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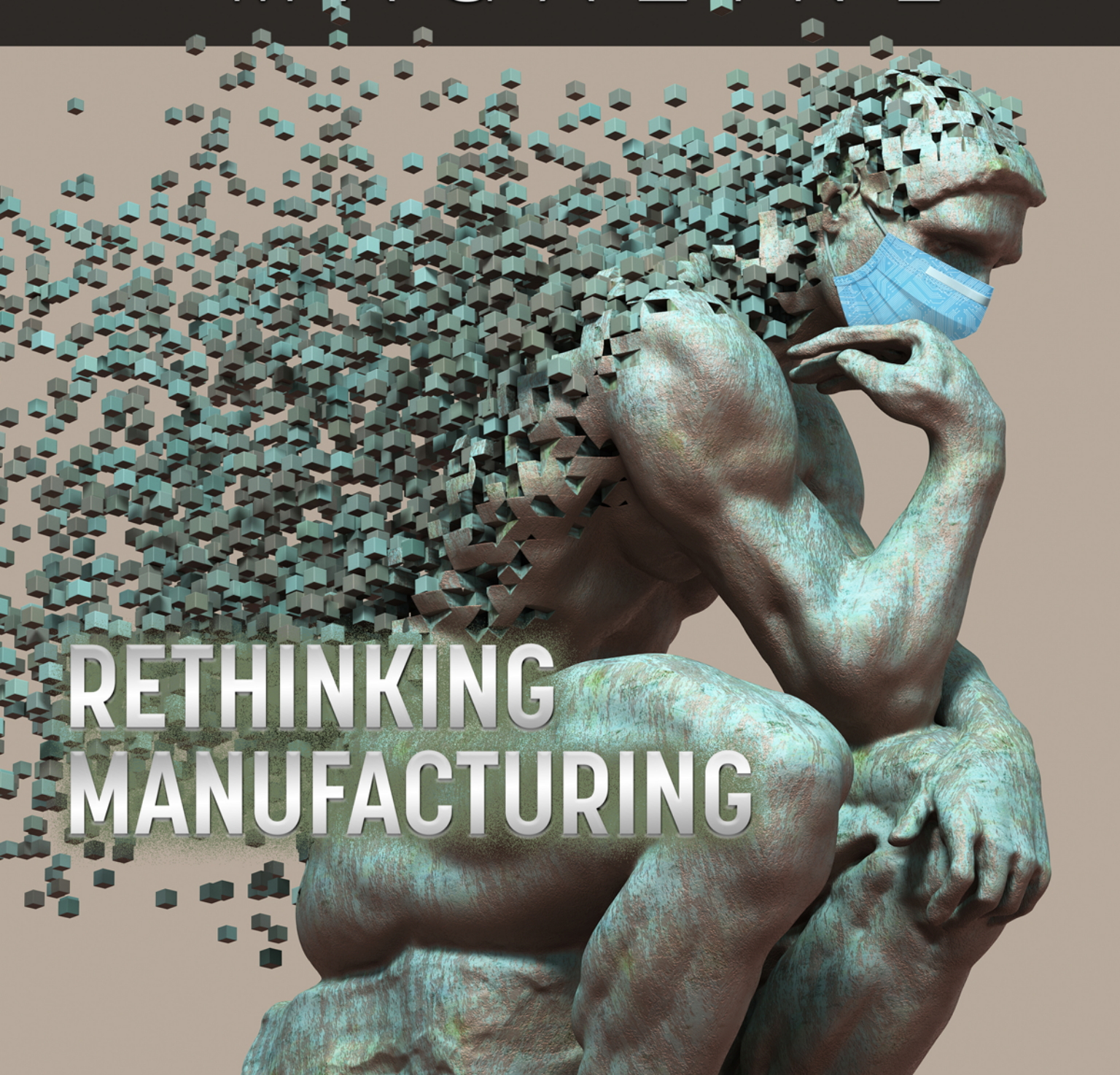

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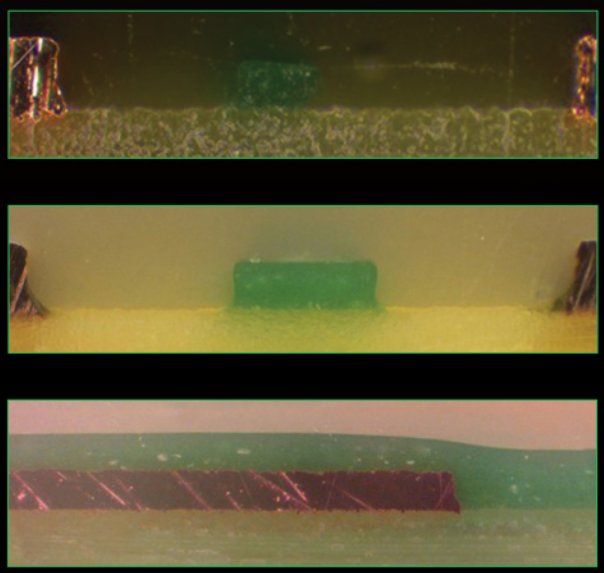

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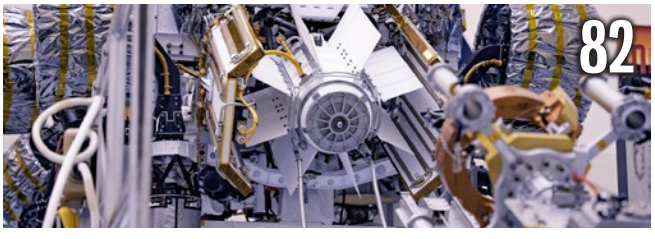

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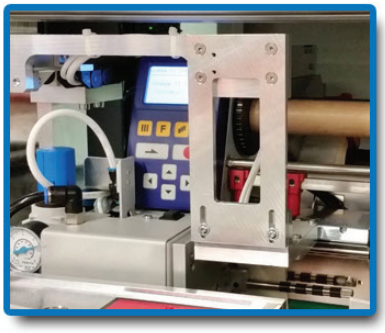

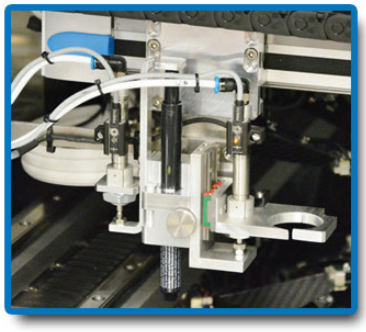

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Rethinking Manufacturing

Nolan's Notes

by Nolan Johnson, I-CONNECT007

Tom Popomaronis wrote an article on Warren Buffett's simple test for making tough decisions. He wrote [1]:

> "If a manager expresses uncertainty, Buffett says he asks them how they 'would feel about any given action if they know it was to be written up the next day in their local newspaper.' He tells them that the article would be 'written by a smart but pretty unfriendly reporter' and read by their family, friends, and neighbors. 'It's pretty simple,' he says. 'If [the decision] passes that test, it's okay. If anything is too close to the lines, it's out.'"

Now, ethics (and sometimes the lack thereof) are always a part of the decision-making process; I'm sure you'll grant me that point. This passage caught my eye not so much because of the discussion of ethics, but because many of us can see some tough decisions coming over the horizon.

Quick! Name a department in your company, and I bet I can identify a challenge. Sales? Lead generation and virtual customer visits. The shop floor? Easy! Interconnected equipment, process tracking, and new wet processes, just to name a few. Marketing? Revamping programs and trade shows for a virtual experience. Human resources? Finding skilled new hires and providing them with safe working environments. Purchasing? Supply chain resiliency. Accounting? Yes, not even accounting escapes the threat of cybersecurity and ransomware extortion.

All of these challenges and changes must be coordinated from the executive ranks. Risks must be assessed, investments ranked, and funding planned. These market dynamics may be changing the calculus of the fabrication business. Supply chain dynamics potentially expand into fabrication dynamics, including new regional and captive fabrication, and capital investment. Businesses throughout the industry are rethinking their

manufacturing, cybersecurity, and supply chain strategies.

And just when we face all these changes and we need to connect even more closely with customers, suppliers, and vendors, we can't. Industry gatherings—trade shows and conferences, among other types of events—are canceled.

We all face the requirement to make potentially pivotal decisions with incomplete and changing information. What's more, we have to make the right decisions. This is why the quote from Popomaronis caught my attention. With so many choices to make, company cash flow at risk, human health and safety on the line, and customer requirements changing so rapidly, the potential damage from a bad decision is very real.

This issue is an exploration of the rethinking currently underway across the industry. Our conversations on rethinking manufacturing include re-imagining wet processes, additive, and subtractive processes. We also explore rethinking the tools available to your incoming CAM department, in the form of best practices for landing pads, the advantages of the new VeCS technology, and more information on Elsyca's sophisticated CAM analysis software. We also take you through a real-world example of how ransomware can be a very real threat to your business.

I recently spoke with an industry insider who commented that working remotely uncovered weaknesses in their procedures that simply weren't visible when everyone was in the office. In an adjacent industry, I heard of a new hire quitting two days into the onboarding process because the training materials given to her were so out-of-sync with working remotely that they made the job impossible to perform.

In unprecedented times, inspiration and insight can come from within or without—self, company, industry, and even further afield. As we all find ourselves running down an unending list of rethinking tasks, remember to keep Mr. Buffett's test in mind. **PCB007**

Reference

1. T. Popomaronis, "Billionaire Warren Buffett has a 'simple' test for making tough decisions–here's how it works," CNBC, May 11, 2019.

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

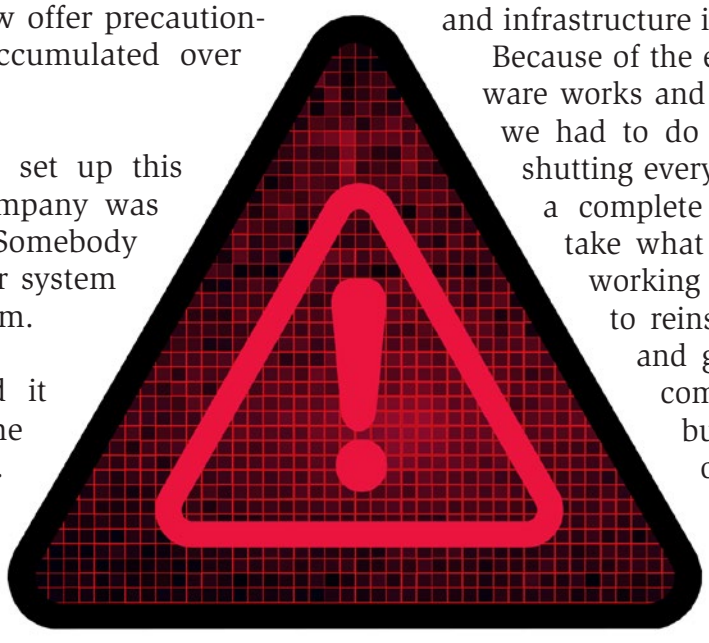
CYBERATTACK!

THINK IT COULDN'T HAPPEN TO YOU? THINK AGAIN!

Feature Interview by Barry Matties
I-CONNECT007

Cybersecurity is a necessity in every business, and this interview is a must-read for helping you and your company to understand vulnerabilities and protect yourself from attacks. Remember, until an attack hits you, you have no idea how devastating it can be.

Eric Cormier and Dave Ryder of Prototron address the ransomware attack that locked them out of their system last December, bringing business to a screeching halt and forcing them into the arduous process of a full rebuild. With things finally starting to normalize, Eric and Dave now offer precautionary advice they've accumulated over the past six months.



Barry Matties: Eric, to set up this conversation, your company was hit with ransomware. Somebody locked you out of your system and demanded a ransom.

Eric Cormier: Yes, and it was actually Friday the 13th in December 2019. It was not a good day. From what we've been able to trace, it came from a piece of equipment that we utilize for certain processes in the shop. It looks like somebody got onto the internet and accidentally clicked on some links.

With ransomware, what's insane about it—especially what we were hit with—is that it was built to not only infiltrate our network, but also determine the types of PCs we had in the shop in order to do the most damage. It ran from one PC, hit a couple of devices that weren't secure, and turned them into what they call "zombies," which wreaked havoc across our facility. It originated in Redmond, and because our facilities are connected in Redmond and Tucson, it branched out and hit multiple PCs and infrastructure in our Tucson facility.

Because of the extent of how this software works and how advanced it was, we had to do a 50,000-foot view of shutting everything down and doing a complete rebuild. We couldn't take what we had that was still working and reuse it. We had to reinstall operating systems and go the full length of a complete infrastructure rebuild. It did some serious damage. And it's not necessarily something that can be controlled from a security perspective once

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it's been let in-house; it was very difficult to root out where it came from.

With the nature of cybersecurity today, we had tools in place that allowed us to determine—from an intrusion detection perspective and traceability of what went outbound—that our data was compromised internally. We were able to even have a third party look at it, and they verified that as well. We had a third party review everything and found that nothing was compromised externally, which meant that while our data was affected, it wasn't transferred out of our networks.

Eric Cormier

Matties: And they were able to access it through a piece of equipment that somebody had clicked the link on, or was it an open port that they found through this equipment?

Cormier: It required user intervention. Again, the best security is only as good as how far you can train your people on looking for and spotting things because 90% of all this kind of stuff comes down to a user error. When a certain user does trigger something, the ransomware gains the rights within the company network, and then it spawns beyond that. It's what started the whole process.

Matties: From that point of view, these ransomware people and hackers are pretty clever, and they disguise their emails to look like normal business emails and trick people into clicking.

Cormier: A lot of times, it could be an attachment that has a link in it that says, "You have to click this link to unlock the document," and it looks like it comes from a valid customer source. Sometimes, we see things come from a fake shipping company that looks like UPS and FedEx. They say, "Here's your invoice on your account or from your last shipment." People click it without realizing what it is. And that's where the "fun" begins.

Matties: Once they got in, they were able to go from system to system. However, they weren't there to access and steal information; they were there to lock you out of your data.

Cormier: Correct. It didn't affect servers, shared documents, or things that we had on our network. It encrypted those, but then it also spawned itself and hit local machines, like your mailbox store on your local PC. It encrypted it, and the ransomware had the key. With the level of encryption that they used, it was almost impossible to decrypt without having some piece of the puzzle, like what passphrase or what key they used.

Matties: You were locked out of the system, and your business screeched to a halt. At that point, you had to make a decision: Do you pay ransom or not? That can be a tough choice one way or the other. Regardless of whether you pay, you were faced with having to reboot your entire system. You were vulnerable.

Cormier: And that's where the threat comes in: how far did it go and what was compromised? After a great deal of time spent analyzing that question, we looked at the amount of time that it would take to either patch all the holes or do a complete rebuild. We decided we didn't want to invest the time—especially with the number of resources that we had available to us. The numbers didn't line up for us to patch the holes and find out how far it went. It was to our benefit to get things back up and running as fast as possible by starting from scratch and restoring what data we had from backups.

Matties: Even if you took the patch approach, in the back of your mind there would always

be some level of doubt or concern as to whether you found everything.

Cormier: Right. You ask yourself, "Did we miss something?" Because all it takes is one thing missing and any amount of time you spent fixing it could be wiped out. If you spend hundreds of hours in a week to fix something and you missed one thing, you're back to square one again, and you lost 100 hours. That's where you weigh the risk. Is it best to start from square one? For some larger companies, that task would be too incredible to even think about. But again, most of those companies have the resources available to make that happen in the agile environment.

Matties: This caused business interruption and a new level of awareness that changed your security protocols. What have you done to keep this from happening again, since it came from somebody clicking on an email?

Cormier: Because we were doing the full rebuild, we went through and reassessed. And I hate saying this, but it was perfect timing because we were going through a process of becoming completely compliant with a few standards, like NIST, DFARS, and ISO 27001 and 27002. A lot of the planning and security required for that helped us. There were things that we needed to implement, push the envelope, and it required us to make those changes. Reviewing the security processes and what we have in place that has been required will help us in the long term.

Matties: We hear about these things, but we never think it could be us. Then, all of a sudden, it is us. And you're not the only one who has been hit by this in the industry.

Cormier: Yes. There's a substantial infrastructure that's been affected by this very kind of situation.

Matties: And other fabricators, I understand, have been hit directly as well. Moreover, what advice do you give to somebody to protect themselves? And specifically, are you keeping all email isolated from your network now?

Cormier: That's one thing that we decided to go toward because a lot of solutions are cost-prohibitive, but there are options now for cloud compute and cloud email systems. It makes sense to make that change because it requires managing less in-house that could possibly be affected if an event like this occurs. Businesses that build this kind of cloud infrastructure put in place a lot more security to provide multiple levels of security. We found that it's much more cost-effective to go with that approach than having things in-house nowadays.

As a recommendation, I would say to look at that kind of transition, even if it's a hybrid cloud environment, to where you're reducing your surface area of attack, the number of areas that could be affected, and services that could be affected if you do get hit with something. We're living in a world where that's not necessarily a requirement, but to do business, it is a good idea.

Matties: Is your email now isolated from your internal networks?

Cormier: Yes, and some of our file sharing and backup systems are now being compartmentalized.

Matties: On your internal systems, as we move into digital factors, a lot of equipment is connected to the internet for firmware updates and such. How have you changed the infrastructure, or do you have any concern about that connection point?

Cormier: I followed a model called "zero trust," where you don't trust anything inbound or outbound. Instead you have to manually approve certain things, including with the network. Now, I compartmentalize. I have a completely separate network where all proprietary equipment requires the internet be placed onto and it uses cloud solutions to share files back and forth. That way, if something hits one of our local machines, we're not going to be affected

by a lot of our proprietary systems like we were before. So, that would be a recommendation I would make: use the cloud-based file systems and file-sharing sources to make that work.

Matties: Because of ITAR and other regulations, how does that cloud-based or hybrid cloud-based service fit into those situations?

Cormier: As of right now, there are only two mainstream providers that can meet the standards: Amazon Web Service's GovCloud (which is its full suite of AWS products, from S3 bucket storage and cloud compute to anything that you're looking for on the compute side), and Microsoft Azure. The GovCloud allows you to be pinpointed as a government entity, and you can tell it what boundaries you require your data to stay within. Then, you still meet those ITAR requirements and some of the defense requirements as well.

Matties: Third-party solutions are providing your security, but it probably provides you some relief in IT concerns or workload.

Cormier: Exactly, because there are services that we're able to turn on to monitor and alert us that are better than most security systems that we could try to bring in-house and pay a lot more money for. Again, the cost-benefit made too much sense not to move in that direction.

Matties: You have some new mechanisms. What other advice do you have for fabricators to consider?

Cormier: I recommend performing a risk analysis quite often to pinpoint your vulnerabilities, know how to drive yourself forward to fix certain points of weakness. Review and confirm on a regular basis that you're reviewing your disaster recovery plans. Then, ensure that everybody's on the same page as you add new services, etc. You have to constantly review those to make sure that you're not going to miss anything in case of an event like this.

Matties: Backup is something that's part of the strategy. You have an isolated backup that is offsite, remote, and not connected as well. Have you changed your backup strategy?

Cormier: Yes. We've gone through a different approach for utilizing more cloud. Again, we're using Amazon AWS's GovCloud services and Glacier storage for a lot of our backup systems. We were originally sharing between facilities so that they were technically offsite, but again, this exposed a weakness that required us to switch gears and change tactics.

Matties: With offsite and go-between facilities, that seems like a reasonable and sound strategy until somebody finds the vulnerability.

Cormier: There are a lot of companies and solutions, and they meet a lot of these industry requirements, such as Veeam Backup Solutions and a couple of others that allow for your backup strategy to slipstream straight into a cloud platform, which is quite nice.

Matties: And you were lucky since it wasn't a data breach. It was a lockout situation.

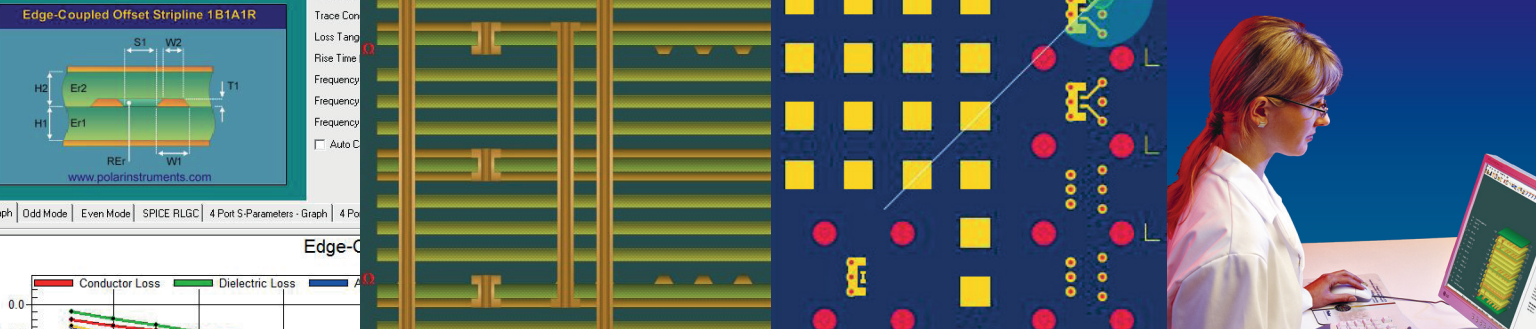
Cormier: It affected availability but not the integrity or confidentiality of the data.

Matties: But even with the lockout situation, this shut your business down.

Cormier: Correct.

Matties: From a leadership and administration perspective, Dave, this is a business interruption that most people don't insure against. I'm not sure what the insurance companies are doing in that regard. Do you have any advice for people on what they should look at when insuring that type of business interruption?

Dave Ryder: First, let me address the insurance side of the issue. There are certain things you can do through your insurance company to ensure that you're covered in cases like this. Unfortunately for us, we were limited on that side of the insurance coverage, and it simply



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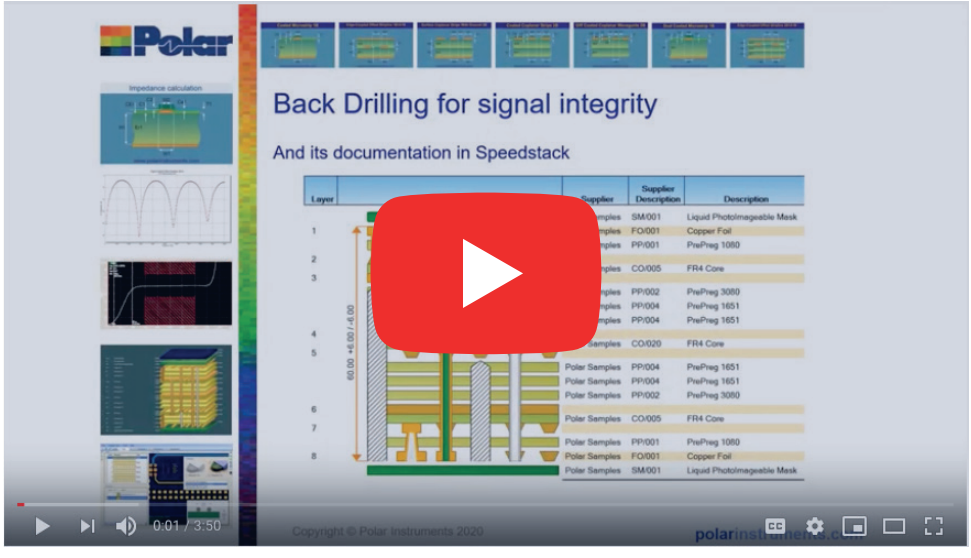

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covered hardware if there was physical damage, meaning they were rendered useless.

We also had another issue with a specific customer. We submitted the invoice onto their system, but with our profile in their system, that's where we submit and place our bank and routing information. Somebody was able to log into our account and change that bank and payment information so that the vendor started paying to that wrong account. But when we reported it, it took them almost two weeks to even stop sending payments to it and to start a process of fixing the situation.

Dave Ryder

Matties: And how did you discover that was an issue—by receivables not coming in and you were making some calls to inquire?

Cormier: Yes. That was the first stage, but we also received an email. One of our accounting people had received an email about an account change. We immediately looked and I told them to change the password on that site. We didn't think anything further because it didn't notify us of what changed. That was another thing the hackers didn't have and didn't include in their system. By not knowing what changed, I assumed it was a password situation. We reset passwords and continued business as usual, and then discovered a couple of weeks later when we weren't getting paid that the information had been changed on their system within their profile.

Matties: The advice is, when you get an account change notification, don't assume anything. You should email them and verify what's being modified, especially when it's a financial account.

Cormier: Right. In most financial accounts, whenever you make changes like that, and you put in your financial information, it generally sends you a confirmation saying, "Your financial information was changed." It gives you specifics and timestamps on when it occurred. In many cases, it will tell you what IP address the change came from. Those are certain things that you think would be a given but weren't in this case, and it has been a long process trying to get intelligence information back to make proper inquiries and resolve it.

Matties: The question that comes to mind is, "Are these two events connected, or are they isolated and coincidental in timing?"

Cormier: They were coincidental in timing. Everything occurred at least a month or two before our ransomware incident.

Matties: Good advice. Back to the insurance review, what changes or recommendations would you have people consider when looking at their insurance coverage?

Ryder: I would recommend getting a cybersecurity incident policy. That's what it has to be. And I've heard that some insurance companies are now at a point of not even writing policies like that because your hands are pretty much tied. These people can get into your stuff, and there's no preventing it.

But as Eric is pointing out, the policy has to be written specifically to that. Otherwise, your typical business interruption policy is not going to cover these kinds of things. We found out the hard way that business interruption insurance covers natural disasters, such as fire and flood. But even floods become an issue because if you don't have specific flood insurance, they may not cover that either.

Matties: This is a real out-of-pocket expense for you.

Ryder: It has been six figures several times over, but that's only in the cost of the replacement and equipment, etc.; that doesn't even begin to cover lost revenue. We were hard down for a full month in the Redmond facility, and we were limping along for the first month in the Tucson facility. We've recently gone back to a more normal sense of business, but the website had to be rebuilt because they seized and locked that up, and the repercussions are devastating. If customers try to look at your website and it's down, they move on.

Matties: There was relief for all customers when they learned that there was no data breach. What's the customer's attitude toward this?

Ryder: Sympathetic, but the first question they have is, "Did they get my files?" Fortunately, that's not the MO of these people. They're seeking Bitcoin ransom money, so it's virtually untraceable. But I don't think that they have any clue whether they're talking to a circuit board shop or an auto repair shop when they're encrypting your stuff. They don't care because they just want your money.

Cormier: There are a few cases where there have been data breaches along with these, but some of these companies had been breached previously without any knowledge of it occurring. It was preemptive in certain instances.

Ryder: Their goal is really about getting the customer's information, such as credit card and social security data. Files for a circuit board design are kind of useless unless you're building that product.

Matties: This happened in December, so it has been nearly a half-year process.

Cormier: There were a lot of odds and ends. We were technically operational within 30 days, but there are a lot of different proprietary software packages and proprietary systems that had to be brought back online individually, as well as the website. Those processes to get back to the pre-event condition have been close to a six-month window.

The attack took out operating software for a lot of the equipment. It took out scripting for the front end, the CAM side of things, and all that was stuff we had built up over years and years of experience. They were able to encrypt the backup on all that. As Eric pointed out, we had to start from scratch. It took us years to accumulate all the technology and software programs that we had, and Eric and his team have been able to fix that in a few short months—a Herculean task.

Matties: With every disaster, there tends to be a silver lining. Any silver lining here?

Cormier: We've been able to implement new technology that we didn't have before. And it's a lot more end-to-end encryption for customers' safety. And there are new processes in-house, too.

We've been able to implement new technology that we didn't have before.

Ryder: We'll be a lot more secure than we had ever been before.

Matties: And there's no doubt you're going to carry that forward. Until it happens to you, you have no idea how devastating it can be. How was the law enforcement aspect of this? Was there an investigation?

Cormier: The Department of Homeland Security was helpful in pointing us in the direction of assessing whether we'd be able to have assistance in recovering from this, but there wasn't much in the way of investigation, or contact from them or the sheriff's office and local authorities. It was fairly minimal, to be honest.

Matties: They probably realize that these people could be anywhere in the world, and it's probably pretty unlikely to find them.

Cormier: At the same time, there are so many different municipalities and infrastructures being hit with ransomware that it has to be a priority for them to be investigated.

Ryder: The city of New Orleans got hit the same time we did. I understand the infrastructure of a city is far more important to society than a circuit board shop is, so their priorities go, as Eric said, with municipalities.

Matties: It's amazing how widespread this problem is. Why aren't more people talking about it and protecting themselves? Hopefully, the point of this whole interview is to get to that level.

There's no honor amongst thieves. There's no guarantee that if we paid we would get our stuff back, and they'd leave us alone.

Ryder: You don't hear much about it in the news. The first few issues that we heard about it seemed to be buried on page 12, and then you don't hear anything more about it. Nobody is immune to this stuff. They've encrypted hospitals and things of that sort, and a lot of them have chosen to pay, but we were advised by the feds not to pay. There's no honor amongst thieves. There's no guarantee that if we paid we would get our stuff back, and they'd leave us alone. There's nothing to say they wouldn't come back a week later and do the same thing.

Cormier: We also heard from technical sources that some paid to receive what is called a decryption key tool but depending on file sizes and things of that nature, it wouldn't work 100% of the time. They had to hire in another firm to rebuild a decryption tool based off what they received to help them get data back that wasn't always 100% recoverable.

Matties: Even if you pay, you still have to go through all that diligence of what you've done to rebuild your systems for your own peace of mind.

Ryder: Yes. It may shorten the time it takes you to get fully operational again by paying, but if you're looking at it from a fiscal standpoint, at the end of the day, we're in it a lot more than we would have been for the price of the ransom, and that's through lost revenue as well as damage. Many people lost a lot of hours. We didn't have anything for them to do, so the damage was very far-reaching.

Matties: It's not just your shop; it's also about all your employees not working for a month.

Ryder: It impacted customers on the local level here. All of a sudden, for a period of a month, there were no quick turns being made in the Northwest.

Matties: In terms of customers, did they stick with you?

Cormier: It's hard to say, definitively, that all of them stuck with us. They were all sympathetic, and they were supportive when it made sense, but some of them have moved on. At the same time, COVID-19 showed up before we were through with the ransomware problem. It's hard to say what the issue with the customers is in a lot of cases.

Matties: Are things picking up for you now? I hear it's quite busy out there.

Ryder: We see a bit of an up and down on a daily basis. Unfortunately, in the Seattle market, we're heavily influenced by a big airplane manufacturer, and they're kind of slow right

now. That has impacted our business, so we don't see the same numbers that I hear about in other areas of the country.

Matties: If you were doing ventilators, you would be full up.

Ryder: And there's not a lot of medical manufacturing in the Northwest here. It's a lot of aviation, aerospace, and software, which doesn't have anything to do with us.

Matties: I'm glad you were able to come back out of this stronger and better. Do you have any final thoughts or advice you'd like to share with the industry?

Cormier: Again, make sure disaster recovery plans are in place, and you're doing business risk assessments to verify where your pain points are. This is key, from an IT perspective.

Ryder: I would recommend that you have an outside party come in and review your level of security, as well as your insurance, for any problems. There's nothing to say that you will be hit with it, but if you are and don't have coverage, you're going to wish you did.

Matties: You were in a great spot because my understanding is the financials of your organization are quite strong, and you have low or no debt, but most companies aren't in such a great position.

Ryder: If we had debt, it would have wiped us out. As I said, we were hit with a one-two punch because the virus problem showed up before we were out of the woods on the ransomware issue. Effectively, in the Seattle market, King County, we're not even in phase one of being back and open for business. It's still a ghost town around here.

Cormier: I'd also note that if you don't have anything at all in place and you're looking, there are some fairly inexpensive online solutions. Some options are within the $200-a-month range to help you put together plans for security awareness training, etc. One that I utilized in the past is securityprogram.io. It's pretty inexpensive to get yourself started on awareness, training, and implementation for the right kind of security that your business needs.

Matties: You have been talking about a stress test on your systems. If you wanted to bring somebody in, is this a company that you would look to? Are there other resources that you would have come into your organization and work with you?

Cormier: Other resources I've utilized include IT firms that do penetration testing and internal security penetration testing. They give you an overview of deficits and where you need to be.

Ryder: Probably the easiest thing that businesses can do is make sure that they've trained and informed their employees who have access to email, the internet, etc., to be suspicious if you don't know who an email is from or if it looks weird. Make sure your IT team checks it out before you click on any attachments or links. Once you've clicked, you're going down a one-way street from which there's no return.

