moving parts. The maintenance is easy.

**Johnson:** Is there anything out of the whole equation that you would say is not as good, maybe is worse?

**Patel:** Not really. I haven't seen anything negative about it.

**Johnson:** Tell me about the install process. What was that like?

**Patel:** The team at InduBond comes to help with the install, but the actual process for our side was pretty easy. We had to make sure the piping was there for the chiller and ensure that all the electrical was in the right spot, like any standard equipment install. I don't remember anything out of the ordinary because it's pretty self-encased except for the water.

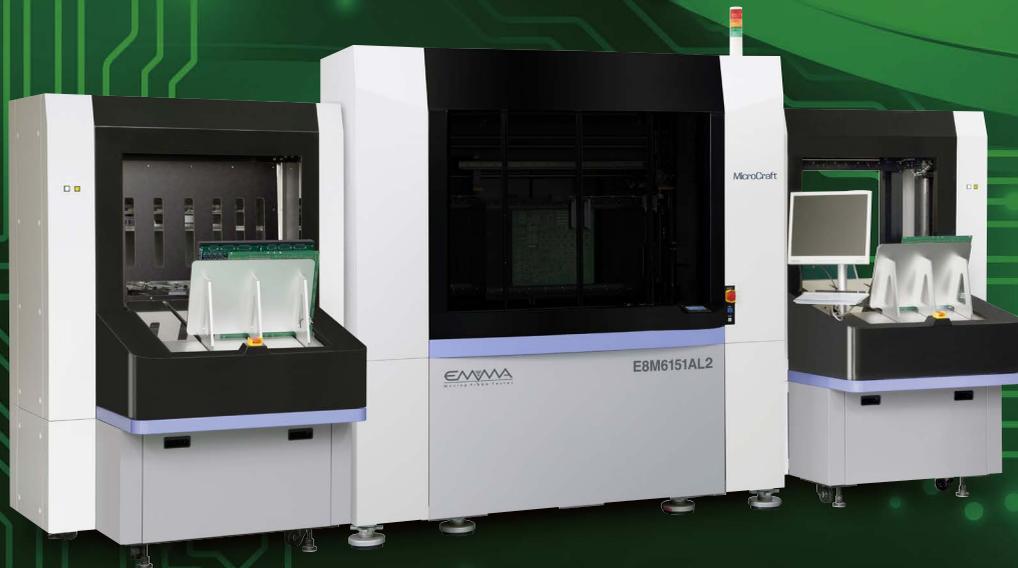
**Johnson:** Was bringing in water something you did not need for the previous press?

**Patel:** That's right. That was the problem with

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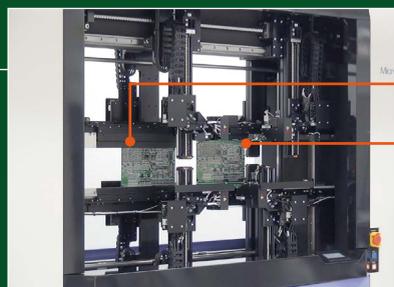
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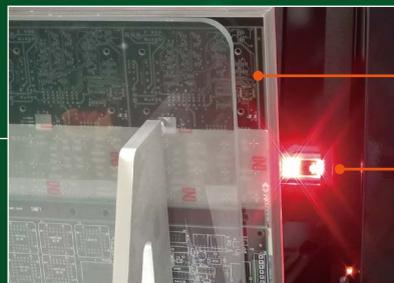


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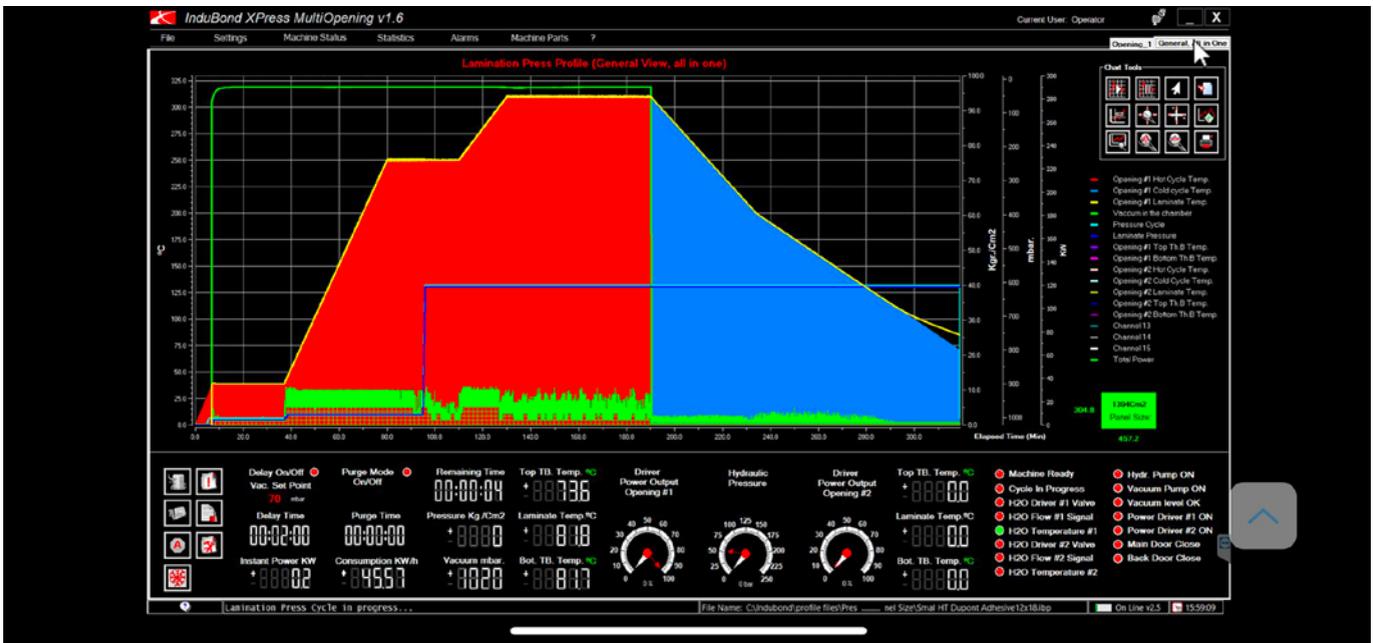
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Precise temperature control enables new process capabilities.

the previous press: it wasn't an active cooler, we had to sit and wait while it cooled itself down.

**Johnson:** Was there anything that surprised you, something that you weren't expecting?

**Patel:** One thing was that it was a lot easier to start. I thought it would be more difficult to get used to, but the transition to the InduBond press was almost seamless.

**Johnson:** Wow.

**Patel:** It surprised me. Maybe one downside was that it took some time to get used to how to actually set up the panels, but even with that, it's easier than before. Like all new technology or processes, there's a learning curve.

**Johnson:** That sounds clean and easy. You're obviously a happy customer.

**Patel:** We're about to push the limit from our side. We're going to run some 300°C press parameters for the DuPont Pyralux® HT material this week, and hopefully this year we can

go into fusion bonding, which is the Teflon® high temperature stuff. We're still trying to push our limits on the press, and so far it's been doing its job.

**Johnson:** Great. That opens the opportunity for you to take on some new technologies.

**Patel:** Yes, exactly.

**Johnson:** Is there anything else you'd like to share?

**Patel:** The nice thing is that the InduBond team is very available. I know that with some companies people can be hard to track down, but Victor Lazaro, the CTO at Indubond, and his team have been easy to deal with. If I have any questions, they're pretty fast at figuring it out and sending me instructions. It's been a good partnership, which is what we expect with our suppliers.

**Johnson:** I appreciate your time. Have a great day.

**Patel:** You too. PCB007

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# DoD is Unarmed Without the PCB

## American Made Advocacy

by Travis Kelly, PCBAA

It's been more than 800 days since the global COVID-19 pandemic upended the supply chains of almost every industry. Whether it's a shortage of commercial and consumer electronics, or automobiles, businesses and their customers are bearing the brunt of what decades of offshoring and billions in foreign manufacturing subsidies have caused.

One sector that sometimes escapes the attention of everyday Americans is aerospace and defense, where high-tech platforms and equipment are essential to mission success. Our modern world relies on electronic systems, and defense applications are no exception. When a semiconductor is connected to a printed circuit board, amazing feats of engi-

neering are possible. The PCB is the central nervous system that connects chips to everything from night vision goggles to next generation fighter aircraft.

Put simply, planes don't fly, ships don't float, tanks don't roll, and weapons don't fire without modern and trusted microelectronics.

Leaders at the Pentagon understand this reliance. That's why the civilian and uniformed leaders have been calling for increased investment by Congress and other agencies of government. The Honorable Heidi Shyu, the Undersecretary of Defense for Research and Engineering, has emphasized repeatedly the need for America to reshore its microelectronics manufacturing capacity. She and others in





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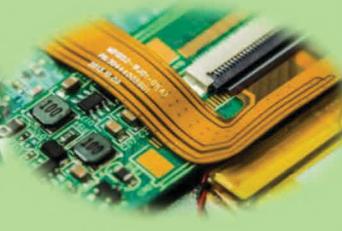
## Applications



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## Markets



Medical



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5G

the national security space see the trends, and they are justifiably concerned. In fact, micro-electronics are one of six “technology pillars” designated by DoD to invest in.

Over the past two decades, domestic production of printed circuit boards has decreased from 26% to 4%. In that same period, the industry has shrunk from nearly 2,500 U.S.-based companies to only 145. This invites unacceptable supply chain and national security risks. As we modernize our military and address global threats, policymakers should consider the following:

- A modern military must be a high-tech military. From electronics that our men and women in uniform wear into battle, to the precision weapons and systems in every military service, printed circuit boards make it all possible.
- Supply chain security is national security. To trust that military systems are secure and reliable, we need to trust where

every component originates. From rare earth raw materials to the most complex platforms, we can't afford to wonder who made it, where it came from or even if it will arrive on time.

The ubiquitous nature of printed circuit boards demands a secure and reliable domestic supply chain. The Printed Circuit Board Association of America was formed to educate, advocate, and legislate with this outcome in mind.

The members of the PCBAA are proud to provide technologies that contribute to our nations' defense. If you're interested in joining our effort, please visit us online or contact me directly. **PCB007**



**Travis Kelly** is CEO of Isola-Group and current chairman of the Printed Circuit Board Association of America. To read past columns or contact Kelly, [click here](#).

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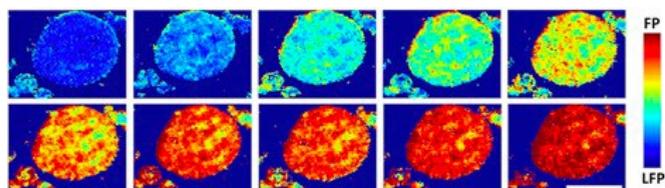
## Lithium's Narrow Paths Limit Batteries

Rice University researcher Ming Tang worked with the U.S. Department of Energy to analyze nano- and micro-scale interactions within lithium iron phosphate cathodes through modeling and imaging offered by the transmission X-ray microscopy capabilities at Brookhaven National Laboratory and Argonne National Laboratory.

Their paper in the American Chemical Society journal ACS Energy Letters supports theories Tang and his colleagues formed several years ago that foresaw how lithium travels in the dynamic environment inside a typical commercial cathode.

Being able to watch sealed cathodes charge and discharge at Brookhaven offered absolute proof.

“Batteries have a lot of particle aggregates that soak up and give up lithium, and we wanted to



know what happens on their surfaces, how uniform the reaction is,” said Tang, an associate professor of materials science and nanoengineering. “In general, we always want a more uniform reaction so we can charge the battery faster.”

In images taken at Brookhaven's powerful X-ray synchrotron, the researchers saw some regions inside the cathode were better at absorption than others. The ability to look at single or aggregated particles in 3D showed that rather than reacting over their entire surfaces, lithium favored particular regions over others.

“This is very different from conventional wisdom,” Tang said. “The most interesting observation is that these reaction regions are shaped like one-dimensional filaments lying across the surface of these aggregated particles. It was kind of weird, but it matched what we saw in our models.”

Tang said the lithium filaments looked something like thick nanotubes and were several hundred nanometers wide and several microns long.

(Source: Rice University)

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# A Textbook Look: Signal Integrity and Impedance



Article by Pete Starkey

I-CONNECT007

*This article originally appeared in Design007 Magazine, May 2022 issue.*

Believing that I knew a bit about signal integrity and controlled impedance, I was pleased to take the opportunity to connect with an educational webinar that I hoped would extend my knowledge. In the event I was surprised at how little I actually knew, and the webinar was an excellent learning opportunity.

Jointly organised by NCAB Group, Polar Instruments and Phoenix Contact, it brought together three expert speakers who shared their knowledge on the theoretical basis of signal integrity, the customer technical and engineering support provided by a global PCB

supplier, and the design and optimization of high-speed data connectors.

The webinar was introduced and expertly moderated by Anna Brockman, team leader campaigns and media management at Phoenix Contact in Germany.

Hermann Reischer, managing director of Polar Instruments in Austria, gave the clearest first-principles explanation of signal integrity and controlled impedance that I have experienced in many years. He made the topic intelligible and understandable by breaking it into its most basic elements and explaining each in plain language with meaningful illustrations.

Against a background of high-speed requirements such as 77 GHz analogue frequencies in

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automotive radar applications, and ever-rising digital data rates with pico-second rise times, the printed circuit board ceased to be a passive interconnecting substrate and became a complex component in its own right. A PCB trace behaved like a transmission line when its physical length was of the same order as the electrical wavelength of the transmitted signal.

He examined the properties of a transmission line: in addition to its DC resistance it experienced a propagation delay depending on the dielectric characteristics of the material surrounding it, which also contributed to losses as well as those attributed to copper roughness and line length. The transmission line had a characteristic impedance determined by trace width, dielectric spacing, and relative permittivity. All of these parameters needed to be considered in order to ensure signal integrity, which became increasingly difficult to maintain as frequency increased. PCB material selection and stack-up, trace width, dielectric separation, design and layout, and component placement were all critical.

Reischer explained how a transmission line could be considered in terms of a series of inductors and capacitors and described how a signal was propagated along it, charging each successive capacitor element. The goal was to achieve constant impedance across the entire length of the line, with a uniform voltage and current wave-front in order to ensure good signal integrity. The propagation speed of an electromagnetic wave was a function of the speed of light and the permittivity of the dielectric, which for air or vacuum was 1.0. In typical PCB materials with relative permittivity around 4.0, the propagation speed was reduced from the speed of light to about half that value.

The “critical line length,” beyond which a conductor would be considered a transmission line, was related to the rise time of the signal.



Anna Brockman

Early semiconductor devices had rise times of around 5 nanoseconds, giving a bandwidth of 70 MHz and a critical length of 36 cm. Current gallium arsenide devices had rise times of 0.3 nanoseconds, giving bandwidth of 1.166 GHz and a critical length of 2 cm.

He clarified the differences in propagation characteristics between low-speed and high-speed signals, and he explained the ways in which electromag-

netic waves were reflected at impedance discontinuities. Impedance matching offered a solution, and he gave an example of a typical transmission system where the impedances of the source, the transmission line, and the termination were matched at 50 ohms. This was generic in a radio frequency environment; 75 ohms was typical in video applications, 90 ohms in USB transmission, and 100 ohms for Ethernet.

Reischer commented that his system example illustrated the essential interaction between the three companies contributing to the webinar: Phoenix Contact supplying interconnects, NCAB Group supplying printed circuit boards,



and Polar Instruments supplying simulation tools for calculating impedance.

So how to make sure that the transmission path had the correct impedance? He took a familiar example of a coaxial cable, whose impedance was determined by its geometry and the permittivity of the insulating material and demonstrated how the principles could be adapted to the planar structure of a PCB in the form of an offset stripline. The geometry and the permittivity of the material determined the impedance, and he showed a range of examples of “single-ended” structures. In contrast were “differential” structures, widely used in digital transmission systems, usually consisting of two traces running in parallel and coupled with a capacitor. The advantages of differential signalling included improved noise immunity, lower voltage requirements, and higher data rates.

Reischer listed the factors influencing impedance. Trace width was the most significant and was simple to modify. Substrate height, relative permittivity, and copper thickness were determined by material selection, and etch-back



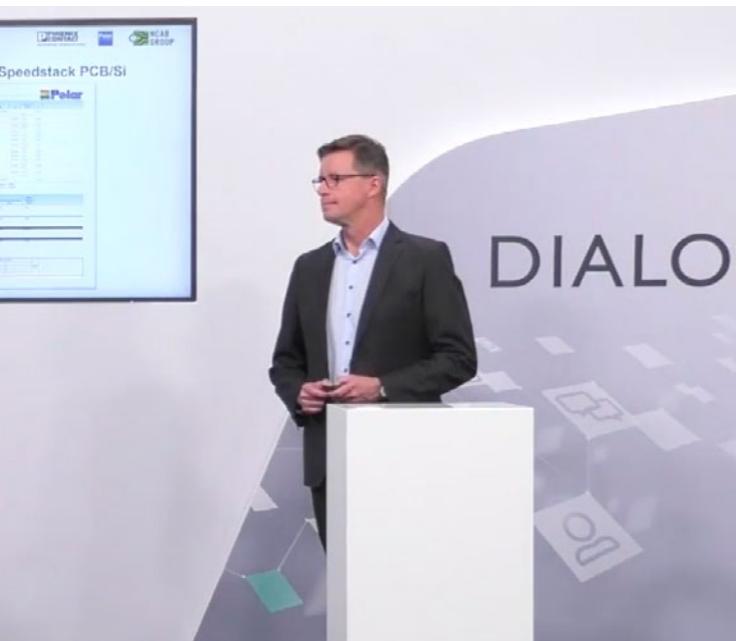
Hermann Reischer

was process-dependent. Solder mask thickness could have a significant effect on the properties of edge-coupled microstrip designs, as could the influence of local resin-rich areas if similar features were embedded within the structure of the PCB. He discussed the practical aspects of resin distribution and thickness control during multilayer pressing.

Vias gave some interesting effects; they were generally quite small compared with the wavelength of the signal, so they could normally be ignored except at extremely high frequencies. But on thick boards, as via stub-length approached a quarter of the wavelength of the signal, they could cause undesirable resonance. Back-drilling was a technique used to mitigate these effects.

Future challenges included tighter impedance tolerance specifications, lower dielectric thicknesses and narrower trace widths. Frequencies beyond 5 GHz resulted in “lossy” transmission lines; dielectric losses could be reduced by using new base materials and smoother copper could reduce skin effects, both at increased material cost. From a design point of view, Reischer recommended keeping traces as short as possible and ensuring uninterrupted signal return paths. For various reasons it was preferred to place critical lines on inner layers. And he emphasised the importance of consulting with the PCB vendor on stack-up design and material selection before commencing the layout.

Reischer’s presentation delivered a comprehensive theoretical background to the concepts of impedance control and signal integrity. His closing comments about consulting with the PCB vendor before commencing the layout provided a perfect opening for Michiel Op den Camp, engineering manager for NCAB Group Benelux, to give an insight into the technical





need for materials with better and more consistent dielectric properties. His triangular representation of low-loss materials had FR-4 grades at the base and PTFE at the apex, with many proprietary products occupying the intermediate levels. Not just price, but availability, could influence the choice and again he stressed the importance of consulting the PCB supplier before specifying a particular proprietary material.

Turning to the characteristics of woven-glass reinforced materials, he illustrated how glass weave and resin content could cause local variations in dielectric constant and hence the impedance uniformity of embedded conductors.

He discussed details of component placement and conductor routing, and gave several examples of good and bad practice in optimising signal integrity. It was clear that Op den Camp himself had high-level expertise as a designer in addition to his knowledge of materials and fabrication technology. He echoed Hermann Reischer's comments on the benefits of back-drilling via stubs, and also recom-

mended the removal of non-functional pads on high-speed vias.

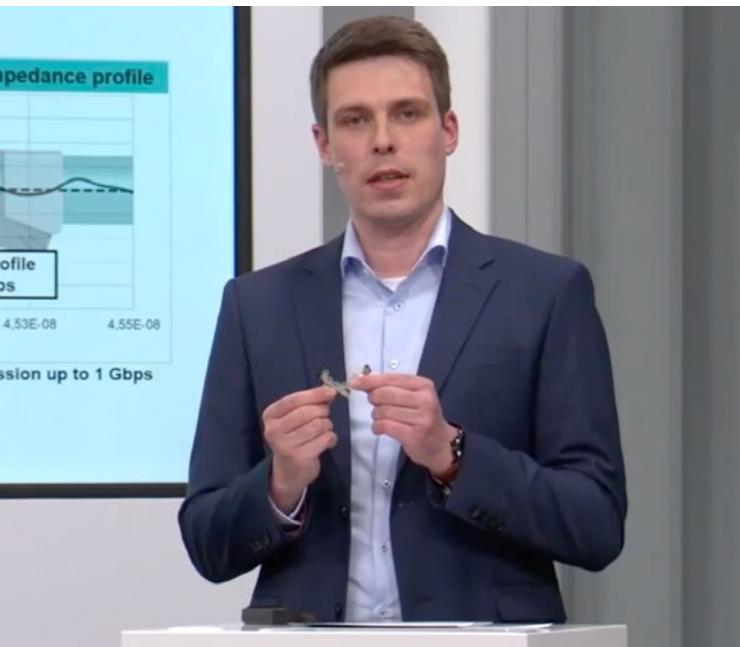
NCAB had a whole series of [design rules and guidelines available for download from their website](#), and their applications engineers were always on hand to answer specific questions.

Having learned the theoretical background of signal integrity and controlled impedance, complemented by a review of the practical aspects of the design and manufacture of printed circuit boards for high-speed applications, it remained to explore the technology of ensuring the integrity of the signal as it passed through interconnecting components. The final presentation came from a Phoenix Contact specialist in the design and optimisation of data connectors, Sebastian Stamm.

He began by making it clear that although signal integrity was a very important consideration, it was one of many product requirements. Cost and installation space were factors that reduced design freedom. Therefore the target was not to achieve signal integrity at any price, but to produce application-oriented connectors with high signal integrity.



Sebastian Stamm



the target was to achieve the same impedance profiles within a product family so that the customer had the advantage of a scalable device design without influencing signal integrity.

In the case of wire-to-board connectors, where transmission frequencies and requirements such as return loss were specified, the target was to optimise impedance profiles until the transmission requirements were satisfied. He took the example of single-pair Ethernet connectors.

The impedance profile of a connector was influenced by the geometry of the signal lines and its effect on the capacitance and inductance per unit length, and small clearances between signal conductors or from ground planes could lead to lower impedance values. Sometimes, the impedance value of a connector was too low as a consequence of the small space available for installation. Stamm explained how impedances had been optimised by targeted adjustment of geometry, again with the objective of achieving a consistent impedance profile within a product family.

He went on to discuss various effects of material and component arrangement before finally mentioning an investigation during a development project of the effect of differences in contact lengths on run time and propagation delay. In fact, it was observed that the delay skew was 80 times less than the propagation delay, and negligible in practical terms.

After the formal presentations, Anna Brockman moderated an open discussion, inviting questions from the audience.

From a personal point of view, I found this webinar extremely informative and well-balanced in content. I learned a lot. It filled in many gaps in my knowledge and brought the whole topic together in a logical and effective configuration. My thanks to the organisers for a first-class event. **DESIGN007**

He pointed out examples of different applications with different requirements on a graphic showing transmission length versus transmission speed.

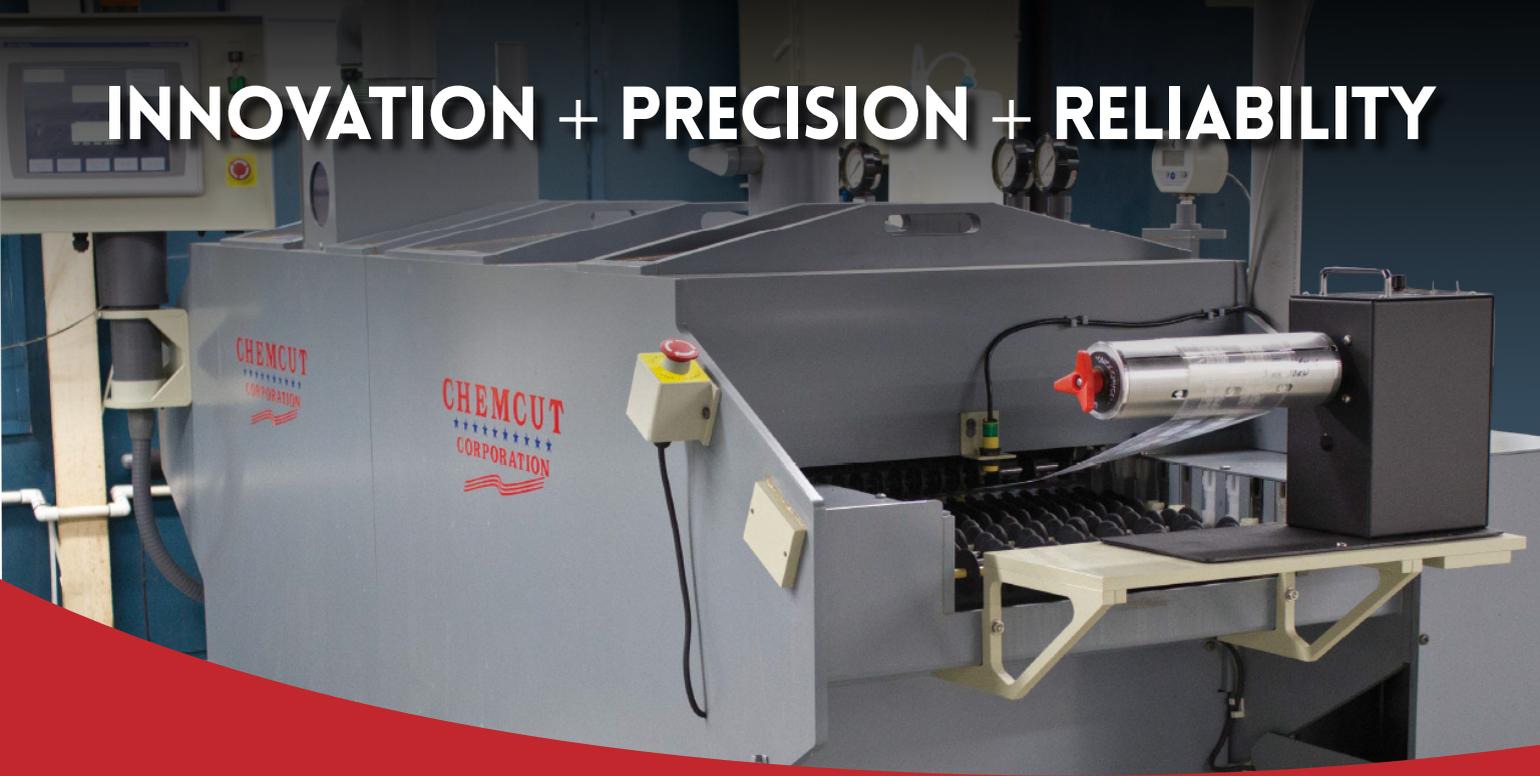
Each connector had its own impedance profile, which was location-dependent. Influencing factors included transmission frequency, geometry and material, and the arrangement of components. Whereas PCB impedances could generally be considered as two-dimensional characteristics, two dimensions were insufficient to describe the characteristics of a connector. Stamm showed the impedance profile of an industrial Category 5 connector as measured with a time-domain reflectometer and explained the deviations from the nominal 100 ohm value.

Discussing cause and effect mechanisms, he described how the impedance profile of a connector depended on the transmission frequency because relative permittivity was frequency-dependent and shorter discontinuities became visible with shorter pulse-rise times, and these caused larger deviations from the nominal impedance. He illustrated the effect graphically.

For standard board-to-board connector designs, the exact applications and transmission frequencies were not always known, but

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# Breaking Down the Current Materials Market

Interview by Nolan Johnson

I-CONNECT007

Nolan Johnson meets with Isola's Ed Kelley at DesignCon and takes a tour of the dynamics in play in the materials market. As Isola prepares to roll out an extremely low-loss, halogen-free product, Kelley says the company continues to work on how to make the product reproducible and available to customers around the world.

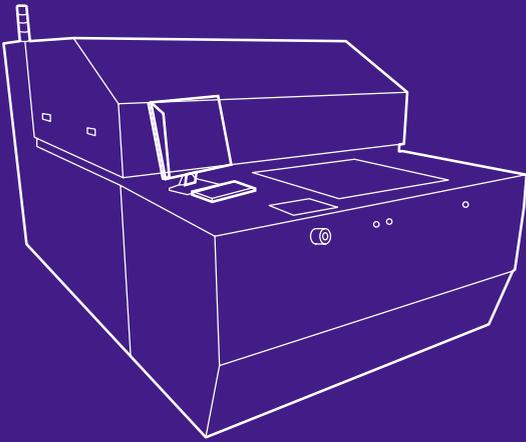
**Nolan Johnson:** What's front of mind for you and Isola in the materials market?

**Ed Kelley:** There are so many areas I could cover, but I'll start with 5G as something critical. It's been talked about for a long time, and even with the 5G rollout, there's still more to do. If you break 5G down into low-, mid-, and high-band, most of the rollout has been low- and mid-band. But the high-band applications get interesting for base material suppliers and others in the supply chain because, where

there are very high operating frequencies, people are looking for extremely low loss materials. Every piece of the base material is critical—the resin system, reinforcement, and the copper foil. There's a lot to consider.

We do a lot of work developing extremely low loss resin systems because a lot goes into them, not just polymers, but fillers and flame retardants as well. Low Dk fiberglass cloth has become common as a reinforcement. The next-generation low-Dk glasses are more available now than a year ago, though still not at full commercial scale, and we're looking at alternative types of reinforcements to achieve certain characteristics. Much of the loss at higher frequencies is due to conductor loss, creating a need for copper foils with lower and lower surface profiles.