Matties: As you said, isolating your mail service from your internal infrastructure is a backup to that vulnerability of an employee clicking on a link, whether they intended to. Sometimes, these things get clicked. I'm glad you're back on your feet. Eric, I know it's a monumental task you went through, so I'm sure there were a lot of IT lessons learned on your part, too.

Cormier: Exactly. It gave me a lot to take with me to school because I'm going back for my master's.

Matties: Thank you both for sharing your story and advice for others. It's greatly appreciated.

Ryder: You're welcome. PCB007

A Lasting COVID-19 Lesson: Resilient Regional Manufacturing Networks

One World, One Industry

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

According to the Society of Critical Care Medicine [1], the U.S. only has 200,000 ventilators to treat the 960,000 COVID-19 patients who are anticipated to need them. The U.S. government and private industry are working more diligently to retool manufacturing to meet the nation's needs. Thanks to these efforts, social distancing practices, and—most importantly—the brave and tireless work of frontline healthcare workers, we will recover from today's novel coronavirus. However, we need to prepare for what's next and the pending unknowns that await us.

Sophisticated global supply chains are generally efficient in meeting societal demands, but the COVID-19 pandemic illustrates that—in times of crisis—these supply chains can break down. One of the pandemic's lasting lessons will be the importance of resilient regional manufacturing networks to ensure the availability of life-saving equipment.

The technology behind medical equipment depends on PCBs. Manufacturers state that a shortage of PCBs has slowed the production of ventilators. U.S. board manufacturers have available capacity, but the established supply chains do not currently support the kind of high-volume manufacturing in the U.S. that the crisis demands. As a result, U.S. PCB manufacturers have limited means to help, given that assembly mostly takes place in Asia.

In affecting China first, COVID-19 disrupted the operations of some of the largest electronics manufacturers in the world—even as China marshaled its industrial resources to support its own medical response. The resulting global demand for medical electronics stretched manufacturing capacity even further without a

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strategy in place in the U.S. to ramp up production to compensate. That led to a tragic but inevitable result: healthcare professionals scrambling and often competing with one another for life-saving ventilators.

The unprecedented COVID-19 pandemic has made clear that our dependency on overseas manufacturing can mean life or death. It also exposes how quickly current supply chains can become disconnected and in peril. Needing to travel across the world to ramp up production of any critical item is a lesson we should avoid repeating.

Needing to travel across the world to ramp up production of any critical item is a lesson we should avoid repeating.

Since the 1990s, electronics have become the heart of thousands of products and hundreds of industries worldwide, with healthcare prominent among them. Much of the electronics manufacturing sector has taken advantage of economic integration across North America to maintain and grow across all three countries. The total value of U.S. electronics trade with Canada and Mexico has increased sixfold over the last 25 years, reaching $155.5 billion in 2017. It helps support 5.3 million jobs across the United States, as well as millions more in Mexico and Canada. Electronics and products containing them constitute a significant portion of trade flow among the three countries and must be protected.

Not only is this sector vital for the functioning of our economy, but it is one of a few continuing to hire workers amid the overall shutdown. Electronics manufacturers added nearly 2,000 U.S. jobs in March 2020 and over 20,000 U.S. jobs in the last year.

In anticipation of future pandemics or even an expected COVID-19 reemergence later this year [2], we encourage the Trump administration to support a sustained and bold policy agenda to combat the virus and overcome the economic downturn. President Trump should work with our neighbors in Canada and Mexico to build a more resilient and robust supply chain. Now, as the United States-Mexico-Canada Agreement (USMCA) is being implemented, is the right time to start a North American Manufacturing Initiative to focus on coordinating pandemic response and strengthening the region's manufacturing competitiveness.

President Trump, along with his North American counterparts, should grow regional capacity for electronics manufacturing and create systems to monitor capacity in times of crisis. Additionally, they should set up metrics for industrial base resiliency with capabilities, capacity, and geographic diversity as key factors. Finally, government leaders should determine a regional definition of what is an "essential activity," which would more easily allow us to support the critical production of crucial materials, parts, or products.

Importantly, all of this should be centered on the manufacturing of electronics and other essential equipment.

This region has an opportunity to think bigger and build stronger, more efficient, and resilient manufacturing supply chains across North America. Anyone serious about strengthening manufacturing in any one of the three countries needs to focus on advancing that goal in all three countries. This same lesson is one that all regions of the world should internalize and address. **PCB007**

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1. Society of Critical Care Medicine, "United States Resource Availability for COVID-19," May 12, 2020.

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

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Alex Stepinski

Rethinking Captive Manufacturing

Feature Interview by the I-Connect007 Editorial Team

Alex Stepinski and Whelen Engineering caught everyone's attention a few years ago when they opted to make their own PCBs in an innovative captive facility: GreenSource Fabrication. Now, with the recent purchase of an equipment manufacturer, Alex is helping to design whole factory solutions for OEMs who are interested in bringing PCB fabrication in-house.

Barry Matties: Alex, why don't you give us your take on what's going on with the mindset from captive facilities?

Alex Stepinski: Everybody probably knows our story, so I won't rehash it, but we were kind of the prototype. And the reason Whelen did it was that our visionary COO at the time thought there would be a better way; there was, and we did it. But now we have this case study in North America with Whelen and GreenSource, and other people are looking at us. I see a lot of interest from folks in doing something similar, and this is driven primarily by people who can't find a fit for their product in the market.

Job shops are jacks-of-all-trades and masters of none, and they have to set up a shop that handles a lot of different customers, in most cases, to provide some safety and diversity to their business. There are some that specialize in broad categories, like flex or microwave. But generally, you see this in Asia more than in the U.S. In the U.S., people tend to do a lot of different things because there's not enough business.

The OEMs in the U.S. market have a tough time finding a fit because they have a lot of specialty products, and there's hardly anybody that's a good fit. In Asia, you can find a better fit, but there are a lot of OEMs that don't have enough volume to get their attention. Everybody is at the mercy of the supply chain. Having your own captive fab gives you control of your capacity and priority. You get 100% of the attention because you control it. And if you wanted to, you could customize this fab for your product design philosophy and get a lot of efficiencies out of that. That's what we did here, and now that we've taken the next step, we've become a job shop to some extent. We're doing third-party work primarily for the defense and aerospace sector, focusing on technologies that weren't historically represented in the U.S.

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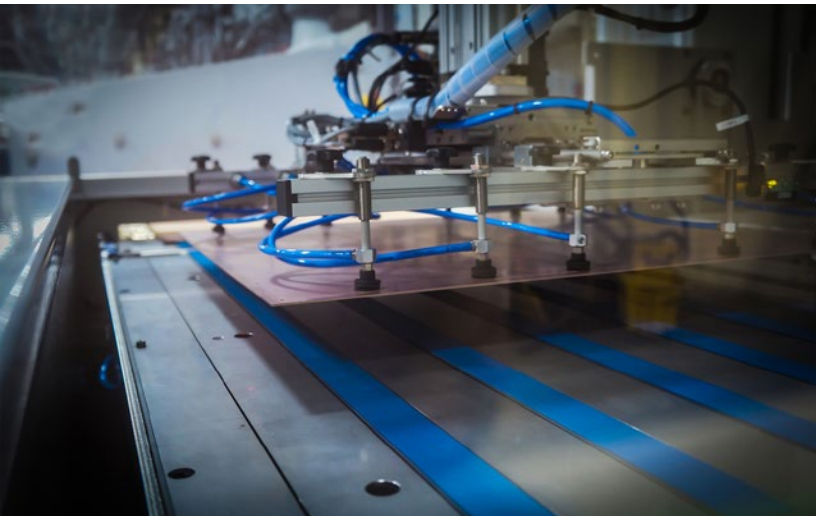

We're doing a lot of semi-additive processing work for different applications. We're doing high-stack microvias with very good reliability. This was also something lacking in the U.S. market. We brought this over here, and with these capabilities, we got interest from OEMs. "How do I get something like this for myself? How do I use you as a third party?" We've also had interest where OEMs asked us to take advantage of the equipment company we bought and offer them a whole factory solution.

We have a couple of projects where we're designing factories for OEMs—one on the East Coast, and one on the West Coast—and then a couple that we're having preliminary discussions with right now. This seems to be a nice niche that no one is covering right now. You could go to an OEM and say, "I can give you a factory customized to your products. It's a 21st century mindset. It's green, automated, and flexible. You can run rigid, flex, and backplanes in the same line. It's a holistic approach to things." There's a lot of interest in this, so we're moving our equipment business to focus on this market.

Matties: You have the blueprint for the factory, but is the challenge finding the skill and expertise of a labor force to manage and run that?

Stepinski: Our approach is that we have a tech center in New Hampshire. If you're an OEM, you send your people. We train them here and get them up to speed. You don't put up a factory in a day. Usually, when someone comes to us, it's a year before they're willing to accept equipment because they have to put up a shell; get everything together for electrical service, HVAC, etc.; get the concrete poured; get their permits, etc. You come to us, and we can take some of your designs, prove everything out, customize your specifications, and train your workforce while that's all happening.

Matties: Interestingly, if you're training your workforce as it's happening, that workforce is also part of the construction of the factory. They're going to have some in-depth knowledge of the facility.

Stepinski: It's a nice business model. It's unique. We're not aware of anyone else who has such a model in the world. We have a showroom training center. We're building the factory and then—based on the experience in the showroom, tech center, and training center—you customize the equipment for their applications.

Matties: Do you think this is the beginning of a trend?

Stepinski: Yes, generally speaking, OEMs are not that satisfied with the supply chain situation right now. COVID-19 has caused a lot of people to be upset and wish they had their own captive fab. I'm not sure if this is across the board, as most of the people we talk to are mid-tier players, but if you're a huge OEM, you command everybody's attention, and everybody jumps when you say jump. If you're a mid-tier or a smaller OEM, sometimes it's tough to find a place in the market. It becomes very interesting to have your own captive entity—especially if you're trying to differentiate your products from others—but job shops still lend themselves to that.

Matties: And there's also the financial gain. What sort of percentage or advantage would somebody have financially from a captive facility?

Stepinski: There is an advantage, if you customize it enough. We looked at our original model and designs and customized the factory for the way they were designing and the way they planned to design over the upcoming years. Whatever capability we could incorporate for free, we did it, or with minimal cost to future proof it. And this same approach holds for OEMs. You have jobs with layer counts, laminations, panel sizes, and materials. Where do you see the trends going? You make a plan.

Generally, this does not look like a typical job shop. Job shops are typically a jack of all trades. Here, you gain with specialization and customization. You can gain a lot of efficiencies, as well as final finish selection, material selection, and things like that. If you do it on your own, you tend to think differently than if you're going out to the market where you're at the mercy of what the suppliers can offer.

And if you did it yourself, you might only have one or two final finishes. If you outsource something, maybe you have three or four because you don't put that constraint on your design department to say, "Everything is going to be ENIG, and that's it." Instead ,you say, "Do whatever you want. We want a good price. We need it on time, and we need it to be reliable." Usually, that constraint isn't there. You give people slash sheet options instead of specific material options, and if you customize everything, you can negotiate contracts that benefit from economies of scale for yourself. We've found it's much more cost-effective to do everything internally.

Matties: Have you found an end-product advantage in terms of designer functionality because you have your own manufacturing facility now?

Stepinski: There are a few points. With our internal company, we couldn't even source some parts on the outside, so we had to build the parts for them, and we continue to support this. Additionally, you have much less variation when you do it yourself. When you go to the job shop world, typically, you need to have multiple suppliers for leverage. And because of this, every supplier has a different result. The processes are not the same in PCB shops.

Everybody has a mishmash of things. It's not just equipment, but it's their people, approach, techniques, and how the whole history of the company developed. Everybody is a little bit different, so your product is not going to be the same between two suppliers. And with the specs that typically flow down to job shops, I haven't found a case where I see a specification that's close to what can be achieved. Most specifications are quite wide in a lot of areas. There's always some key point where they want to focus on a couple of different variables and keep those tight.

But it's hard to find a print from any customer where every single thing is super tight. Usually, some things are per IPC, and when you look at IPC, you see it's wide open with general specifications. This runs across the variation from multiple shops, and it can be a critical variation.

Matties: And, of course, the obvious thing is that you have better IP protection as well.

Stepinski: That's another key point, especially if you're trying to bring new products up. Not too many board shops are going to reverse engineer and get into another OEM, but it is possible.

Matties: It's not even so much that the board shop is going to reverse engineer it, but you

have your own security for your infrastructure, whether it's cybersecurity or whatever the case for security happens to be. In one of the conversations we had recently with John Mitchell, he shared that he was having a conversation with a colleague in the industry about the shift to more regionalized fabricators. He thinks we're going to see more regionalized manufacturing as well. This goes to what we're talking about. Whether people want to go to a job shop or start a captive facility, it seems like the whole supply chain is in a big shift.

Stepinski: That's what we did. In our new version of our facility, after we went to the merchant market, our vision was that this would be a tech center for the East Coast. It's a place where OEMs can touch, feel, and see what's going on, and then have conversations with engineering. We have an equipment company, and we can invent processes together—if needed—to support next-generation requirements. I felt that there was a lack of R&D in the U.S. market, and this was missed by customers. We made an R&D technical center here to support people who want next-generation technology and not me-too technology.

Nolan Johnson: I know this is early in the process, and it's a complex bit of mathematics, but do you have a sense of what the ROI would be in setting up a shop through your system? Are we talking an ROI in weeks, months, or years?

Stepinski: For any legitimate PCB factory, it's in the "years" and how many years. Our first shop was a three-year ROI working at only half capacity, so it depends on what you have for a product. I would say three to five years from production start is probably reasonable based on what I've seen so far.

Matties: One of the concepts that we've been chatting about is the co-op captive shop because there may be these mid-tier OEMs that would like to have a captive facility, but they don't need one full time, or they want to save the expense. Have you explored looking at putting together four or five OEMs—they could be non-competing type companies—to set up a co-op shop?

Stepinski: That's what we do. I have one OEM where their employees are in our factory every day building their own PCBs. You have to make sure everybody is vetted to be there because of some of the security requirements.

Matties: But in your case, you're still making a profit because you're leasing them time in your line. Is that your business model?

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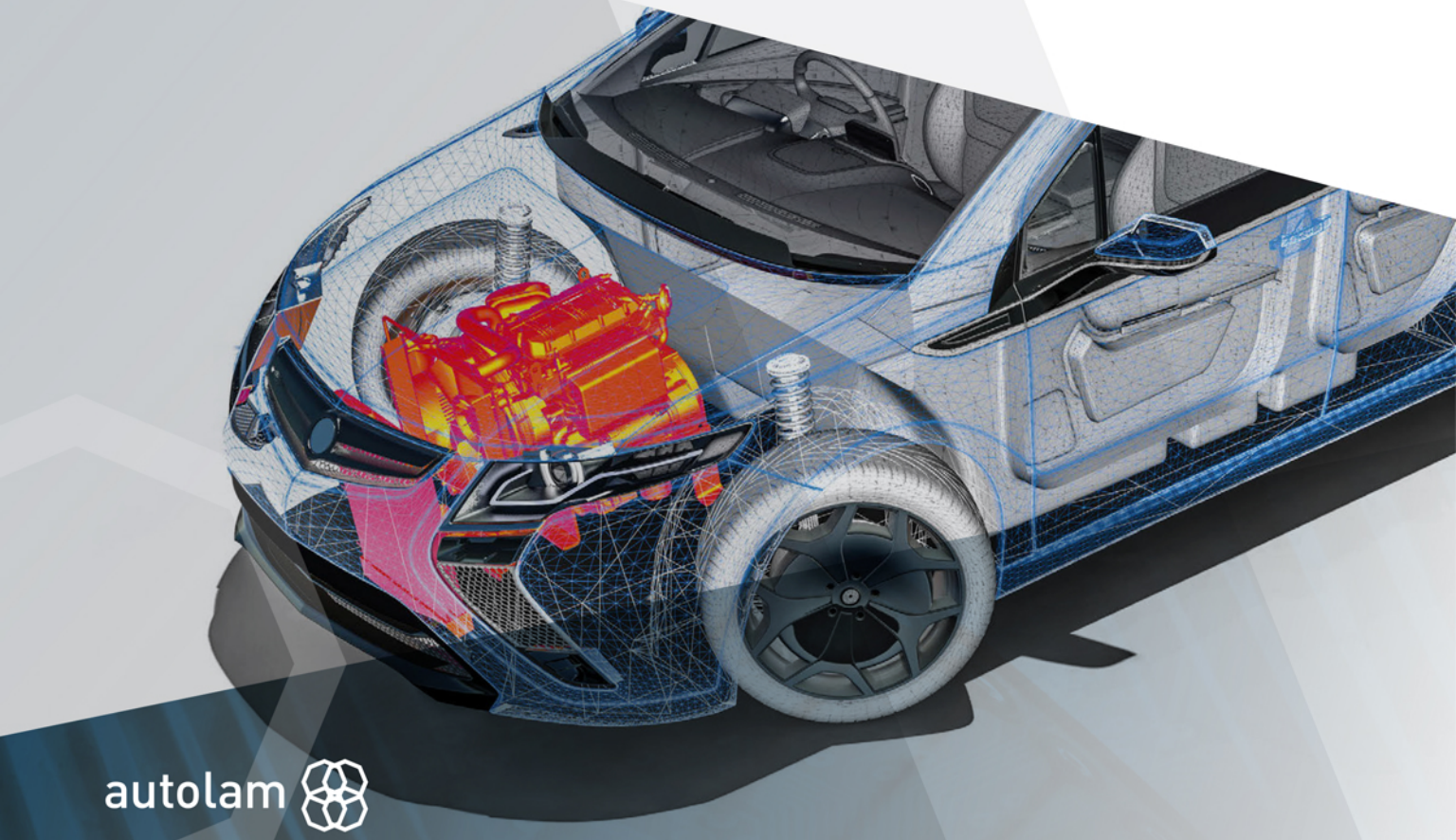

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Stepinski: It's mutually beneficial. We come to an arrangement regarding the cost to build parts and for our process equipment development. Then, the next step is a factory of their own, depending on what their outlook is and what their forecasts are. We have one client that's planning a whole factory on the same scale as the one we're facilitating right now.

Matties: Are you nearing capacity in your facility, or where are you at on that scale?

Stepinski: No, we're not nearing physical capacity. Because of our location, labor is more of a constraint than anything else. We're going to 24/7, but it's taking longer than we'd like. We're making progress, so we'll be there by the end of the year. Right now, we have two shifts and operate five or six days a week with plans for 24/7 by the end of the year. The biggest gate we have in getting physical capacity is qualification work. For example, if someone has a specific product, usually people aren't coming to us with standard stuff, like requests I have for 15:1 aspect ratio blind structures. I have requests for half-mil and less, one-micron line and space, and then they want SAP on weird materials that no one has ever done SAP on before.

We'd have to do a big qualification cycle with that. That's probably our biggest gate—sorting out what the process rules are and how efficient that is with our selection of processes. Should we consider an NRE to get a separate process for this application so that they can have an efficient o peration? W hat's t he operating cost delta? Do we want to sink some money into it? We have clients who are buying equipment here and placing it at our facility and in their facilities. We're facilitating a big reshoring effort here. That's our niche.

Matties: Exactly. If you could get four or five—maybe 10—companies each kicking in $10–20 million apiece to build a new factory in Texas, for example, and let them have ownership and not just leasing part of the line, is that a viable business model?

Stepinski: We fit in by providing the blueprint. We're the only experienced factory equipment building company in the U.S. right now. We don't do facility equipment, but we design a factory that's zero waste, and we build circuit boards every day. It's not easy to build equipment and hand it over. It's different when you have to use it every day.

Matties: With your model of training the team, setting up the factory from the ground up, making it zero waste, getting it off and running, and not having an ownership stake in the factory but letting these OEMs own it as a captive facility or a co-op facility, it seems like there will be quite a bit of interest in that.

Stepinski: The market right now would be interested in that. We have not made any attempt to sell that model yet. This is all happening because of the way we've been doing it.

Matties: Right, but as you approach this with greater intent, with the timing as such, you're in such a wonderful position, and it seems like the reshoring effort could accelerate this model.

Stepinski: We've been doing a lot of internal R&D on the factory design side, as well as on the equipment side. We've been focused on getting our equipment factory in Europe to support all these new technologies that we're being asked to do. It's a very interesting verti-

cal integration of having a competent equipment facility. Especially as you're doing this SAP-type product, there are a lot of requirements. You can't have any particles. You can't touch anything inside the circuitry area. But still, there are processes when you're doing SAP that should be spray for the anisotropy aspects to get some reduced diffusion layers.

Matties: Can you find stuff like that on the market?

Stepinski: Not really. Everybody does SAP in some vertical mode, and it's all kind of hokey, but it's the best-known practice at this time, so we're working to develop alternatives. It's nice when you're building boards every day because you get a lot of feedback from your equipment group.

Matties: Even with this co-op model, you could then extend the maintenance contract and be responsible for all site maintenance as well.

Stepinski: We're doing that. We are offering short service levels, from maintenance to engineering support for factories. We see that this is also a niche. One of the biggest challenges in the market is that no one knows how to build a factory anymore. This is all lost knowledge. No one knows how the pyramids were built anymore, either. It's all a mystery. The same thing is true with the board shops. They all kind of got there by decades of trial and error, and everybody who knows how it got there is retired or dead. We're trying to fill this niche and be the educators. "Here's why we do or don't do this." With our resources and recent experience of bringing up our own factories, we've done two major projects of our own. And we have a lot of lessons learned that we can bring to the market.

Matties: The market needs to be aware that a viable solution is in place for them that they can rely on. But labor is going to be an ongoing issue no matter what, and even with framing the facility, it's still a challenge across the industry. You're setting up these facilities to be operator-free, essentially. What sort of labor requirement would still be there for these captive facilities to address?

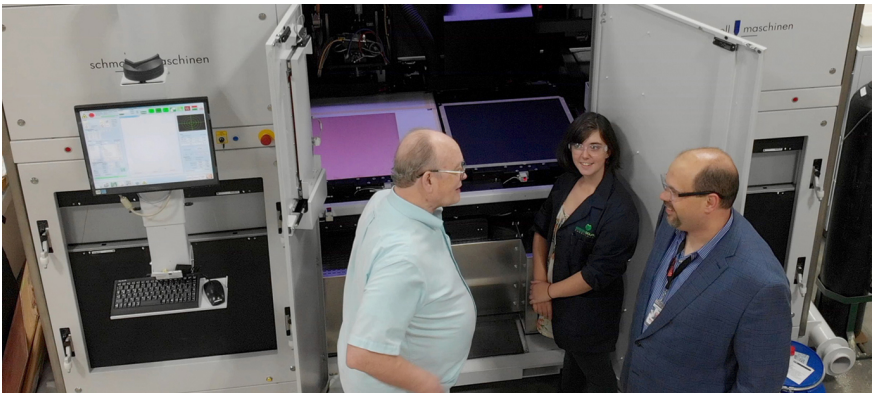
Stepinski: It's technical and maintenance. Those are the big areas—all trainable. You need good technical and maintenance staff to do a modern facility.

Matties: But if your company is providing the maintenance benefits or maintenance service, then all they need on their end is a deploying team.

Stepinski: We're doing it a couple of different ways. We can provide some maintenance service. We can train their people. We can have a person on-site, but we're also not trying to. One of the standard equipment business models out there in sales is service and spare parts. That's not our model. We're trying to make products that don't need any spare parts or service. People are willing to pay more for a machine with more controls, and they are looking at total cost-to-quality typically in the U.S. market than they would in another place.

Our equipment typically is not manufactured in the U.S. The U.S. industry has fallen behind the industry leaders of the world. We all accept and know that. It stands to reason that every area of what we do is a little bit behind. We're trying to provide the equipment that's the highest quality standard on the market, that you could achieve at a reasonable cost, and that doesn't need service or spare parts. We provide the training that's needed. We can connect to our remote leads, diagnose, and say, "Do this." This is our model. Otherwise, it's not substantial.

You can't sell somebody something that needs constant maintenance, and then import a team of people who are used to dealing with that to come and do it for you. It's not a practical approach because the biggest reason people are doing captive facilities in the OEM is IP or security. That's not a workable model. We have to do everything domestically. Especially with the COVID-19 situation, you can't get somebody over here. You have to quarantine for two weeks.



Happy Holden: This has me reminiscing my days at Hewlett-Packard. One thing I experienced was that HP valued innovation. Whatever we came up with, it had to be 10 times better than what the industry thought they needed because we were doing test equipment that had to be much more accurate than what it was testing. In the '70s, I was working with 30–60 gigahertz, which is what everybody is pulling their hair out about today not even realizing we had that mastered in the early '70s—some OEMs did, and even the board fabricators. When a project was started, they would collect all of the key players—including printed circuit fabrication and design and mechanical fab—and we would brainstorm innovations in which the product manager would describe the next generation of what he wanted. The manager would go around the circle, and each one of us would explain how we would contribute to that goal and what the obstacles would be. One person would say, "I can solve your problem, but I have this problem." And then the next person would say, "I can solve that problem for you, but it creates this problem."

And in every single case, the PCB contributed a unique property that wasn't delivery cost or standard design rules, for some reason. Whatever the problems were, there was some unique thing about the PC board that it was going to contribute. And because of that, we always had R&D budgets and manpower, just like the product designers and semiconductor people. It was because we made a contribution that never made its way down to a merchant or a job shop; our job was to contribute to the competitive advantage of the final product. Many people don't realize that HP was always on top and superior in profits because it didn't use standard PCBs. I don't know how many times I had to explain why we didn't plate tin-lead—never plated tin-lead or tin-lead reflow—because it was a dumb process to have. We had a far superior one, but we didn't always plate gold. We invented a replacement for gold for keyboards. The things you could do are almost endless.

Because once you have a staff that's used to innovating and solving problems and knows how to do that through the scientific method, enormous contributions can be had there that result in OEM superior products. It wasn't just us. Our biggest competitor was the Tektronix PC shop since they were also in the test equipment business. It was particularly difficult for me, being from Oregon. All my classmates went to Tektronix, and I went to HP. An OEM printed circuit facility can deliver superior performance, in addition to cost and delivery.

Stepinski: Especially now that we haven't had much of it for a while, people are interested in it because it's a breath of fresh air after all this commoditization.

Holden: I never tried to fight this idea that PC boards are commodities, like soap.

The biggest job I had in Taiwan was convincing the Nanya folks that there were not different grades of PCBs. If the computer board didn't work, you couldn't lower the price and sell it as a TV board. It had to be perfect, or it was junk. With plastics, you can have multiple grades. Even in the semiconductor industry, if you don't meet the specs, you can bin it, change the specification, and sell it at a different price with a different name. But the PCB is custom built to order, and that's not a definition of a commodity.

Matties: You're bringing up a good point of collaboration. The product advantage with Whelen is you are captive. Your teams can now collaborate and bring in creative solutions.

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Thinking of R&D, for example, you mentioned HP, but there's also IBM. When they introduced the fluid head technology into our industry, that was like, "Wow." That was a big R&D, and we don't have that anymore. Do you think the timing is good for a resurgence in R&D in the circuit industry?

Stepinski: The timing is quite good. One of the big drivers, and why it hasn't happened before, is also because there was no case study. Nobody did it. You need to have some evangelists, and that's what we've ended up doing right now—the people who are communicating this to everybody that you can do this. There are a lot of advantages to having a captive facility that is customized to your needs, especially if you're an OEM.

There are OEMs that may come out of these PCBs. It's a true story, but you want to do all the development as tight to the vest as possible, and then you make specs for the mass market. That is more of a commodity. But some people never get to that point. They don't have the superhigh volumes to be a commodity, and they need constant innovation for their overall business to stay ahead. Also, some OEMs aren't big enough to enjoy the benefits of pushing people around in the supply chain. And this is where there's essential interest in these captive facilities.

On a larger scale, the big OEMs might be interested in maybe a green factory in Silicon Valley or something like that because you can't get one right now. That might be an interesting area for somebody to want us to have a prototype shop. It's something all of us have been considering.

Matties: With a reduction in the labor force compared to a traditional shop, to a modern facility and the COVID-19 supply chain reaction, it seems like there's a great opportunity. What advice would you give to an OEM that wants to start exploring whether this is the right situation for them?

Stepinski: It's a two-step process. First, we have a phone call and they explain what they're doing. If we think there's a fit, we invite them over for a walkthrough and a more detailed discussion, and we see how it goes from there. That has been our engagement approach.

Matties: What about a large automotive company that might be spending millions or more on circuit boards? Is there a case to be made

for those? Because you're saying that the larger you are, the more leverage you have with your supply chain. But it seems like there's still a case for these people to go to a captive facility as well.

Stepinski: I'm not going to say that I'm competent to answer that. I have not analyzed the product mix for a large OEM or looked at their pricing and lead times to say if it makes sense. I've only been approached by people in the small- to mid-tier OEM range who are interested. I have been approached by larger OEMs talking about prototype shops and not mass production of a commoditized product. We have not discussed that with anybody. It's hard to engage with people who do that because they have very professional supply chains that are extremely focused on the supply chain. The tendency seems to be these aren't the kind of people you talk to about reshoring. They're trying to find every penny in the supply chain. In my experience of selling boards to people like that, it's not typically the right skillset to talk with them about building a factory.

Matties: It has to come from another voice in the organization to make that shift.

Stepinski: Correct. That has to be driven by engineering or C the suite.

Matties: Let's talk about your factory. The last time we chatted, you were pretty close to having it up and running, and the warehouse was the last component going in.

Stepinski: All of the equipment is here. We're still developing all the time, and we have a lot of new equipment we've built that we're shuffling around because of that. We've developed some new processes that we're going to be releasing as new to the market. As an example, we have developed an etch technology. We have chemical-less etching, and you regenerate it, depending on which etching it is, with electricity or air. It's zero waste with 95% less variation than anything else on the market in terms of etch quality, etch alignment distribution, or feature size distribution.

This is something that we're currently building for ourselves internally—self-qualifying work cells where we have the metrology incorporated; it's self-checking and not just percent metrology but product metrology to do automated feedback. This is something not in the market right now that we're focusing on, and we plan to have available generally next year. Another one is our wastewater systems, which is going to be coming to the market next year. We already have plans for going commercial, but we are fine-tuning some of our IP before we do it. There's a lot of interest in this around the world. It looks like the initial orders will be in the U.S. market, and probably Japan as well.

This is our focus. Rather than being the person who sells an individual piece of equipment, we're trying to be the person who sells a work cell with all aspects of the process engineered for you. Whether you buy the chemistry from a supplier or we tell you how to do it with air or electricity, or some homebrew, we're trying to provide the whole process. Our methodology now is that with any new process we bring to market, we make it first for ourselves in New Hampshire. We build it in Europe, ship it to ourselves, qualify and debug it, and then incorporate improvements. After all that, we make it generally available.

Matties: Are you seeing a lot of interest in capital equipment investment in the U.S. right now?

Stepinski: There's a lot of interest in what we have to offer, although I don't know if there's a

lot of interest in capital equipment investment, in general. Because we build the equipment for ourselves, it has optimized the voice of the customer. And this isn't the first place where I've worked. I have worked in a lot of shops in the U.S. market. On our staff, we have people who work in the European division, and we're optimizing what we believe the market needs in, let's say, the higher cost regions where you need a lot of flexibility with your equipment.

With our automation, you can run ultra-thin, unclad copper cores. There's no copper on them, paper-thin, and the same machine can handle a 10-millimeter, 20-pound backplane. It adjusts panel size and vacuum level. It does everything by reading the RFID code or 2D code associated with the product, and this way, you can get good productivity out of a machine where you have a high-mix, low-volume situation. We've focused on this rather than mass production, where you don't need too much engineering and controls. In mass production, you need the simplest possible machine, it works only for a certain small range, and that's it.

We're focused on engineered solutions that replace people in complex environments. You can't take a loader/unloader from China, put it on a line in the U.S., and expect it to replace a human because that equipment is catered to mass production, limited product specifications. In the U.S. market, the person has to run flex, a backplane, subcomposite, and heavy copper all with the same machine. Everything has to be considered to do this; otherwise, you can't replace the person. When you automate it, if you can't replace the person, it makes no sense. This is our focus.

Matties: And if you're a captive facility, you tune that automation to whatever your needs are, so you have more flexibility.

Stepinski: Yes, and metrology is a big part of the process in a high-mix factory. You have to measure everything and change your recipe. We're automating this as well. This is our focus. How do you automate a factory in a high-cost region?

Holden: I know you have been looking to hire a process director. What's the quality of the applicants you've seen?