How do you ensure those low-profile copers stick to your dielectric material and give you a reliable printed circuit board? It's one



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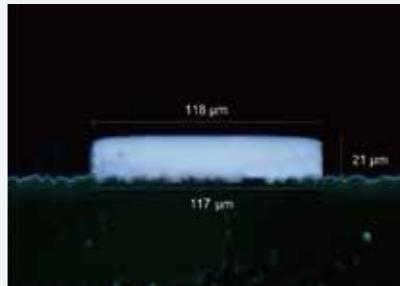
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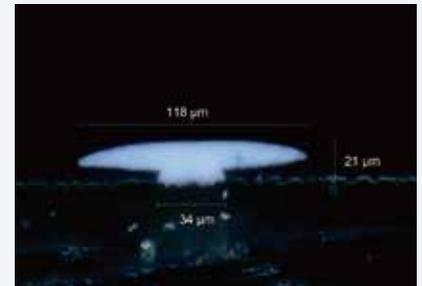
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thing to achieve an electrical performance target by itself. It's not as easy to get the electrical performance and satisfy everything else the material has to do. In addition to meeting signal integrity requirements, the material also needs to meet thermal reliability and CAF resistance requirements in complex, high-layer-count boards. We also focus on PCB manufacturability. We want our products to be as easy to use in PCB manufacturing as possible so that our customers can achieve high yields. So we spend a lot of time up front developing resin systems and integrating them with glass and copper options to meet all these requirements.

Back to electrical performance, we also have to consider how materials are used by the PCB fabricator. It's important to recognize the nuances of keeping the system as low loss as possible. When the fabricator takes our material, makes an innerlayer circuit, and runs it through oxide-alternative chemistries, that's another area of attention for 5G signal integrity performance. If you roughen up the copper surface too much, you degrade the loss performance. We're all working as hard as possible to make sure the end product achieves the goals of the OEMs.

**Johnson:** That's a lot to balance those constraints. You're already working iteratively on known solutions, so how do we develop materials that help open a more reliable high-speed 5G application?

**Kelley:** We're about to release a new product called TerraGreen 400G. As the name implies, it's extremely low loss and halogen-free. We've got our UL certification. We're focused not just on the performance of the material itself, but whether we can manufacture it repeatably day in, day out. As the product grows, is the supply chain stable enough to support demand growth? We are wrapping up some of the final qualification testing, not just to meet internal requirements, but with suppliers; we want to make sure we have a robust supply of the materials that go into it. Our goal with the product, with the combination of resin, glass, and copper, is 25% lower loss than our best performing high-speed digital product currently, which is Tachyon 100G.

With the combination of resin, glass and copper, we're hitting those signal integrity targets with this product. We've done the thermal



Example of one type of equipment used for measuring Dk/Df of base materials.

reliability testing. The CAF resistance we're seeing is excellent. In fact, with these very smooth copper foils for high frequency applications, we've seen cases of copper migration at the bond line between an etched laminate surface and the prepreg that's bonded to it.

Traditionally with CAF, people think of migration along the resin-to-glass interface, which is the most common failure. With some of these very low-profile copper foils, the copper suppliers are determining how to get a better chemical bond vs. mechanical bond between the copper and dielectric. There are various adhesion promoters that can be used, but some may not be compatible with all the resin systems that companies like us are trying to develop.

If you use the wrong adhesion promoter, when you etch off the copper it may still be on the surface and interfere with the bond of the prepreg to the etched laminate. We've spent considerable time making sure we understand what's driving that and what we need for the right adhesion promoter for our resin system. As we wrap up that work, we are seeing some very good results.

Even as we introduce this new product, we're looking at what comes next. Our chemists are looking to synthesize some of our own polymers, which would still be used in combination with commercially available resins, but may offer us some unique attributes in our applications.

As we develop resin systems, we recognize there is a range of operating frequencies to consider, and you don't always need the lowest loss material. When you don't, you don't want to pay for the loss performance you don't need. We are offering a halogen-free resin system which is extremely low loss, but we could put it on E-glass, low Dk glass, next-generation low Dk glass, and different copper combinations. With that one resin system, we can tar-



Thermal analysis equipment in the new facility.

get certain loss properties and combinations that are attractive, both for performance and cost. You don't always need to use the most costly option.

**Johnson:** This starts to sound pretty customized.

**Kelley:** We want to offer our customers the best cost-performance combination that they're looking for, but we also need to be able to supply in volumes. We don't want a lot of changeovers between one resin system and another in our process because it's very disruptive. If we have the same resin, but we can use different combinations of glass and copper, there is minimal impact to operational efficiencies. We can offer combinations that satisfy customer needs for cost and performance, and we can manufacture at high volume with relatively short lead time.

**Johnson:** This customization results in a lot of options, and the one you choose will affect the overall performance of your design. Nowadays, the material—the substrate itself—becomes a key part of the specification of your design, more than it ever was before. Now you have to specify the material as well as component values in the design process to get a certain kind



The Isola QTA and R&D facility in Chandler, Arizona.

of performance. How does a material supplier have that conversation with the designer and fabricator?

**Kelley:** For many years, I was a printed circuit board engineering guy, so I've been on both sides of the fence. It used to be that the material supplier talked to the fabricator, and the fabricator talked to the OEM—but that changed. Material suppliers began talking to OEMs and convincing them to specify their material, sometimes to the dismay of the PCB fabricator.

**Johnson:** Because the fabricator must certify something.

**Kelley:** They might even tell the fabricator, "You're going to use this product." As a former fabricator, I never liked that either. We prefer to work collaboratively with both the fabricator and OEM, particularly on new products or new programs. As much as our customers will allow, Isola tries to have the conversation with both the fabricator and OEM together. That's the general trend. For example, with TerraGreen 400G, we regularly have simultaneous calls with fabricators and OEMs. On the OEM side there are those who are in charge of qualifying materials, and often designers or sup-

ply chain people, as well as fabricator representatives. We're all on the same call, hearing the same things, and marching to the beat of the same drummer to make sure we're all aligned.

When you look at 5G and these next generation materials, it will be even more important because with small variations in our process and the fabricator's process, signal integrity can be affected. For example, oxide alternative chemistries play a significant role in loss performance. Maybe we pull in the chemistry suppliers as well. It's more complicated,

but there is value in everyone working together. You test something once or twice and get a certain performance level, but how do you know you'll get that every day? It worries me.

On our side, we implemented a stage gate development process a few years ago, and we're always refining and improving that process. We want to test the boundaries of our process. For example, if a resin is at the end of its shelf life, what does that mean for the performance of our product in our customer's hands? Is the Tg lower? Does it affect loss performance? We want to understand these factors before we fully commercialize a product.

**Johnson:** I understand certification takes some time to complete.

**Kelley:** Yes, and that's the challenge with the stage-gate development process. It's more accurate to say we use a modified stage-gate process, because we are doing as many things as we can in parallel. Even when we're testing formulations at a lab scale, we have to understand how it's going to react in a printed circuit board structure. So very early on we're building thermal reliability, CAF, signal integrity, and other test vehicles to understand and test those boundaries—not just related to the resin formulation but processing as well. When the

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resin formulation looks good, we'll submit for UL certification, and we can continue with process development and testing those boundaries during the time it takes to finish the UL process. We must understand how our products will perform.

**Johnson:** Isola has a global presence. The three major regions—Asia, Europe, and North America—tend to have different specialties. Where do you see TerraGreen 400G material being in most demand?

**Kelley:** We expect the greatest demand in Asia and the United States. But while the largest demand will be in the high-speed digital space in these regions, it's certainly capable for millimeter wave, RF/microwave. We have several customers in Europe looking at millimeter-wave applications, and we're capable of production at our site in Germany. In the U.S. we'll see more prototype, pre-production, and smaller scale production. I like the conversations about onshoring, but that's going to take time to happen. The highest volume demand will remain in Asia for the coming years.

Therefore, as we commercialize a new product, we focus not just on product performance and process repeatability, but on our service model as well. Do we have the capacity to man-

ufacture it? Where is that capacity and where will our customer want it sourced? With the supply chain issues in recent years, we're very sensitive to that.

We've expanded capacity in one of our Taiwan sites, which can support not just TerraGreen 400G, but the existing high-speed materials that are growing as well. We've engineered the treaters such that we can do quick changeovers, and support both halogen-free and non-halogen-free products.

In the U.S. we opened a quick-turn facility in Chandler, Arizona, where we can keep an inventory of the prepreg materials and press [make laminate] on demand to support needs in North America. As North American demand grows, we'll adjust accordingly.

**Johnson:** We've been concentrating our conversation on the leading-edge products. That's the realm of the early adopters. What about the many designers who are working back in the thick part of the bell curve? Do you see a shift in what they're buying?

**Kelley:** It varies by region. In North America, certainly all the supply chain issues are top of mind for a lot of our customers.

**Johnson:** Thankfully you're quick turn.

**Kelley:** Yes. Our timing worked out. Though we still have to deal with some of those supply chain logistics issues. But having the ability to stock prepreg and press on demand in Chandler is a big deal for us. And in that bell curve, the trend is shifting a little bit and you see some migration to the higher performance materials.

**Johnson:** Even the majority buyers are starting to move toward higher performance materials?

**Kelley:** Maybe it's more of a broadening bell curve. When COVID first started, we had a spike in demand for high Tg FR-4s, for things like ventilators and other medical equipment.



The Isola QTA and R&D facility in Chandler, Arizona.



Additional lab equipment.

Today, we see 370HR, one of our workhorse products that was introduced in 2003, still going strong. Demand remains at a high level.

**Johnson:** Okay, that's not declining?

**Kelley:** That curve is broadening; there's still the high Tg FR-4s, whose growth is mostly tied to overall economic growth. But it's a very competitive segment. There are always those who try to be low-cost producers coming after your share. But 370HR is a very robust product. It's reliable and customers don't want to change. While you'll find that everyone has their own definitions for loss segments of materials, we haven't seen significant demand changes for mid- or low-loss materials in the United States. You see prototypes and small volumes, but much of the volume is in Asia.

In the U.S. there's a combination of the standard and high loss materials, and growing amounts of very low, ultra-low, extremely low—whatever your adjective is—materials. In Asia, it's the full range. In Europe, you have a lot of FR-4 products because the automotive industry is still going strong there. Many prototypes start there and it's important to support those. On the OEM side, you have many key telecom and automotive companies. So we see demand for FR-4 products on one hand, and high performance materials, including for millimeter-wave applications, on the other. That includes automotive ADAS, 77 GHz radar systems and the like.

As we talk with our customers, it's important for us to look at our ability not just to supply them materials, but to help solve problems. In my role, I'm always asking, "What are our customers' unmet needs?" Whether that's in the automotive sector for charging stations, where materials have to pass CAF testing at a thousand volts or more, or in the extremely low loss 5G applications we discussed. Those are some of the emerging requirements that I need to understand. I need to determine, "Does Isola have an opportunity to develop a product to meet those requirements?"

**Johnson:** That's got to be an ongoing thing.

**Kelley:** Yes. At any given time, we would like to have products at various stages of our development process. Historically, Isola hadn't offered a lot of halogen-free materials so we're looking to fill in our portfolio, partly to support hybrid builds where somebody might want to use an extremely low loss product in certain layers, but something less expensive in others while keeping the whole package halogen-free. We have another product coming that's a very low loss halogen-free material—not as low as TerraGreen 400G, but it fits a niche in loss performance at a very attractive cost point. Many of our customers use the term "loss for cost."

**Johnson:** That's catchy.

**Kelley:** We're trying to get as low in loss as possible before having to jump to a much more expensive type of resin system. We're pretty excited about it. We're hitting some pretty good electrical performance numbers with a material that we expect to be attractive in terms of cost. Thermal reliability has been very solid from the beginning. We've just gone through our second round of CAF testing with excellent CAF resistance results. And we are currently testing it in various circuit designs to validate performance in different applications.

We've locked down the formula and submitted it for UL certification. It's now in the stage of manufacturing repeatability validation. It will be several months before the UL certification is complete, but I expect that we'll be offering samples to customers for testing and qualification while we're waiting. There are a couple other halogen-free developments in the higher loss categories that are still attractive also. They're much more cost sensitive, but we think they are important markets for us to be in, both by themselves and for the hybrid opportunities.

**Johnson:** Now let's talk about an important issue in Europe, where they are pushing the idea of sustainable, green, recyclable, decomposable materials. That's an additional set of constraints, pushing into certain sorts of materials that can decompose yet be electrical performers. How do you get there?

**Kelley:** That's a long haul, but it doesn't mean we shouldn't be working on it. We need to be. But trying to have a reliable circuit, lead-free assembly, multiple assembly cycles, good CAF resistance with long field operation—and be decomposable? That's a big ask.

**Johnson:** It feels like there are enough competing constraints to cause a disruptive shift toward a completely different set of materials.

**Kelley:** You're right. Whether it's decomposable materials, or government regulatory bodies looking into various flame retardants, there's a lot going on. Most of our products need to meet the UL94 V-0 flammability rating. But are we, as an industry, over-specifying in certain applications? As the list of requirements grows, the technical challenges increase, and often so does the cost. As we add new requirements, should we consider relaxing others, at least in specific applications?

Consider mobile devices, where sustainability is probably the most urgent given these devices are mass produced and used for a relatively short period of time. Maybe there are cases where you need to start relaxing some of the requirements in other areas in order to enable degradable materials. In other applications maybe CAF resistance or thermal cycling requirements have been

over-specified and can be relaxed without sacrificing reliability, making it easier to meet sustainability or cost goals.

**Johnson:** It's a completely different calculus regarding the constraints.

**Kelley:** Right, even on the flammability side, where the way the industry has been doing flammability tests, hasn't changed in probably my lifetime. For those familiar with the test, is that representative? Does it tell you what you think it does, or is there a better test that says, "Yes, I can be confident that my material won't burn in an application, while enabling more sustainable materials or processes. Maybe I can



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formulate it differently for lower cost or I can get to even lower loss levels because I'm not using a flame retardant that increases loss." I think those types of conversations are going to happen more often going forward.

**Johnson:** Regarding automotive Europe and charging stations, what is happening, from your perspective as a manufacturer, with global copper supply? There is going to be such a huge demand globally because the very idea of building out an electric vehicle charging network creates the need for an almost unimaginable amount of copper.

**Kelley:** Yeah... buy copper (laughs). I've seen different projections, but they all forecast an incredible amount of copper that's needed.

**Johnson:** This creates very stiff competition to get the copper we need. How big is that challenge for the industry?

**Kelley:** There are two areas to discuss. First, there are batteries, but if you put that aside for a minute and think about printed circuit boards that support electric vehicles and charging stations, there are technical challenges in addition

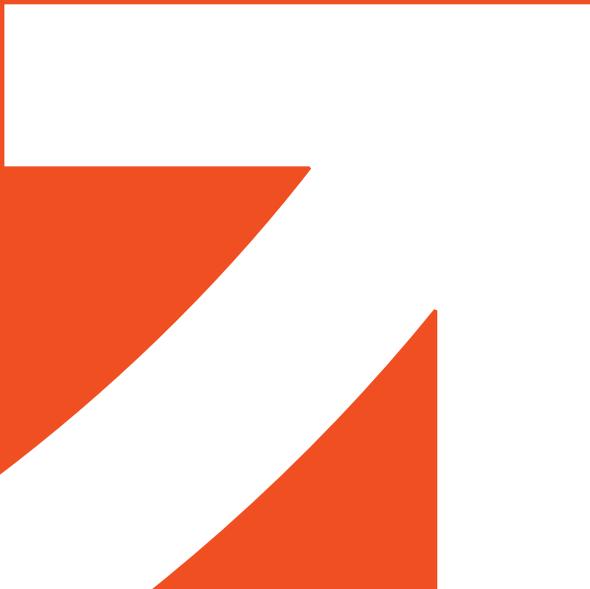
to the supply question. OEMs continue to look at the relationship between circuit design, operating voltage, thermal reliability and CAF resistance. The automotive industry used to test at 100 volts, went to 350, then 500, and now 1,000 and 1,500; we're bringing in CAF test capability to go to 2,000 volts internally. We're learning a lot of things about that because it's different at 1,500 volts than it is at 100 volts, I can assure you. With materials, there's some interesting phenomena happening that you don't see at the lower voltages. In designs that

may use 6- or 12-ounce copper innerlayers, there are additional challenges the base materials and printed circuit processes face.