Stepinski: We have some good candidates, but nobody is based in the U.S.

Matties: It's tough. This is the ongoing conversation we're having with everyone that the greatest challenge in the future is labor.

Stepinski: For key people, you have to look at emigration. But you need a strategy that works at a few different levels. You need a program for new engineering graduates, where you bring them in and teach them appropriately. We have that in place. You have to ask, "Who are the best people in the world that I could get into my factory to help with the next generation stuff?" We have a plan in place for that, but it means longer lead times and a lot of restrictions.

Because of ITAR, you can't utilize the resources as much as you'd like. There are restrictions on what international resources can do for you that you have to manage. But it's not unmanageable, and there is a big return on investment for bringing someone from overseas who has 20 years of experience solving complex problems in 200 factories. We have a process for getting people like this on board to assist us as we ramp up. On the engineering side, we are doing some outsourcing in the European market.

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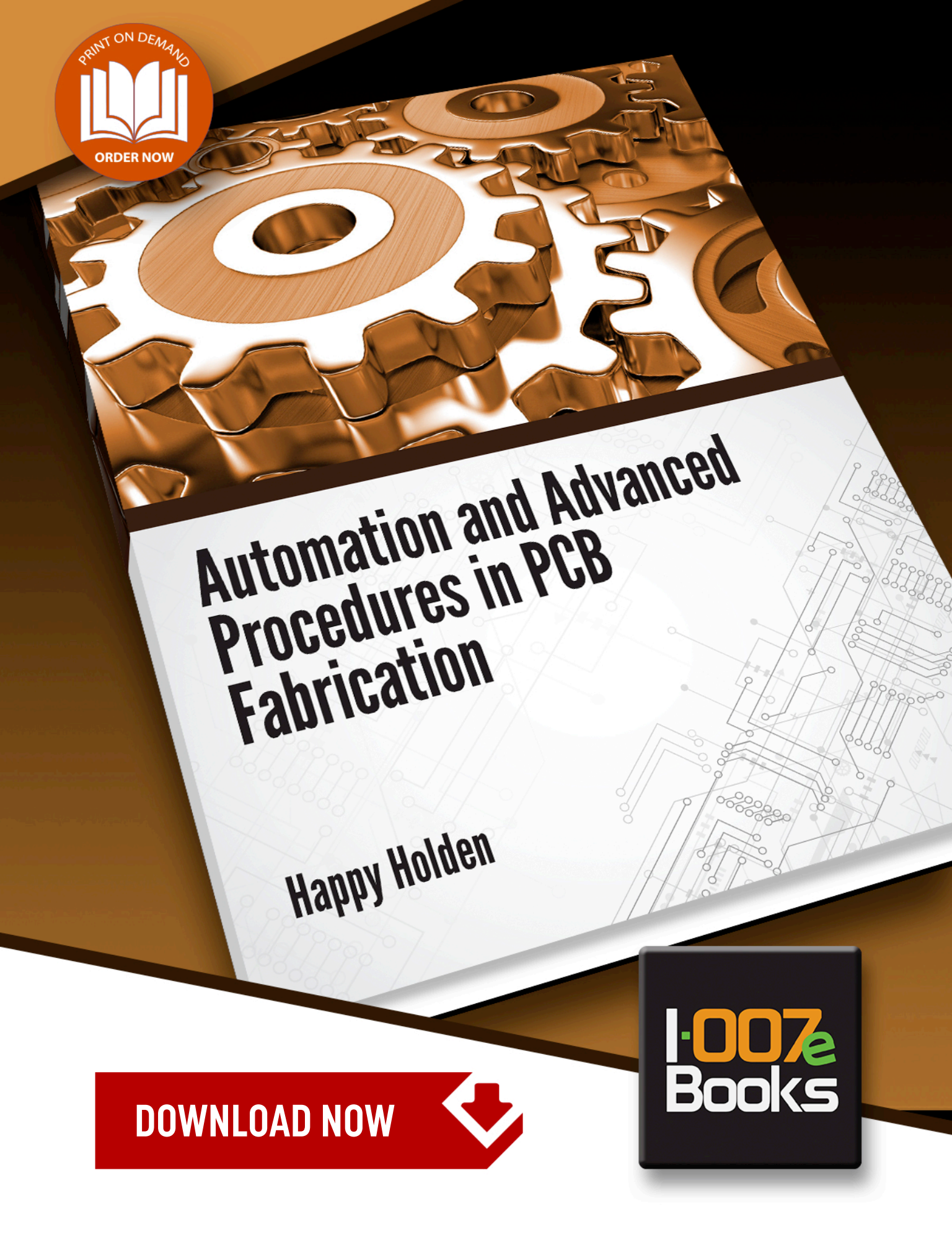
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Matties: What kind of engineering?

Stepinski: In process engineering, we make our own equipment, so we have to ask how much process engineering we can do with either ours or third-party equipment to develop the process and only do what needs to be done. The only thing that needs to be done here is product-related stuff. But general process-related optimization should be done in Europe because we tend to have a much easier time finding technical talent in the European market than in the U.S. market—Germany manufactures a lot more than the U.S., as a percentage. Our factory in Poland, which is close to the German border, is in a region that's very influenced by this mentality because a lot of companies have manufacturing operations near our equipment factory. It's been very easy to find very competent people there, so we're leveraging that to improve our capabilities as well.

Matties: You have to go where the talent is.

Stepinski: Right. And you keep the local talent focused only on what needs to be local. I might have a complex project where I want to figure out how to reduce drill deflection by X amount with these different types of materials and go build a model that says, "I know hot material X, Y, and Z drill. I know the parameters. I know how much variation I have." Then, I take the raw materials and build a model. The deliverable I want is a model for drills, but deliverable isn't how I build part X, Y, and Z.

The deliverable is I want a model so that I don't have to worry about that. I do a study, determine the material drills this way, and then build a model. We're missing modeling in our market. We do a terrible job at this, in general. Plating easily could have a model. Drilling can easily have a model where all the parameters are calculated by algorithms. You do some standard empirical testing, incorporate it, and there you go; you're all set.

We've focused on this on our European side, building the models, and we've found you can even sell this as well. You can go to the market and say, "We have a general model for drilling, so you don't have to do any more of the drill studies." To me, this is something that's missing, but don't ask me why. A lot of other industries are decades ahead in this area.

Matties: Do you think it's because they rely on the manufacturers to understand this? For example, "Here's my design, build the board, and don't trouble me with it."

Stepinski: Why is it that way? I don't think people step back and look at the big picture. If you step back and look at the big picture, you don't need to add too many resources. You get a couple of engineers focused on a project—and even potentially partner with a university—have students assigned to do your modeling for you, and it's pretty straightforward. For some reason, people don't ask about things like this.

Matties: The other side of what you're doing for your factory, though, is that it's becoming aggressively driven manufacturing, where your engineering on the front end was important, getting work into your production. And how do you see that? Is there a mindset? We have an issue coming up on documentation, for example, with manufacturing notes because we always hear about that when a designer sends a board over for fabrication. There are always deficiencies. And in your shop, it has to be 100% to go through your line. It doesn't go

through without that being correct. There's no interrupting.

Stepinski: I don't think you're ever going to get rid of the translation piece up front. The challenge is somebody has to drive industry standardization. And the market kind of fights this a bit. The market says, "Give us your order, and we won't ask you a million questions." Some people do things this way: "We'll solve these problems for you, and you'll leave it alone." Most designers have never built a circuit board, and that's a big challenge if you're a fabricator because there are multiple fabs that can build products for somebody. You can't push back too much because then they will go to somebody else. And to me, these kinds of variables prevent standardization.

Matties: It's not just a challenge for the fabricators; it's a large cost.

Stepinski: Not all people accept the challenge from the fabricator. Why don't we try to do this in a different way? Some people do, but some don't. Some people want to send the design out at 5:00 p.m. on a Friday, have a nice weekend, and don't want to get 20 questions. They don't want to fill out your form, so the data is all standardized. That's human nature.

Matties: With the margin so slim, though, that's a large cost because—a lot of times—you're putting all that effort in to make a quote before you even get the job.

Stepinski: Yes, the only way you get through that is if you share some of the savings with the customer and give them a reason to work with you on that or have a unique technical offering that you can provide. It differentiates you from the other person because they're going to gravitate toward the path of least resistance that can produce the parts.

Matties: That's my point. "Why do I need to do it? The fabricators are going to take care of it for me."

Stepinski: Right, and they'll go to the one that does it for them. That's the nature of the market for this. That's why we've never achieved standardization in this area, and I don't think we will.

Matties: Interesting. Alex, I always enjoy our conversations. Thank you so much.

Stepinski: Thank you. PCB007

GreenSource Fabrication: Previous Coverage

GreenSource Fabrication has made the news quite a bit over the last two years. Its innovative approach to PCB fabrication developed at the New Hampshire facility has extended the boundaries in technology, configurability, automation, environmental stewardship, and precision. Here is a sampling of some of I-Connect007's coverage of GreenSource Fabrication.

- ***GreenSource: The Future*** by Nolan Johnson, *PCB007 Magazine,* October 2018
- ***GreenSource: Good for the Industry, Good for the World*** by I-Connect007 Editorial Team, *PCB007 Magazine,* March 2018
- ***GreenSource Fabrication Boosts HDI E-Test Capabilities With New atg A8a Tester*** PCB007: atg Luther & Maelzer, July 26, 2018
- ***GreenSource Fabrication: Redefining Automation*** *PCB007 Magazine,* October 2018
- ***Schmoll and Burkle: Lasers and Drills for GreenSource*** by Patty Goldman, *PCB007 Magazine,* October 2018
- ***GreenSource Fabrication Announces Acquisition of AWP Group*** PCB007: GreenSource Fabrication, December 17, 2018
- ***Automation Attracts: The New Guard to PCB Fabrication*** I-Connect007 Editorial Team, *PCB007 Magazine,* October 2018
- ***Ascentech GEN3 Bare Board Contamination Tester at GreenSource*** PCB007: Ascentech LLC, March 13, 2019
- ***Alex Stepinski: GreenSource Fabrication Update*** by Barry Matties, *PCB007 Magazine,* January 2020

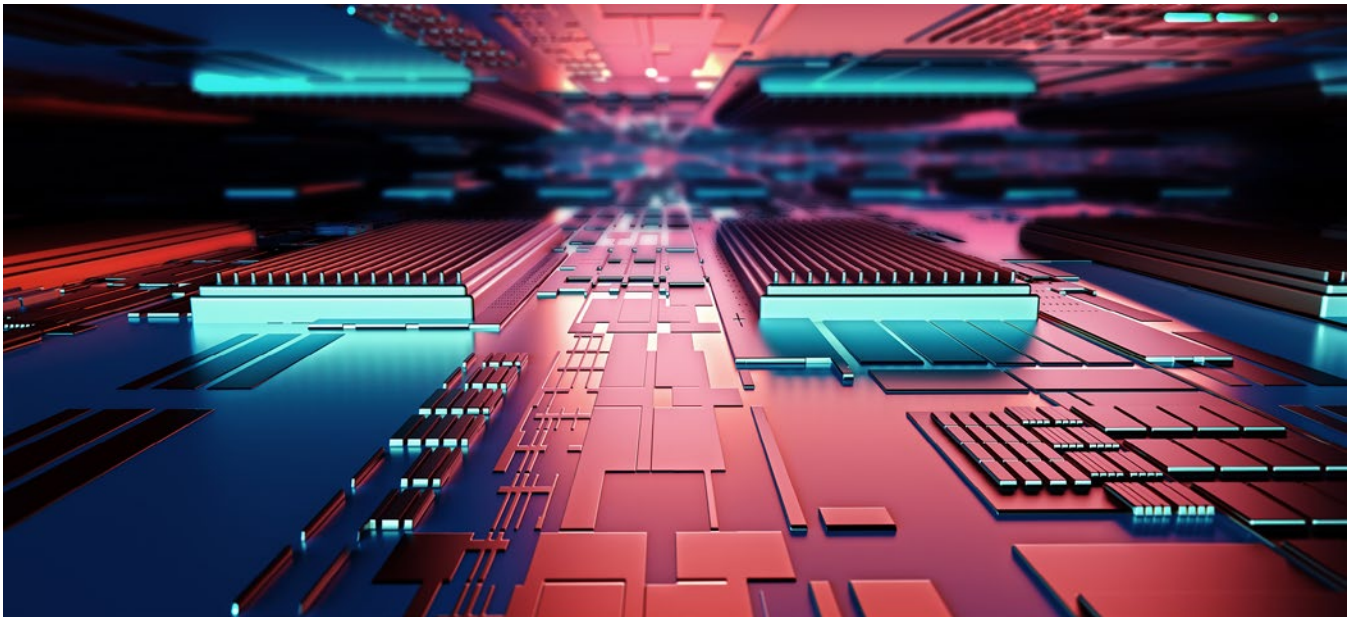
Additive and Subtractive: When Opposites Attract

Flex Talk
Feature Column by Tara Dunn, OMNI PCB

The majority of my career has been spent working in the PCB industry. Like many, I landed here "by accident." Fresh out of college with a brand-new economics degree, I was looking for a position in finance and was offered a position in accounting and human resources in a small flexible circuit manufacturing company. Honestly, I did not even know what a flex circuit was, so they were truly taking a risk with me. My initial training there was not in accounting; it was in manufacturing, spending time working on the product, and learning the processes so that I would be better able to understand what I was doing when I did start working in accounting. The manufacturing processes I learned during that time were the traditional subtractive etch processes, essentially starting with copper laminate and etching away the unwanted copper to create the designed circuit pattern.

Not to date myself, but back in those days a design with a 125-micron (5-mil) line and space on flex or rigid materials was pushing technology limits. Today, PCB fabricators are manufacturing designs with 25-micron (1-mil) line and space. In fact, most of us are using smartphones with PCBs with 30-micron trace and space. These extremely high-volume, commercial designs are produced using mSAP or modified semi-additive technology. This process starts with a very thin layer of copper foil and uses an additive rather than a subtractive chemistry process to create the circuit pattern. Fabricators offering mSAP technology typically serve very high-volume requirements, and the process requires significant capital investment.

Market dynamics in the electronics industry are quickly changing. Today, it is not only high-volume applications that are being driven to the need for 25-micron trace and space.



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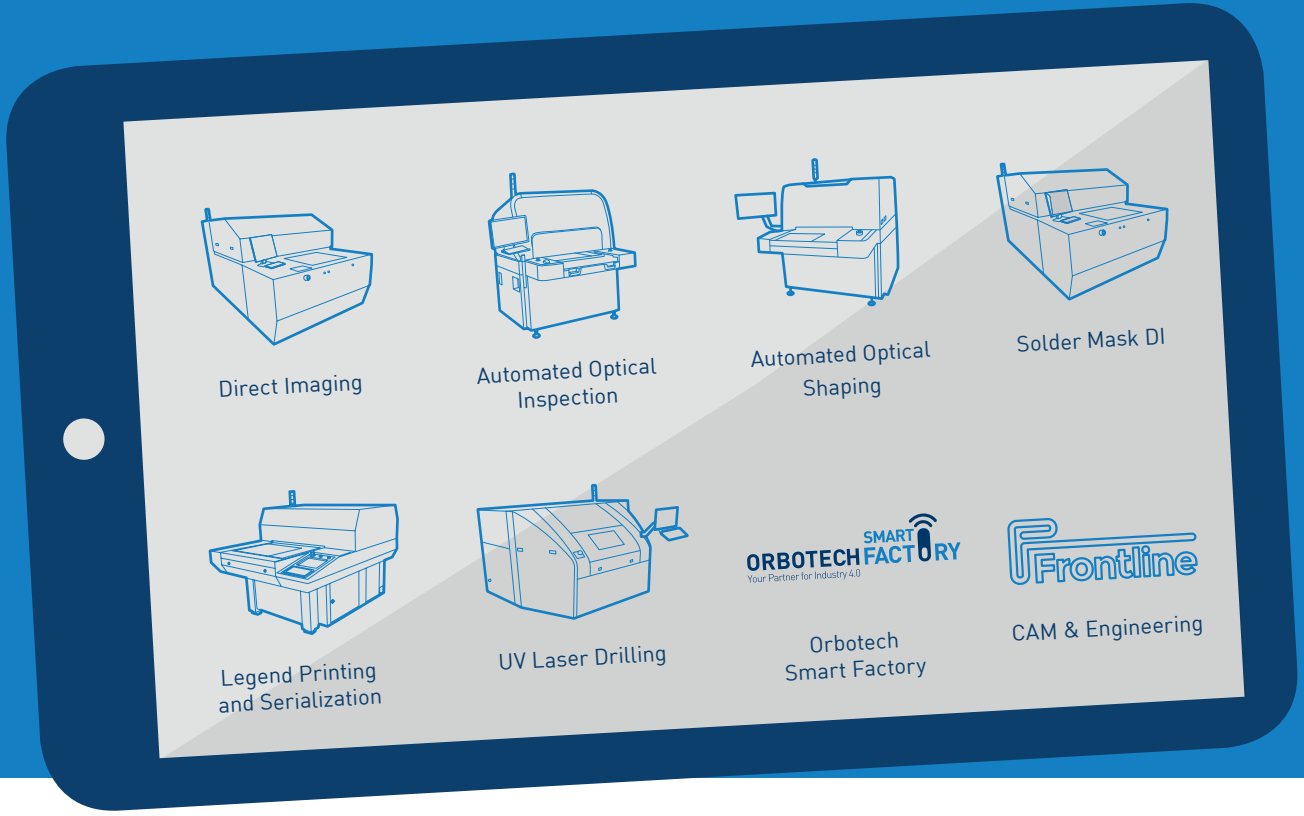

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www.orbotech.com/pcb

Military, aerospace, medical, automotive, and industrial designs are also being driven to smaller and smaller feature sizes. With the currently available subtractive etch process, the design solution often requires multiple layers of stacked microvias and multiple lamination cycles. This solution adds considerable cost to the PCB and often introduces reliability and yield concerns.

Today, there is an alternative that has been installed in three U.S.-based PCB fabrication facilities: the A-SAP™ process, which is Averatek's semi-additive process. As a broad overview, this process starts by etching away all copper from the laminate, applying a liquid metal ink (LMI™), which enables an extremely thin layer of electroless copper—a photolithography process defines the circuit pattern, and electrolytic copper builds the circuit pattern. This process is currently capable of achieving line widths and spaces at 15 microns with advanced processing enabling even finer feature sizes.

Additive processes bring exciting new options to the PCB design community and PCB fabricators. Using finer lines and spaces could allow designers to route with fewer layers, shrink the overall size and weight of the PCB, reduce the need for multiple levels of microvias, or—looking at it from another perspective—enable the designer to increase the functionality of an existing PCB footprint. That is a lot to think about and wrap your head around. And as is true with any new technology, exploring and implementing A-SAP™ technology to its full potential will push designers and fabricators to look at things in a creative new way.

From a fabrication perspective, even though additive processing is the opposite of subtractive processing, the A-SAP™ process fits well with the traditional subtractive etch processes and equipment. The process requires the addition of a relatively simple series of tanks and heaters but utilizes the fabricators' existing copper plating chemistries and photolithography equipment. Once the circuit pattern is created, the panels proceed through fabrication as would any subtractive etch panels.

Not only does this additive process fit well with existing PCB fabrication processes and equipment, but additive layers also can be used selectively and combined with subtractive etch layers in a PCB design. Reviewing one example, a highly complex 12-layer design with stacked microvias and multiple lamination cycles can be re-imagined and re-designed. A-SAP™ layers could be used on four layers and combined with another four layers using subtractive etch technology, significantly simplifying the design. Four layers are removed, reducing material costs, and only a single lamination process would be required.

Reviewing a second example, the original design is 10 layers, 75-micron trace and space, and three lamination cycles. The goal in this example is to significantly reduce the overall size of the PCB. Using the A-SAP™ technology, the design was adjusted to 25-micron trace and space on all layers. Overall, this reduced the layer count from 10 to eight, still with three lamination cycles, but it had a significant impact on the number of PCBs per fabrication panel. The original design allowed 70 parts per panel. With 25-micron trace and space, this was increased to 400. That is a significant decrease in size to meet packaging goals and is also a significant decrease in the overall cost of the design.

Yes, opposites do attract—at least with additive and subtractive PCB fabrication. As the rapidly changing electronics market drives designs to smaller packages with increasingly sophisticated technology, fabricators have the opportunity to implement new additive technology to meet the needs of PCB designers in new and exciting ways. It will be interesting to watch and learn as the early adopters of this technology work with their customers to develop design and fabrication best practices. **PCB007**

Tara Dunn is the president of Omni PCB, a manufacturer's rep firm specializing in the PCB industry. To read past columns or contact Dunn, click here.

MilAero007 Highlights

Defense Speak Interpreted: C4ISR ▸

Only the U.S. Defense Department would lump together seven concepts—command, control, communications, computers, intelligence, surveillance, and reconnaissance—into a single acronym: C4ISR. Denny Fritz explains how C4ISR has been called the "nervous system" of the military.

FLIR Captures $23.5M in Additional Orders for Centaur Unmanned Ground Vehicles ▸

FLIR Systems Inc. announced that the United States Army and Navy have ordered in total more than 160 of the company's Centaur™ unmanned ground vehicles (UGV), plus related spares and accessories. The two contracts, totaling $23.5 million, are being sourced through the Army's Man Transportable Robotic System Increment II (MTRS Inc II) program.

Murrietta Circuits Appoints Alliam LLC to Cover Sales in South-Central U.S. ▸

Andrew Murrietta, CEO and co-owner of Murrietta Circuits, announced that his company had appointed the sales firm Alliam LLC to handle Murrietta's sales in the South-Central United States.

From Drones to Flying Taxis: The Future of Traffic Is in the Air ▸

Get ready for takeoff: Food deliveries and work commutes might be airborne sooner than you think.

Integra Technologies Wins $3 Million Contract Award From Northrop Grumman ▸

Integra Technologies—a world leader in semiconductor packaging, assembly, test, characterization, and related services—was awarded a $3 million contract from Northrop Grumman.

Northrop Grumman Awards Contracts to Kitron ▸

Northrop Grumman Corporation has awarded Kitron a contract for the production of Integrated Communications, Navigation, and Identification (ICNI) modules for the F-35 Lightning II program. Deliveries will secure a backlog into 2021 and have a total value of more than USD 18 million.

KBR Wins $570M NASA Contract to Propel Human Space Exploration Endeavors ▸

KBR announced it had been awarded a $570.3 million contract by NASA to develop and execute spaceflight operations at Marshall Space Flight Center in Huntsville, Alabama.

AeroVironment Receives $9.8 Million Raven and Puma 3 AE Awards From NATO Support and Procurement Agency ▸

AeroVironment Inc., a global leader in unmanned aircraft systems (UAS), announced its receipt of two firm-fixed-price orders totaling $9,804,448 from the NATO Support and Procurement Agency (NSPA). The orders—received on March 5, 2020, and April 16, 2020—encompass the procurement of Raven and Puma3 AE tactical UAS and spares. Delivery for the first order is anticipated by August 2020 and the second order by October 2020.

Cobham Advanced Electronic Solutions Names New Board of Directors ▸

Cobham Advanced Electronic Solutions (CAES)—a leading provider of differentiated RF and high-reliability space, power and computing solutions—announced a newly comprised Board of Directors.

Atotech Looks to Expand Product Portfolio

Feature Interview by Barry Matties
I-CONNECT007

When I toured Atotech's facility in Feucht, Germany, last year before productronica, I spoke with Andreas Schatz, Atotech's global product manager of equipment, and Daniel Schmidt, Atotech's global director of marketing. Andreas and Daniel break down the global plating and chemistry trends they see, most notably around horizontal plating and smart factory automation. We also discussed how this impacted the company's systems approach while continuing to expand into new markets such as mid-level PCB production.

Barry Matties: Thanks for joining me, Daniel and Andreas. Please start by telling us a little about yourself.

Daniel Schmidt: After receiving my business degree in economics and marketing, I started my career at Atotech in 2005. In the beginning, I started in various electronics departments, where I was responsible for marketing, and product and project management. During this time, I developed a deep technical understanding of our electronics products and capabilities. In 2009, I became responsible for global marketing for the Atotech Electronics business, as well as corporate communication. Since 2018, I am responsible for global marketing electronics, technology roadmaps, and training.

Andreas Schatz: After obtaining my degree in mechanical engineering, I started my career at Atotech in 2010. In the beginning, I started in the engineering department, where I was responsible for the calculation and design of all necessary system components. Here, I acquired a deep technical understanding of all of our product lines and features. In 2017, I joined our global product management team, where I am responsible for all of our horizontal equipment products—Uniplate, Horizon, and Polygon.

Matties: Andreas, as a product manager, what is your job?

Schatz: Working closely with the other global product teams, including central marketing

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Ultra-low Transmission Loss Multi-layer Circuit Board Materials for ICT Infrastructure Equipment

MEGTRON7 (G)type NEW

Laminate **R-5785(GN), R-5785(GE)**
Prepreg **R-5680(GN), R-5680(GE)**

(GN):Low Dk Glass cloth type (GE):Normal Glass cloth type

Features

- Improved lamination processability compare to MEGTRON7 R-5785(N)
- Glass transition temperature (Tg): 200˚C (DSC)
- Multi-site production in Japan/China

	Dk	Df
R-5785(GN)	3.4	0.002 @ 12GHz
R-5785(GE)	3.6	0.003 @ 12GHz

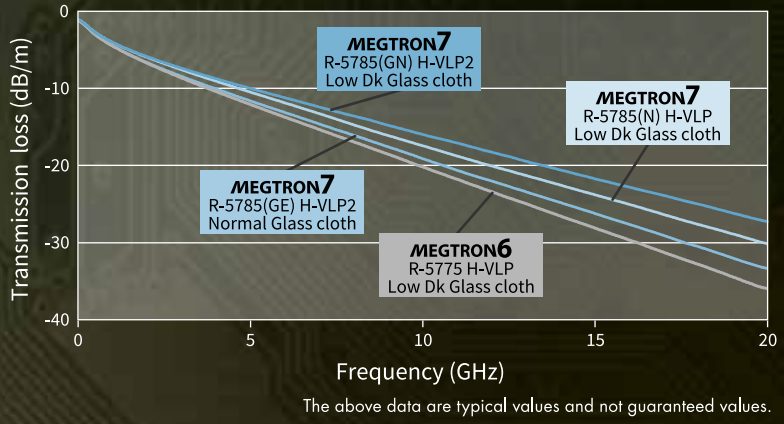
Applications

- High-end servers, High-end routers, Supercomputers, and other ICT infrastructure equipment, Antenna (Base station, Automotive millimeter-wave radar), etc.

Transmission Loss

- Construction

Trace thickness(t)	18μm
Dielectric thickness(h)	300μm
Copper thickness	18μm
Inner treatment	No-surface treatment
Core	0.15mm (#1078 x 2ply)
Prepreg	0.15mm (#1078 x 2ply)
Line length	1000mm
Impedance	50Ω



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and the OEM groups within Atotech, my job is to essentially understand where and how the industry is moving forward, and then consider how this may potentially impact our equipment business.

We follow what is important for the future regarding equipment, and from this, we can determine the features that are needed. Let's take finer line and spaces in high-end PCBs as an example. In this regard, laminate materials are getting thinner and thinner, which means we need to continuously improve our transport capability to maintain process reliability for our customers—even under increasingly more challenging conditions. In simple terms, it's all a question of how to ensure the safe transport of thin and highly flexible materials through turbulent fluid areas.

High-end PCB makers are reducing the copper foil thickness to enable finer lines and spaces, which allows for more functions and performance within the same PCB area. Processing PCBs with thinner copper layers is quite challenging and leads to improvement in our existing plating technologies and their key features. One such feature would be the clamps contacting the PCB during the electrolytic plating process. The challenges are to maintain the tight and accurate clamp closing mechanism, which is required to enable uniform plating performance, while not damaging the thin laminate material itself. We're making good progress, but the critical point is that it must be carried out in close cooperation with our customers, and it has been.

To understand our customer's pain points, it's vital that we visit and speak with them directly and on a regular basis. That's why I, and our other process experts, frequently travel to various regions. After such a visit, we have a clearer understanding of where the demand is, what improvements in the customer processes are needed, and—equally as valuable—which of the current features are running well.

Once back at our equipment development center in Germany, I share that information with our R&D and engineering groups, as well as with the process chemistry experts based in Berlin. Regular discussions with the Berlin team are fundamental to understanding what is needed from the process chemistry point of view and it means we can harmonize our efforts and then get back to our customers with the most advanced technical solution available. For example, if the chemistry is foaming excessively, we need to consider which equipment features can reduce that foaming, and then ensure that they are applied at the design stage.

Andreas Schatz

Another example is that some chemistries are prone to crystallization; this may not sound particularly important, but if solid particles build up in the machine, it can lead to defects on the PCBs themselves. Knowing which chemistries suffer from this, and where it can occur, means we can apply the relevant countermeasures and avoid particle generation. Subsequently, our equipment products are known to be well equipped with several smart features that avoid particle generation or effectively reduce the number of free particles within the process chambers.

This direct dialogue with our diverse customer base is what drives us forward and enables the innovation, which means we keep providing the best solutions available in the market.

Daniel Schmidt

Matties: You have a lot of information from the global industry. What trends do you see that stand out?

Schmidt: High-end customers have an increased demand for process and data automation, which today means the adoption of a smart factory. Production equipment that is connected and provides live data in real-time is vital in a modern production environment, as it allows operators and engineering teams to focus on that process and optimize it.

In the factory of the future, it will not be enough to have isolated automated processes; the next step is to understand how you can use production data in an intelligent way and how that can help to improve your production yield and reduce machine downtime. One example there is condition monitoring, where through the use of intelligent software algorithms, the machine can effectively notify the maintenance team when a certain part has to be replaced. This can avoid unplanned downtime, which is one of the main objectives of a coordinated predictive maintenance scheme and is something many high-end PCB facilities are implementing.

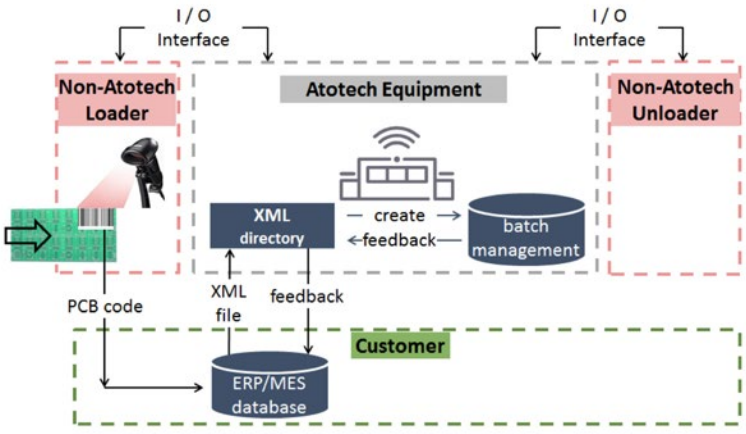
Another major trend is that of particle avoidance and reduction. As Andreas mentioned earlier, this is something that the high-end PCBs producers are looking at closely, especially as they tighten their line and space needs. Here, our task has been to find solutions that avoid, or at a minimum, drastically reduce particle generation within the machine. Today, we utilize our "fine-line filtration" concept, where we install a five-micron filtration system to each pump circuit, which helps the process solution to be distributed over the entire panel surface virtually particle-free.

The other trend is thin panel transportation. Again, panels are getting much thinner, and we already have customers running 30-micron laminate clad with 2-micron copper foils. It's quite challenging to transport such thin material horizontally, but this is where our expertise lies, and we continuously invest in research and development to keep our position.

Matties: The trends that you're talking about are primarily coming out of Asia. What trends do you see in Europe and the U.S.?

Schatz: The PCB shops in the U.S. and Europe, in most cases, serve niche markets and typically require lower volume equipment solutions. While our expertise has been clearly gained in high-volume production equipment typical to Asia (i.e., line speed of approximately 2.0m/min), we provide lower capacity lines that are usually much shorter and custom-configured to address the needs of production schedules here in Europe or the Americas. For example, we offer desmear and electroless copper equipment with a line speed as low as 0.5 or even 0.25 m/min. The benefit of these smaller lines is not only a lower capital investment, but this is also supported by a reduced total cost of ownership, as these smaller lines require less floor space and have less consumption of resources, such as chemistry, water, and energy.

Matties: Getting the board through a process is one thing, but is the drive behind the request tied to process automation and the smart factory?



Networked production control.