We introduced a product last year called IS550H, which was developed for high voltage applications. The automotive OEMs are asking, "What are my design rules for a PCB at these voltages? How close together can I put features?" Well, that will depend on the material you're using. There's this chicken and egg or iterative process where OEMs are testing existing materials, asking for better, and we're all working on better materials. Then we have to test those materials and say, "Here's how your design rules can change with this material." But again, that all assumes there's going to be enough copper.

**Johnson:** It sounds somewhat like the same dynamic you have in 5G.

**Kelley:** True. And the automotive OEMs are starting to request low loss materials for automotive applications, the in-car, connected computer-on-wheels kinds of things rather than electric vehicles, per se. But it's not something we're used to having the automotive OEMs ask us.



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**Johnson:** We recently learned that that our cars are becoming data centers on wheels.

**Kelley:** Yes. It's reasonable to assume that the number of vehicles sold may decline, but the electronic content per vehicle will keep going up. When you net it all out, there's still an increase of electronics in automotive applications and the range of requirements is growing in automotive as well. You still need the high Tg FR-4s but you also need lower loss materials for these data centers on wheels.

**Johnson:** And the collision avoidance, ADAS and high voltage stuff for the drive train.

**Kelley:** Right. If you look at vehicles of the near future, they could be using a pretty broad range of materials in every single car.

**Johnson:** Any closing thoughts?

**Kelley:** Some of the fundamental trends are not going to change. We're always looking to develop lower loss laminates and prepregs that you can easily build complex printed circuit boards with. We're looking at alternative types of reinforcements. When you talk about CAF, so much of it's the glass fabric. Well, what if you get rid of the glass fabric? And if you do, what do you replace it with? Do you use a film-based material? If it's a film, it likely can't be used in every layer of a rigid multilayer circuit board. How do you solve those types of questions? There's going to be a lot more hybrid constructions, not just with different materials and different loss parameters, but hybrids with some layers of glass-reinforced, some no reinforcements, some alternative reinforcements.

Skew mitigation is still a hot topic. Isola was



Isola's analytical services workstations.

working on a product that was pretty good in terms of skew mitigation. But as we vetted the product performance, we found that it solved a unique electrical performance challenge, but we had some issues with thermal reliability properties. We haven't given up on that, and we're evaluating an alternative approach. There are always these types of problems to solve. We want to be the guys who solve problems for customers. And as we talked about, we have to make sure that we're talking together with the fabricators, the OEMs and, in many cases now, the chemistry suppliers. There is an increasing number of people who need to work together to address some of these real challenges.

**Johnson:** With way more choices, configurations, and permutations than ever before.

**Kelley:** Yes.

**Johnson:** Thank you.

**Kelley:** My pleasure. PCB007

Read more about the importance of material selection in *The Printed Circuit Designer's Guide to... High Performance Materials*.

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# Supplier Highlights



## Testing Todd: Has Universal Fixture Testing Gone the Way of the Dodo? ▶

Although flying probe testers have become common place in today's manufacturing theatre, one must wonder if the fixture tester—specifically the universal grid or “pin in hole” fixture—has any valuable use in the electrical test arena? The advancements in flying probe technology are undisputed with the new abilities to do many of the tests that benchtop testing historically required.

## Insulectro Gears up for More Business in Canada ▶

Insulectro, North America's largest distributor of materials for use in manufacture of printed circuit boards and printed electronics, has broadened its commitment to Canadian business. It has acquired more warehouse space at 237 Unit 1 Finchdene Square, Scarborough Ontario M1X 2E1 Canada significantly increasing its local presence and capabilities in Canada.

## Camtek Posts Preliminary Q1 2022 Revenue ▶

Camtek Ltd., announced that its revenues for the first quarter exceeded expectations, and it expects to report first quarter revenues of approximately \$77 million.

## Hitachi High-Tech Sets New Pace for Plating and Coatings Analysis with FT230 ▶

Hitachi High-Tech Analytical Science, a global company within Hitachi High Tech Group, has expanded its plating and coatings analysis range with the launch of the breakaway FT230.

## IEC Announces Exclusive North American Representation Agreement With ASS-Luippold ▶

Automated Systems Service (ASS-Luippold) have come together with IEC to provide North America with best-in-class automation machines to help with the manufacture of printed circuit boards. These include DI/LDI/AOI robotic systems, vertical electroplating robotics, load/unloader stations, and more.

## Altix Receives Bundle Machine Order from Major Chinese FPC & PCB Player ▶

Altix is delighted to announce a significant order for both direct imaging and contact printer equipment. The bundle encompasses both panel and RtR solutions to be installed at a new plant in Jiangxi province.

## Nano Dimension Moves its U.S. Headquarters to Greater Boston Area ▶

Nano Dimension Ltd., an industry-leader in Additively Manufactured Electronics (AME), Printed Electronics (PE), and Micro-Additive Manufacturing (Micro-AM), announced the opening of its new U.S. headquarters in the Boston metropolitan area.

## Atotech Files 2021 Annual Report on Form 20-F ▶

Atotech, a leading specialty chemicals technology company and market leader in advanced electroplating solutions, announced that it has filed its 2021 annual report on Form 20-F, including its audited financial statements for the year ended December 31, 2021, with the U.S. Securities and Exchange Commission on EDGAR.

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# Copper Etchant Regeneration

## Happy's Tech Talk #8

by Happy Holden, I-CONNECT007

Copper has become a valuable metal, and with the growth of EV has come higher currents needed in PCB resulting in increased weight of copper in PCBs. This creates the need for increased copper etching and consumption of copper etchants.

Alkaline ammonium chloride and acidic cupric chloride remain the most used etchants with various peroxide-sulfurics as micro-etches. Still in use, but in much smaller applications, are ferric chloride, alkaline ammonium sulfate, alkaline cupric chloride, and sodium persulfate.<sup>1,2</sup>

Any ammonium compounds in rinse water complicate water treatment as they will chelate any metals in the final effluent and make it more expensive to treat.

### Etchant Regeneration Techniques

Karl Dietz wrote on this topic several times in his Tech Talk Series. No less than eight columns were devoted to etching chemistry, but

only one went into details about chemical regeneration (TT#92). The etching Tech Talk columns were:

- **TT#92:** Etchant Recycling (*CircuiTree*, May 2003)
- **TT#112:** Ammoniacal Etching (Part A) (*CircuiTree*, January 2005)
- **TT#113:** Ammoniacal Etching (Part B) (*CircuiTree*, January 2005)
- **TT#119:** Fine Lines in High Yield (*CircuiTree*, August 2005)
- **TT#151:** Ferric Chloride Etching of Copper (*the PCB Magazine*, April 2008)
- **TT#158:** Fine Line Etching Revisited, Part A (*the PCB Magazine*, November 2008)
- **TT#159:** Fine Line Etching Revisited, Part B (*the PCB Magazine*, December 2008)
- **TT#160:** Fine Line Etching Revisited, Part C (*the PCB Magazine*, January 2009)



ISLAND OF AUTOMATION

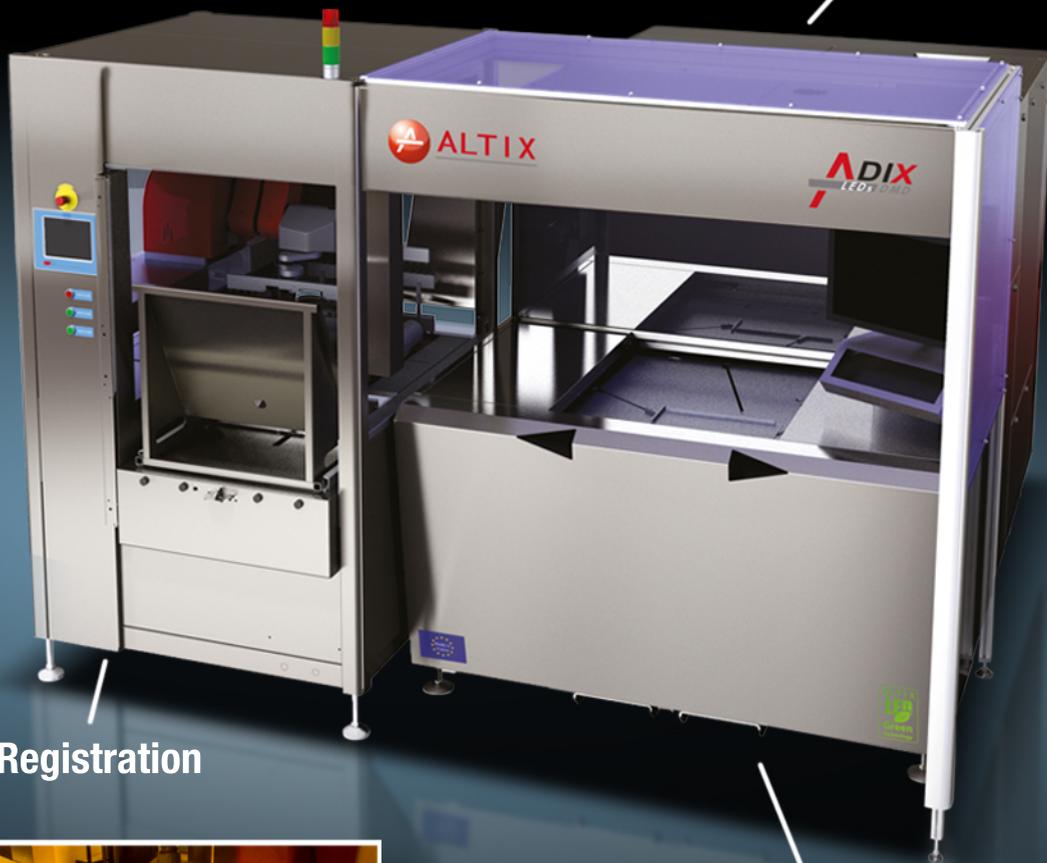


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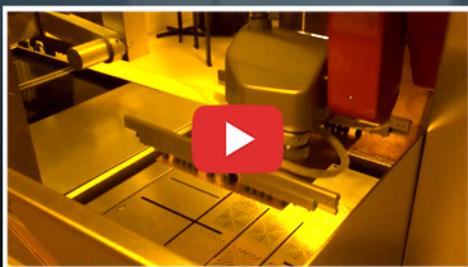
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## Liquid-Liquid Extraction

Liquid-liquid extraction (LLE) or Liquid ion-exchange has been used for metal recovery from mining for many years. But in the early 1970s, a new organic extractant was developed out of wheat by General Mills. This new metal chelating agent is 7-ethyl-undeca-2,4-dione, trademarked by General Mills as LIX64N and LIX65N. This organic is dissolved and mixed with kerosene (~20% dissolution) and has an extremely high affinity for copper and zinc.<sup>3</sup>

The unique feature of these compounds with respect to metal chelating is that, in the extraction step, the base metal is capable of being loaded to the exclusion of ammonia or chlorides, thereby resulting in essentially a zero carryover of ammonia/chlorides to the stripping step. Moreover, in the stripping step the extractant does not form a salt with the acid present and hence can be

recycled directly to the extraction stage without the necessity of further treatment.

The extraction and regeneration process are shown in Figure 1.<sup>4</sup>

Figure 2 is a diagram of a mixer-separator unit that shows the mixing and separating chamber where the organic phase is less dense and floats on the aqueous phase to extract

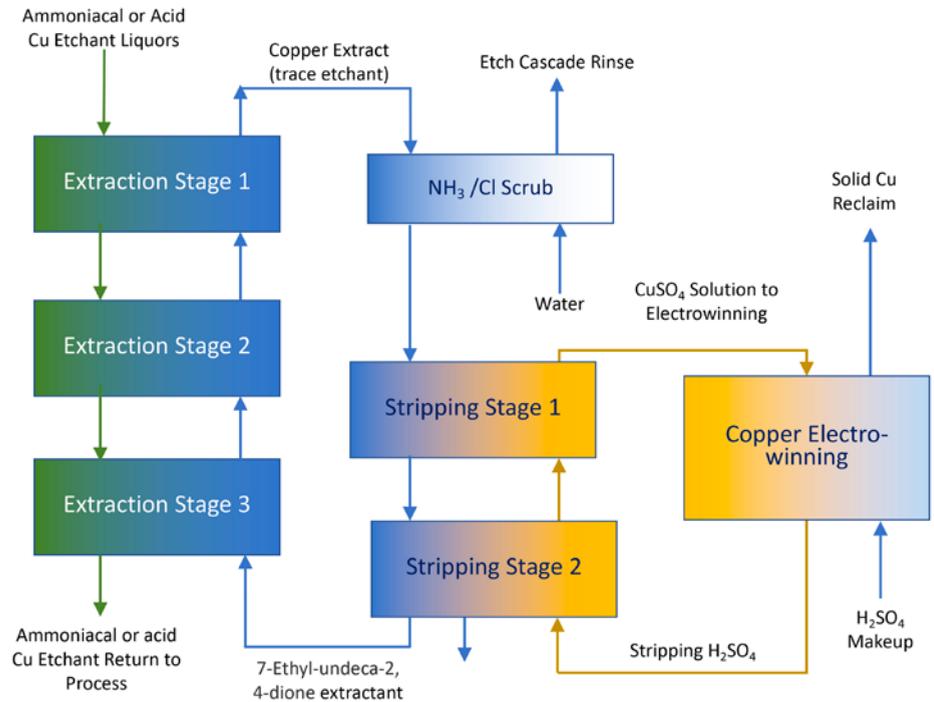


Figure 1: The LLE process for alkaline or acid etchant Cu recovery. (Source: King Industries)

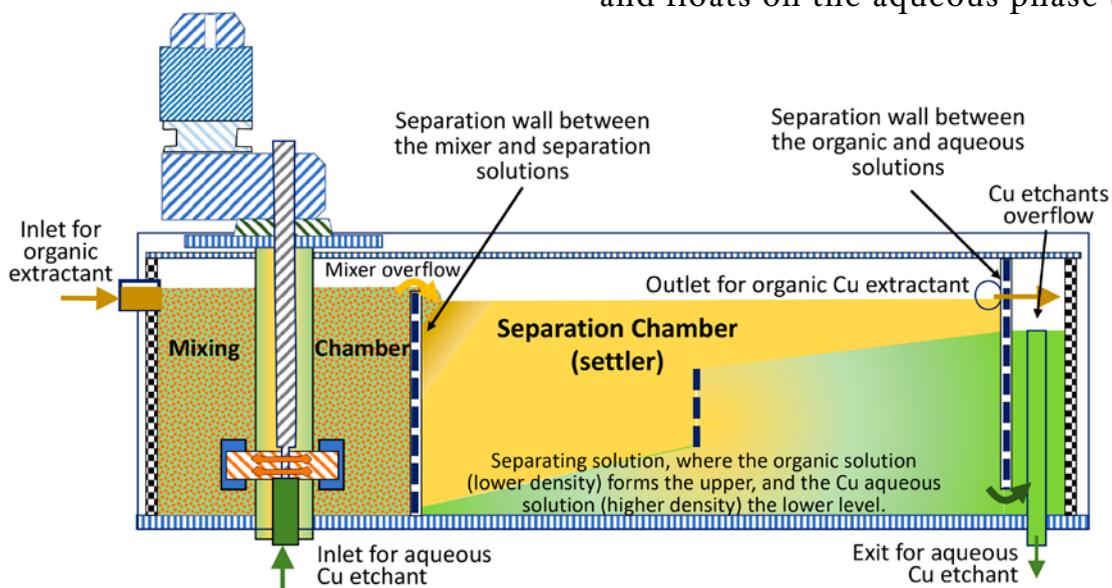


Figure 2: Diagram of a mixer-separator for LLE. (Source: Sigma Engineering)

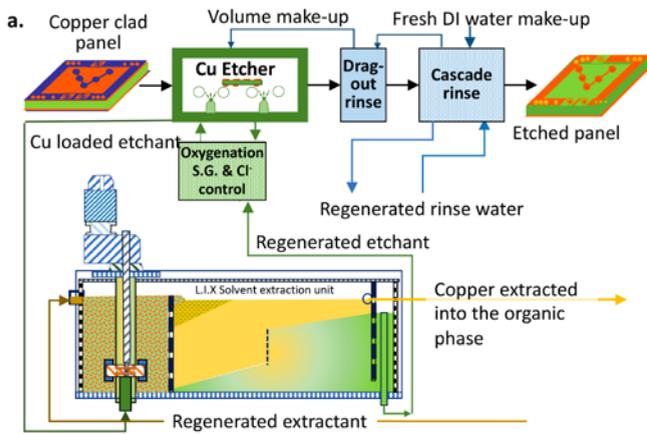


Figure 3a: The copper etcher with rinse water and the primary mixer-separator for removal of copper and regeneration of the etchant.

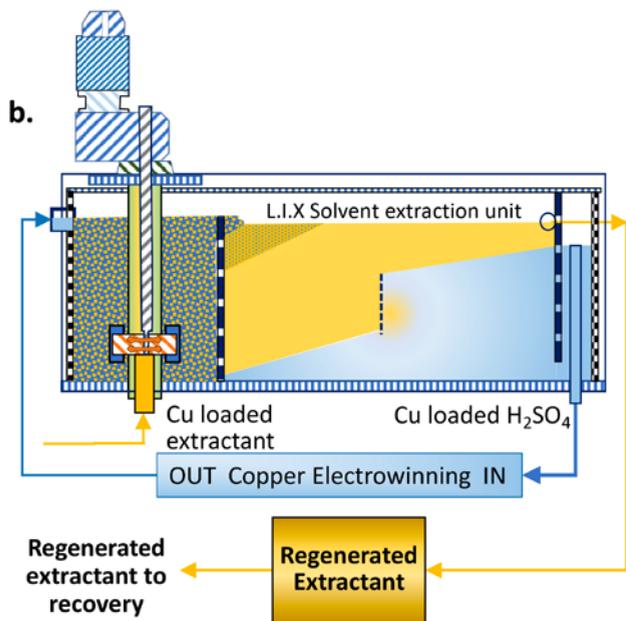


Figure 3b: Once the copper is in the organic phase, a mixer-separator strips the copper out of the kerosene and into the sulfuric acid aqueous phase.

the copper into the organic phase. Other unit operations equipment used for LLE are sieve tray and bubble-cap towers, but the mixer-separator is the simplest and easiest to maintain.

Figure 3 shows diagrams of an LLE system for printed circuit etching of either alkaline or acid types of etchants with copper recovery. Many of these have been installed over the years. Figure 3a is the mixer-separator unit that

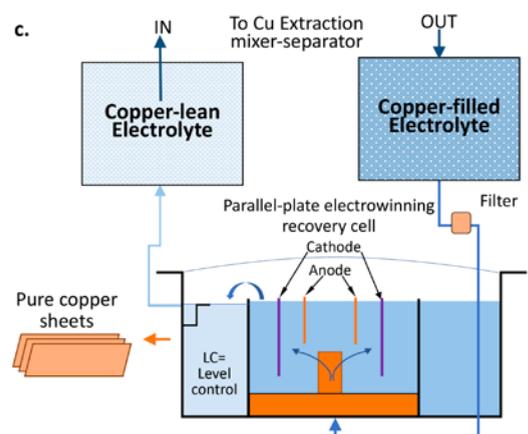


Figure 3c: Now back into the electrolyte, the copper is plated onto stainless steel cathodes and sold as scrap copper.

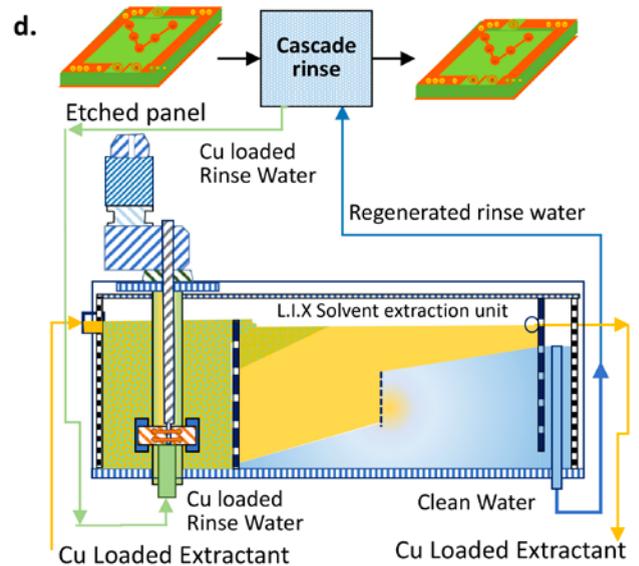
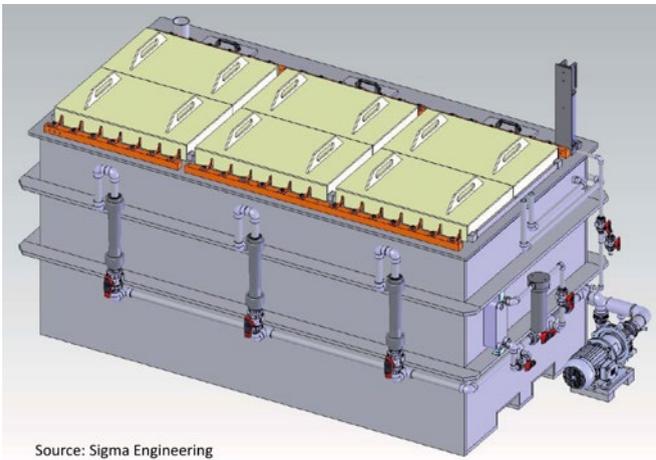


Figure 3d: A smaller mixer-separator is used to remove copper from the etcher's rinse waters.

strips the copper out of the etchant. In Figure 3b, another mixer-separator unit can strip the copper into the acid electrolyte, whereas in Figure 3c, the copper is plated out as sheets from the copper sulphate electrolyte. Figure 3d is the final mixer-separator that removes copper from the etcher's rinse water and returns it to the cascade etcher rinses while the organic phase is combined with the etchant extract. All streams are 100% recycled.



Source: Sigma Engineering

Figure 4: Diagram of multiple mixer-separators used for extracting copper from PCB etchants. (Source: Sigma Engineering)

Figure 4 shows a typical industrial mixer-separator drawing used for etchant regeneration. Six separate mixer-separators are contained in this one unit. Many times, more than one unit is used for the extraction stage and for the stripping stage, as seen in Figure 1. Figure 5 shows an actual copper recovery unit installed in a printed circuit fabrication facility.<sup>5</sup>

## Conclusion

When the LLE extraction and recovery unit was first designed in 1974 by Hewlett-Packard's PCB Group for its alkaline etching system in Palo Alto, California, no others were in use. Today, more than 100 units have been installed around the world recovering copper and regenerating their PCB etchants. One of the most recent, installed at Whelen's Green-Source Fabrication in New Hampshire, recovers over \$375,000 in copper every year.

This puts the chemical and water recovery system into a profit generator for the facility. Their daily water use for the 100-panel per hour facility is less than what is used by their toilets. PCB007

## References

1. "Improved Inner Layer Etching by Simultaneous Cupric Regeneration and Copper Recovery System," by Paul Watson, ILS Conference, Leeds, UK, 1999.



Figure 5: An actual LLE mixer-separator in operation at a working PCB fabricator. (Source: Sigma Engineering)

2. CEMCO Etchant Regeneration Brochure for Cupric Chloride, 2 Relay Rd. Waterlooville, Hampshire UK, 1999.

3. Liquid Ion Exchange in Metal Recovery and Recycling, by Lawrence V. Gallacher, 1980.

4. "New Horizons in Metal Removal And Recovery," by W. Daniel Ernt, P.E., American Institute of Chemical Engineers Annual Technical Meeting, April 17, 1990.

5. The Mecer™ System Brochure for PCB etchant recycling and copper recovery, Sigmametallextraktion AB, Datavagen 51, Sweden.



**Happy Holden** has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa Westwood, Merix, Foxconn, and Gentex. He is currently a contributing technical editor with I-Connect007, and the

author of *Automation and Advanced Procedures in PCB Fabrication*, and *24 Essential Skills for Engineers*. To read past columns or contact Holden, [click here](#).

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# MilAero007 Highlights



## **The Government Circuit: Robust U.S. Electronics Industry in Everyone's Interest ▶**

I've been saying for months that decisions made in 2022 will be critical to the future of electronics manufacturing for years to come. After years of government policy neglect, we have unprecedented opportunities to make things better and position the industry for long-term success. But we certainly cannot take this progress for granted; we must pull together and work for it.

## **Standard of Excellence: From Adversaries to Collaborators— Let's Do This Together ▶**

Because of the results of the pandemic, we are experiencing shortages like we have never faced in our lifetime. Therefore, it is more important than ever that we all work together—and I really do mean all of us. Those of us who fabricate PCBs must open our minds and doors to the idea of working together. Where for so many years we competed to the point of treating one another as adversaries, we now must come together to form a cohesive partnership.

## **Elbit Systems UK JV Introduces Sustainable Aviation Pathfinder for Ministry of Defence ▶**

Elbit Systems UK and KBR Inc's joint venture, Affinity Flying Training Services Ltd (Affinity), has embarked on a series of battery-powered flight tests for the UK Ministry of Defence to assess the feasibility of environmentally friendly alternatives to current military aircraft.

## **Calumet Electronics Chooses Fully Automated atg A9a Flying Probe for High-Speed Electrical Test ▶**

atg Luther & Maelzer GmbH confirms delivery of high-speed bare board testing technology to PCB fabricator Calumet Electronics, in Calumet, MI.

## **The Reality of Regulated Manufacturing ▶**

Nolan Johnson speaks with Ryan Bonner, CEO of DEFCERT, about government regulations for data and cybersecurity. A key component of moving to a digital factory will be to ensure security of the data required to operate a digital factory, and most importantly, customer design data.

## **Ultra and Sparton JV (ERAPSCO) Awarded \$11.6M for U.S. Navy Production Contract ▶**

Ultra Electronics Holdings plc (ULE) and Sparton DLS, LLC announce the award of a contract valued at \$11.6 million to their ERAPSCO joint venture, against the \$222 million competitive Indefinite Delivery Indefinite Quantity (IDIQ) production contract for the manufacture of next-generation sonobuoys for the United States Navy.

## **Boeing, AWS Join Forces to Transform Aerospace Design and Manufacturing ▶**

Amazon Web Services, Inc. (AWS), an Amazon.com, Inc. company, and Boeing announced an expanded relationship that extends the aerospace leader's existing cloud operations and streamlines Boeing's approach to cloud computing.

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# Simple Secrets for Effective Mentorships

## The New Chapter

by Paige Fiet, TTM-LOGAN

Mentoring the next generation is a hot topic in the industry, as many are asking what needs to happen for the electronics industry to maintain young talent. How do we close the tribal knowledge gap that persists across several generations? One way to better understand the needs of up-and-coming engineers is through mentorship programs. According to the Mentor Coach Foundation, 79% of millennials report mentorship as being crucial to their career success. Further, one of the top reasons millennials leave their current position is due to “lack of learning and development opportunities.” Creating an active environment for young professionals to learn and grow profes-

sionally throughout their career can drastically affect retention in these positions.

### Benefits of Mentorship

Mentorships are not just valuable to the mentee. Rather, they are mutually beneficial to each party. Mentees are given the opportunity to learn from those who have come before them. They have an opportunity to learn from the mistakes of their mentors and gain an advantage on their peers. In turn, mentors receive a sense of fulfillment in teaching their successors. They can improve their leadership skills and are given recognition for their contributions. In most mentor/mentee rela-



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tionships, I would argue that the mentor has as much to gain and learn from the partnership as the mentee.

## What I've Learned

In my professional career, I've had several incredible engineering and business mentors whom I credit for my early career success. Each mentor helped me refine different skills that have been proven essential to my first full-time job. One of my first mentors worked on my technical writing skills while another focused on expanding my professional network. I've had mentors who focused on more of my day-to-day activities and how they might go about a project I am facing, while others have focused on the bigger picture. Each mentor, whether officially defined as a mentor, was very valuable to me. Over the past couple of years, I have learned that the regularly scheduled meetings allow me to ask questions and receive feedback in an open environment. If my mentor was unsure of an answer, they were always able to introduce me to someone who could help me. This allowed me to expand my professional network and meet professionals in other disciplines besides my own.

However, the most important aspect of each of my mentorships was that they held me accountable to my goals. I am always grateful to share in my celebration with them with the completion of each goal, no matter how small. One of my dearest mentors, Dr. Chris Middlebrook, has provided me with endless support. During my second year of college, he encouraged me to apply for IPC's Student Board Member position. He read through my application and provided a letter of recommendation. During the rest of my college career, Dr. Middlebrook held a weekly "Coffee Chat" session for us to work on career development. When it was time to choose a full-time career, he provided a listening ear and a sounding board for my thoughts. He made sure to allow space for me to make my own decision while providing his input. Although we don't talk as much as



Figure 1: Paige Fiet with her college mentor, Dr. Chris Middlebrook.

we used to, I still love to hear about his endeavors as much as he does mine.

## What I've Given Back

Recently, I've been able to participate on the other side of this relationship in an informal way. My mentee is passionate about the industry and brings a new perspective. She has helped me expand my leadership skills while getting me out of my comfort zone. The energy she brings to the table each time we meet is contagious. It's been very rewarding to watch her progress into a young professional and I can't wait to cheer her on as she transitions into a full-time career.