Schatz: Yes. We don't only look at bringing the board through the machine. With a smart manufacturing solution, you gain an increased level of flexibility, all at the touch of a button. This can offer the ability to process multiple panel types through the same equipment by automatically changing the related process and production parameters, which would currently need to be done by hand or even require a completely separate production line. This can be achieved by creating recipes for specific product types that contain all the process related settings, such as speed, pressure, temperature, dosing, etc.

When the product arrives at the line, an integrated bar code or similar can be scanned, the associated recipe is loaded to the line, the configuration is rapidly changed automatically, and production can begin. This way, the PCB provides the equipment information it needs to process itself and enables a paperless workflow with minimal risk of operator error yet with full traceability.

Matties: A lot of the smaller companies in America would say we don't need the automation. What would you say to somebody with that mindset?

Schatz: Automation is not only important to reduce current process handling needs, but at the same time, it can also enable a safer user environment. Through automation, we enable stable, repetitive, and reliable process sequences, and let's remember that we are dealing with chemicals, where instability can lead to unsafe working conditions. For instance, chemical cleaning cycles have to follow a very specific order, and drain and inlet valves have to be in the right position at the right time to ensure that you do not get undesirable chemical mixtures, which may lead to a dangerous condition. Here, automation is the only choice to mitigate user and environmental risk. On the other hand, process automation helps you reach higher quality control levels and ultimately increases your product reliability.

Of course, the cost of such equipment is generally higher, but this can quickly be recouped through the reduction in scrap and lower rework levels. At the same time, you also gain the benefits of improved process and quality control, paperless workflow, and—most importantly—a safer working environment; that would come hand in hand with reduced consumption of chemistries, water, and energy.

If you consider both the global or local environmental targets, PCB shops are under increasing pressure to develop and are becoming more motivated to switch from older equipment—such as vertical plating systems—to more environmentally sound units, such as our automated horizontal lines. Our production equipment is completely encapsulated, which minimizes fume escape and helps to reduce energy loss and achieves this with minimal operator intervention. Our Uniplate system, for example, allows a single in-line plating process where PCBs run through all processes sequentially, without interruption. A Uniplate line with a P/LB/Cu configuration enables our customers to run the desmear, electroless copper, and electrolytic copper processes in one line without interruptions and fewer operators than the equivalent vertical approach.

Matties: In many cases, a lot of these companies still have manual processes—especially in some of the smaller shops. Is there a demand to move from vertical to horizontal?

Schatz: Last year, we had several U.S. customers approach us and ask for our horizontal solution, and we are in discussion with more again this year in both the U.S. and Europe. In contrast to Asia, it's a handful of customers, but we take every business opportunity to enhance our customers' manufacturing process and provide the most reliable, flexible, and long-lasting production solution. The PCB community is surprisingly small, and it's very well connected, so innovative solutions spread quickly. We find that once PCB shops have experienced our processes and support levels, we become long-lasting partners.

Matties: Alex Stepinski said that the most important aspect of a PCB facility is the plating process and that you can build from there. Many factories already have existing plating processes, but they may want to upgrade. What should they consider when looking at their plating process?

Schmidt: The whole plating process is a complex system. Our horizontal copper plating modules are the result of decades of intensive research and development, and we continue to develop new features to guarantee the best solutions. From our patented segmented anodes and rectifier system to our sophisticated clamps and advanced fluid delivery system, we do not stop improving our total solution. Today, we have nearly 1,000 horizontal copper plating modules in the global market. Since the beginning in 1987, we never stopped pushing our development team to always stay ahead of the market and offer the best production systems to the industry.

Last but not least, let's not forget about uniformity. When it comes to uniformity, there are three important criteria that influence your copper plating results. First, you must consider advanced fluid dynamics to generate stable flow rates with uniform pressure distribution across the entire panel surface. The second criterion is pulse rectifier control to enable specific plating parameters for every product and plating application. Lastly, one must address a process solution to realize specific plating applications, such as conformal plating and BMV, or through filling. In our Uniplate system, all three of these criteria are coordinated with one another, offering excellent process control and performance that lead to great plating results.

Matties: You also have a fantastic installation in America at the GreenSource Fabrication facility. I imagine that's quite a showcase for Atotech. What were some of the challenges in setting up that revolutionary smart factory?

Schmidt: The special request from GreenSource was to create a very flexible and customized capability. For instance, we had to set up a single copper plating process, which can run three different plating applications while maintaining a choice of two electrolytic copper tanks, and everything had to be automatically controlled. When production needs to switch from one PCB application to another, the installed electrolyte is transferred to a holding tank, and all the transfer pipes, etc., are automatically cleaned with rinse water. Then, the second or other electrolytic is pumped automatically into the plating module, and the dosing parameters, temperatures, etc., are automatically uploaded and adjusted.

As you can imagine, initially, this was quite a challenge, but working closely with the team at GreenSource, we have shown that it's not only possible but that it also works extremely well. Today, we can look at the partnership between Atotech and GreenSource and really appreciate the trust they placed in our capabilities, products, and services. It has been a fruitful collaboration, and we look forward to continuing it.

Matties: And that's good for North American or European high-mix, low-volume facilities. Had you produced this previously?

Schmidt: The system configuration at GreenSource is unique, and Alex had many ideas and requirements that we were able to successfully implement across several plant projects. Basically, you have to say that every system project is unique. We have a wide range of options available, which results in a very customer-specific product. In the case of Green-

Source, there were many requirements that were beyond our options portfolio when the project started, but in the end, we met all their needs.

Every line is customized, and it's a simplification to say that in the high-volume Asia production facilities, they produce the same boards with the same process, and if they want another process, they buy another line. But to have the flexibility to run different plating applications with one line was a special requirement from GreenSource, which we were happy to fully realize.

Atotech team at GreenSource Fabrication plant, NH, USA.

Matties: You're introducing three or four new pieces of technology right now. That's rather ambitious. What was the motivation to bring out all of this technology in the same timeframe?

Schatz: To bring several new products to the market can be quite ambitious, especially when you launch several at the same time. We look back at a long history in equipment development and have constantly refined our standard operating procedures, the communication with customers and OEMs, as well as our technology forecasting. We can also provide chemical process technology and the required manufacturing equipment out of the same hand, which means we have a unique and strong competitive advantage. This understanding of the synergies between the equipment system and chemistry is what strengthens our total process solution and delivers a true value-add to our customers.

There are several new equipment products on their way. At the moment, we are expanding our core horizontal system product line, as well as building up a new vertical copper systems product line. For horizontal PCB transportation, we have recently launched two new systems—a new Uniplate concept and our Polygon platform. Our new Uniplate combines several new features and is the latest extension of our well-established product line for desmearing and electroless copper metallization processes in high-end PCB manufacturing.

The system is more maintenance-friendly and is equipped with more efficient pumps and new features for particle control. For example, by using tailor-made impellers in process pumps, in combination with flow-optimized piping, we have reduced the power demand by 50% but retained the same pump performance. This means that for a Uniplate P/LB, power consumption is reduced by 30kW, which offers a considerable cost saving across the year. We have redesigned the way samples are collected from process tanks, protecting the operator—most importantly—as well as the system components from any chemical splashes. To make the overall operation clearer and easier, the human-machine interface (HMI) is currently being improved, with a focus on allowing the user to easily navigate through the system through standardized icons, objects, and messages. Another new feature is a revised electrical concept in which we have integrated everything into the line itself, making it easier and faster for installation on-site and reducing the overall machine footprint.

Our new Polygon platform aims to meet the needs of those customers who are looking for a reliable, capable, and affordable systems solution. Designed in Germany and using many of the same features as our high-end Uniplate lines, Polygon machines are manufactured in Guangzhou, China, utilizing locally sourced parts that offer a high standard of quality. Currently focused on the desmear and electroless copper processing, Polygon P/LB targets the mid-level PCB segments found in multilayer,

Atotech equipment product portfolio.

flex, rigid-flex, and HDI production. An example of the Polygon P/LB is installed at our technical center in Guangzhou, China, and is available for customer inspection and sampling. Since its launch, a number of Polygon systems have been installed, with more currently on order for delivery later this year.

Last but not least, let me briefly emphasize our vertical systems. vPlate is our new vertical panel and pattern plating equipment for PCB targeting fine line and space application down to approx. 8/8µm. Used in combination with our existing vertical process chemistry, vPlate extends our unique and successful system approach to cover both horizontal and vertical process users. Meanwhile, MultiPlate is a revolutionary wafer and panel-level packaging tool designed to process embedded systems, SiP, or other advanced packaging technologies. With this development, we are at the forefront of packaging development and offer excellent deposition quality with the highest performance in RDL, pillar, and tall pillar plating.

Matties: Is there anything else that we haven't talked about that you feel like our readers should know?

Schatz: In the field of horizontal plating, we are proud to announce that we are about to launch a new horizontal system for pattern plating—Uniplate IP3. This is a unique and revolutionary product. It's the first horizontal pattern plater for (a)mSAP applications in the market and is based on the experiences gained installing nearly 1,000 Uniplate lines worldwide.

With Uniplate IP3, we have developed something truly special for all high-end PCB makers. The highlight of this new tool is the anode fluid basket, which controls the panel position in the middle of the anode pair. In combination with a number of other improvements, and with an increased nozzle density per anode, we are now able to support the panel within the process fluid itself. This means that apart from the main panel clamps, which are always needed to deliver the plating current, there is no other surface contact across the PCB during electrolytic plating.

This new feature brings two major advantages: no contact in the active surface area minimizes the risk of dry film damage and the associated plating defects, and the equidistant position between the top and bottom anodes helps to further improve thickness variations between both sides of the panel—both of which are essential when targeting fine line pattern plate products!

Matties: Andreas and Daniel, this has been wonderful. I appreciate your time today.

Schatz: You're welcome. Thank you very much for having us.

Schmidt: Thank you, Barry. We appreciate you visiting.

Matties: It has been our pleasure. PCB007

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Too Much Automation?

Testing Todd

Feature Column by Todd Kolmodin, GARDIEN SERVICES USA

The last six months have brought monumental changes to commerce, manufacturing, recreation, and almost every aspect of our daily lives. As we slowly begin to emerge from this pandemic, we are finding that what was routine six months ago has drastically changed and may never be the same.

This has caused us all to rethink our daily lives and how we go about existing in this new normal. Workplaces have changed for those that still exist, while others have become extinct. Virtual workplaces are gaining traction, as well as telecommuting and more reliance on the internet for virtual meetings, webinars, and many other daily activities that required face-to-face collaboration. For many of us, life has changed forever.

We have to rethink our personal lives and adjust to the changing conditions so that we can continue to thrive. As humans, we have the ability to experience, review, react, and change quickly to adapt to changing conditions. Whether it's staying home, wearing a mask, telecommuting, or doing nothing, those decisions come from our ability to think and analyze. We rethink, adapt, and thrive.

With that in mind, it causes us to rethink other aspects regarding manufacturing. The hot topic over the last decade or more has been automation—automate, automate, automate. Of course, after the initial investment, automation can save on costs. Fewer humans are required, throughput is predictable, and repeatability can be expected. Flip the switch, turn off the lights, and the required products will be ready to ship in 12 hours. Right? Not so fast.

Although automation can save costs and provide repeatable results, when something goes wrong, very bad things can happen, as

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Apple and Foxconn have learned [1]. Automation lacks one critical component: the ability to question, reason, and evolve on its own. At the end of the day, the robot does exactly what it is told to do, over and over again. Yes, robots are predictable, can work in the dark and don't need breaks except for periodic maintenance. However, all the optics, conveyors, arms, and brute strength that automation can provide is no match for the grey matter of the human brain. Highly skilled human labor is still needed.

In many aspects of automation, providing the human replacement for mundane, repetitive tasks works out fine. More complex tasks, although campaigned for automation, should be rethought. Here, the human element still makes a valuable difference—the ability to question, analyze, think critically, and create are traits that automation will always lack regardless of how strong the AI may be or the complexity of the program driving the process. It is not thinking. It is doing exactly what it is told. To quote David Bourne, principal systems scientist at The Robotics Institute at Carnegie Mellon University, on his work with Apple and Foxconn [1], "Robotics and automation are fantastic and amazing when it works, But when something breaks, God knows what happens." Enough said.

As we are all in our rethinking mode, retooling our lives and considering how we do business, we must ask, "How much automation is enough?" We can easily get caught up in the cost savings and immediate gratification. But remember, the automation you implemented is a snapshot of today's technology. It will do what you want today, but it will not evolve. It cannot learn without costs. (maintenance contract, service agreement, etc.).

However, your employees at these critical processes think dynamically, analyze, criticize, ask questions, provide options, and evolve. They will always be necessary. There is a place for automation, but balancing the cost savings vs. the liability the automation may create are bullet items that should be on any engineer and management whiteboard.

Be safe. **PCB007**

Reference

1. W. Gallagher, "How Apple learned automation can't match human skill," AppleInsider, June 5, 2020.

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.

Travel Intel's Autonomous Superhighway

It has more than 27 miles of multilevel thoroughfares on which 1,700 autonomous vehicles shuttle Intel's most precious cargo. It's the automated material-handling system (AMHS) at Intel's D1 factory in Hillsboro, Oregon. Intel runs overhead transport systems like this in every one of its six chip fabs worldwide.

The boxes scooting along on the overhead tracks are front-opening unified pods (FOUPs) that carry as many as 25 wafers, each containing hundreds of Intel chips, on their weekslong fabrication journey starting as blank silicon discs.

Oregon's wafer superhighway connects nine buildings, including the D1X and D1D factories. The two factories together are a little larger than 12 U.S. football fields.

Take a quick 2-minute tour around Oregon's D1 factory, captured before pandemic recommendations for social distancing took effect, to learn more about what AMHS leader Mutaz Haddadin calls "the heartbeat and blood flow of the fab."

(Source: Intel Newsroom)

Electronics Industry News and Market Highlights

Digi-Key Electronics Named Semiconductor Catalog Distributor of the Year by Vishay Intertechnology ▸

Digi-Key Electronics, a global electronic components distributor, received the 2019 Semiconductor Catalog Distributor of the Year award by Vishay Intertechnology—one of the world's largest manufacturers of discrete semiconductors and passive electronic components.

PTC Extends Alliances With Rockwell Automation and Microsoft ▸

PTC and Rockwell Automation Inc. announced Factory Insights as a Service, a turnkey cloud solution that enables manufacturers to achieve unprecedented impact, speed, and scale with their digital transformation initiatives. The new offering, unveiled during PTC's Global Partner Summit event at the LiveWorx® 2020 digital transformation event, marks a significant advancement to the collaboration among Rockwell Automation, Microsoft, and PTC.

NXP Semiconductors HoverGames Challenge 2: Help Drones Help Others ▸

NXP Semiconductors N.V. announced HoverGames Challenge 2: Help Drones Help Others. The second installment of NXP's challenge-based, interactive coding competition encourages developers to create drone and rover solutions for frontline support during pandemics.

Startup With MIT Roots Develops Lightweight Solar Panels ▸

Joel Jean, Ph.D. '17, spent two years working on "The Future of Solar Energy," a report published by the MIT Energy Initiative (MITEI) in 2015. Today, he is striving to create that future as CEO of Swift Solar—a startup that is developing lightweight solar panels based on perovskite semiconductors.

Qualcomm and Infinite Collaborate to Facilitate Powerful Digital Transformation in Smart Cities ▸

Qualcomm Technologies Inc. and Infinite Computer Solutions, a global technology company and provider of products and platforms for digital transformation, announced a strategic collaboration to promote the widespread adoption of smart cities solutions and deliver internet of things as a service (IoTaaS) for plug-and-play deployment.

Deep Learning Robotics Granted New Patent for Robotic Learning ▸

Deep Learning Robotics Ltd.—a technology company, focused on robotics and automation solutions—announced that the United States Patent and Trademark Office granted the company a new patent, No. US10,571,896.

NVIDIA Provides More Tools for Working Remotely ▸

For many organizations, the coronavirus pandemic has created a permanent shift in how their employees work. From now on, they'll have the option to collaborate at home or in the office.

SEMI Supports CHIPS for America Act to Increase Semiconductor Manufacturing in the U.S. ▸

Facing a 50% decline in the U.S. share of global semiconductor manufacturing capacity over the past 20 years, Congress introduced the Creating Helpful Incentives to Produce Semiconductors for America Act (CHIPS for America Act), highlighted by a federal investment tax credit (ITC) strongly supported by SEMI, the global industry association representing the electronics manufacturing and design supply chain.

Atotech: A System Supplier With Total Solutions

Feature by Happy Holden
I-CONNECT007

Before productronica last year, the I-Connect007 team had the opportunity to visit Atotech's equipment R&D and production site in Feucht, Germany (near Nuremberg). Atotech started more than 60 years ago in this location as multilayer and PTH processes were being adopted by PCB fabricators. They also have a manufacturing facility in Southern China (Guangzhou), as well as 14 chemistry production sites and 17 tech centers around the world.

Atotech's product lines started with chemical processes and expanded early into equipment and services. Today, Atotech offers surface-finishing solutions with 4,000 experts in over 40 countries, generating an annual revenue of $1.2 billion in 2019. Through a systems-and-solutions approach, the company delivers chemistry, equipment, and service to support diverse industries, such as consumer electronics—especially mobile devices and computing—global automotive, communication infrastructure, and many other industrial end-markets. Atotech's R&D efforts and global tech center presence allow the company to deliver pioneering and sustainable products with on-site customer support.

Atotech can supply a total systems solution for electronics (IC, packaging, and PCB), as well as for general metal finishing. The company introduced significant new products in 2019 for wafer fabrication, panel-based package substrates, and advanced PCBs (substrate-like PCBs, HDI substrates, flex/rigid-flex, and MLBs). The three major product categories are:

- Chemistry (wafer, package substrates, PCB, GMF)
- Equipment and spare parts (wafer, package substrates, PCB, GMF)
- Service/training (all)

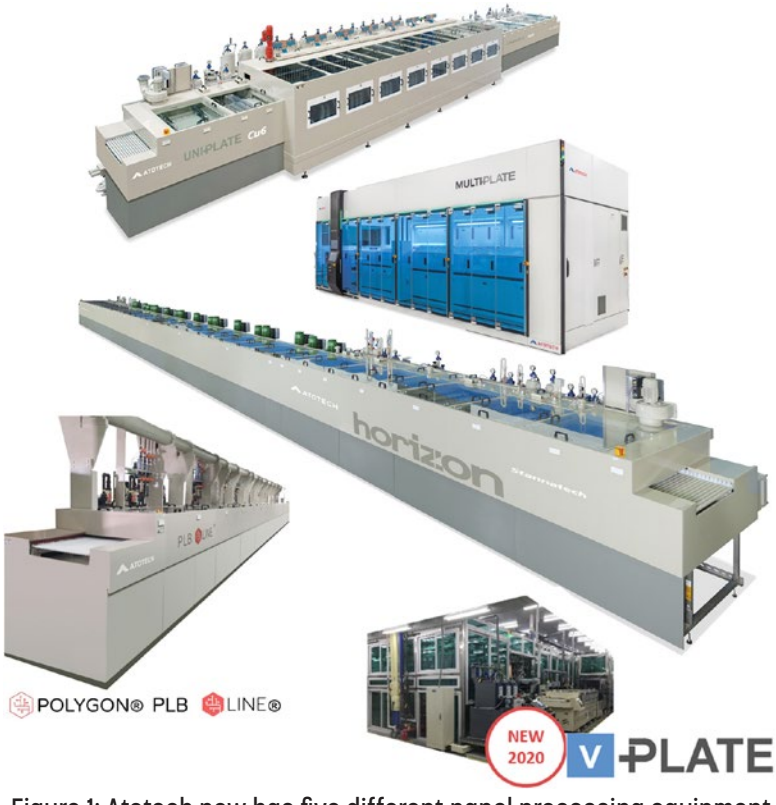

Figure 1: Atotech now has five different panel processing equipment (three for horizontal processing and two new vertical systems).

Product Lines: Horizontal

The two traditional equipment product lines for horizontal processing of panels (Uniplate and Horizon) were augmented by a new lower-cost horizontal machine, the Polygon series, and by two vertical panel processing lines, MultiPlate and vPlate (Figure 1).

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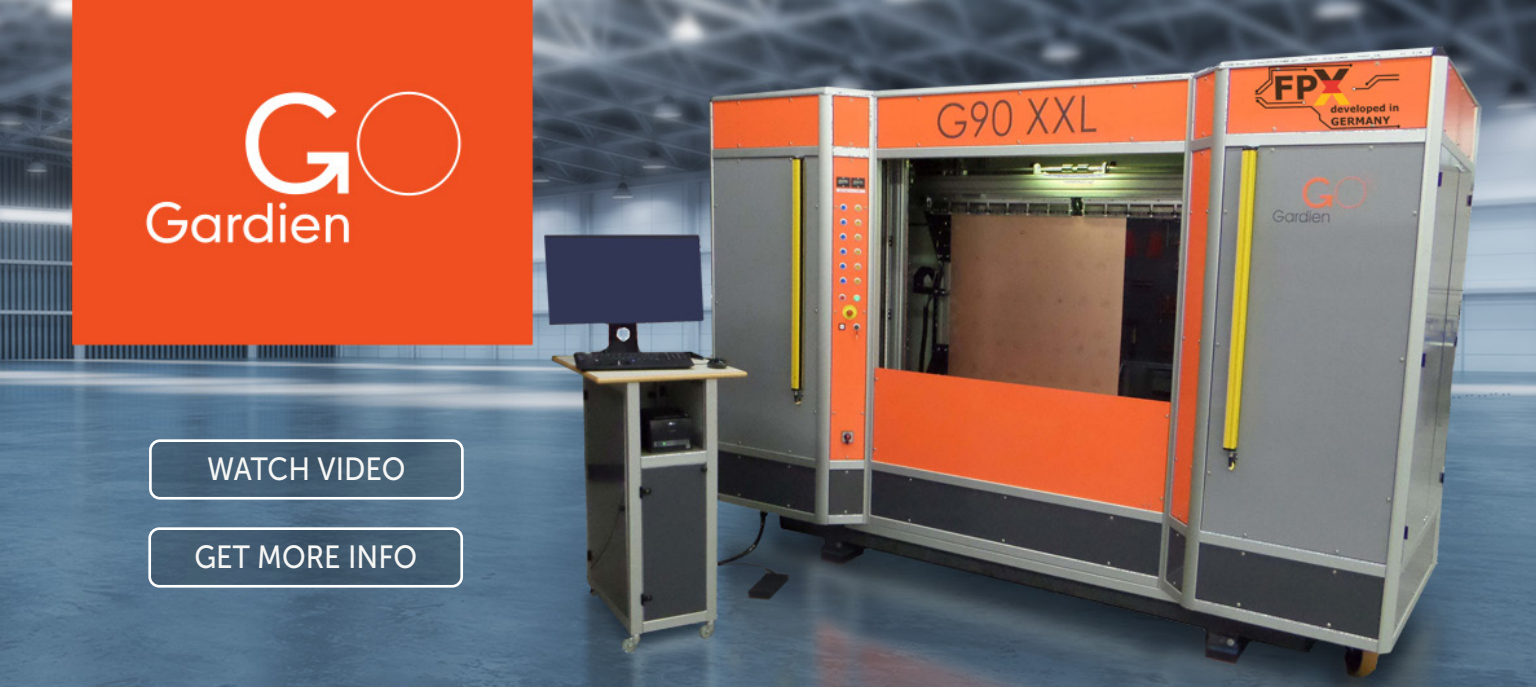

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Uniplate

Since the rapid increase in HDI production for mobile phones and other handheld products in the early 2000s, the Uniplate and Horizon series of machines have been installed over 1,500 times for copper plating, desmear, electroless copper metallization, direct metallization, surface treatment, and immersion tin processes. Uniplate equipment includes custom-engineered systems exactly suited to their intended use; some have reservoirs of 6,000 liters and lengths of 120 meters. Atotech's chemical process development is tightly connected with its equipment design to ensure best-in-class performance (e.g., Uniplate LBCu6 with Printoganth® U plus is the POR for smartphone OEMs requiring mSAP technology for the latest generation of substrate-like PCBs). Supported by a strong local service level (e.g., for process consultancy and optimization) via the company's global tech center network, Atotech is a supplier for several industries.

The innovative, universal transport system (UTS) is a design element highly suitable for the transportation of very thin material (Figure 2). Other unique components are the specially designed pulse-plating power supplies connected to segmented anodes for uniform plating distribution, specially engineered flow patterns and controls, automation control sequences, automatic chemical analysis, and dosing for constant chemical concentrations (Figure 3). Figure 4 shows the cost and quality advantage of

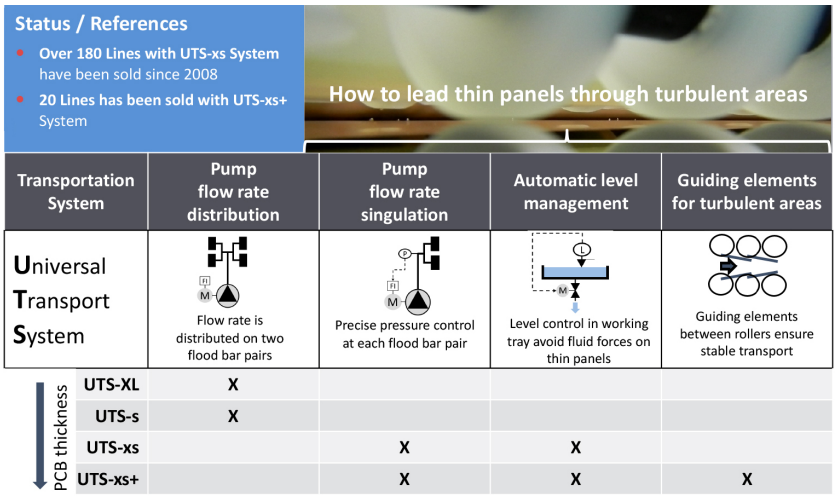

Figure 2: Atotech pioneered the thin-material UTS that now has three variants (-s, -xs, and -xs+).

Figure 3: Automatic chemical analysis and dosing are automation features from Atotech.

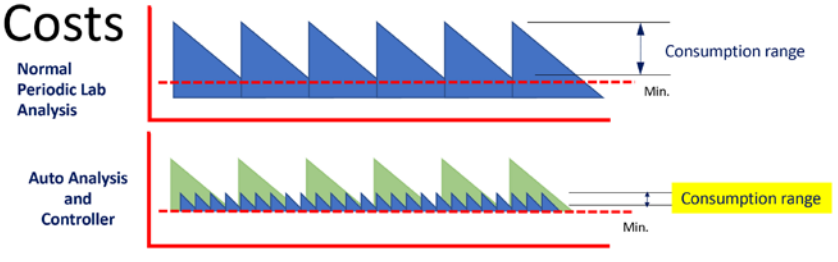

Figure 4: The big advantage of continuous analysis, especially for copper plating additives, is that a consistent lower-level concentration can be maintained without exceeding the low-level limit. This is a 30% lower usage of chemicals than allowed by periodic laboratory analysis by conventional CVS instruments. New nozzle and pump control allow the centering of thin cores inside the equipment without being touched.

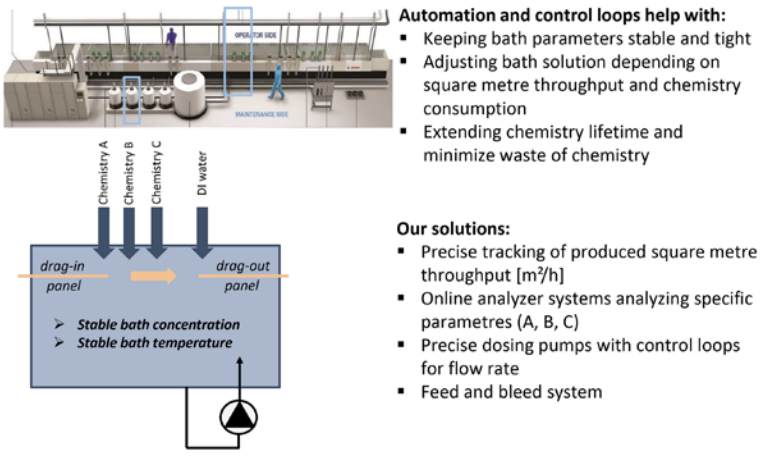

Figure 5: Uniplate has extensive automation and control features that provide stable and tight process parameters.

Technology	Application	Process	Cu Ip2	Cu Ip2 adv.
Conformal Panel Plating	TH & BMV Plating		+	+
	Panel plating & High dense TH pl.		+	+
	Flex Plating (R-t-R)		+	+
Copper Filling Panel Plating	BMV Filling (with THs)		+	+
	BMV "Super-Filling"(without THs)		+	+
	TH Filling (higher aspect ratios)			+

Figure 6: The advanced substrate's need for conformal panel plating and copper filling are provided by the Cu IP2 and Cu IP2 advanced. In 2020, the Cu IP3 series was introduced for horizontal pattern plating for (a)mSAP applications.

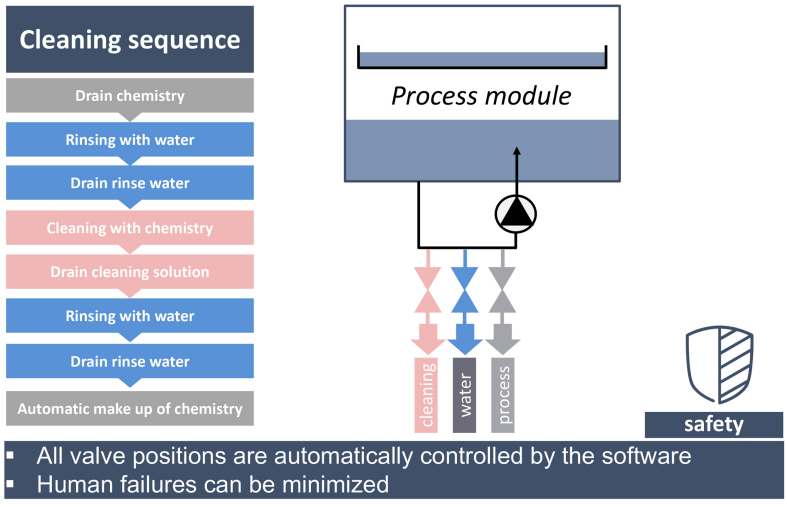

Figure 7: Advanced automation includes automatic cleaning and equipment preparation, ensuring that these sensitive processes have the proper conditioning.

having this improved control of sensitive concentration in critical processes.

Improvements in fluid dynamics, transportation, automation, and control have led to the next generation of Uniplate Cu—IP3. This is an improved machine for finer structures, blind vias, and modified semi-additive processes, or mSAP (Figures 5 and 6). This new product targeting L/S (lines/spaces) capability down to 20-micron traces and spaces. Some of the automation features are automatic cleaning sequences that protect the operator and guarantee the machine is properly set up for products with fine structures (Figure 7).

Horizon

Horizon is the other long-standing series of horizontal machines. Not intended for metallization, these provide for the bonding enhancement, surface treatment, and metal stripping with the Horizon Bondfilm, Horizon NovaBond, Horizon PallaStrip. This series of equipment is used for surface treatment technology or STT (Figure 8). For the final finishing of PCBs, Atotech provides the immersion tin system solution with the Horizon Stannatech equipment and process.

Polygon (New Product Line)

New for 2019, and manufactured in Atotech's China plant, the Polygon series is engineered for higher through-put of thin materials and larger PCBs with patented fluid bar technology for state-of-the-art solution exchange on the panel surface in BMVs and THs. With the tech-

nology to reduce the consumption of water and chemistry, it is the answer to environmental friendly PCB production. The processes supported are desmear, electroless copper, and surface treatment (Figure 9).

Product Lines: Vertical

vPlate (New)

New in 2020 is the vPlate series of equipment. This vertical-continuous electrolytic plating line runs all of Atotech's conformal and blind microvia filling plating and hole-filling processes. Designed for the production of advanced thin substrates for HDI/SLP, rigid-flex, and IC packaging, it is capable of geometries of 15-micron traces/spaces down to 8/8-micron geometries using SAP and mSAP (modified semi-additive processes). This new equipment is designed for pattern-plating and panel-plating (Figure 10).