## About the Opportunity

The opportunities to mentor up-and-coming professionals are endless. Some companies have created internal mentorship programs for both potential mentees and mentors to get involved in. Other opportunities happen more

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organically. Several of my mentorships have happened from natural relationships that have progressed into them becoming an “unofficial” mentor. Another opportunity geared toward industry is IPC’s Emerging Engineer Program. This program aims to introduce engineers to varying sectors of the electronics industry as well as the standards that regulate it. Engineers in their first five years in industry can join the program as a mentee. They will then be assigned a mentor who has participated in the industry for at least 10 years.

Mentorship is one of the best ways to grow and retain your employees. Creating these

relationships within a company or within the industry can be essential to decreasing the generational divide. All parties win in these relationships. Regardless of whether you’ve mentored in the past, I highly recommend giving it a try. After all, we grow by helping each other. **PCB007**



**Paige Fiet** is a process engineer at TTM-Logan and part of the IPC Emerging Engineer Program. To read past columns or contact Fiet, [click here](#).

## COLUMN EXCERPT: Additive Reality

# Let’s Drop a Line About PCB Cross Sections

By Luca Gautero

My article in the April 2022 issue of Design007 Magazine, titled “Additive Manufacturing Requires Additive Design Techniques,” presented several cross sections of solder mask coated with an inkjet technology. However, the choice of the cut’s location, and therefore the highlight of the picture, is slightly different from the usual dam or copper edge coverage. This illustrated my point and most structures of solder mask showed in the figures would not be anything new to my readers. Several articles have explained lateral definition and stacking principles.

Still, when the knowledge used as a starting point to examine these cross sections is from traditional

solder mask (which mostly resembles rectangles), it is difficult to trust right away that any other shape will be as reliable.

The best way to highlight this difference is not necessarily with a cross section, but with a top view.

Figure 1 shows one of the concepts explained in my March 2022 column titled, “Drop-forging Solder Mask Thickness With Inkjet.”

The usual questions refer to the solder mask adhesion to copper or laminate, its inertness to chemical attacks of post-treatments at high processing temperatures, and temperature stability during further manufacturing or product ageing.

The wetting behavior of the surface, controllable by the pre-treatment choice, has a wide process window<sup>1</sup>. The contact angle imposed by

the wetting behavior, when combined with the low viscosity of the ink, fills any intricate roughness created by pre-treatments. This ensures the mechanical bonding of the anchor effect. Additional to the safety of this mechanical bonding is the inherent tapering of the solder mask thickness towards its edge.

**To read the entire column,** [click here](#).

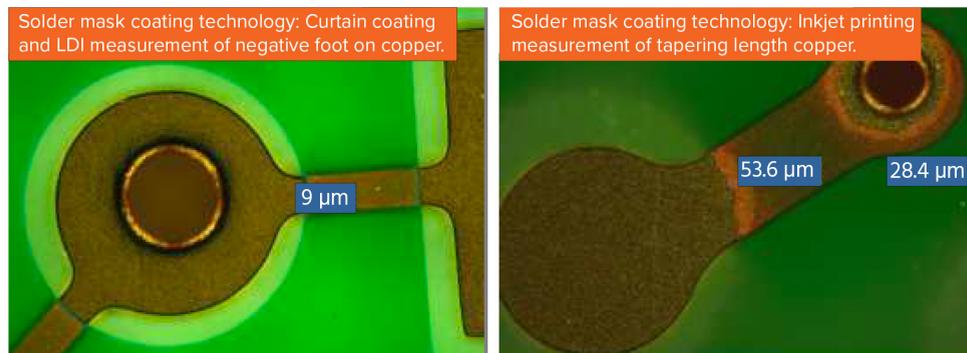


Figure 1: Comparison of traditional vs. solder mask. The tapering of the solder mask thickness towards the edge of the pattern is especially visible on copper. (Source: ACB-Atlantec SAS)

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<sup>1</sup>IPC. (2017). Findings on the Skills Gap in U.S. Electronics Manufacturing.

# **ein** Electronics Industry News and Market Highlights



## **Nokia to Exit Russian Market, No Impact to Financial Outlook** ▶

It has been clear for Nokia since the early days of the invasion of Ukraine that continuing our presence in Russia would not be possible. Over the last weeks we have suspended deliveries, stopped new business, and are moving our limited R&D activities out of Russia.

## **CyberOptics Highlights Best-Practices for Detecting Particles in Semiconductor Environments** ▶

CyberOptics Corporation, a leading global developer and manufacturer of high-precision 3D sensing technology solutions, exhibited at SPIE Advanced Lithography and Patterning in San Jose, California.

## **Rolls-Royce Launches New mtu NautIQ Products With Sea Machines Technology** ▶

Rolls-Royce is expanding its range of mtu NautIQ ship automation systems with three new products: mtu NautIQ CoPilot, mtu NautIQ CoOperate and mtu NautIQ CoDirect, which each offer different levels of intelligent crew support, autonomous control, and remote command capabilities.

## **Keysight Delivers New Digital Wideband Transceiver Test Solution** ▶

Keysight Technologies, Inc., a leading technology company delivering advanced design and validation solutions, announced Keysight's new Digital Wideband Transceiver test solution, which unveils true radio frequency (RF) performance characteristics of mixed-digital RF devices.

## **Siemens' SynthAI Revolutionizes Machine Vision Training with Artificial Intelligence** ▶

SynthAI automatically generates thousands of randomized annotated synthetic images from 3D CAD data within minutes without the specialist knowledge typically required.

## **Intel Launches New Intel Blockscale Technology for Energy-Efficient Blockchain Hashing** ▶

Intel announced details for its new Blockscale ASIC. Building on years of Intel research and development, this application-specific integrated circuit (ASIC) will provide customers with energy-efficient hashing for proof-of-work consensus networks.

## **Kyocera Integrates Walkie Talkie Application in Microsoft Teams** ▶

Kyocera, a North American leader in rugged mobile solutions, has entered into an agreement with Microsoft to integrate the Walkie Talkie application in Microsoft Teams on ultra-rugged 5G Android smartphones.

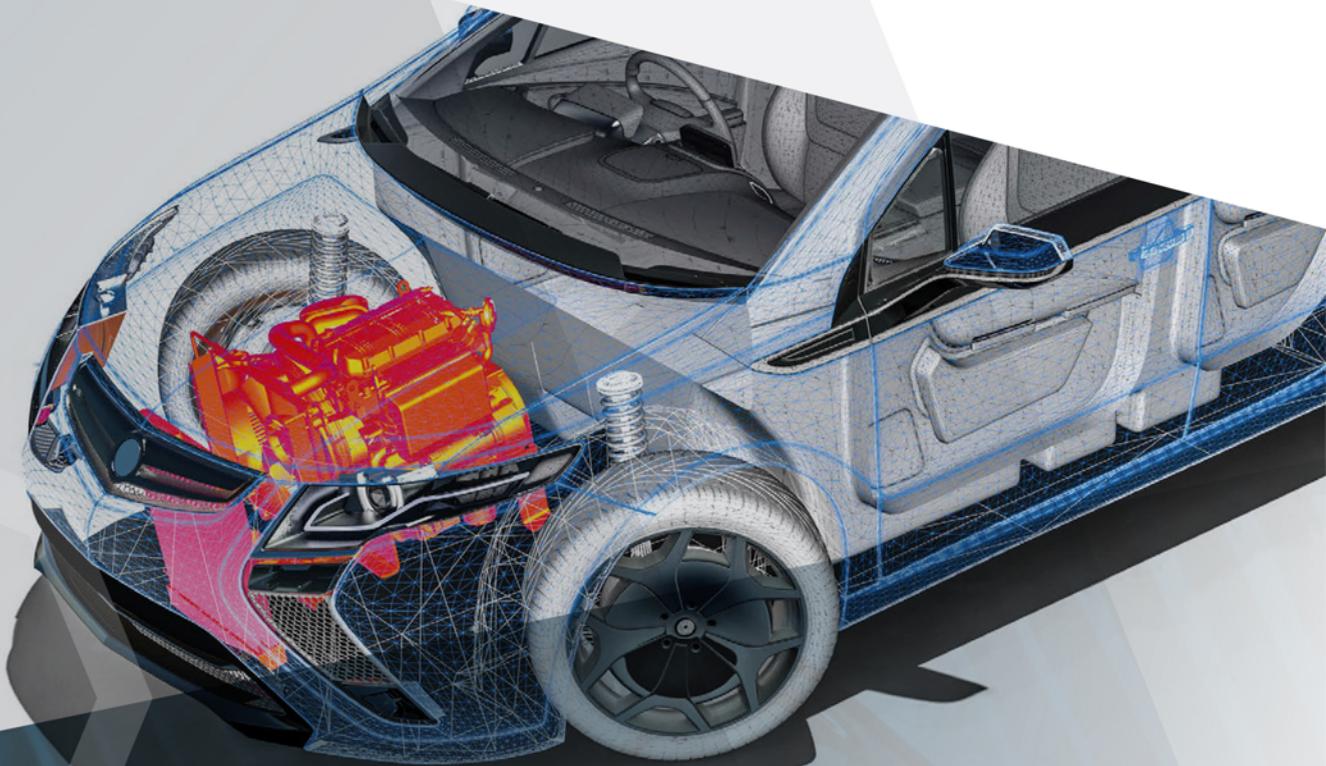
## **Apple Helps Suppliers Rapidly Accelerate Renewable Energy Use Around the World** ▶

Apple announced that its suppliers more than doubled their use of clean power over the last year, with over 10 gigawatts operational today out of nearly 16 gigawatts in total commitments in the coming years. In 2021, these renewable projects avoided 13.9 million metric tons of carbon emissions.



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## **autolam:** Base-Material Solutions for Automotive Electronics



**autolam** 

Automotive electronics technologies are evolving at an increasing rate. Paying attention to the properties of materials at the substrate level is the first step towards achieving the most stringent performance targets of today's automotive manufacturers. autolam offers the solutions demanded by the diverse and unique requirements of automotive applications today and in the future.



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# What's in the Electrical Test Crystal Ball?

## Testing Todd

by Todd Kolmodin, GARDIEN SERVICES USA

We live in an ever-changing environment of evolution. From analog, carburation-driven automobiles and tube televisions to the fully electronic fly-by-wire automobiles and UHD televisions of today, we had to evolve. Today you can speak to your car and your home, executing commands by just your voice. More than once during my weekly meeting with my colleague Rick Meraw, I hear him telling Alexa to “shut up.” AI has become routine in smart homes and smart cars. Siri, Alexa, and others can learn your specific voice and perform tasks on command. Pretty slick, especially when you think about the computers of Apollo 13 that

now could be powered by your latest generation of cellphone.

It is amazing what the collaborative minds of men and women over the years have accomplished. As technology has evolved, so have our minds. More thinking out of the box, making the improbable probable, and never giving up.

So, how are we achieving these goals? We are working smarter. Processes are robust, waste is minimized, and employees are given the chance to improve and strive to their full potential. We are building better and smarter machines, incorporating more intelligence



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The world's top PCB fabricators rely on ESI to stay ahead. Geode uses latest-generation high-speed CO<sub>2</sub> laser technology paired with new beam control capabilities to optimize HDI PCB and IC Substrate manufacturing.

- Meet aggressive production targets
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and features, and adapting to the volumes demanded by this everchanging audience thirsty for the next new breakthrough in technology. But how are we doing this regarding electrical test (ET)?

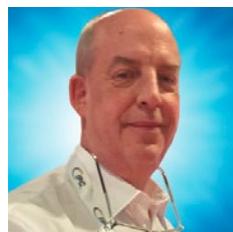
We are adapting. Automation is the key. ET is usually a final quality process prior to shipping. Thinking out of the box again has made the argument that test can and should be placed “in-line” during the manufacturing process. Just like AOI, ET can provide beneficial outcomes earlier in the manufacturing process, rather than just at the end. This can be very beneficial post-plating after outer strip and etch, especially in the sequential lamination process. Imagine being able to capture sample panels to be screened with a 4-wire Kelvin test, for example, before returning them to the line. Think out of the box. I’m sure a process engineer just had an amazing idea. Defects can be found early and dispositioned before any further costly processes are done on the panel.

Speaking of 4-wire Kelvin, evolution is making the incorporation of this popular test into fixture technology. Historically this has required on-bench testing or flying probe. Putting this test into the fixture arena is extremely beneficial with the volumes processed, especially commercial products such as cellphones. Fixture technology is improving too. It has not gone by the way of the dodo. It is now possible

to test down in the 20–35-micron range while incorporating the 4-wire test.

Now, stepping back to AI. You likely cannot talk to your test machine (yet). You could, but your coworkers may look at you funny. It will not be in the too distant future where you will be able to. However, AI is alive and well in the AOI/AVI theatre. Although you cannot speak to the machines, they can learn from their activities and make beneficial decisions based on the criteria they have been told and results they obtain from their scans. This negates the extra time and eyeballing of nuisance false errors that just slow down the entire process. With the high-resolution CCD cameras, they do not tire and find anomalies that the human eye may miss.

From my crystal ball, the evolutionary curve is still strong. Just like in the last 52 years since Apollo 13, we have seen amazing things. I predict the future is just as bright and I think evolution will accelerate as our brilliant minds continue to collaborate, think outside the box, and make extraordinary discoveries in what was once just plain impossible. **PCB007**



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

A dark blue banner with a textured background. On the left, the text "jobCONNECT007" is displayed in a large, bold font, with "job" in light blue, "CONNECT" in white, and "007" in yellow. Below this, in smaller white text, it says "Companies seeking talent with circuit board industry experience post their jobs with us." On the right side, there is a large magnifying glass icon. Inside the lens of the magnifying glass, the website address "jobconnect007.com" is written in white.

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Insulectro, the largest distributor in North America of materials used in the manufacture of printed circuit boards and printed electronics, salutes our premier suppliers.

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## Denkai America



Denkai America is a leader in the manufacture of high-quality electrodeposited copper foils for printed circuit board (PCB), industrial, and energy.

With the strength of domestic manufacturing, and backed by a global presence, Denkai America delivers both conventional cladding and application specific copper foils required by technology leading companies.



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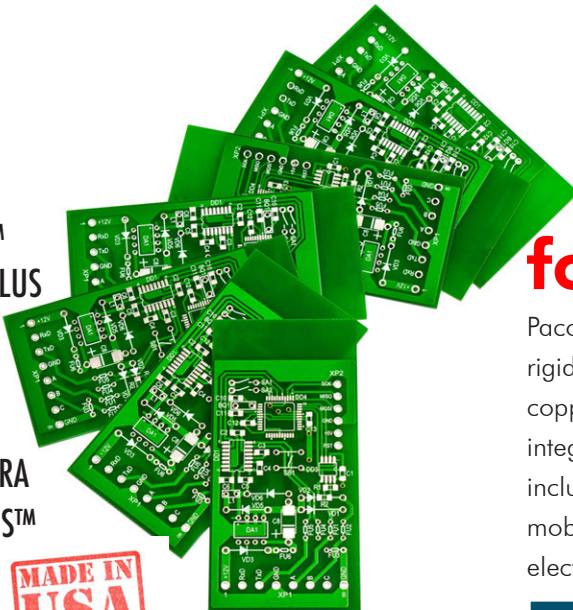
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Pacothane services the worldwide PCB market, which includes rigid multilayer, rigid/flex, cover-layer flex, flexible multilayer, copper and unclad Laminates. These circuit boards are integrated into a wide variety of applications and markets that include telecom, data communications, high-speed computing, mobile devices, military, smart cards, medical and effectively all electronic products.