MultiPlate (New)

Another new vertical processing line is the MultiPlate series (Figure 11). These are intended for cleanroom applications, such as through-silicon vias (TSV), wafer/panel-level packaging (WLP), advanced packaging solutions, or embedded systems. MultiPlate W is capable of standard wafers and Taiko wafer with only 50 µm. MultiPlate P can handle large panels up to 650 x 610 mm. Special features like direct solution flow through the anode and free programmable agitation achieve a unique combination of high-speed plating with a distribution of <10%. The control is such that geometries of 2/2-microns are possible as well as complex

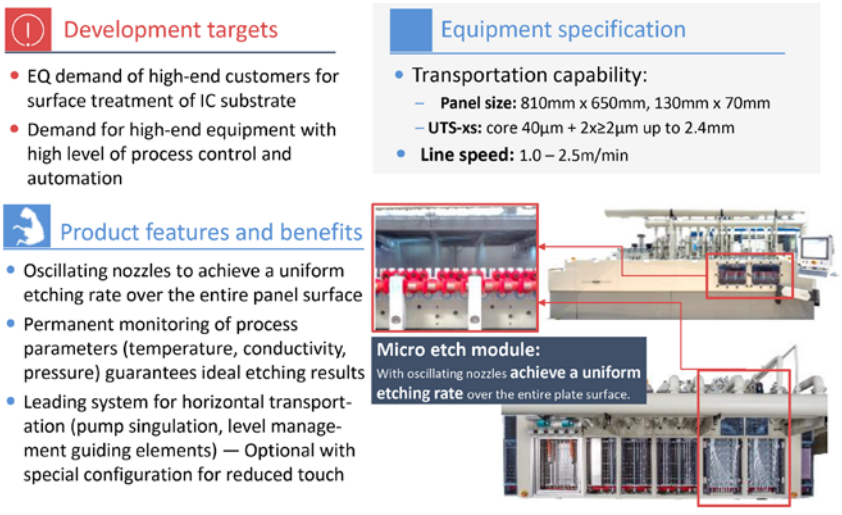

Figure 8: New Horizon modules for high-end processes for the surface treatment of IC substrates.

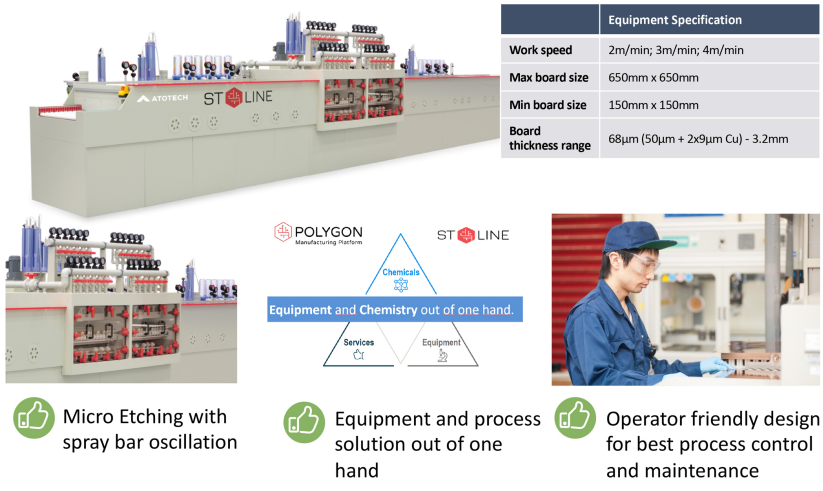

Figure 9: Polygon system, transportation specifications (Polygon is the new series of horizontal processing equipment built by Atotech China).

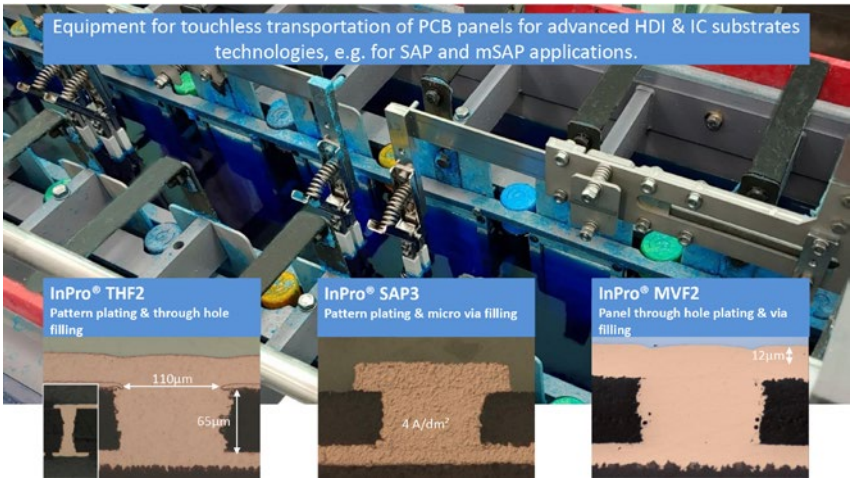

Figure 10: vPlate for continuous vertical electrolytic plating is a new series of equipment released in 2020 and suitable for thin substrates and advanced HDI/SLP, rigid-flex, and IC substrate technologies.

Figure 11: Another new vertical panel processing system is the cleanroom MultiPlate targeted for redistribution layer (RDL) and wafer pillar applications as well as advanced pattern-plated embedded components and SAP and WLP panels.

Decreasing line and space / increasing circuit density

Process	mSAP	amSAP	SAP
CCL thickness	2 – 5 µm	1 – 5 µm	N/A
Target E'less-Cu thickness	0.35 µm	1.0 µm	1.0 µm or less
Flash reinforcement	Yes (about 5 µm)	No	No
Fine L/S capability	Down to 35 µm	Down to 25 µm	Down to 8 µm

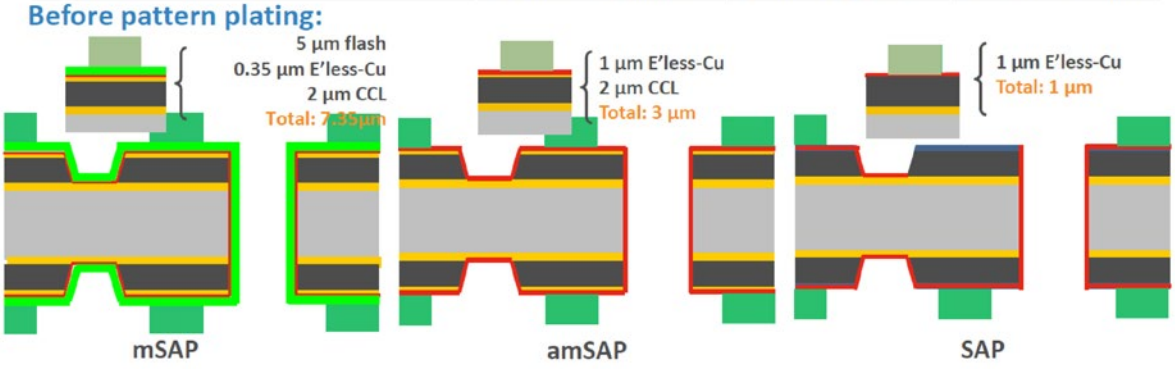

Figure 12: SAP is required for metallization and the creation of geometries down to 8 µm. Depending on finished L/S capabilities, pattern-plating is also required.

MVF and pillar structures using dedicated RDL and Pillar Atotech chemistries.

The MultiPlate series has been in development for many years with the assistance of the semiconductor industry. It has been refined and evolved from earlier experimental machines.

The targeted applications of both new vertical products and the related Atotech processes are shown in Figures 12 and 13.

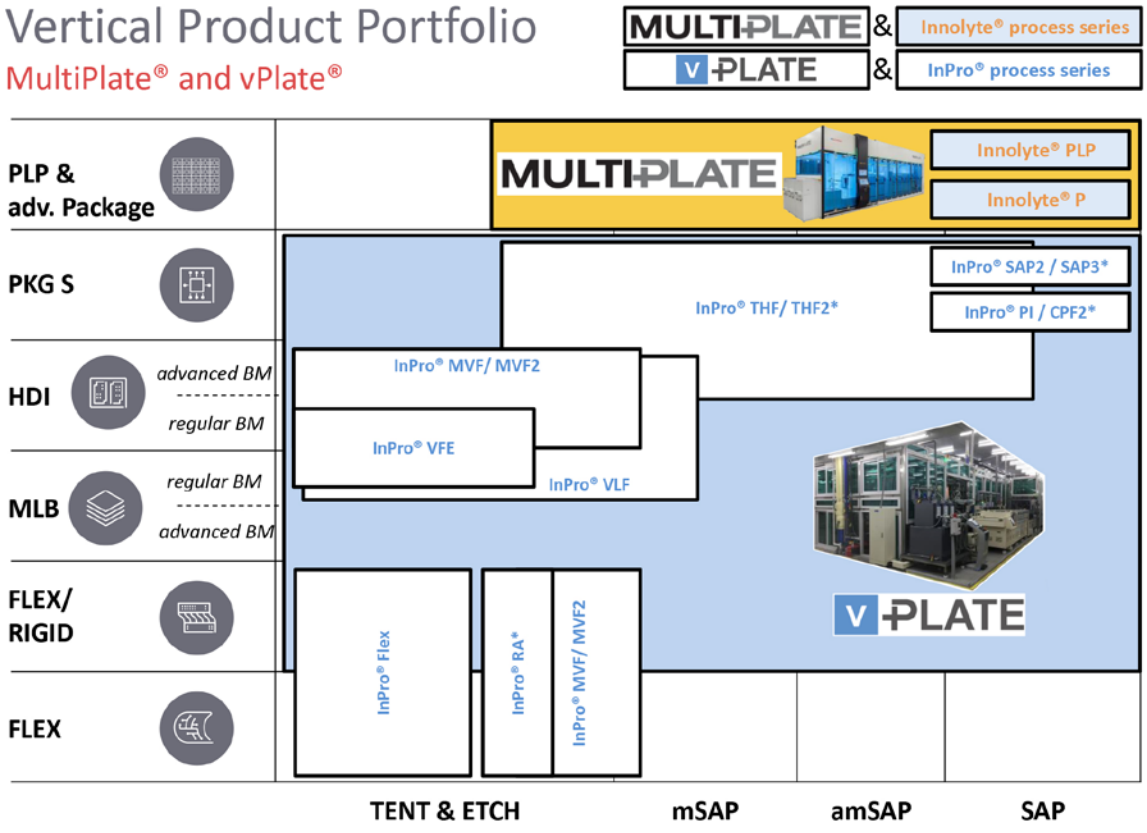

Figure 13: Depending on the applications, the two new vertical products are targeted for advanced electroplated substrates.

Automation and the Smart Factory

Atotech has invested a lot of engineering and research resources to provide the most complete automation solution for its equipment. Automation is defined as mechanization and systemization (information). The mechanization features include their thin-panel transports, optimized fluid distribution, and control of physical properties, such as temperature, pressure, valves, chemical concentrations, and current distributions (Figure 14).

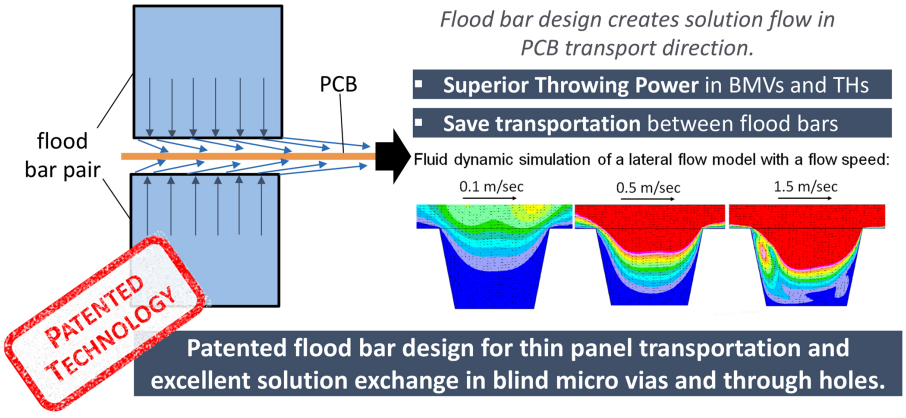

Figure 14: Uniplate PLB Cu fluid transport optimization for advanced products with PTH and MVF.

The systemization (information) part of automation is equally highly developed. Figures 15 and 16 show the training aspects for operators based on sensor and processing history, including the fluid system, pump, filter, fluid bar, and circuit. The information can be displayed for operators to then act upon this information. Atotech uses industrialized computers to provide this information and communications, including redundant networking.

Industry 4.0

As the use of sensor and processing data is collected and acted upon, there is a need for

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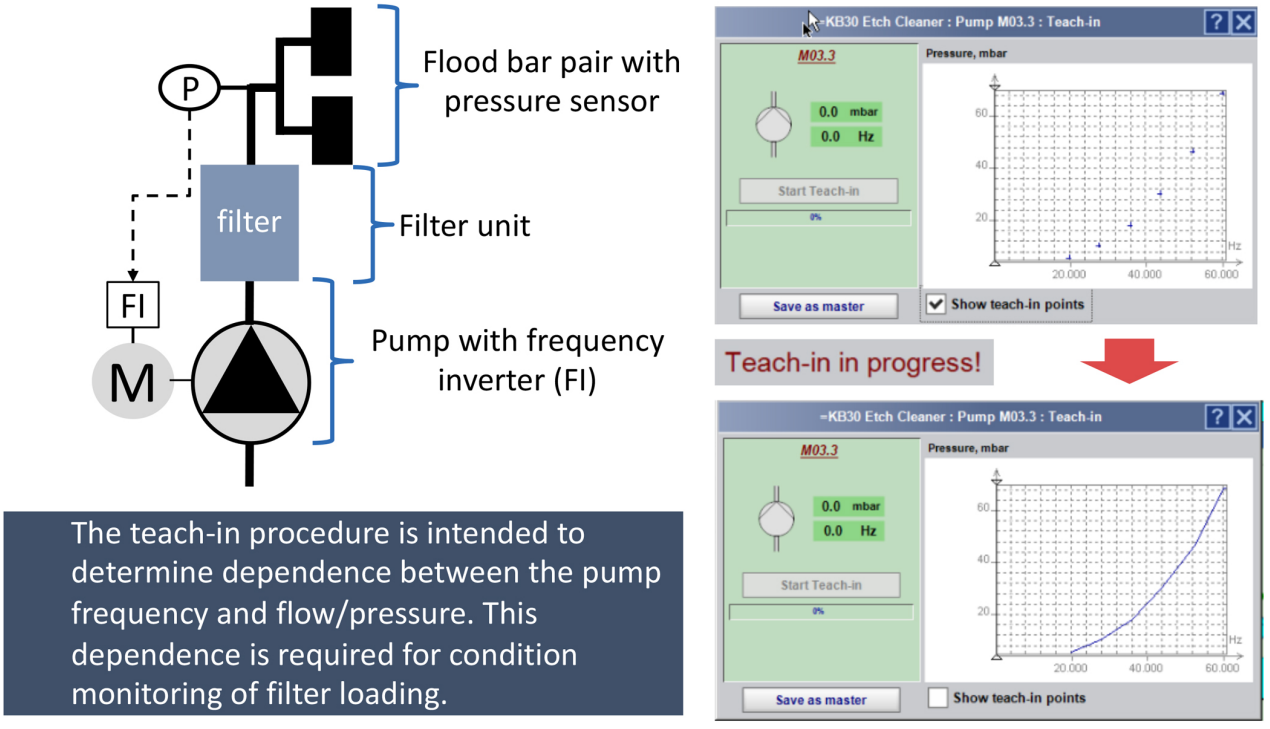

Figure 15: Automation training (Fab 4.0) automated solutions cleaning and exchange.

- *Visualization of filter loading status for each pump circuit*
- *Identify which filter needs to be exchanged and which do not*
- *Enable efficient maintenance planning*
- *Reduce waste of filter cartridges*

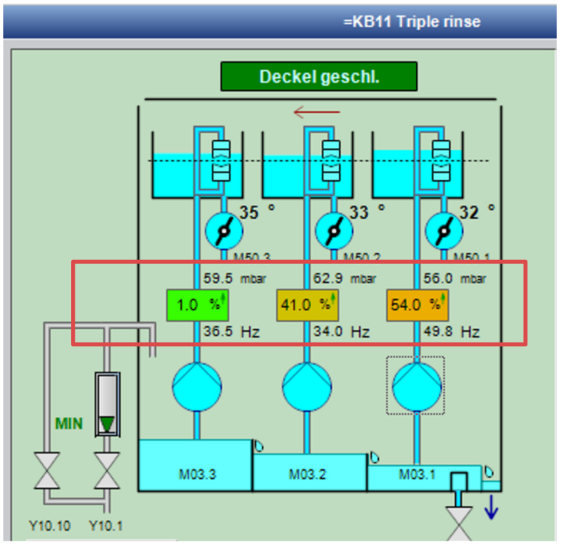

Figure 16: Fab 4.0 automation solutions, which help to visualize the filter status.

communication with higher-level MES software. Atotech used the ISA-95 model for hierarchical control and communications (Figure 17). Factory equipment is at Level Zero, sensing the production process at Level One, loop control at Level Two, MOM or MES at Level Three, and ERP and other enterprise systems at Level Four.

The equipment communication standard used is the European OPC standards for sensors and devices at Level 0 and Level 1 (Figure 18a). The standard for higher-level recipes, alarms, instructions, and analysis is the SEMI SECS/GEM interface standard (Figure 18b). Since Atotech is collecting so much data, the company is now working on techniques to put

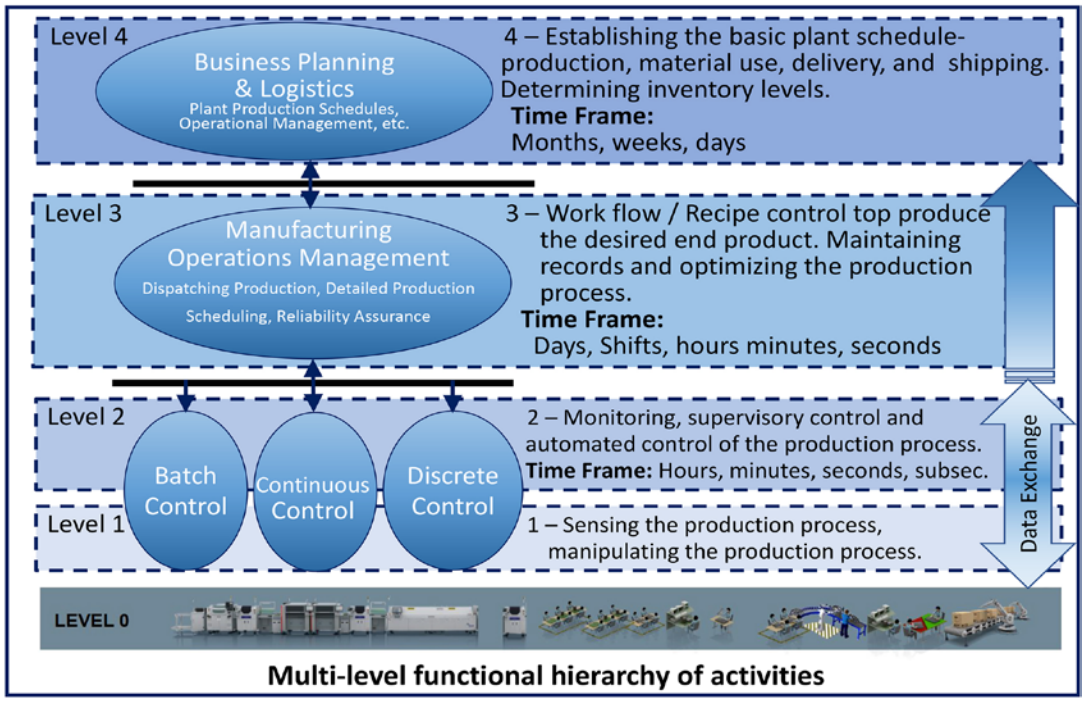

Figure 17: ISA-95 systems hierarchy model.

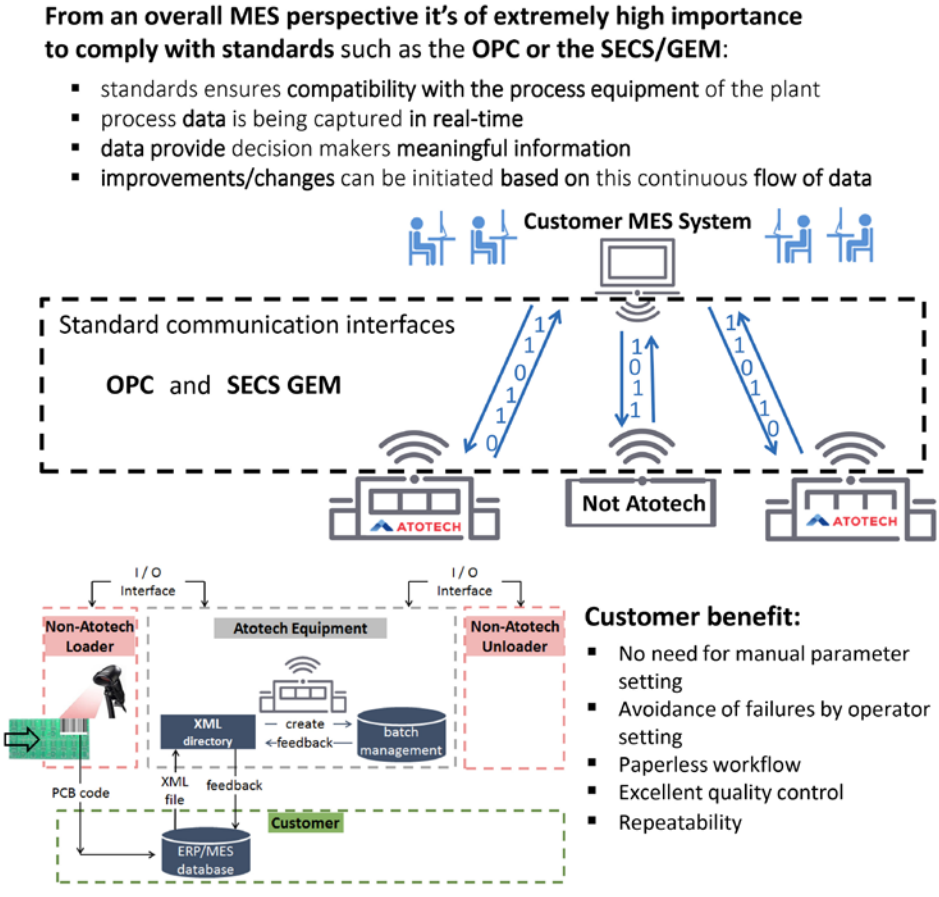

Figure 18: (a) Equipment communication standard protocols and the capability to communicate production data to customer MES-system; (b) under Atotech's Fab 4.0, the production panel can control its production parameters by a predefined recipe and therefore reduces handling needs and costs and improves quality control.

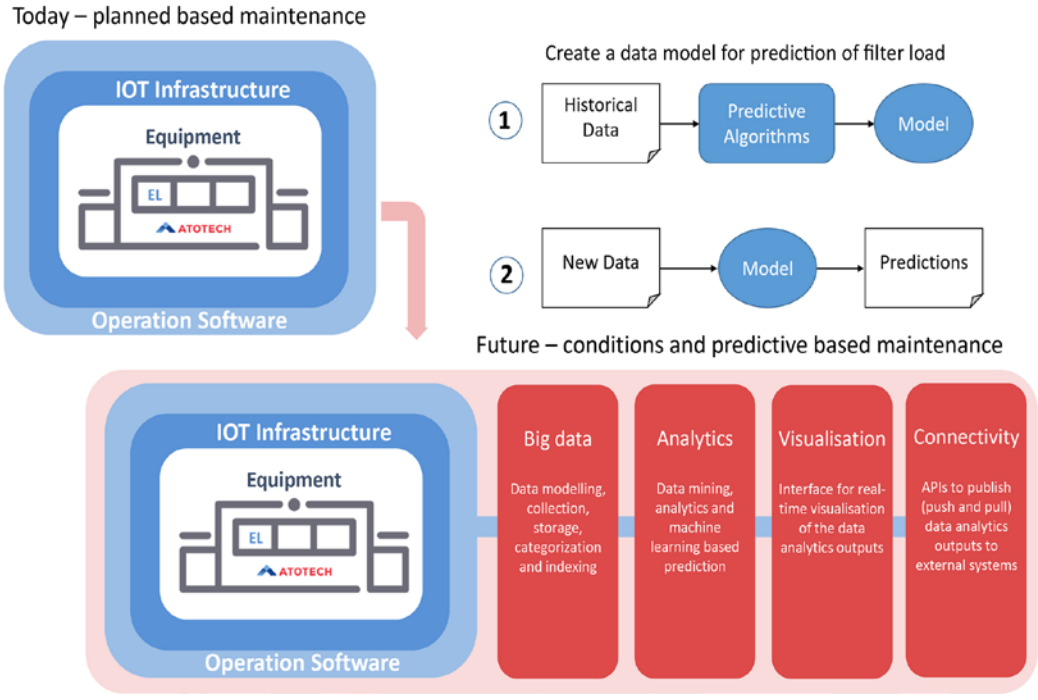

Figure 19: Pilot project for future maintenance solutions using predictive models.

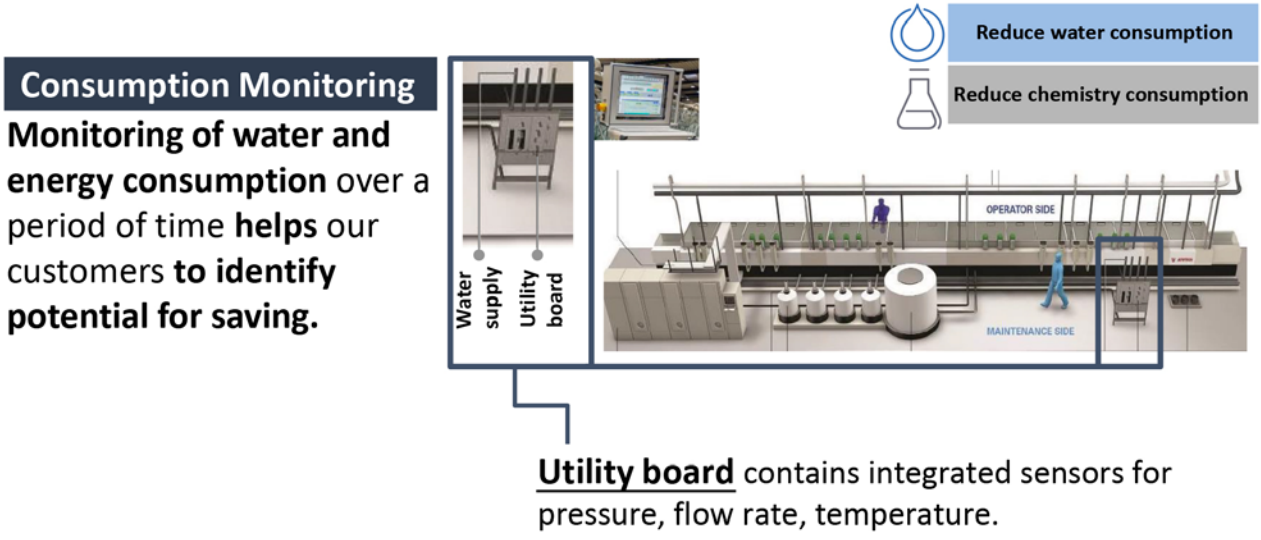

Figure 20: Fab 4.0 enables the customer to identify potential energy or consumption savings.

that data to additional uses. One of those applications is the expansion of preventive maintenance to the algorithmic predictive maintenance (Figures 19 and 20).

Atotech's Field Services are working with OEMs, suppliers, and fabricators to develop the optimum total solutions for electronics and surface finishing. With the unique combination of German engineering and customer needs, assisted by Fab 4.0, Atotech will continue to innovate and provide total solutions for its customers. PCB007

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. To read past columns or to contact Holden, click here.

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Fein-Line Associates, Inc.
P.O. Box 73355
San Clemente, CA 92673

Telephone: (949) 498-7866
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A Process Engineer's Guide to Advanced Troubleshooting, Part 2

Trouble in Your Tank

by Michael Carano, RBP CHEMICAL TECHNOLOGY

Introduction: Etching-Related Defects, or so It Seems

In my last column, I presented issues that were found at final assembly. However, the defects that manifested themselves after the boards were assembled had their genesis in electrolytic copper plating. In this month's edition, I will discuss two interesting technical problems. The first defect I will present is the case of circuit open or etch-out, which will also include circuit width reduction related to undercut. The second defect relates to extraneous copper remaining on the board. Both issues illustrate the complex nature of PWB troubleshooting and defect analysis.

Most process problems that appear during the etching stage of printed circuit production can be traced to one of two general areas. The most common and obvious cause of etching problems is the etching equipment itself, either through component failure (spray nozzles, pressures) or mis-adjustment, including conveyor speeds.

The second most common cause during the etching step is with problems that occur during prior processing steps but are not detected until the boards are processed through the etcher. One example is resist scum left on the board during the stripping of a plating resist, which can cause uneven etching to occur.

Another factor relates to the control or lack of control related to the chemical operating parameters. These are just a few of the possibilities that will be presented in future editions of "Trouble in Your Tank." For the purposes of this month's column, the main defects to be discussed are the etched-out circuit trace and extraneous copper remaining after etching.

Etched-Out Circuit Trace

One of the most disconcerting issues related to bare board fabrication is to find an opening in one or more of the circuit traces after etching (Figure 1).