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## Measuring Multiple Lamination Reliability for Low-loss Materials

Taiwan Union Technology Corporation (TUC) provides copper-clad laminates and dielectric resin composites used to manufacture printed circuit boards. The enthalpy of these resin composites meets and exceeds customers' objectives and shows the deterioration of the resin's physical properties as a result of multiple lamination cycles (up to 10X).



## Catching up With EISO Enterprises' President Gary Chien



While there are many Chinese companies now selling in the United States, I wanted to find one

in Taiwan that is penetrating the U.S. market. I was delighted to come across EISO Enterprise Co. Ltd., a printed circuit board fabricator located in Taiwan. I know that the American companies are usually looking for PCB global partners in countries other than China, which made my conversation with Gary (Jung Kun) Chien more interesting, especially when he shared his thoughts on the U.S-China trade wars.

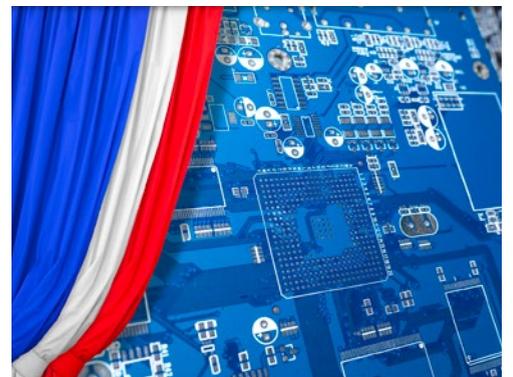
## The Right Approach: The Law of Priorities

There are three questions to ask to understand the Law of Priorities that must be embraced during the journey to become a great leader: What is required that only I can do? What gives the greatest return? What brings the greatest reward? Let's dig in and discover how to embrace these principles in your leadership.



## Uncovering the Electronics Ecosystem

Nolan Johnson speaks with Will Marsh, vice president of TTM Technologies and president of the Printed Circuit Board Association of America, about the work the PCBAA has been doing in Washington, D.C., to get the industry better recognized by the country's decision-makers. Marsh is optimistic, not only about the companies and individuals joining the effort, but in the recognition by Capitol Hill to secure the nation's defense systems.



# The Carbon Footprint of HDI: Direct Metallization vs. Electroless Copper

As the electronics supply chain contends with the struggles of moving out of the pandemic and into a new normal, it is increasingly obvious that a new normal will be one with sustainability and resource conservation as the top priority. Over the past year, we have seen printed circuit board manufacturers encounter challenges associated with environmental regulations, water and power outages, and pressures from the supply chain to reduce environmental footprints.

## FIRST Program Inspires Next Generation of Innovators

In this interview, Barry Matties speaks with Adrienne Collins, director of programs at FIRST Washington, about the success of a student robotics program that fosters innovation, builds problem solving skills, and cultivates a concept that most of us have never heard of—gracious professionalism.



## One World, One Industry: Working Together to Address Workforce Challenges

While the conflict in Ukraine has captured all the headlines for the past several weeks, the challenges facing companies on the workforce front have not abated. When I speak with executives around the world, they are singing the same song in two-part harmony: supply chain and people. Let's talk a little about the people challenges that are keeping management up at night.

## Fein-Lines: Is Windows 11 the Greatest Operating System of All Time?



I held off upgrading to Windows 11 for several months, but finally took the plunge and it has quickly become my favorite operating system of all time. I know that's a bold statement but let me tell you why I've come to this conclusion.

## Training the Future Manufacturing Labor Force

To better understand what's needed for upskilling your labor force in today's job climate, we reached out to Sunstone Circuits, a PCB fabricator in the Pacific Northwest. We posed our set of questions to individuals in three departments to hear their perspectives.



## Prototron Circuits Installs Maskless Model 5600 LED Direct Imager

Prototron Circuits of Tucson, Arizona, has recently installed a Maskless Model 5600 LED direct imaging machine, which allows for processing .003 mil lines on most applications.

For the latest news and information, visit [PCB007.com](http://PCB007.com)

# Career Opportunities



## Is your team growing?

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

For just \$750, your 200-word, full-column ad will appear in the Career Opportunities section of all three of our monthly magazines, reaching circuit board designers, fabricators, assemblers, OEMs, suppliers and the academic community.

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# Career Opportunities



## Printed Circuit Board (PCB)

### Layout Designer (Designer-Drafter 3/4)

Los Alamos National Laboratory  
Los Alamos, New Mexico

Los Alamos National Laboratory (LANL) is a multidisciplinary research institution engaged in science and engineering on behalf of national security. The ISR-5 Space Instrument Realization Group is currently seeking an entry level Printed Circuit Board (PCB) Layout Designer. You'll design and develop rigid and flexible PCBs directly supporting the design, prototyping and manufacturing of innovative space satellites for a variety of important scientific and national security missions.

#### Requirements:

- 3–5 years relevant experience
- Associate's in engineering or technical field (or an additional 2 years related experience)
- Working knowledge of PCB fabrication or electronics assembly requirements
- Familiarity with PCB layout CAD design tools
- Demonstrated commitment to safety, security environment and quality

#### Desired Qualifications:

- Basic experience using software tools to produce models, drawings, layouts and sketches of components/systems
- Familiarity with PCB design concepts, IPC design and performance standards
- Experience using PCB design software, such as Eagle, Altium or Mentor Graphics

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search IRC102937lanl.gov/careers

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## Printed Circuit Board (PCB)

### Technologist (Engineering Technologist 1 / 2)

Los Alamos National Laboratory  
Los Alamos, New Mexico

Los Alamos National Laboratory (LANL) is a multidisciplinary research institution focused on solving national security challenges. The Intelligence and Space Research Division is seeking an experienced Printed Circuit Board (PCB) Layout Technologist to directly support the design, prototyping and manufacturing of innovative space instruments for important science and national security missions.

#### Requirements:

- 2–5 years related experience
- Bachelor's in engineering technology, science or math (or an additional 8 years of related experience)
- Advanced knowledge of PCB layout CAD design tools/current best practices
- Ability to determine technical requirements/objectives for new PCB designs
- Ability to identify problems, create solutions and effectively navigate institutional systems

#### Desired Qualifications:

- Experience using Siemens (Mentor Graphics) Xpedition PB design flow software
- Experience interpreting and applying IPC-6012 and IPC-6013 qualification and performance standards
- Experience designing high-speed, controlled-impedance PCBs for digital and RF applications
- Experience designing PCBs for space flight applications

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Los Alamos National Laboratory is an EO employer – Veterans/Disabled and other protected categories. Qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, sexual orientation, gender identity, disability or protected veteran status.

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# Career Opportunities



## US-Based Technical Sales Specialist

Polar Instruments, Inc. (Beaverton, OR) is looking for an additional US-based technical sales specialist to assist in selling our growing family of PCB signal integrity tools for the PCB fabrication/design industry and the electronics supply chain.

A background in the PCB industry and fabrication knowledge are an advantage. A B.S. in engineering or physics (or other science or technology degree) and related technical sales experience preferred. Willingness to travel 8-10 times a year for a week at a time and 1-2 weekends.

Polar has been in business for over 40 years and are a small, eclectic group of people spread around the world. Our values are centered on enjoying what we do—which is working to make things just right for our customers. We approach challenge as an opportunity, frequently an adventure. We work together as a team, without politics, and with our team's welfare at the forefront of our concerns. We are successful. We have grown year-upon-year, and we take great pride in pretty much owning our niche in a very large marketplace. We command great respect from our users and industry partners.

If interested, please contact Lupita at [jobs.usa@polainstruments.com](mailto:jobs.usa@polainstruments.com)

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## Sales Technical Engineer

ALTIX, a French company, designs, manufactures, markets and services exposure equipment for the printed circuit board, flexible circuit, metal etching, touch panel and other industries. The U.S. subsidiary, focused on the sale and service of Altix equipment in North America, is looking for a sales technical engineer to support their growth.

### Responsibilities

- Promote Altix's products by visiting customers
- Serve as a technical lead & product expert to provide technical recommendations to customers
- Gather on-the-ground market intelligence through customer contact
- Ensure sustainable growth in sales, profits, and market presence
- Develop new business and achieve targets for market penetration, sales and profit
- Manage sales partners

### Skills & Qualifications

- Minimum 2 to 5 years' experience in sales for capital equipment in the PCB market or related industries
- Business development and marketing background preferred
- 5+ years' North American business leadership experience in related field
- Strong leadership, decision-making and communication skills.
- Proficiency in standard computer software applications such as Microsoft Office
- Excellent written and oral communication skills
- Willingness to travel within the US, Canada and to France for training

Email contact: [sylvain.dromaint@altix.us](mailto:sylvain.dromaint@altix.us)

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# Career Opportunities



## Global Account Manager, e-Mobility & Infrastructure

**Location:  
AZ, CA, TX (remote)**

### Job Summary:

The Global Account Manager, e-Mobility & Infrastructure is a key position for the sales organization, serving as Indium Corporation's lead sales contact responsible for developing targeted accounts in the e-Mobility and related infrastructure space.

### Responsibilities will include:

- sourcing for new global business opportunities
- implementing effective sales strategies
- interfacing with customers' senior management
- execution of action plans through the regional teams
- interaction with internal customers (R&D; Inside Sales; Technical Support; Logistics; Product Management; Operations; Engineering; Quality; etc.) resulting in evaluation, qualification, specification, and maximum customer share for designated customers
- providing risk assessment of the business to senior management

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## Director of Operations State College, PA

Chemcut Corp., a world leader in wet processing equipment for the manufacture of printed circuit boards and chemical etching of various metals, is seeking a Director of Operations.

### Objectives of the Role:

- Collaborate with the CEO in setting and driving organizational vision, operational strategy, and hiring needs.
- Oversee manufacturing operations and employee productivity, building a highly inclusive culture ensuring team members thrive and organizational outcomes are met.
- Directly oversee manufacturing operations, production planning, purchasing, maintenance & customer service (product support) and partner with the CEO and controller on sales management to budget for sufficient investment capital to achieve growth targets.
- Aggressively manage capital investment and expenses to ensure the company achieves investor targets relative to growth and profitability.

### Qualifications:

- Bachelor's degree in mechanical, electrical, or related fields
- 5+ years' experience in leadership positions
- Leadership skills, with steadfast resolve and personal integrity
- Understanding of advanced business planning and regulatory issues
- A solid grasp of data analysis and performance metrics
- Ability to diagnose problems quickly and have foresight into potential issues

### Preferred Qualifications:

- Master's degree in business or related field
- International business experience

To apply, please submit a cover letter and resume to [hr@chemcut.net](mailto:hr@chemcut.net)

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# Career Opportunities



Flexible Circuit Technologies is a premier global supplier providing design, prototyping and production of flexible circuits, rigid flex circuits, flexible heaters, and membrane switches.

## Application Engineer/ Program Management

### Responsibilities

- Gain understanding for customer and specific project requirements
- Review customer files/drawings, analyze technical, application, stackup, material, and mechanical requirements; develop cost-effective designs that meet requirements
- Quote and follow up to secure business
- Work with CAD: finalize files, attain customer approval prior to build
- Track timeline and provide customers with updates
- Follow up on prototype, assist with design changes if needed, push forward to production
- Work with customer as the lead technician/program manager or as part of FCT team working with an assigned program manager
- Help customer understand FCT's assembly, testing, and box build services/support
- Understand manufacturing and build process for flexible and rigid-flex circuits

### Qualifications

- Demonstrated experience: PCB/FPCB/rigid-flex designer including expertise in design rules, IPC
- Demonstrated success in attaining business
- Ability to work in fast-paced environment, on broad range of projects, while maintaining a sense of urgency
- Ability to work as a team player
- Excellent written and verbal communication skills
- Must be willing to travel for sales support activities, customer program support and more.

FCT offers a competitive salary, bonus program, and benefits package. Preferred location Minneapolis, MN area. [www.flexiblecircuit.com](http://www.flexiblecircuit.com)

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

### Responsibilities

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

### Qualifications

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

FCT offers a competitive salary, bonus program, and benefits package. Preferred location Minneapolis, MN area. [www.flexiblecircuit.com](http://www.flexiblecircuit.com)

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# Career Opportunities



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## Operations Supervisor Elk Grove Village IL, USA

As operations supervisor at Ventec USA LLC, you will have a hands-on and quality-driven approach to coordinating and overseeing the operations in Elk Grove Village, Illinois. You will plan, organize, and implement the day-to-day warehouse activities to ensure customer expectations are met. Tasks will include planning, implementing performance improvement measures, procuring materials and resources, and assuring compliance to the Quality Management System. You will be a mentor to team members, find ways to maintain and improve the highest quality of customer service, and implement best practices across all levels to help the company remain compliant, efficient, and profitable.

### Skills and abilities required:

- Proven experience as operations supervisor or similar role
- Knowledge of organizational effectiveness and warehouse management
- Experience with ISO9001 or similar QMS
- Experience in budgeting and forecasting/ familiarity with business and financial principles
- Excellent leadership ability and communication skills (English)
- Outstanding organizational skills
- Qualification in distribution, logistics, transportation, or business studies is preferential

### What's on offer:

- Excellent salary & benefits commensurate with experience

This is a fantastic opportunity to become part of a successful brand and leading team with excellent benefits. Please forward your resume to [HR@Ventec-usa.com](mailto:HR@Ventec-usa.com) and mention (Operations Supervisor) in the subject line.

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## European Product Manager Taiyo Inks, Germany

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

### Duties include:

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

### Skills and abilities required:

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

### What's on offer:

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

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

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# Career Opportunities



**American Standard Circuits**

Creative Innovations In Flex, Digital & Microwave Circuits

## Wet Process Engineer

ASC, the largest independent PCB manufacturer in the Midwest, is looking to expand our manufacturing controls and capabilities within our Process Engineering department. The person selected will be responsible for the process design, setup, operating parameters, and maintenance of three key areas—imaging, plating, etching—within the facility. This is an engineering function. No management of personnel required.

### Essential Responsibilities

Qualified candidates must be able to organize their own functions to match the goals of the company.

### Responsible for:

- panel preparation, dry film lamination, exposure, development and the processes, equipment setup and maintenance programs
- automated (PAL line) electrolytic copper plating process and the equipment setup and maintenance programs
- both the cupric (acid) etching and the ammoniacal (alkaline) etching processes and the equipment setups and maintenance programs

### Ability to:

- perform basic lab analysis and troubleshooting as required
- use measurement and analytical equipment as necessary
- work alongside managers, department supervisors and operators to cooperatively resolve issues
- effectively problem-solve
- manage multiple projects concurrently
- read and speak English
- communicate effectively/interface at every level of the organization

### Organizational Relationships

Reports to the Technical Director.

### Qualifications

Degree in Engineering (BChE or I.E. preferred). Equivalent work experience considered. High school diploma required. Literate and functional with most common business software systems MS Office, Excel, Word, PowerPoint are required. Microsoft Access and basics of statistics and SPC a plus.

### Physical Demands

Exertion of up to 50 lbs. of force occasionally may be required. Good manual dexterity for the use of common office equipment and hand tools.

- Ability to stand for long periods.

### Work Environment

This position is in a manufacturing setting with exposure to noise, dirt, and chemicals.