Of course, this defect did not manifest itself until after the inner layer etching step was

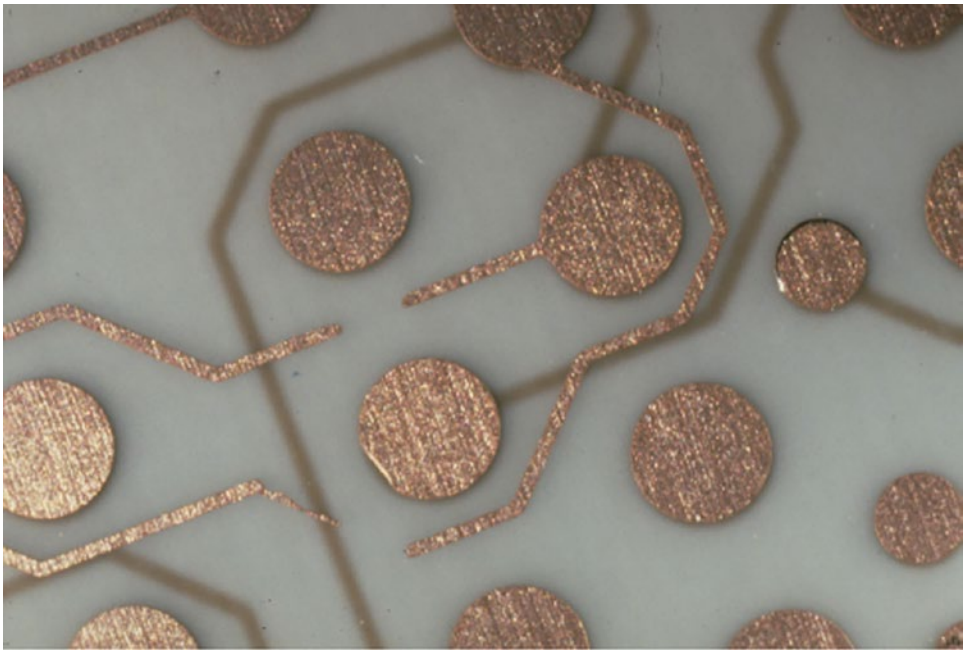

Figure 1: Circuit traces etched away. (Source: RBP Chemical Technology slide library)

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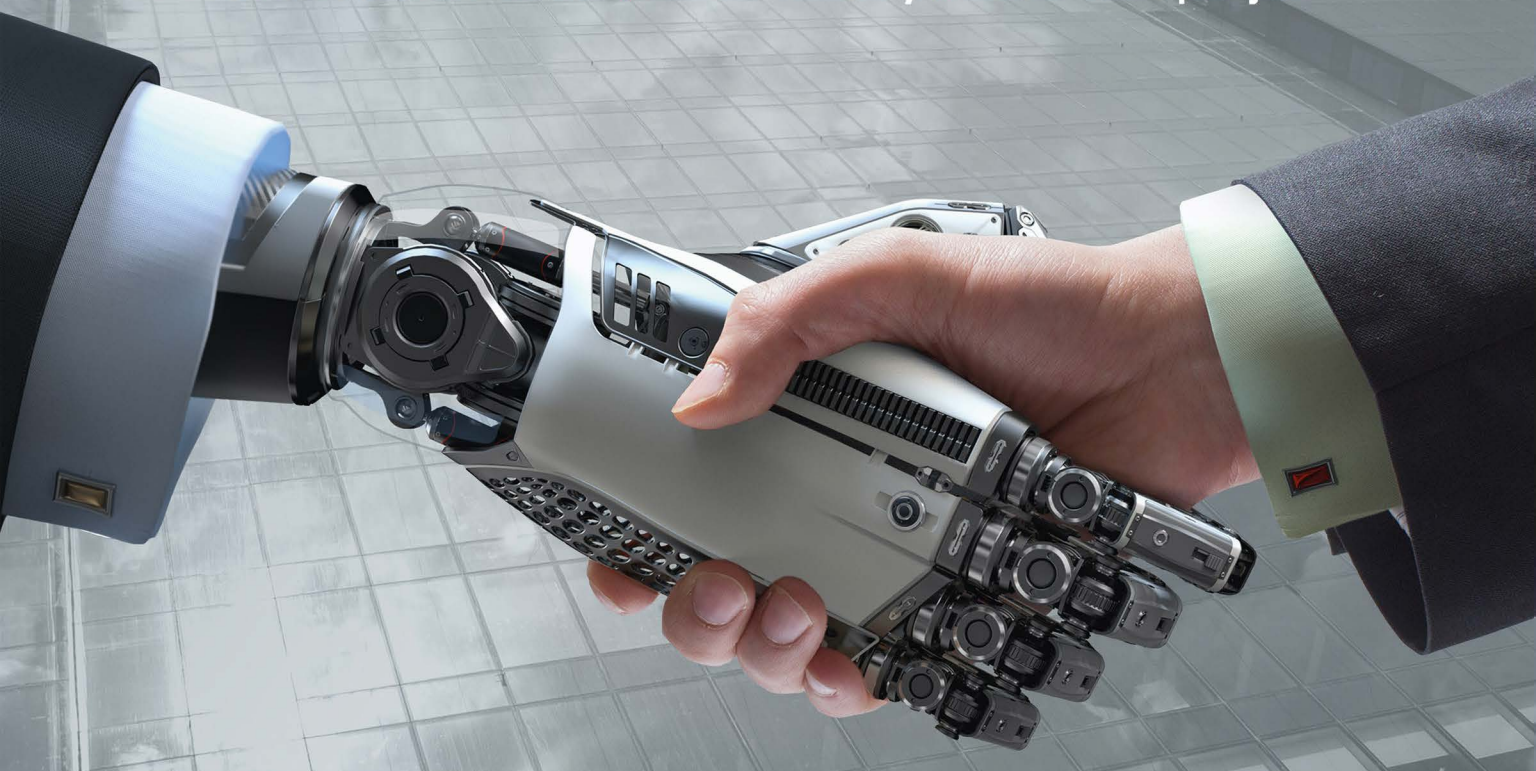

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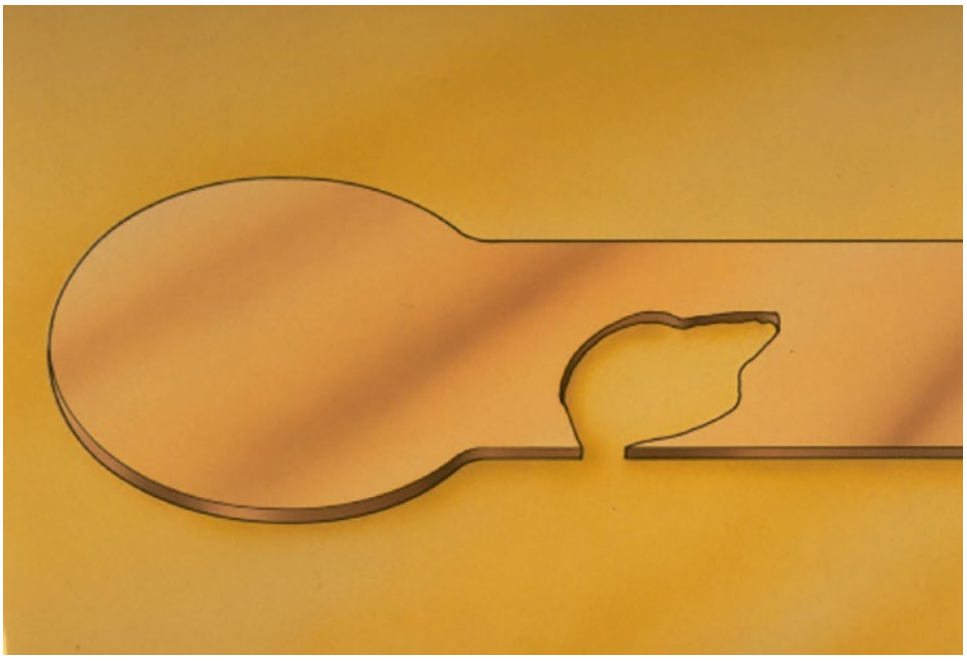


Figure 2: Schematic shows partial etch-out of the copper trace (Source: IPC)

completed. There are several possibilities related to the root cause of this defect. Figure 2 shows a partial etch-out of the circuit trace.

It is not likely the issue was caused by the etching process since the areas of partial etch-outs were sporadically seen on the panel. The most likely causes for the defect relates to surface preparation of the copper surface and the potential for resist lifting, allowing the etchant to gain access to the underlying copper. Essentially during the resist lamination process, resist did not completely conform to the copper surface. Remaining moisture on the panel may have vaporized, allowing the resist to blister at that point. In addition, when you investigate the glass weave texture related to the copper foil you see that a heavy glass weave may have negatively impacted the adhesion of the photoresist at that point.

Extraneous Copper

Now for something completely different. The view of the layer in Figure 3 shows excess copper that remained after etching (this is an inner layer).

In broad terms, this is clearly a develop-etch-strip (DES) issue. However, do not discount concerns with imaging. First, as part of the troubleshooting protocol, consider the actual etching operation as a starting point. At first glance, the panel is under etched, but why? Check the following variables in the etching system:

- Conveyor speed too fast
- Temperature of etching solution too low
- Spray pressures have dropped for any number of reasons, including plugged spray nozzles
- Inadequate replenishment of required chemical additives

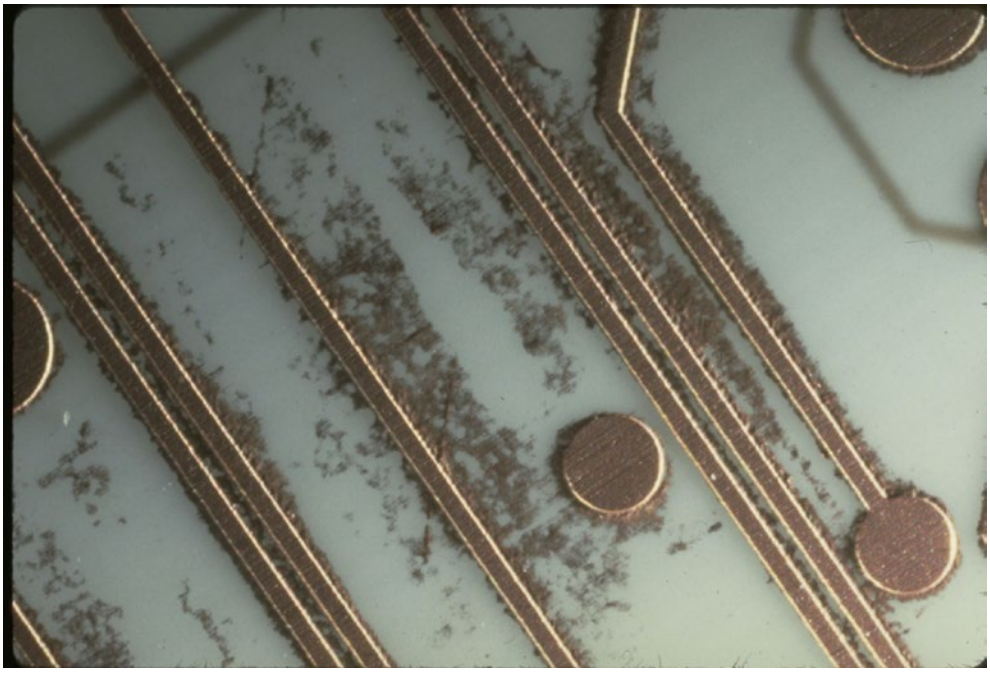


Figure 3: Unetched copper remaining. (Source: RBP Chemical Technology slide library)

The last bullet point requires a deeper dive, depending on what final etching process is in use (cupric chloride or alkaline ammoniacal). The specific features of these two processes will be presented in a future column.

After reviewing and making any adjustments in the etching process, one should revert to the developing, surface prep, and imaging processes. Clearly, there are spots of copper remaining on the inner layer. One is then able to discern extraneous copper near the edge of the traces. It would be prudent to investigate lam-precleaning, resist lamination, hold times, exposure, and development. For now, the focus will be on development.

Underdevelopment of Resist

Underdevelopment of resist will leave residual resist on the surface of the copper where it acts as an etch resist. Certainly, resist film thickness will play a role. It is reasonable to conclude that the remaining residues are easily able to inhibit the etching reaction. There are several possible conditions that are the potential root cause of the unetched copper:

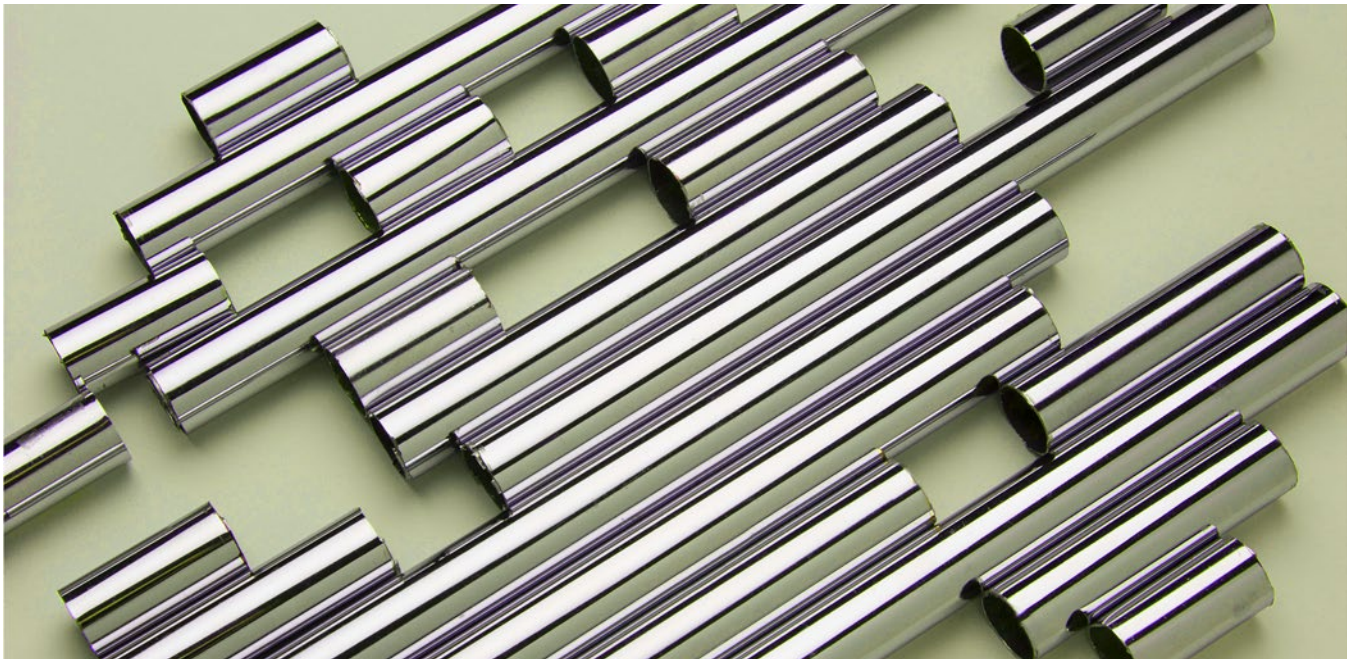
- Operating temperature of the developer is too low: verify the temperature gauge reading periodically with a hand thermometer.
- Time in the developer is too short: while this is rare in conveyorized modules, it is possible. Use a stopwatch or timer to gauge time in the developer.
- Has the breakpoint of the resist changed, meaning the resist appears to be breaking or is being cleaned off later in the chamber? Perhaps additional time is required. Additional time in the developer is needed to improve the breakpoint (Note: A late breakpoint may cause incomplete development in areas with poor mass transfer or poor spray impact, typically at the bottom of narrow resist channels. Excess copper will be seen here especially between narrowly spaced traces).
- Low developer concentration: Check the pH. Effective development is seen between a pH of 10.4–10.8 for most fully aqueous resists.

Regardless, if the developing operation is controlled with an automated feed and bleed system tied to pH, this should not be an issue. However, it does not hurt to spot check the pH and concentrations of the carbonate.

Finally, be cognizant of resist locking onto the surface. This would make developing more difficult.

More on this when lamination and imaging are presented in a future column. **PCB007**

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



Rethinking Interconnects With VeCS Technology

Feature Interview by the I-Connect007 Editorial Team

Nolan Johnson and Happy Holden chat with Joe Dickson of WUS about the work he's done with VeCS, the continuing development of the technology, and the potential impact it can have on the manufacturing floor.

Nolan Johnson: Joe, you recently posted some information on interconnect strategies.

Joe Dickson: Yes. The last thing I posted on that topic was regarding HDI, VeCS, and other interconnects in one PCB, and that's the evolution of VeCS. Happy can talk to the PCB, HDI, and the idea that HDI would be the replacement of vias early in the development. There were some PCBs; it did happen where through-hole connections were no longer required. But in many applications, HDI became a collaborative tool to be utilized in specific locations, and the rest of it maintained a relatively conventional product. And that's where the highest level of benefits came, both from value engineering and the standpoint of cost reductions with performance.

That's where WUS sees VeCS moving to now; initially, the thought was VeCS could somehow replace all types of interconnects in the early stages, and that's what many people were considering. That's not going to be the case, at least from what we see. That will be used as an application tool with HDI with through-hole and most likely in combination with those moving forward.

Johnson: Theoretically, a board could be using VeCS, HDI, and traditional at the same time—three different topologies—depending on what you need?

Dickson: I expect that. If you look at where the industry is going, as well as the roadmap of system-on-chip and FPGA-type technologies, you're trying to do more and more on organic substrates outside of the PCB. That's going to work well as an enabling process to leverage technology and get it to the forefront for performance now. Right behind that should be some level of value engineering, where those systems can be utilized and moved into the PCB. That's where some of the transformational value engineering will come. You'll enable

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it. It's the same type of evolution that's happening with 400G, which is already out there. We're building products to support it, initially using flyover optical cabling and even flyover copper cabling, because the interconnects and PCB technologies may not have been there to support that.

But in the long run, they'll want to have that type of system built back into closer interconnects, and that's where the opportunities come in PCBs. Also, even moving to the next generation of products may need those chips closer and closer and closer together, where flyover may not be the most desirable method of interconnect. Chip-to-chip locations will be there and most desired. I'm sure you see these types of requirements.

Moving to the next generation of products may need those chips closer and closer and closer together, where flyover may not be the most desirable method of interconnect.

Johnson: It's interesting how the dynamics are. You identified one of the technologies that is unique at WUS: VeCS.

Dickson: Initially, we thought it would be cost-driven and that VeCS would be the pressure point because of cost. While that's still an avenue of interest with almost everyone we talk to, the real pressure now is that it can innovate and do things that other interconnect technologies are going to struggle with. For example, if you look at HDI technology, there are some significant issues with stacked HDI and reliability. Happy has made that very clear in some of the writings that he's done. We've worked on simulation tools to lower the amount of stress with stacked HDI and created HDI structures that have lower Z-axis CTE stress, above the Tg of the material, so that they can form higher levels of stacked HDI. But there's still an endpoint where you're going to probably have to stagger those vias. Many of the advanced SI requirements don't want to do that. That's one area where VeCS can be a real adjustment in HDI because that's not an influence in the reliability of a VeCS structure.

The second thing that's moving it is that VeCS can utilize thicker dielectrics in layer-to-layer than HDI can. The capability of blind routing is over 10x HDI, and the plating depth is over 20 times the depth of HDI. If you had a 26-layer board that was six or seven lamination cycles of HDI, you can typically design it into a single lamination with VeCS and still have dielectric thicknesses between the layers of 0.1 millimeters or greater. That allows the high-speed signals to have much lower loss dB per inch from the signal itself. Those are two areas that the next-generation products are looking at, as chips are required to move closer and closer together, and technologies like PCIe try to put multi-chips on a single PCB. Those are some of the areas that we see that VeCS, with HDI or with through-hole, will enable copper interconnects on the PCB through the next generation, and maybe even the next generation.

Johnson: What's the impact on the manufacturing floor for technologies like VeCS?

Dickson: In the beginning, the technology was designed to be built with conventional PCB manufacturing techniques, and that was NextGIn's goal. In the early stages, WUS utilized conventional technologies, conventional routers, drill machines, and plugging lines to build the VeCS structures. But we've collaborated with suppliers to build much more advanced equipment now than the original equipment we used, including high vacuum encapsulation and via fill machines that helped us with the encapsulations to match or be better than laminate-type vacuum installations and applications.

We have very high-speed routing capabilities and CCD visual alignment now with our

new routing, drilling machines, and controlled depth capability beyond where we were when we first started. These allowed the technology to evolve now to a point where we have what we consider, in those steps, robust processes to perform VeCS even better than we did when we first started. And these technologies are continuing to evolve.

Johnson: What started as a technique that could use existing machines, requiring zero additional investment in equipment, benefits from going to an equipment optimization step. It's good when it's general-purpose but it's better when optimized.

Dickson: Yes. In the beginning, it's like a chicken or an egg; you start something and want the equipment to match the technology capability, but you have to move that out. And that's also true from the software side. In the beginning, one of the limiters with the technology was that the CAD tools had never seen this before. They had no idea how to even use a slot signal vertical connection with their software systems. All of the major CAD designers were challenged to utilize that. Now, most of them have the capability of doing this and are able to work with OEMs on how to utilize their systems with minor changes on some of them, but some of them already have the capability built into their systems.

Johnson: PCB designers have an obligation to look at manufacturing in different ways, too. How did the CAD tools adjust to support VeCS?

Dickson: Each one was a little bit different. I don't know how much of it is confidential IP, but I can tell you the end results were positive. By the way, that is not my background. The early adopters didn't seem to require special automated tools to create the VeCS structures. They were able to utilize most of their current technologies with their current tools and were able to work around the CAD via structure concept and create VeCS structures that utilize DFM rule basis where it created VeCS-type structures.

Joe Dickson

Johnson: There wasn't much that had to be done on the CAD tool side.

Dickson: Maybe there was a lot of work done on how to do those concepts, but once they got the concepts, they were able to leverage them pretty quickly. The hardest part involving VeCS from a software standpoint is the CAD operation and learning how to use VeCS concepts—not necessarily learning how to use the CAD tools. There are so many different types of structures that you can build, and that's one of the reasons I posted the latest one that I did. It's a 0.35-millimeter by 0.5-millimeter HDI interposer in single lamination, and no technology on the market can do that.

However, it's pretty easy to do in VeCS. It's a relatively conventional VeCS interconnect structure, but that can be embedded in a PCB or done inside the CAD tools. The techniques and operation of routing with through-hole in HDI—along with columnar routing with VeCS in very tight, dense structures—is unique to this technology. You can build out either very large BGA contacts or very dense, small-fit structures that could not be built with traditional PCBs today—at least not in technology I've seen.

The next great step in this particular technology to me is when the design houses start embracing this and moving into VeCS and HDI and via expertise. Once there are multiple design houses that have that technology, that's when I feel true integration. At the OEM levels, integrations are isolated because they consider their movement into this as IP. There's going to be a limited amount of communication inside the industry because they're utilizing this as a competitive advantage. But the design houses are where HDI made its transition into a more global and operational level. VeCS will be the same type of concept. When you see design houses understanding the strengths and weaknesses of it—as well as where it should be applied and where it should be done—you'll see a more open acceptance in the industry and the interconnect structure.

The next great step in this particular technology to me is when the design houses start embracing this and moving into VeCS and HDI and via expertise.

Johnson: What's the plan for making designers aware of the knowledge required for VeCS?

Dickson: WUS has a collaborative team where we have worked with equipment, process, and material suppliers. We even have PCB competitors participating in our collaboration team primarily because this technology needs multiple supply chain resources. We understood that from the very beginning. Our CEO is very open to that because we believe that once this evolves, it won't just be that VeCS is a concept; it will be the application of VeCS, how it fits with everything, and the expertise that will allow WUS to be leaders in that technology for many years.

We already have two and a half years of manufacturing experience with it and over two years of application experience. We're not worried about someone developing the manufacturing capability, now taking this technology away from WUS; it's the opposite. The more competitive this technology becomes, the better it is for WUS.

Happy Holden: Talk to me about the reliability data.

Dickson: WUS is building our own reliability data, and we'll be publishing more and more as the months go on. The coronavirus slowed us down on that particular deliverable. And we probably won't have that data available until August or September for high-volume reliability. But we have no lack of interest in this technology from a chip and from an OEM standpoint. It's at a point now where even if we had three or four other suppliers involved, I don't think they could cover all of the interest.

Since we haven't had anything since HDI as an interconnect structure, OEM leaders decided that HDI would be something that they would market to the industry. They educated the industry not just on what it is but also how to do it, as well as when it was an advantage and when it wasn't. When HDI first rolled out, people thought it was going to eliminate through-holes. No, there are still technologies today, but WUS makes excellent money off alternatives to HDI for structures that are mechanically drilled.

We can do technology with mechanical drills that we never dreamed of 15 years ago that is much more high-performance and cost-effective than HDI. But HDI has a significant design application; it fits very well when you understand how to use it. And now those two technologies have aligned to the point where it's not uncommon to have a PCB built at WUS that has 15% HDI, and the rest is mechanical interconnects. It's selective use of high-performance, high-value engineering, low-cost materials, close chip-to-chip locations, and packaging so that you're getting the best value chip to chip that you can get. That's where VeCS will

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eventually position itself; it will be somewhere in between. And today, what I'm seeing that's going to try to replace that is optical. The next generation of chips is trying to go optical chip-to-chip because there are no other alternatives below 0.8 millimeters on large chips.

Holden: If you filled the trenches with an optical polymer waveguide material, VeCS might also be a convenient way to do chip-to-chip optical bussing, along with electrical bussing.

Dickson: Correct. The concept is already in the patent. There's embedded optical that you could use with VeCS, but even without optical, say you leave off of it for a second, if you're talking dB per inch—your loss budget—you're looking at the inches of the signal link, which is simplifying it for me. But the SI engineers look at what they have in their budget, and if the location of their chips is too far apart, they have to come up with an alternate technology to conventional PCB. We're chasing that to match cabling. Our goal is to come up with a signal structure that is nearly as high-performance as a single cable between two chip points.

We'll never get there, but that's our goal. And if you use that as your baseline, there are lots of opportunities still left in 28 gigahertz—and maybe even 56 gigahertz—until you get to back panel level structures. Inside of that, inside the 15 inches that you need to route, we can stay in copper all the way through two generations. And that's a significant difference from where the roadmap is today for network and 5G structures.

Holden: What we need right now is data on how VeCS improves SI. To the electrical engineers, those graphs show performance they haven't figured out how to meet, and they don't want to go to optical.

Dickson: Multiple OEMs already have the simulations finished, and the structure concept finished. That part of their step is complete. They already understand the SI benefits. But they're not willing to share any of it because it's individual IP. The next generation or phase two of HDPUG, after the reliability vehicles are done, will be SI, which will be valuable for the industry. But most of the ones that want to use it for the next generation have already started that simulation, completed it, or are near completion and starting their own SI test vehicles to look at the technology themselves.

The industry level interest will be there once multiple OEMs are utilizing it in volume. But by the time they do that, the benefit of achieving that will not be in that generation; it will have to be in the next. Happy, I'm sure you had this with HDI with a blind via, where there's nothing routed underneath it. For many designers, that was a three-dimensional paradigm where they could not shift. VeCS is even more because it's not only capable of doing deep blind vias that have nothing routed underneath them, but it has super dense two-dimensional pitch with no issues with CAD, as well as large change routing and areas that are keep-out.

This is a real paradigm shift for a conventional CAD designer. They're used to copper and laminate; they don't understand a slot or routing down a sidewall. We're at a point now where we're trying to optimize the VeCS trace and physical characteristics with the slot width so that we can create a matched impedance—say at 85 ohms—with the signals running 85 ohms into the VeCS slot, 85 ohms down the slot, and then 85 ohms back to the connections. That is the disruptive technology that I haven't seen even in substrate-level technology. To be able to do differential continuity all the way down the interconnect and back through to the other chip is unique to VeCS.

Holden: Have you created any trenches, or are they all just mechanical?

Dickson: Right now, we've been able to do all the way down to 0.35-millimeter interposers with mechanical. The technology is there to do it. The biggest driver for using a laser or not is the cost of the dielectrics. If somebody was willing to pay for non-glass reinforced dielectrics, the HDI concept or laser concept of building the trenches is relatively easy, but we don't need it yet. And the cost is too prohibi-

tive today to utilize it in a conventional PCB. But that doesn't mean it won't be there two generations from now. I doubt if VeCS is going to become obsolete any time soon. It's something that will be desirable for a flat signal in a vertical plane, which potentially can be advantageous to any kind of radial interconnect.

When we first started this technology, I had no idea about the significant issues that ground isolation for differential signals and the problems that would be coming with the next generation SI performance. Typically, you have HDR through-holes, and you have a differential signal coming off the BGA that's going down into the PCB. If you're using HDI, you're using multiple layers to connect that, and you're building ground shields around it. But those ground shields are not solid. They're spaced and based at the pitch of the HDI or the BGA circuits or paths.

The advantage of VeCS is that it doesn't have to be like that. You can leave the slot completely solid all the way around and disconnect it only where there are two differential signals. Say you're going down to layer eight and stop the signal routing at layer eight, but that ground goes all the way through the PCB. Now, not only are you using an interconnect with the correct impedance on that signal, but you also shielded it from any parasitics, RF, or any type of power radiation coming from anywhere else in the PCB. Three sides of that signal interface are shielded. And if you use VeCS on every other slot of every other row, now you shielded it on the other side, and you almost have a full Faraday cage going down inside the PCB.

Again, I know people who are trying to put multiple holes in BGAs and do HDI in through-holes, and the through-holes are only to create shields. But no matter what they do, they leave pockets of the anti-pad open, and in that area, the higher speeds are going to pick up that parasitic signaling. The VeCS is already blocked and part of that structure. That's a unique application—shielding—which looks like it's going to be valuable for RF, but it's also valuable for digital signals.

Johnson: Joe, thanks for your time.

Dickson: Great. Thank you. **PCB007**

Related article: The Current State of VeCS Technology, PCB007 Magazine, March 2020, page 94.

Qualcomm Invests in Jio

Reliance Industries Limited and Jio Platforms Limited announced that Qualcomm Ventures, the investment arm of Qualcomm Incorporated, has committed to invest up to ₹ 730 crore in Jio Platforms at an equity value of ₹ 4.91 lakh crore and an enterprise value of ₹ 5.16 lakh crore. Qualcomm Ventures' investment will translate into 0.15% equity stake in Jio Platforms on a fully diluted basis. The investment will deepen the ties between Qualcomm and Jio Platforms to support Jio Platforms on its journey to rollout advanced 5G infrastructure and services for Indian customers.

Jio Platforms, a majority-owned subsidiary of Reliance Industries, is a next-generation technology platform focused on providing high-quality and affordable digital services across India with more than 388 million subscribers. Jio Platforms has made significant investments across its digital ecosystem, powered by leading technologies spanning broadband connectivity, smart devices, cloud and edge computing, big data analytics, AI, IoT, augmented and mixed reality, and blockchain. Jio's vision is to enable a digital India for 1.3 billion people and businesses across the country, including small merchants, micro-businesses, and farmers so that all of them can enjoy the fruits of inclusive growth.

(Source: Qualcomm)

7 Steps for MIL-PRF-31032 Certification

From the Hill

by Mike Hill, MIL-Q-CONSULTING LLC

Background

My past columns have detailed how military electronics are being used in an ever-increasing application rate. Looking forward, this trend is likely to continue and will be further accelerated by space exploration and the Space Force. Space also promises new technologies, materials, and processes that might become a gamechanger for the industry.

Rethinking the milaero market for the next decade might be worth considering. Furthermore, a segment of this market is PWBs fabricated to MIL-PRF-31032. The key to accessing this market is certification to MIL-PRF-31032. This column will explain seven certification steps, resources, and timetables for consideration.

Certification for MIL-PRF-31032

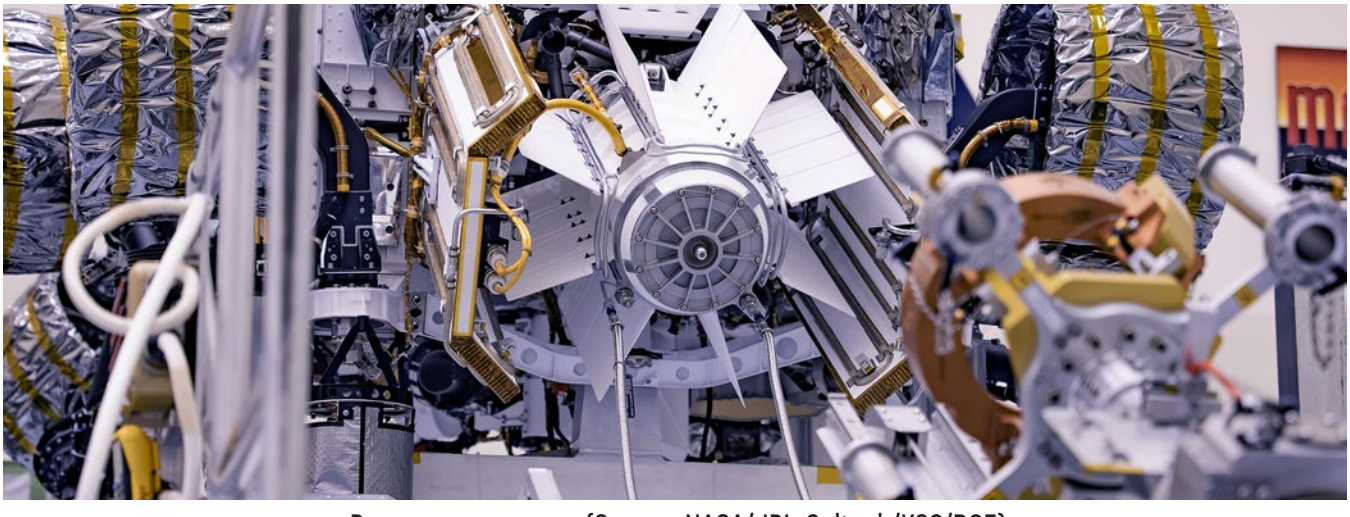
This is a summary of the basic steps to certification. As you read these steps, please remember that MIL-PRF-31032 does not spell out a step-by-step process. The steps outlined here are what I consider to be the most logical and efficient method.

The process can be segmented into seven distinct subgroups or phases. The timeframe for each phase is listed as a range. The range depends on familiarity with MIL-PRF-31032, resources available, and ISO-9000 status. Also, note that the time ranges listed assume ISO-9000 registration has already been obtained.

Certification entails implementing a quality management system (QMS) for MIL-PRF-31032, building and testing products that meet all the requirements, conducting a self-audit that validates requirements, and verifying of all these actions by the Defense Logistics Agency (DLA) at your site.

Step 1: Certification Initiation and Training

In this first phase, your company must notify the DLA in Columbus, Ohio, of its intent to certify. Following that, an implementation team should be formed and trained.



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Once the start is acknowledged by DLA, a thorough review of the MIL-PRF-31032 documents must be done and communicated within the implementation team. The implementation team will carry the title of the Technical Review Board (TRB) per MIL-PRF-31032. TRB's first assignment should be to get basic MIL-PRF-31032 training/familiarization. Once this training is complete, the next step of system documentation can begin.

The certification initiation and training phase will take about 30–45 days.

Step 2: Documentation Phase: Quality Management Plan

The documentation for certification is contained in the QM plan (i.e., the military quality manual, which is the central heart of the process). A manufacturer's QM plan is its means of ensuring that printed boards meet the requirements of MIL-PRF-31032. The QM plan is a controlled document or set of documents that cover each requirement of MIL-PRF-31032.

The time required for this step will range from 1–3 months.

Step 3: Three Phases of Fabrication—Planning, Fabrication, and Testing of Qualification Parts

As the QM plan is being completed, the qualification test plan can also be finished and sent to DLA for approval. This qualification plan defines the design attributes, fabrication steps, testing, and associated documentation for such parts.

When the QM plan is approved by DLA, the TRB can begin the building of the qualification boards. Regardless of when the boards and/or test vehicles are fabricated, they are built using the new QM documentation.

The time required for this step is 20–60 days.

Step 4: Self-Audit Process

The audit phase of MIL-PRF-31032 consists of a self-validation audit (per the checklist as defined in your QM documentation).

Self-validation is the manufacturer's means of determining compliance with MIL-PRF-31032 and the QM program. This self-validation process is exactly the same as the self-audits of ISO-9000/AS9100.

The time required for this step is 1–2 weeks.

Step 5: Pre-Validation Submittal

Once the self-validation is complete, it's time to prepare the pre-validation submission for DLA. The pre-validation package consists of the QM plan, the self-validation audit and corrective actions, and the qualification test plan and results. These three items are necessary to obtain a validation audit from DLA.

The time required for this step is 1–5 days.

Step 6: DLA Validation Audit

The qualifying activity (DLA) will review the pre-validation submission for compliance with MIL-PRF-31032. DLA will schedule a validation audit once all of the pre-validation information is approved. This audit is a detailed review of your entire military management system (QM) and its potential effectivity. The audit report will identify all validation findings that do not meet MIL-PRF-31032.

The time required for this phase is a function of internal and DLA resources and can vary considerably. DLA's validation audit depends on how much time has been allocated to audits and how many companies are ahead of your request.

As a result, this phase can take from 2–7 months.

Step 7: Implementation and Certification

In this final phase, the TRB must respond with actions to all initial DLA validation findings. Any rejected corrective actions to audit findings will be communicated in writing to the attention of the TRB. TRB is responsible for closing each finding with DLA.

Once all the corrective actions have been approved by the qualifying activity (DLA) and all the qualification fabrication data is accepted, a MIL-PRF-31032 certification will be issued. The certification letter from DLA will detail the approved technologies of your qualified manufacturers list (QML).

This last phase will take 30–60 days, and adding the times of all the seven phases results in a range of 5–12 months to complete the certification.

Summary

Certification to MIL-PRF-31032 offers a wider range of the PWB military aerospace sector than just the parts built to IPC-6012. Certification, of course, does not come easy and requires some hard, dedicated work. However, as they always say, "No pain, no gain." Life certainties are said to be only death and paying taxes, but the consistent revenue stream of future military aerospace electronics is a close third. **PCB007**

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

Printed Coatings Enable More Efficient Solar Cells

Photovoltaics, or solar cells, work by absorbing sunlight to produce clean electricity. But photovoltaics can absorb only a fraction of the solar spectrum, which limits their efficiencies. The typical efficiency of a solar panel is 18-20%.

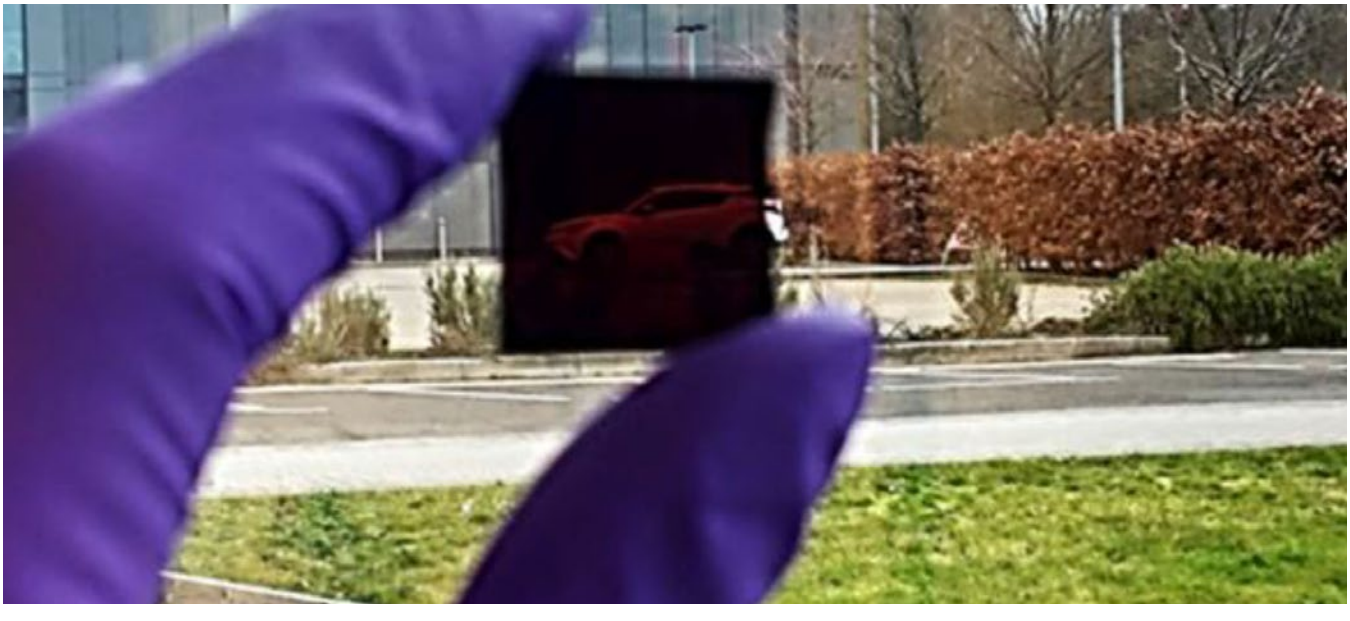
Researchers have started developing "tandem" solar cells by stacking two solar cells, absorbing complementary parts of the solar spectrum, on top of each other. The most promising of these tandem solar cells is a perovskite device stacked on a silicon device.

Perovskites absorb visible light, whereas silicon absorbs near-infrared light. A perovskite-silicon tandem solar cell could realistically achieve 35% efficiency within the next decade.

The challenge with these tandem solar cells is that the electrode covering the perovskite solar cell needs to be transparent, and this transparent electrode is deposited using high-energy processes that damage the perovskite.

A team of researchers from Cambridge's Department of Materials Science, working with Imperial College London and the Solar Energy Research Institute of Singapore, developed a method to "print" a protective coating of copper oxide over the perovskite device. Only a 3-nanometer coating is sufficient to prevent any damage to the perovskite after depositing the transparent top electrode. These devices reach 24.4% efficiency in tandem with a silicon cell.

(Source: University of Cambridge)



Guerilla Tactics to Pass Any QMS Audit, Part 4

The Right Approach
by Steve Williams, THE RIGHT APPROACH CONSULTING

Introduction

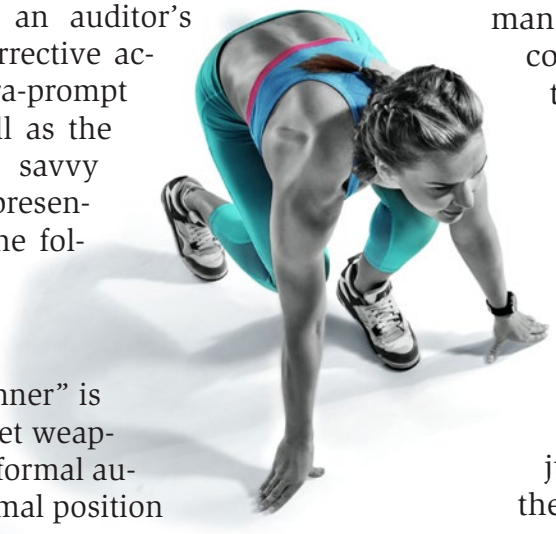
Concluding this four-part series on "Guerilla Tactics to Pass Any QMS Audit," I will share Tactic 10. Hopefully, through this series, you found a number of solid strategies you could apply immediately to improve your audit success.

Guerrilla Tactic 10: Techniques to Reverse a Finding

> ***Williams' Law 10***
> *The more wins you can bank with an auditor/customer, the greater the chance they will write off a negative observation as an isolated anomaly.*

> ***Williams' Law 10.5***
> *The more findings an auditor/customer identifies, the deeper they will dig into all subsequent areas.*

The key to reversing an auditor's finding is on-the-spot corrective action. Responsive, ultra-prompt action is required as well as the aforementioned political savvy of the management representative in administering the following techniques.



The Runner Strategy

The concept of "the runner" is somewhat of a super-secret weapon to be used during any formal audit. It's not so much a formal position as it is a relationship between the management representative and the person filling the role of the runner. The runner needs to be someone who is extremely familiar with all aspects of the quality system. The ideal person for this role is the quality analyst (ISO coordinator, quality systems administrator, etc.), which is the position responsible for the administration of the quality management system. With a seasoned team, the management representative and the runner will develop a set of "silent codes" between themselves; something as simple as eye contact could send the runner to retrieve some supporting documentation to satisfy an auditor's request.

The purpose of the runner is to maintain a clean record as the audit progresses by supplying real-time supporting information, records, or any other proof of execution that the auditor may request. Most companies typically handle this by having the management representative/escort compile a long laundry list that the auditor asked to see during the tour that would need to be reviewed and/or verified at the end of the audit. This approach invariably results in findings and/or observations due to a variety of reasons, including time constraints, disagreement on the original request, and flat out just forgetting to address all the issues.

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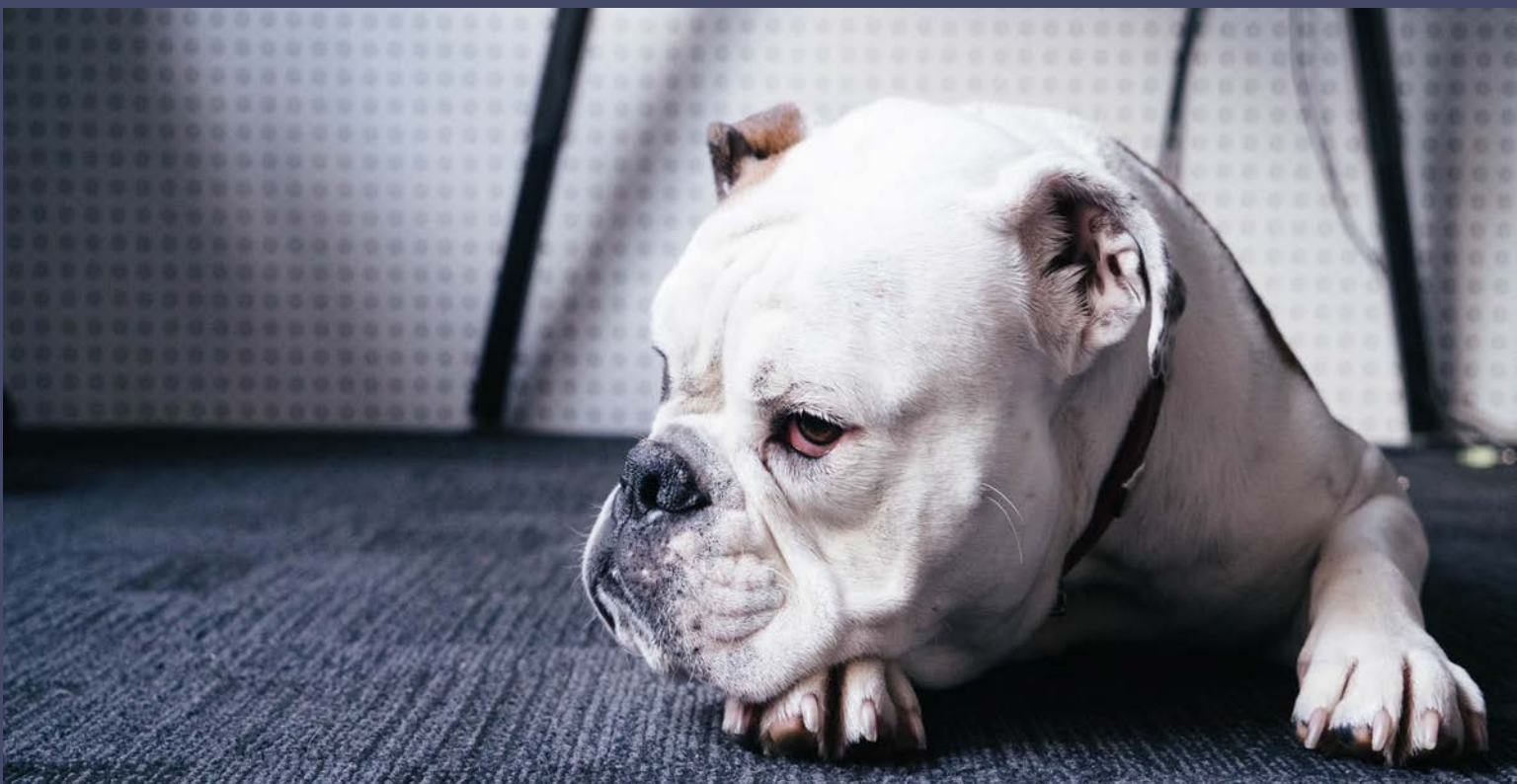

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The goal of the runner is a rapid response and one-touch of all documents and departments by satisfying all auditor needs, requests, and questions before moving on to another area. The runner is a key strategy to support the guerrilla tactical strategy of getting in and out.

Examples

1. Auditor issue: Observes an operator imaging panels.
Auditor: "How do I know this person has been properly trained to perform this operation?"
Rapid response: As the employee is explaining their training status to the auditor (badge, color code, matrix, etc.), the runner should retrieve the employee's training record and certified operator test to present to the auditor on the spot—signed, sealed and delivered.

2. Auditor issue: Observes a machinist measuring dimensions.
Auditor: "How do I know that instrument is accurate?"
Rapid response: As the employee is showing the auditor the calibration sticker on the tool and explaining the tool calibration system, the runner should retrieve the calibration certification and NIST traceability records to present to the auditor on the spot.

Instant Gratification

Collateral benefits of the runner strategy include that it demonstrates competence at the operator level, system robustness, management commitment, and quality system compliance. It also supports employee interaction, fosters teamwork, and instills auditor confidence.

The Page Swap Technique

The page swap technique can be employed to correct minor mistakes or omissions in a procedure. This technique is perfectly legal as long as there is a page swap clause in your document control procedure outlining the rationale and rules for its use. If an error and/or omission is identified by an auditor, utilizing the page swap technique to immediately correct the error and present the auditor with a corrected procedure before he/she finishes the audit will generally result in a non-finding.

Situations that allow a page swap include when:

- You can swap a single page in a procedure
- Re-approval of the entire procedure is not required
- Page content integrity remains intact
- Page numbering does not change
- There are typos
- There are minor wording changes
- There's a missing word/phrase
- Obvious intent was implied

Procedure Revision

On-the-spot procedure revisions are the reason that key employees and procedure signatories must be present and available for all major audits and customer visits. The ability to rapidly change, approve, and distribute a procedure revision in reaction to an auditor's finding will be the difference between a formal finding and a clean audit.

Examples

1. Auditor issue: Identifies an omission or a typo in a procedure.
Rapid response pages swap: Tell the auditor that the changes are being made and that you will revisit with them promptly. As an audit is continued, the runner should make the necessary changes via a page swap and catch up with the auditor to present the revised page, also presenting the auditor with the approved document control procedure and explaining the page swap clause. One touch!

2. Auditor Issue: Identifies an issue not addressed in the procedure but being performed by the operator.
Rapid response revision: Tell the auditor the changes are being made and will revisit with him/her promptly. As the audit is continued, the runner should have the necessary changes made to the procedure, changing the revision on the procedure and the master document list (MDL) and hand-carrying the new procedure to secure a signature from each procedure sig-

natory. The runner catches up with the auditor and presents the revised and approved procedure to the auditor, along with the MDL.

Top 10 Auditor Hot Buttons

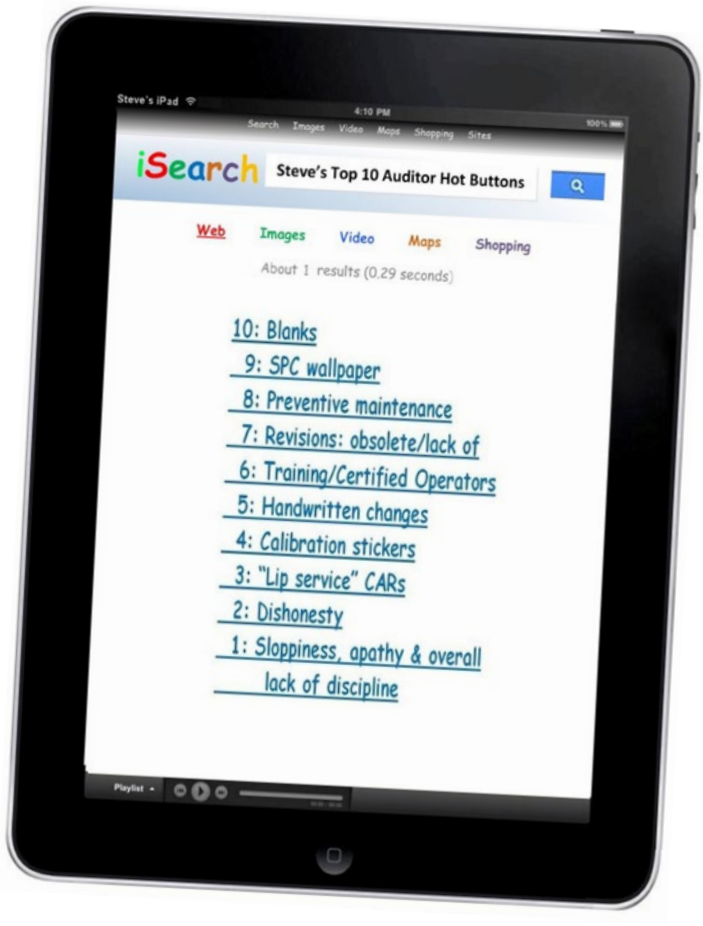
These auditor hot buttons should be included in the internal audit program and be part of the scavenger hunt activity during the ISO rallies.

Conclusion

It is my hope, should you survive all four installments of this series, that you will have found a few helpful takeaways in the development or improvement of your own quality system and internal audit program. The strategies, techniques, and tactics presented throughout this series are tried-and-true, practical applications with lessons learned over the course of my career that I hope you will find some value in. As you go through your quality journey, I will remind you to always remember Williams' Master Law.

> ***Williams' Master Law***
> *It's always about the dollars!*

I would argue that any pursuit can, and will, be quantified by cost. In other words, it must make financial sense. I believe you will find that everything we have discussed in this series makes perfect sense from both a practical and financial perspective. **PCB007**



Editor's note: Read Part 1, Part 2, and Part 3.

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

Simulation Technology in Acid Copper Pattern Plating

Feature by Pete Starkey
I-CONNECT007

In the early days of printed circuit manufacturing, when the only available photoresists were solvent-processed, the choice of copper plating chemistry was broader, and alkaline systems—such as those based on pyrophosphate copper—were feasible alternatives. Pyrophosphate electrolytes have good throwing power and give excellent physical properties, as well as being less corrosive to plating equipment than acid sulphate. But along came aqueous-processed photoresists, which effectively revolutionised the printed circuit manufacturing process.

Toxic solvents and expensive stainless steel equipment were no longer necessary, and many new players were attracted to printed circuit manufacturing. Being alkali-strippable, these aqueous-processed photoresists were essentially acid resists; acid copper electroplating became the industry-standard for pattern-plating, and a whole technology evolved around it. Its physical properties were limited, and its throwing power was limited, but it was a cost-effective starting point for development.

The chemists got to work and formulated proprietary systems with optimised copper and sulphuric acid concentrations. They added minute amounts of chlorides together with organic carriers, suppressors, levellers, and brighteners to influence the diffusion layer and improve throwing power, grain structure, and ductility. Development work carries on as enhanced performance for specific applications continues to be demanded: modification of the chemistry, mass transfer and agitation aspects, the mechanical design of the plating cell, the anode configuration, the electrical waveform of what began as a simple direct-current power supply, and numerous other details.

But electrodeposits are notorious for being non-uniform—especially in acid copper pattern plating—and it can be a real challenge to achieve an acceptable thickness distribution on surfaces and in plated through-holes. Isolated features become high current density areas, relative to larger ground plane areas with corresponding low current density. In high as-

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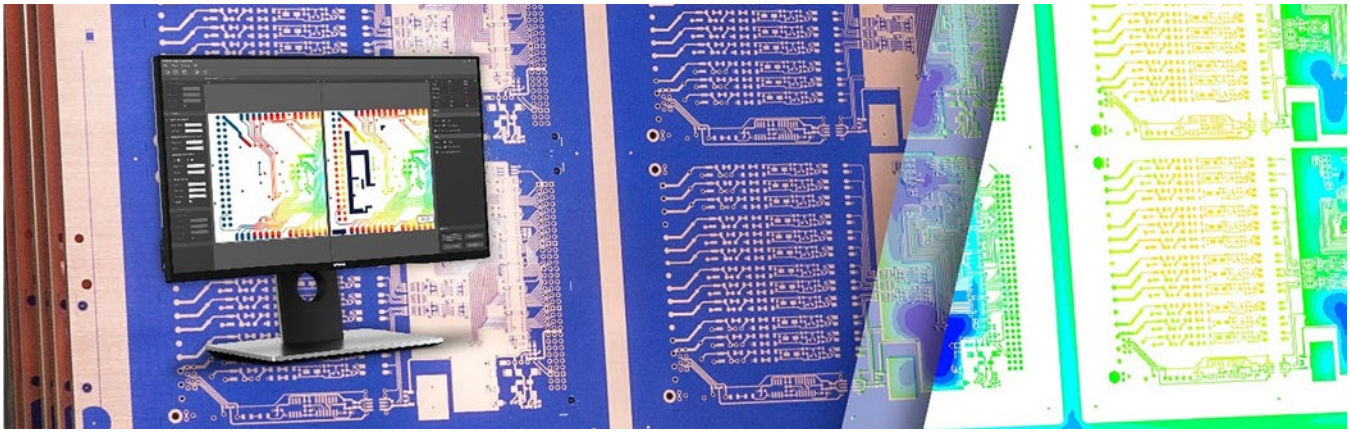
pect ratio holes, another challenge is to meet the minimum copper thickness requirements in the centre of the hole.

As the PCB manufacturing industry deals with designs of increasing complexity, in a market that demands higher-quality boards on shorter lead-times and at a lower cost, it is vital that production yield is maximised. Pattern plating is a critical process stage, where thickness uniformity within close tolerances can be extremely difficult to attain—despite the efforts and expertise of the chemical formulator and the equipment engineer. However experienced and ingenious the process engineer may be, their chances of success are largely determined by the actions of the PCB designer. In the worst case, the quality engineer has to deal with the non-conformance specification issues, and the production manager is left to worry about the shortfall in yield and its consequent effects on manufacturing cost, delayed delivery, and lost capacity while remaking the deficit.

The PCB designer is primarily concerned with achieving electrical functionality and interconnection requirements within a defined mechanical area using specified design rules. Design industry veteran Rick Hartley advocates for the following: "Every PCB designer should be taught the many benefits of copper balancing and incorporate the concepts into their board designs." Most designers appreciate the need to maintain reasonable symmetry within the layer build-up to minimise warpage, but many would benefit from a better understanding of the basics of plating distribution when configuring their outer layers—an important element of the DFM philosophy.

The CAM engineer is the person receiving the design data, with the responsibility to prepare the production tooling and set up the panel layout. The panel format may have been specified by the customer—for example, a step-and-repeat array to suit an assembly process or alternatively by an in-house requirement to achieve the best utilisation of material by incorporating a number of individual circuits in a production panel. The outcome of the production process depends on the PCB design and the panel layout that is committed to production. PCB designers and CAM engineers may feel there is little or nothing they can do to achieve uniform finished copper thickness of PCB traces and holes.



In an illuminating discussion with Robrecht Belis, manager of surface finishing and e-coating with Elsyca NV in Belgium, I learned that nothing could be further from the truth, provided they act on time and use the right tools, as he referred me to Elsyca's white paper on plating simulation.

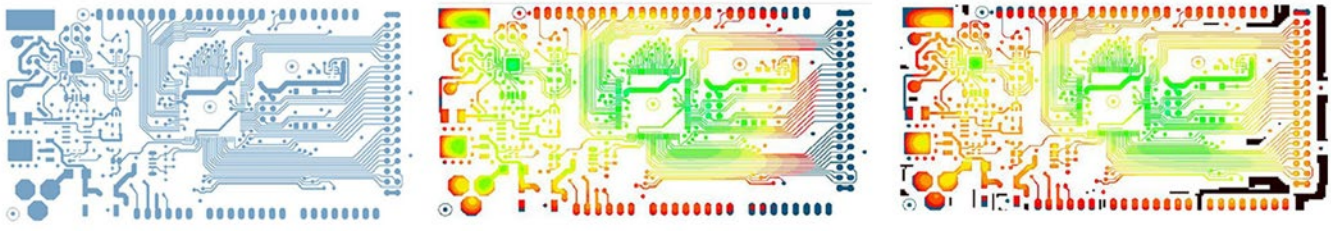
Robrecht Belis

Beginning with the designer, and with regard to my earlier comment that many designers would benefit from a better understanding of the basics of plating distribution when configuring their outer layers, Belis explained how Elsyca's PCBBalance simulation software made the task straightforward. It predicted the copper thicknesses to expect, with reference to a virtual model of the production copper plating bath with realistic electrochemical characteristics. The software offered the option to use its auto-intelligent copper balancing algorithm to add non-functional dummy copper features—and thereby increase the uniformity of finished copper thickness without compromising the design—and to visualise the thickness distribution using an interactive graphical display. Once the algorithm had completed its optimisation, any out-of-specification thickness issues were automatically resolved. The procedure only took a few minutes, working directly from a simple Gerber input. And the software integrated well with existing design tools.

The before and after versions of the design could be compared side-by-side with graphics providing objective information on average thickness, standard deviation, and the ability of the production process to deliver the end product within specification limits. The front and rear copper balancing layers could be output as Gerber files and used to update the board design in the CAD system.

Why had designers not used simulation techniques in the past? Why would they change? Belis described the situation 10 years ago. Maybe the capability of computer simulation systems was not as advanced, but even if it had been, a typical attitude was, "I know what I'm doing. I've been doing it for 30 years." But if they got into trouble and "the house caught fire," they would have to call the "fire department"—specialists from outside who would resolve the problem using simulation techniques. "Maybe we ought to consider using these tools to stop the fire from starting in the first place rather than relying on guesswork and classic trial-and-error approaches," Belis stated.

The facility to improve the design was demonstrated, but what happens when the upgraded data reaches the CAM engineer at the PCB manufacturer? They are responsible for setting up the layout of the production panel. The individual circuit layout has been optimised for plating. But whether the panel consists of a multiple of identical design or a composite of several different designs, the copper pattern-plating process will not produce identical



(calculated by Elsyca PCBBalance)

boards; the finished copper thickness will be greater on circuit boards positioned near the panel edges.

As Belis continued to explain, the CAM engineer can use Elsyca PCBPlate simulation software to quickly identify any out-of-spec areas by estimating the finished copper layer thickness for single or multiple panels and comparing the finished copper thickness distribution for different panel layouts. Then, they have the option of modifying the panel layout or using the copper balancing algorithm to add dummy copper features near the panel edges and between individual boards to achieve a more uniform distribution of finished copper thickness across the entire panel. They can also resolve any out-of-specification issues without the need for guesswork or trial-and-error.

The graphical overview also enables the CAM engineer to identify the most critical areas and advise which features on which PCBs may need critical inspection and test—through-hole copper thickness, for example—and eliminate the need for expensive set-up changes during production. In addition, Elsyca's simulation software can enable process engineers to run in-depth what-if analyses and explore various scenarios to fine-tune process parameters and production settings on a digital twin of the production line.

The PCB industry has been slow to adopt simulation techniques for the plating process. What about the general metal finishing industry? Belis took the example of chromium plating of automotive parts and commented that the OEMs needed a balance between aesthetics and functionality while controlling costs. Components varied in geometrical complexity. The throwing power of copper, nickel, and chrome plating processes ranged from reasonable to very poor, so accurate prediction of the thickness distribution of each metal layer was essential for both quality and cost control. Elsyca's simulation software was widely employed; in fact, simulation capability was seen as an essential requirement in the vendor approval of plating contractors to automotive OEMs.

Belis's comments raised another interesting point about how simulation was not just an aide to getting right-first-time results in production; it was a very effective communication tool in discussion with end-customers when used to illustrate graphically the effect of proposed changes—even when talking with non-technical people.

Quality assurance was a further topic we discussed. Simulation data became a valuable constituent of the full panel history of the job and gave a new perspective on the traditional reliance on test coupons. Test coupons are typically incorporated into non-functional areas on panel borders. In terms of plating thicknesses, they can tell you something about the coupon itself but don't provide very meaningful information on layer thicknesses a few centimetres away, whether on the surface or down the holes.

Yes, the PCB industry has been slow to adopt simulation tools. This has partly been due to a lack of awareness of their availability and capability, as well as a clinging-on to a reliance on traditional skills and experience. Belis used the analogy of a carpenter working with hand tools and being introduced to an electric drill: he was apprehensive un-

til he understood its advantages and felt comfortable using it. Before long, he didn't even think about it; he just accepted it as an essential part of his toolset. Look at a state-of-the-art PCB today, compare it with its equivalent of only a couple of years ago, and realise how important simulation is becoming.

Belis reflected on being taught about knowing your circle of competence. "The size of that circle is not as important as knowing its boundaries. When you need to learn something, the first thing is that you're not aware that you're not capable of doing something. If you're not aware, you're not looking for a solution. Then, you become aware, and you decide it sounds interesting, so you will very cautiously look for a solution and have to pay a lot of attention to get the job done. It's a new process; there are new skills you need to learn. But after a while, you use all those skills without being aware that you're doing it. You just do it, like riding a bike. That's where we are today in chrome plating for automotive. It's a no-brainer anymore."

How long before the PCB industry goes the same way? **PCB007**

Pete Starkey is technical editor for I-Connect007. Based in the UK, Starkey has more than 40 years experience in PCB manufacturing technology, with a background in process development and technical service. To contact Starkey, click here.

Intel Launches First Artificial Intelligence Associate Degree Program

Intel is partnering with Maricopa County Community College District (MCCCD) to launch the first Intel-designed artificial intelligence (AI) associate degree program in the United States. The Arizona Commerce Authority will also provide a workforce grant of $100,000 to support the program. It will enable tens of thousands of students to land careers in high-tech, healthcare, automotive, industrial, and aerospace fields.

Based in Tempe, Arizona, MCCCD is the largest community college district in the U.S. with an estimated enrollment of more than 100,000 students across 10 campuses and 10,000 faculty and staff members.

The AI program consists of courses that have been developed by MCCCD's faculty and Intel leaders based on Intel software and tools such as the Intel® Distribution of OpenVINO™ Toolkit and Intel Python. Intel will also contribute technical advice, faculty training, summer internships, and Intel mentors for both students and faculty members. Students will learn fundamental skills, such as data collection, AI model training, coding, and exploring AI technology's societal impact. The program includes a social impact AI project that is developed with guidance from teachers and Intel mentors.

AI technology is rapidly accelerating with new tools, technology, and applications requiring workers to learn new skills. Recent studies show the demand for artificial intelligence skills is expected to grow exponentially.

(Source: Intel Newsroom)

LED UV Cure: Does It Really Work?