**Click on 'apply now' button below to send in your application.**

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# Career Opportunities



## R&D Scientist III Orange, CT

**Job Description:** The scientist will be a leader in technology for plating chemistry development, electrolytes, and additives. The position is hands-on, where the ideal candidate will enjoy creating and testing new aqueous plating processes and materials to meet the most demanding semiconductor applications related to Wafer-Level Packaging and Damascene. The qualified candidate will work as part of the R&D team while interacting with scientists, product management, and application engineers to commercialize new products for the advanced electronic solution business.

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## Technical Marketing Specialist Waterbury, CT

This position provides information from the product team to the marketing communications team. It is a multifunctional role that requires some experience within electronics manufacturing supply chain or knowledge of how electronic devices are manufactured, specifically PCBs, semiconductors, and the chemical processes utilized therein. The primary function of this role is to help in the generation of product marketing collateral, but also includes assisting in tradeshow content development, advertising, and launches.

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## Regional Manager Midwest Region

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

### DETAILS OF FUNCTION:

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

### QUALIFICATIONS:

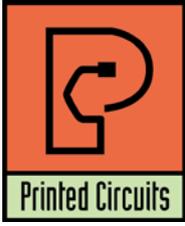
- 5-7+ years of related experience in the manufacturing sector or equivalent combination of formal education and experience
- Excellent oral and written communication skills
- Business-to-business sales experience a plus
- Good working knowledge of Microsoft Office Suite and common smart phone apps
-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

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

[fernando\\_rueda@kyzen.com](mailto:fernando_rueda@kyzen.com)

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# Career Opportunities



## Printed Circuits, a fast-growing printed circuit board fabricator, offers:

- Excellent opportunities for advancement and growth
- Dynamic manufacturing environment
- Excellent health, dental and other benefits
- Annual profit-sharing plan
- Signing bonus
- Additional incentives at the leadership level
- Clean facility with state-of-the-art manufacturing equipment
- Highly collaborative corporate and manufacturing culture that values employee contributions

### Laminator Technician

#### Nature of Duties/Responsibilities

- Layup cover lay
- Layup rigid flex
- Layup multilayer/CU core boards
- Oxide treat/cobra treatment of all layers/CU cores
- Shear flex layer edges
- Rout of machine panel edges and buff
- Remove oxide/cobra treatment (strip panels)
- Serialize panels
- Pre-tac Kapton windows on flex layers (bikini process)
- Layup Kapton bonds
- Prep materials: B-stage, Kapton, release sheet
- Breakdown: flex layers, and caps
- Power scrub: boards, layers, and caps
- Laminate insulators, stiffeners, and heatsinks
- Plasma cleans and dry flex layers B-stage (Dry)
- Booking layers and materials, ready for lamination process
- Other duties as deemed necessary by supervisor

#### Education/Experience

- High school diploma or GED
- Must be a team player
- Must demonstrate the ability to read and write English and complete simple mathematical equations
- Must be able to follow strict policy and OSHA guidelines
- Must be able to lift 50 lbs
- Must have attention to detail

### Wet Process/Plating Technician

Position is 3<sup>rd</sup> shift (11:00PM to 7:30AM, Sunday through Friday)

#### Purpose

To carry out departmental activities which result in producing quality product that conforms to customer requirements. To operate and maintain a safe working environment.

#### Nature of Duties/Responsibilities

- Load and unload electroplating equipment
- Fasten circuit boards to racks and cathode bars
- Immerse work pieces in series of cleaning, plating and rinsing tanks, following timed cycles manually or using hoists
- Carry work pieces between departments through electroplating processes
- Set temperature and maintains proper liquid levels in the plating tanks
- Remove work pieces from racks, and examine work pieces for plating defects, such as nodules, thin plating or burned plating
- Place work pieces on racks to be moved to next operation

- Check completed boards
- Drain solutions from and clean and refill tanks; fill anode baskets as needed
- Remove buildup of plating metal from racks using chemical bath

#### Education and Experience

- High school diploma or GED required
- Good organizational skills and the ability to follow instructions
- Ability to maintain a regular and reliable attendance record
- Must be able to work independently and learn quickly
- Organized, self-motivated, and action-oriented, with the ability to adapt quickly to new challenges/opportunities
- Prior plating experience a plus

### Production Scheduler

#### Main Responsibilities

- Development and deployment of a level-loaded production plan
- Establish manufacturing plan which results in "best possible" use of resources to maximize asset utilization
- Analyze production capacity of manufacturing processes, equipment and human resource requirements needed to produce required products
- Plan operation manufacturing sequences in weekly time segments utilizing production labor standards
- Maintain, align, and communicate regularly with internal suppliers/customers and customer service on key order metrics as per their requirements
- Frequently compare current and anticipated orders with available inventory and creates replenishment plan
- Maintain master distribution schedule for the assigned facility, revise as needed and alert appropriate staff of schedule changes or delays
- Participate in periodic forecasting meetings
- Lead or participate in planning and status meetings with production, shipping, purchasing, customer service and/or other related departments
- Follow all good manufacturing practices (GMPs)
- Answer company communications, fax, copy and file paperwork

#### Education and Experience

- High school diploma or GED
- Experience in manufacturing preferred/3 years in scheduling
- Resourceful and good problem-solving skills
- Ability to make high pressure decisions
- Excellent written and verbal communication skills
- Strong computer skills including ERP, Excel, Word, MS Office
- Detailed and meticulous with good organizational skills
- Must be articulate, tactful and professional at all times
- Self-motivated

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# Career Opportunities



MACHINES FOR PRINTED CIRCUIT BOARDS

## Field Service Engineer

**Location: West Coast, Midwest**

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

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

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

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

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

**Must be able to travel extensively.**

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## SMT Field Technician Hatboro, PA

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

### Duties and Responsibilities:

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

### Requirements and Qualifications:

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

### We Offer:

- Health and dental insurance
- Retirement fund matching
- Continuing training as the industry develops

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# Career Opportunities



## Rewarding Careers

Take advantage of the opportunities we are offering for careers with a growing test engineering firm. We currently have several openings at every stage of our operation.

The Test Connection, Inc. is a test engineering firm. We are family owned and operated with solid growth goals and strategies. We have an established workforce with seasoned professionals who are committed to meeting the demands of high-quality, low-cost and fast delivery.

TTCI is an Equal Opportunity Employer. We offer careers that include skills-based compensation. We are always looking for talented, experienced test engineers, test technicians, quote technicians, electronics interns, and front office staff to further our customer-oriented mission.

## Associate Electronics Technician/Engineer (ATE-MD)

TTCI is adding electronics technician/engineer to our team for production test support.

- Candidates would operate the test systems and inspect circuit card assemblies (CCA) and will work under the direction of engineering staff, following established procedures to accomplish assigned tasks.
- Test, troubleshoot, repair, and modify developmental and production electronics.
- Working knowledge of theories of electronics, electrical circuitry, engineering mathematics, electronic and electrical testing desired.
- Advancement opportunities available.
- Must be a US citizen or resident.

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## Test Engineer (TE-MD)

In this role, you will specialize in the development of in-circuit test (ICT) sets for Keysight 3070 (formerly HP) and/or Teradyne (formerly GenRad) TestStation/228X test systems.

- Candidates must have at least three years of experience with in-circuit test equipment. A candidate would develop and debug our test systems and install in-circuit test sets remotely online or at customer's manufactur-

ing locations nationwide.

- Candidates would also help support production testing and implement Engineering Change Orders and program enhancements, library model generation, perform testing and failure analysis of assembled boards, and other related tasks.
- Some travel required and these positions are available in the Hunt Valley, Md., office.

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## Sr. Test Engineer (STE-MD)

- Candidate would specialize in the development of in-circuit test (ICT) sets for Keysight 3070 (formerly Agilent & HP), Teradyne/GenRad, and Flying Probe test systems.
- 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.
- Some travel required. Positions are available in the Hunt Valley, Md., office.

Contact us today to learn about the rewarding careers we are offering. Please email resumes with a short message describing your relevant experience and any questions to [careers@ttci.com](mailto:careers@ttci.com). Please, no phone calls.

We proudly serve customers nationwide and around the world.

TTCI is an ITAR registered and JCP DD2345 certified company that is NIST 800-171 compliant.

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# Career Opportunities

## INSULECTRO

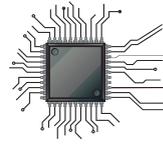


## Are You Our Next Superstar?!

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

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

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## MivaTek

Global

## Field Service Technician

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

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

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

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

### More About Us

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

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# Career Opportunities



## eptac

TRAIN. WORK SMARTER. SUCCEED.

### Become a Certified IPC Master Instructor

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

#### Qualifications and skills

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

#### Benefits

- Ability to operate from home. No required in-office schedule
- Flexible schedule. Control your own schedule
- IRA retirement matching contributions after one year of service
- Training and certifications provided and maintained by EPTAC

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## SIEMENS

### Siemens EDA Sr. Applications Engineer

Support consultative sales efforts at world's leading semiconductor and electronic equipment manufacturers. You will be responsible for securing EM Analysis & Simulation technical wins with the industry-leading HyperLynx Analysis product family as part of the Xpedition Enterprise design flow.

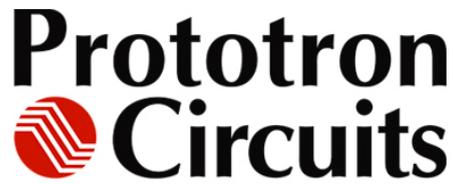
Will deliver technical presentations, conduct product demonstrations and benchmarks, and participate in the development of account sales strategies leading to market share gains.

- PCB design competency required
- BEE, MSEE preferred
- Prior experience with Signal Integrity, Power Integrity, EM & SPICE circuit analysis tools
- Experience with HyperLynx, Ansys, Keysight and/or Sigrity
- A minimum of 5 years' hands-on experience with EM Analysis & Simulation, printed circuit board design, engineering technology or similar field
- Moderate domestic travel required
- Possess passion to learn and perform at the cutting edge of technology
- Desire to broaden exposure to the business aspects of the technical design world
- Possess a demonstrated ability to build strong rapport and credibility with customer organizations while maintaining an internal network of contacts
- Enjoy contributing to the success of a phenomenal team

*\*\*Qualified applicants will not require employer-sponsored work authorization now or in the future for employment in the United States. Qualified Applicants must be legally authorized for employment in the United States.*

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# Career Opportunities



## Sales Representatives

Prototron Circuits, a market-leading, quick-turn PCB shop, is looking for sales representatives for all territories.

Reasons you should work with Prototron:

- Serving the PCB industry for over 30 years
- Solid reputation for on-time delivery (99% on-time)
- Excellent quality
- Production quality quick-turn services in as little as 24 hours
- AS9100
- MIL-PRF- 31032
- ITAR
- Global sourcing
- Engineering consultation
- Completely customer focused team

Interested? Let's have a talk.

Call Dan Beaulieu at

207-649-0879

or email to

[danbbeaulieu@aol.com](mailto:danbbeaulieu@aol.com)

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**U.S. CIRCUIT**

## Plating Supervisor

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

Competitive benefits package.

Pay will be commensurate with experience.

Mail to:

[mfariba@uscircuit.com](mailto:mfariba@uscircuit.com)

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# Career Opportunities



## APCT, Printed Circuit Board Solutions: Opportunities Await

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

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

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

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

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

*Independent contractor,  
possible full-time employment*

### Job Description

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

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

### Qualifications

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

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

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

Send resumes to Sharon Montana-Beard at [sharonm@blackfox.com](mailto:sharonm@blackfox.com).

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# Career Opportunities



Arlon EMD, located in Rancho Cucamonga, California, is currently interviewing candidates for open positions in:

- **Engineering**
- **Quality**
- **Various Manufacturing**

All interested candidates should contact Arlon's HR department at 909-987-9533 or email resumes to [careers.ranch@arlonemd.com](mailto:careers.ranch@arlonemd.com).

Arlon is a major manufacturer of specialty high-performance laminate and prepreg materials for use in a wide variety of printed circuit board applications. Arlon specializes in thermoset resin technology, including polyimide, high Tg multifunctional epoxy, and low loss thermoset laminate and prepreg systems. These resin systems are available on a variety of substrates, including woven glass and non-woven aramid. Typical applications for these materials include advanced commercial and military electronics such as avionics, semiconductor testing, heat sink bonding, High Density Interconnect (HDI) and microvia PCBs (i.e. in mobile communication products).

Our facility employs state of the art production equipment engineered to provide cost-effective and flexible manufacturing capacity allowing us to respond quickly to customer requirements while meeting the most stringent quality and tolerance demands. Our manufacturing site is ISO 9001: 2015 registered, and through rigorous quality control practices and commitment to continual improvement, we are dedicated to meeting and exceeding our customers' requirements.

For additional information please visit our website at [www.arlonemd.com](http://www.arlonemd.com)

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

## CAD/CAM Engineer

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

### ESSENTIAL DUTIES AND RESPONSIBILITIES

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

### ORGANIZATIONAL RELATIONSHIP

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

### QUALIFICATIONS

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

### PHYSICAL DEMANDS

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

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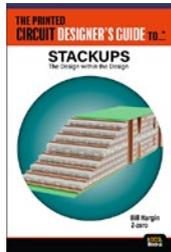
## Latest I-007eBooks



### ***The Printed Circuit Designer's Guide to... High Performance Materials***

by Michael Gay, Isola

This book provides the reader with a clearer picture of what to know when selecting which material is most desirable for their upcoming products and a solid base for making material selection decisions. [Get your copy now!](#)



### ***The Printed Circuit Designer's Guide to... Stackups: The Design within the Design***

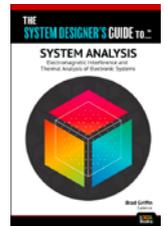
by Bill Hargin, Z-zero

Finally, a book about stackups! From material selection and understanding laminate data-sheets, to impedance planning, glass weave skew and rigid-flex materials, topic expert Bill Hargin has written a unique book on PCB stackups. [Get yours now!](#)

## ***The Systems Designer's Guide to ... System Analysis***

by Brad Griffin, Cadence

In this book, the author, Brad Griffin of Cadence, focuses on EM and thermal analysis in the context of data center electronics systems. Be sure to also [download the companion guide](#) for end-to-end solutions to today's design challenges.



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



### ***Thermal Management: A Fabricator's Perspective***

by Anaya Vardya, American Standard Circuits

Beat the heat in your designs through thermal management design processes. This book serves as a desk reference on the most current techniques and methods from a PCB fabricator's perspective.



### ***Thermal Management with Insulated Metal Substrates***

by Didier Mauve and Ian Mayoh, Ventec International Group

Considering thermal issues in the earliest stages of the design process is critical. This book highlights the need to dissipate heat from electronic devices.



### ***Flex and Rigid-Flex Fundamentals***

by Anaya Vardya and David Lackey, American Standard Circuits

Flexible circuits are rapidly becoming a preferred interconnection technology for electronic products. By their intrinsic nature, FPCBs require a good deal more understanding and planning than their rigid PCB counterparts to be assured of first-pass success.

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COVER: **SHELLY STEIN**

COVER IMAGE: **ADOBE STOCK © PHILIP STEURY**

# PCB007

MAGAZINE

PCB007 MAGAZINE®

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

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May 2022, Volume 12, Number 5  
PCB007 MAGAZINE is published monthly,  
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