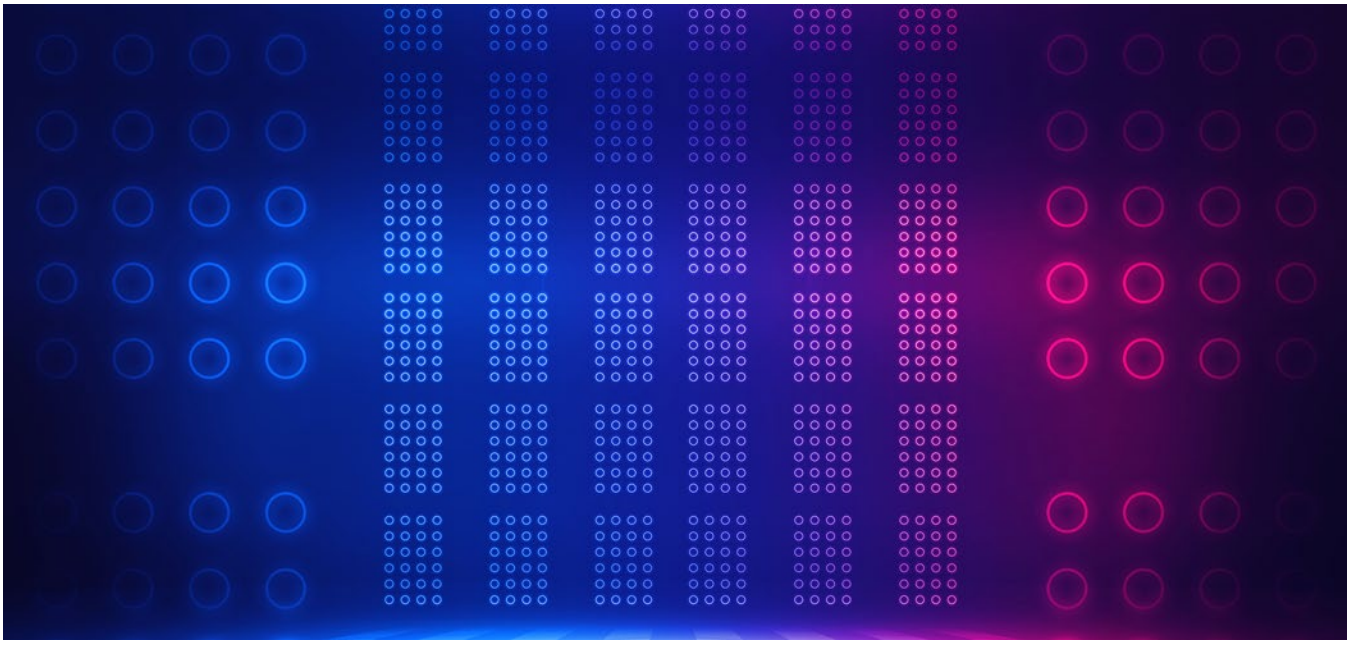
Ladle on Manufacturing
by Marc Ladle, VIKING TEST LTD.

Machines that have been made to UV cure inks used in printed circuits and other manufacturing processes have largely used vapour lamps as the UV light source since the earliest development of UV-cured materials. Typically, vapour bulbs contain a proportion of mercury, which is in the process of undergoing a worldwide ban. In turn, this means that alternative UV light sources with enough power to complete the UV curing process have a very clear commercial interest.

The development of the photoinitiators, which are the components in UV ink that enable cure when exposed to UV light, was based on the best UV source available at the time. If you want to guarantee that you will achieve exactly the same result when you switch light sources, you will need to accurately mimic the output of the vapour bulb in both spectrum and intensity.

In the search for good alternatives, LED technology has been hovering in the background, but for a number of reasons, it has struggled to position itself as a serious contender.

UV LEDs have worked well for the photoimage exposure of dry film and solder mask, and there are quite a number of established machines available for this purpose. I have set a few of these machines up at customer factories, and the empirical test methods—such as using step wedges to control the exposure power—work much better when assessing the output of the LEDs. The good results from the LED exposure machines suggest that the same LED method should be suitable for other UV light processes, such as bump of solder mask (additional exposure after developing the photoimageable mask) to make the ink more robust for the aggressive chemical and heat processes that some



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When it comes to ensuring consistent quality and reliability, IPC standards are the backbone of the electronics manufacturing industry. With Certified Standards Experts (CSEs) on your team, you'll have in-house subject matter experts on specific IPC standards who can navigate the ins-and-outs of those standards quickly and efficiently. They draw upon the same knowledge as Certified IPC Trainers (CITs) but are not required to train. Your CSEs will be the know-it-all go-tos for questions, issues, updates and best practices on standards specific to your organization.

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circuits are subjected to as part of their manufacturing process.

It is quite hard to make a direct comparison of vapour bulb and LED machines due to the difference in the spectrum available. A vapour bulb has a wide spectrum of output with strong spikes that can be controlled by different doping of the bulb. An LED has a single distinct output wavelength, so even the tools available to measure intensity and exposure power may not give a very true reading of the LED's output, as these tools were designed for use with vapour bulbs.

A little reading about the subject of UV curing of solder mask reveals that different wavelengths can have a different effect on the ink. The exact wavelength can have quite an effect on the penetration through the depth of the mask material. Longer wavelengths penetrate deeper, and short wavelengths are good for surface cure. A vapour lamp covers this with a wide variety of available wavelengths, but there is no possible control of the proportions of long and short wavelengths once you have selected a bulb. All that is possible in terms of adjustment is to vary the power. Over time, each bulb degrades and also loses some intensity, which means that a pattern of constant adjustment has to be followed over the life cycle of the bulb to ensure the effect on the product is within the acceptable range.

With UV LED, we have to deal with the problem of distinct wavelengths, but thankfully, a variety of types are available—namely 365, 385, 395, 405, and 415 nanometres. If these are arranged and connected in the right way, it is possible to control the proportion of each wavelength, which allows you to tune the output to suit individual products and ink application methods—a level of control that has never been available with vapour bulbs.

After some amount of research and development, one of my colleagues in China produced what we believe will be an LED-powered machine suitable for bump processing of photoimageable solder mask, as well as cure of other UV curable inks. Finding a place to make empirical tests, however, proved to be very difficult.

Finding a potential end-user for a machine like this is reasonably easy, but for obvious reasons, they are always very keen to make sure

IMC5009R/H					
Panel number	Type	Belt Speed	Lamp Power %	IL390B Light Bug	Finish
1	No bump	n/a	n/a	n/a	None
2					Ag
3					ENIG
4					HAL
5	Hg bump	0.8m/min	100%	2505mj/cm2	None
6					Ag
7					ENIG
8					HAL
9	LED	3.0m/min	100%	1160mJ/cm2	None
10					Ag
11					ENIG
12					HAL
13	LED	2.0m/min	100%	1716mJ/cm2	None
14					Ag
15					ENIG
16					HAL
17	LED	1.0m/min	100%	3387mJ/cm2	None
18					Ag
19					ENIG
20					HAL

Table 1: Testing schedule matrix.

their UV ink supplier is happy with the proposed change of equipment. When you do this for the first time, nobody is able to say with any level of certainty that it will work.

I did talk directly to the ink supplier, and they were extremely helpful but also quite skeptical that it would be possible to get a positive result. It seems that poor past experience of LED-based curing had galvanised opinions against this format of machine.

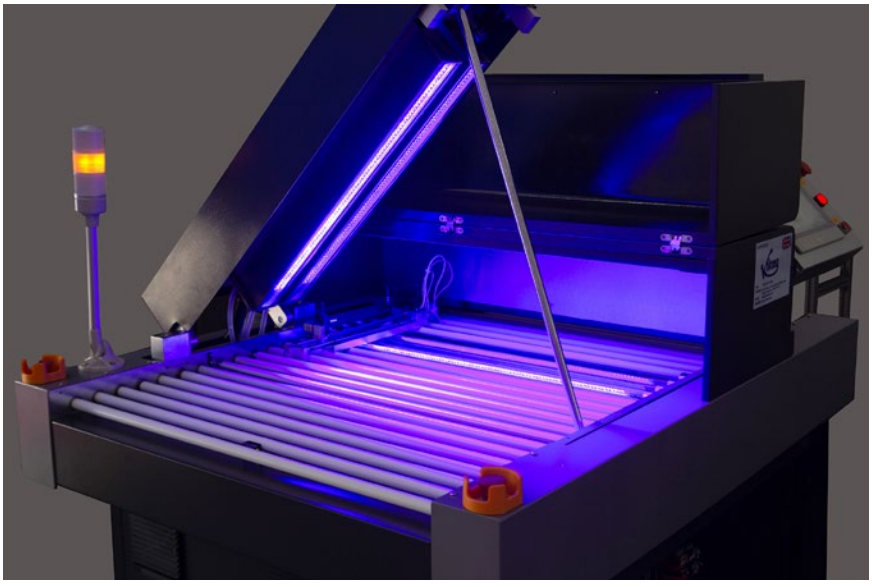


Figure 1: A two-light-bar machine format.

There is no substitute for testing on real products, and in this respect, Merlin Circuits in North Wales has been a huge help. They have run the machine alongside their old vapour lamp machine and made a true side by side comparison with testing and verification of the results being made by their UV ink supplier. The target for the company I work for is to sell these machines, but the results we have seen from the testing work at Merlin Circuits (Table 1) have raised some points which may have some wider technical interest.

The results for the LED machine were all good when running at 1 m per minute and 2 m per minute, but one of the adhesion test results was poor when running at 3 m per minute. This is not surprising, as the processing speed was quite extreme for a machine formatted with only two LED light bars (Figure 1). The modular design approach means that an appropriate number of bars could be fitted if higher speeds are important to the user.

One interesting result from the trial was the difference between vapour bulb and LED machine with regard to printing component ident onto the panels. The panels were UV bumped on both types of machines and then printed with component ident. There was a notable difference in ident adhesion between the two processes. The ident did not adhere well on the panels processed with the vapour lamp machine (Figure 2), but the adhesion was very good on panels processed with the LED machine (Figure 3).

Figure 2: Vapour bulb processed panel with poor ident adhesion.

Figure 3: LED processed panel with good ident adhesion.

The significance of this result is that the LED machine has the potential to be fitted directly to the end of the solder mask developer, greatly simplifying the process route. The component ident will still adhere well to the panels. When processed with the vapour bulb, the panels have to be notated after developing and then run through the UV bump as a separate stand-alone operation.

I spoke again to the ink supplier after the tests had been completed, and he told me they were very impressed with the results. In all tests, the LED machine performed well and achieved a good level of cure. For all parties involved, this was certainly a big step forward. Some of the potential advantages of LED-based machines are obvious—such as the low power usage and long service life of the light source—but without good process results, there is no way forward.

If you are concerned about the ongoing availability of vapour lamps, then perhaps the future is a little brighter when it is lit with UV LEDs. **PCB007**

Marc Ladle is a director at Viking Test Ltd. To read past columns or contact Ladle, click here.

IPC: Shawn DuBravac and Chris Mitchell on USMCA

On July 1, 2020, the USMCA trade act (United States-Mexico-Canada Act) phased in as a trade agreement guiding economic trade and growth in North America. Nolan Johnson spoke with both Shawn DuBravac, IPC's chief economist, and Chris Mitchell, IPC's vice president of global government affairs and an I-Connect007 columnist, about the impact of USMCA on North American electronics manufacturing.

DuBravac and Mitchell use the automotive industry as just one example of how the electronics manufacturing networks in the U.S., Canada, and Mexico are interwoven. They discuss the interaction between pre-existing market forces, such as tariffs and the coronavirus, and the intended goals of the USMCA. Together, DuBravac and Mitchell outline not only the competing forces at play but IPC's ongoing work to facilitate stronger regional economics in North America.

Click here to read the full transcript of this audio interview.

Supplier Highlights

Book Excerpt: Thermal Management With Insulated Metal Substrates, Part 2 ▶

The following is an excerpt from the second half of Chapter 1 of The Printed Circuit Designer's Guide to… Thermal Management With Insulated Metal Substrates written by Ventec International Group's Didier Mauve and Ian Mayoh. In this free eBook, the authors provide PCB designers with the essential information required to understand the thermal, electrical, and mechanical characteristics of insulated metal substrate laminates.

Isola Opens Expanded R&D and Analytical Laboratory in Arizona ▶

Isola, designer and developer of copper-clad laminates and fabrication materials for multilayer PCBs, officially opened an expansive R&D and analytical services laboratory at the company's new global headquarters in Chandler, Arizona.

Matrix Electronics Expands Flexible Circuit Materials Manufacturing ▶

Matrix Electronics is pleased to announce the completion of a new larger flexible circuit materials conversion center at its Santa Ana, California, location. This new, larger facility will accommodate our growth and improve productivity with state-of-the-art automated processing equipment.

Elsyca Offers Free Webinars on Simulation Tools for PCB Copper Balancing ▶

Elsyca recently developed a new technology for PCB CAM engineers and designers to validate their panel layout against plating targets and automatically add copper balancing. This results in panels with a more uniform layer thickness distribution and fewer plating-related production problems.

Advanced Copper Foil Inc. Granted Trademark Registration for EUROPADS ▶

Matrix USA Inc. is pleased to announce the official Trademark registration for their Lamination Assist products—EUROPADS®. Designed as PCB lamination press pads, they are manufactured to offer both heat-lagging insulating characteristics as well as pressure equalization benefits. EUROPADS proprietary elements of design is a consistent performing option for PCB lamination optimization.

Insulectro to Distribute Brushes From Industrial Brush Corporation ▶

Insulectro, the largest distributor of materials for use in the PCB and printed electronics industries, announced it would distribute IBC PCB pumice and deburr scrubber brushes effective immediately.

PV Nano Cell Launches New General-Purpose Gold Ink for Digital Conductive Printing ▶

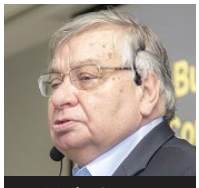
PV Nano Cell Ltd., an innovative provider of inkjet-based conductive digital printing solutions and producer of conductive digital inks, announced that it launched a new, general-purpose conductive gold ink to be used with inkjet and aerosol printing.

Rogers Corporation's Advanced Connectivity Solutions Business Adds North America Distribution Channel ▶

Rogers Corporation's Advanced Connectivity Solutions (ACS) business announced the introduction of a new distribution channel in North America with the addition of Bonding Source, a Krayden Company, to their sales and service team effective July 6, 2020. ACS provides global customers with market-leading high performance and high-reliability RF material solutions.

Editor Picks from PCB007

1 Walt Custer's EIPC Business Outlook Webinar: 'You Can't Sugarcoat This Stuff!' ▶


Walt Custer

In normal circumstances, it would have been the time of year for the EIPC Summer Conference, and Walt Custer would have opened the proceedings with his business outlook for the global electronics industry. However, circumstances were far from normal. Pete Starkey discusses some of the takeaways from Custer's global business outlook webinar, organized by EIPC.

2 Dan Beaulieu, Part 1: Lead Generation ▶


Dan Beaulieu

Dan Beaulieu, president of D.B. Management and an I-Connect007 columnist, spoke on the importance of continuing to generate leads and new customers. Beaulieu made a strong case that sales and marketing is a process that must be constantly ongoing to keep a full funnel of customers and business.

3 Elmatica's Didrik Bech Accepts Role as IPC Cybersecurity Task Group Vice-Chair ▶


Didrik Bech

On June 18, Nolan Johnson spoke with Didrik Bech, Elmatica CEO and I-Connect007 columnist, who was recently selected as vice-chair for IPC's Cybersecurity Task Group. Didrik outlined the task group's mission statement and the target audience for its work.

4 Materials for Automotive Applications: Thermal Management Issues ▶


Alun Morgan

For Pete Starkey, the highlight of the recent HDP User Group Automotive Technology webinar was Alun Morgan's presentation on materials for automotive applications. This forward-looking informational session covered the latest developments in automotive standards and automotive electronic packaging.

5 Eagle Electronics Reduces Cycle Time for IPC-4761 Type VII Via Fill Process ▶

Mike Kalaria—president and CEO of Eagle Electronics of Schaumburg, Illinois—announced that his company made significant cycle time improvements in the via fill process.

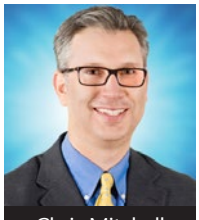
6 American Standard Circuits Installs New Post-Etch Punch System ▶


Anaya Vardya

Anaya Vardya, president and CEO of American Standard Circuits, announced that his company acquired a new eight-camera post-etch punch from C.A. Picard. The new VIP-25 is the final piece in a plan to establish the highest front-end registration capabilities possible.

8 IPC: Shawn DuBravac and Chris Mitchell on USMCA ▶


Shawn DuBravac


Chris Mitchell

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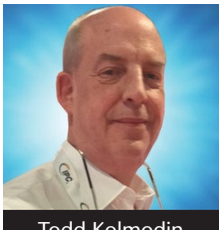
7 Sunstone Circuits Continues to Invest in the Future ▶

Sunstone Circuits—a PCB solutions provider for prototypes, medium-volume, and production quantities—recently added new 2020 state-of-the-art manufacturing equipment to its Oregon-based facility.

9 It's Only Common Sense: Dreaded Cold Calls ▶

There are ways to leave effective and productive messages that will get end results. From the book The Pocket Sales Mentor: Proven Sales Strategies at Your Fingertips by Gerhard Gschwandtner, Dan Beaulieu shares tips on how to leave great voicemails and get customers to call you back.

10 Testing Todd: Down-Shifting to the New Normal ▶


Todd Kolmodin

Today, we find ourselves in a place none of us even thought could happen due to the global COVID-19 outbreak. Todd Kolmodin encourages readers to be heroes and shift down to the new normal for a bit.

For the Latest PCB News and Information, Visit: PCB007.com

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Royal Flex Circuits is looking for an experienced Director of Business Development to increase company revenue by identifying and nurturing profitable business opportunities and developing long-term sales strategies. The successful candidate will have experience contacting potential clients, establishing lasting relationships, and converting leads to sales.

Responsibilities include but not limited to:

- Consistently meet or exceed monthly sales objectives with profitable sales revenues for a specific territory
- Develop new customers and maintain business relationships through active and personal communications
- Work with internal departments to efficiently handle customer data and order needs
- Provide ongoing account management by holding regular discussions with customers
- Understand the customer's general business needs, and be able to effectively communicate Royal Circuits' unique approach to provide quick-turn PCB fabrication
- Develop and maintain technical knowledge of the various aspects of circuit board fabrication

PCB sales experience strongly preferred.

The successful candidate will demonstrate excellent communication and leadership skills as well as strong business acumen.

Please send resumes to
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SOMACIS Inc. is a well-established (over 45 years in business), advanced technology, high-reliability PCB manufacturer, located in Poway, California.

The CTO will be our first technology go-to expert and play an integral role in setting the company's strategic direction, development and future growth.

CTO will:

- Be responsible for the implementation, maintenance, and improvement of all processes and procedures
- Review current and future technologies and make recommendations as to the most suitable direction for the future technical development of the company
- Ensure company is in compliance with legislative and regulatory requirements
- Supply technical support in all areas throughout the company in accordance with instructions of the operations director
- Collaborate with both quality and production departments to ensure the quality of the product
- Plan and manage the evaluation, introduction and acceptance trials of new equipment and processes
- CTO will manage the operational and fiscal activities of PCB engineering processes, procedures, technology, and the Somacis Process Engineering Team

Required skills:

- B.S. degree in chemical, electronic, mechanical or manufacturing engineering technology or 10 years of progressively responsible experience as an engineer in the PCB industry
- Minimum ten years' engineering experience in related manufacturing industry
- Ten years' progressively complex technical experience in PCB manufacturing processes involving the latest state-of-the-art applications and techniques

Excellent benefits and relocation reimbursement.
Salary negotiable and dependent on experience.

Send resume to:
Cindy Brown, cindyb@us.somacis.com

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Career Opportunities

LENTHOR ENGINEERING
MAKING THINGS FLEXIBLE IN A RIGID WORLD®

Sales Account Manager

Sales Account Management at Lenthor Engineering is a direct sales position responsible for creating and growing a base of customers that purchase flexible and rigid flexible printed circuits. The account manager is in charge of finding customers, qualifying the customer to Lenthor Engineering and promoting Lenthor Engineering's capabilities to the customer. Leads are sometimes referred to the account manager from marketing resources including trade shows, advertising, industry referrals and website hits. Experience with military printed circuit boards (PCBs) is a definite plus.

Responsibilities

- Marketing research to identify target customers
- Identifying the person(s) responsible for purchasing flexible circuits
- Exploring the customer's needs that fit our capabilities in terms of:
  - Market and product
  - Circuit types used
  - Competitive influences
  - Philosophies and finance
  - Quoting and closing orders
  - Providing ongoing service to the customer
  - Develop long-term customer strategies to increase business

Qualifications

- 5-10 years of proven work experience
- Excellent technical skills

Salary negotiable and dependent on experience. Full range of benefits.

Lenthor Engineering, Inc. is a leader in flex and rigid-flex PWB design, fabrication and assembly with over 30 years of experience meeting and exceeding our customers' expectations.

Contact Oscar Akbar at: hr@lenthor.com

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LENTHOR ENGINEERING
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Senior Process Engineer

Job Description

Responsible for developing and optimizing Lenthor's manufacturing processes from start up to implementation, reducing cost, improving sustainability and continuous improvement.

Position Duties

- Senior process engineer's role is to monitor process performance through tracking and enhance through continuous improvement initiatives. Process engineer implements continuous improvement programs to drive up yields.
- Participate in the evaluation of processes, new equipment, facility improvements and procedures.
- Improve process capability, yields, costs and production volume while maintaining safety and improving quality standards.
- Work with customers in developing cost-effective production processes.
- Engage suppliers in quality improvements and process control issues as required.
- Generate process control plan for manufacturing processes, and identify opportunities for capability or process improvement.
- Participate in FMEA activities as required.
- Create detailed plans for IQ, OQ, PQ and maintain validated status as required.
- Participate in existing change control mechanisms such as ECOs and PCRs.
- Perform defect reduction analysis and activities.

Qualifications

- BS degree in engineering
- 5-10 years of proven work experience
- Excellent technical skills

Salary negotiable and dependent on experience. Full range of benefits.

Lenthor Engineering, Inc. is the leader in Flex and Rigid-Flex PWB design, fabrication and assembly with over 30 years of experience meeting and exceeding our customers' expectations.

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SUMMARY

Quality engineer with supervisory responsibilities, reporting to operations manager at Indium Corporation, European Operations. Candidate should be based within one-hour travel distance of Milton Keynes, U.K. M-F, 40 hours per week. Open until filled.

RESPONSIBILITIES

- Preventive/predictive maintenance, servicing, calibrations of equipment and facility in the work area
- Overseeing document control
- Approval of departmentally controlled docs
- SOP updates
- Full involvement in external audits, supported by the rest of the supervisor team and operations manager
- Internal and supplier auditing
- Product audits
- Sign off on TEOs and MRBs
- Reporting KPI performance to operations manager
- PPAP
- FMEA, control plan
- Customer complaints, RMAs investigation and reporting
- Project lead
- MSA design and implementation
- Maintenance of approved supplier list (ASL) and approved parts list (APL)
- Supplier risk assessments
- CAPAs, including SCARs
- Product qualifications
- Maintenance of equipment list
- Control of non-conforming product
- Sign off on change management (minor)

REQUIREMENTS

- IT literate
- Excellent written and verbal communication skills
- Strong interpersonal skills
- Numerate
- Six Sigma green belt
- Core Tools trained and certificate held
- Experienced auditor to IATF standard
- VDA trained auditor
- Several years' experience in a quality department within the automotive industry, including experience of IATF16949
- A recognised degree-level qualification in science
- Member of a certified industry organisation (CQI) or equivalent

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Image Department Operator

Alpha Circuit Corporation is a manufacturer of printed circuit boards located in Elmhurst, IL. We are currently seeking an operator in our Image department.

- All safety gear will be provided
- No experience required but a plus
- Full paid training provided
- Benefits: Health Insurance, 401(k), paid time off

Responsibilities:

- Expose dry film and liquid photo imageable ink
- Develop exposed photo imageable ink
- Develop exposed dry film
- Laminate dry film resist on inner layer and outer layer printed circuit panels
- Learn, understand, apply, and accept responsibility for in-process quality standards
- Be able to lift up to 15 lbs. shoulder high

If you are interested in this position, please contact Nita Buccino.
Email: nvb@alphacircuit.com,
cell: +1-847-489-2341.

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Career Opportunities

BURKLE
NORTH AMERICA, INC.

Service Engineer
Schmoll Laser Drilling and Direct Imaging

Burkle North America seeks a full-time service engineer in the Northeastern U.S. This position will provide expert-level service on multiple laser drilling and direct imaging product lines. Install, commission, and maintain Schmoll products at multiple customer sites across the Northeast. The candidate will perform modifications and retrofits as needed. Maintain complete and detailed knowledge of Schmoll products and applications and handle a wide variety of problems, issues, and inquiries to provide the highest level of customer satisfaction. Assist customers with the potential optimization of their machine functions and work with clients on application improvements.

Qualifications

Required: Bachelor's degree from a technical college/university in an associated field. Three years directly related experience, or equivalent combination of education and experience. Must possess a valid driver's license and have a clean driving record.

Preferred: Experience in control systems and electronic troubleshooting, as well as in general electrical and mechanical service tasks. Experience and knowledge in the PCB manufacturing process, with a focus on laser drilling and/or direct imaging.

Send resume to hr@burkleamerica.com.

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WHELEN®
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Process Engineering Director

Whelen Engineering Co., Inc. seeks full-time process engineering director in Concord, NH, to develop, plan and execute GreenSource Fabrication, LLC Div.'s process technology business strategy; manage process engineering activities, staff and compliance; improve process design, cost, quality and resource utilization; interact w/ customers and incorporate feedback; develop financial capital and labor projections; travel internationally for conferences, supplier and customer visits (15-25% worktime); write white papers, IP applications and give talks re. Division's products/processes.

Min. req.: U.S. Bachelor's or foreign equivalency in environmental science or engineering; min. 10 yrs. work exp. in: PCB fabrication process engineering; comprehensive and current experience in PCB fabrication/substrate markets w/ SAP tech; developing chemical and mechanical processes, chemistries and equipment for PCB manufacturing demonstrated by international experience implementing complex processes; ability to direct and troubleshoot PCB manufacturing problems; min. 5 years exp. leading, managing and training process engineering teams, developing and executing process technology business strategies and plans in worldwide PCB markets, including Japan, Taiwan, China, Europe; min. 3 years exp. giving talks, writing and presenting white papers; ability to travel internationally (15-25% worktime).

Send CVs to: Corinne Tuthill,
ctuthill@greensourcefab.com
or GreenSource Fabrication, LLC,
99 Ceda Road, Charlestown, NH 03603.

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Career Opportunities

eptac
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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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APCT
Passion | Commitment | Trust

APCT, Printed Circuit Board Solutions: Opportunities Await

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

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

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

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

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Career Opportunities

TAIYO AMERICA

Development Chemist
Carson City, NV

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

Essential Duties:

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

Required Education/Experience:

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

Working Conditions:

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

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Manncorp™

SMT Field Technician
Huntingdon Valley, PA

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

Duties and Responsibilities:

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

Requirements and Qualifications:

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

We Offer:

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

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Career Opportunities

U.S. CIRCUIT

Sales Representatives (Specific Territories)

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

- Florida
- Denver
- Washington
- Los Angeles

Experience:

- Candidates must have previous PCB sales experience.

Compensation:

- 7% commission

Contact Mike Fariba for more information.

mfariba@uscircuit.com

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ZENTECH

Zentech Manufacturing: Hiring Multiple Positions

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

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

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

Please email resume below.

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Career Opportunities

BLACKFOX
Premier Training & Certification

IPC Master Instructor

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

For more information, click below.

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For information, please contact:
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President, Company Leader, Business Builder
This professional has done it all. Built new businesses and turned around hurting businesses and made them successful. A proven record of success. This candidate is a game-changer for any company. He is seeking a full-time leadership position in a PCB or PCBA company.

General Manager PCB and PCBA
Senior manager with experience in operations and sales. He has overseen a number of successful operations in Canada. Very strong candidate and has experience in all aspects of PCB operations. He is looking for a new full-time position in Canada.

Regional Sales Manager/Business Development
Strong relationship management skills. Sales experience focused on defense-aerospace, medical, high-tech PCB sales. Specializes in technical sales. Also has experience in quality, engineering, and manufacturing of PCBs. He is looking for a fulltime position in the Southeastern U.S.

Field Application Engineer (FAE)
Has worked as a respected FAE in the U.S. for global companies. Specializes in working alongside sales teams. Large experience base within the interconnect industry. He is looking for a full-time position.

Business Development Manager
Understands all aspects of interconnect technical sales from PCB design and fabrication to assembly and all technologies from HDI microvias to flex and rigid-flex. Has also sold high-tech laminates and equipment. Proven record of sales success. He is looking for a full-time position.

CEO/President
Specializes in running multi-million dollar companies offering engineering, design, and manufacturing services. Proven leader. Supply chain manager. Expert at developing and implementing company strategy. Looking to lead a company into the future. He is looking for a full-time position.

PCB General Manager
Forty years of experience serving in all capacities, from GM to engineering manager to quality manager. Worked with both domestic and global companies. Available for turn-around or special engineering projects. He is looking for long-term project work.

Process Engineering Specialist
Strong history of new product introduction (NPI) manufacturing engineering experience: PCB/PCBA. Held numerous senior engineering management positions. Leads the industry in DFM/DFA and DFX (test) disciplines. He is looking for either a full-time position or project work.

VP Sales Global Printed Circuits
Worked with a very large, global company for a number of years. Built and managed international sales teams. Created sales strategies and communicated them to the team. One of the best sales leaders in our industry. He is looking for a full-time position.

Plant Manager
This professional has years of experience running PCBA companies. Led his companies with creative and innovative leaderships skills. Is a collaborative, hands-on leader. He is looking for a full-time position.

National Sales Manager
Seasoned professional has spent the past 20 years building and growing American sales teams for both global and domestic companies. Specializes in building and managing rep networks. He is looking for a full-time position.

Global Engineering Manager/Quality Manager
Has experience working with large, global PCB companies managing both engineering and quality staff. Very experienced in chemical controls. She is interested in working on a project-by-project basis.

CAM Operators and Front-end Engineers
These candidates want to work remotely from their home offices and are willing to do full-time or part-time projects.

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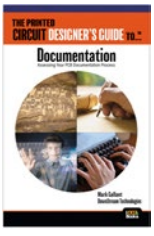
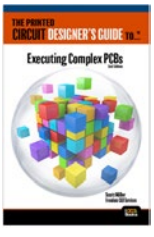
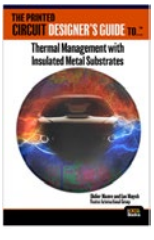


Documentation, by Mark Gallant, Downstream Technologies
When the PCB layout is finished, the designer is still not quite done. The designer's intent must still be communicated to the fabricator through accurate PCB documentation.



Executing Complex PCBs, by Scott Miller, Freedom CAD Services
Designing a complex circuit board today can be a daunting task. Never before have PCB designers on the cutting edge faced more formidable challenges, both electrical and mechanical.

Producing the Perfect Data Package, by Mark Thompson, Prototron Circuits
For PCB designers, producing a comprehensive data package is crucial. If even one important file is missing or output incorrectly, it can cause major delays and potentially ruin the experience for every stakeholder.



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.

Fundamentals of RF/Microwave PCBs, by John Bushie and Anaya Vardya, American Standard Circuits
Today's designers are challenged more than ever with the task of finding the optimal balance between cost and performance when designing radio frequency/microwave PCBs.

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MANAGING EDITOR: **NOLAN JOHNSON**
(503) 597-8037; nolan@iconnect007.com

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

SALES MANAGER: **BARB HOCKADAY**
(916) 608-0660; barb@iconnect007.com

SALES: **ANGELA ALEXANDER**
(408) 489-8389; angela@iconnect007.com

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

CONTRIBUTING EDITOR: **PATRICIA GOLDMAN**
(724) 299-8633; patty@iconnect007.com

CONTRIBUTING TECHNICAL EDITOR: **DAN FEINBERG**
baer@iconnect007.com

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

ASSOCIATE EDITOR: **KIERSTEN ROHDE**
kiersten@iconnect007.com

ASSOCIATE EDITOR: **MICHELLE TE**
michelle@iconnect007.com

CONTRIBUTING TECHNICAL EDITOR: **HAPPY HOLDEN**
(616) 741-9213; happy@iconnect007.com

PRODUCTION MANAGER: **SHELLY STEIN**
shelly@iconnect007.com

MAGAZINE LAYOUT: **RON MEOGROSSI**

AD DESIGN: **SHELLY STEIN, MIKE RADOGNA, TOBEY MARSICOVETERE**

CREATIVE TECHNOLOGIST: **BRYSON MATTIES**

COVER: **SHELLY STEIN**

COVER IMAGE: **ADOBE STOCK © 3DSCULPTOR**

PCB007 MAGAZINE

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

July 2020, Volume 10, Number 7
PCB007 MAGAZINE is published monthly,
by BR Publishing, Inc.

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EDITORIAL CONTACT

Nolan Johnson
nolan@iconnect007.com
+1 503.597-8037 GMT-7

SALES CONTACT

Barb Hockaday
barb@iconnect007.com
+1 916 365-1727 GMT-7

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