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MAGAZINE



Customer service is
proactive, not reactive.
~ I-Connect007

Customer service is
not a department,
it's everyone's job.
~ Ken Blanchard

"A dissatisfied
customer does
not complain, he
just switches."
~ W. Edwards
Deming

"Without great employees
you can never have great
customer service."
~ Richard F. Gerson

"The customer's
perception is
your reality."
~ Kate Zabriskie

"Customers are like teeth.
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M A G A Z I N E

Customer Service

Your true impression of a company comes down to your own personal experience. It comes down to customer service. We all like to think we've got it mastered, but do we really? In this issue, we look at customer service for what it is: an achievable goal.

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an I-Connect007 Compilation

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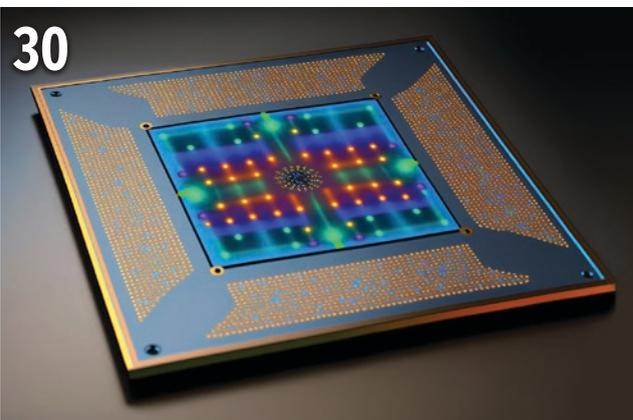
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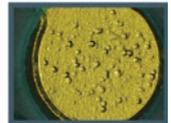
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A Tale of Quality Customer Service

Nolan's Notes

by Nolan Johnson, I-CONNECT007

Companies can deliver stunning ads and effective marketing plans that create strong emotional reactions. But your personal experience creates a long-lasting impression. It comes down to customer service. What's your amazing customer service story? Here's one of mine.

In 1998, I was running a technical training department, selling capital equipment into semiconductor facilities. At the time, there was a lot of investment in new memory fabs in China, and that meant I spent a big chunk of my time in Shanghai, running onsite training programs.

One three-week trip routed me through the Narita, Tokyo, airport before heading to Shanghai. As I started my journey at security before boarding for Narita, I placed my luggage on the conveyor and moved forward. Unbeknownst to me, my planner binder (Remember those?) somehow got free of my laptop case and became wedged in the X-ray machine—where it stayed for an hour before they were able to get it out. Meanwhile, I had already boarded the plane and never heard the page calling me back to security. While it might seem a minor inconvenience to leave your planner at the airport, this particular book contained my passport,

entry visa, boarding pass into Shanghai, and \$500 in cash. I was in the air, headed to Tokyo, and completely unaware.

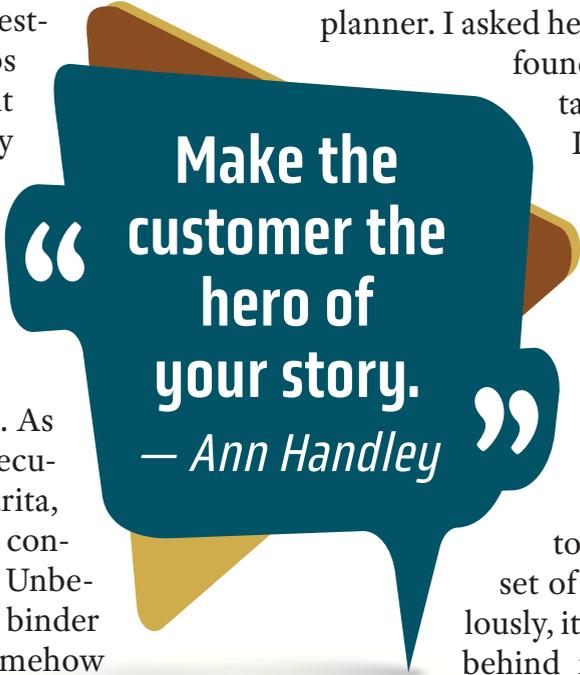
Somewhere over the Aleutian Islands, a voice in my head said to check on my planner. Imagine that profoundly sinking feeling when I realized I didn't have it. Being this was 1998, I pulled out my credit card and used the airplane's pay phone to call home. My wife quickly answered and I explained that I had lost my planner. I asked her to call the airport's lost and

found department, as well as Delta's customer service number.

I said I would call back in 30 minutes. Let me tell you, never had time moved so slowly as that half-hour.

When I called her back, she had plenty to report. Airport security had my planner, and would surrender it to Delta's customer service, which had offered to put my planner on the next set of flights to Shanghai. Miraculously, it would arrive about 18 hours behind me. My planner would be delivered to my Shanghai hotel just as if it had been lost luggage.

Now, how did I get to Shanghai from Narita without a passport or boarding pass? I knew I could manage 18 hours without my planner, but I needed that paperwork for my connecting flight. I was pleasantly surprised once again when a Delta representative met me at



“Make the
customer the
hero of
your story.”

— Ann Handley

the gate in Narita with a replacement boarding pass and a photocopy of my passport's ID page. They said they would vouch for me at the gate, and when I arrived in Shanghai, another Delta agent would walk me through passport control with the photocopy.

Everyone involved knew that this was a high-risk plan; passport control officers might not let me through, in which case, I would have to wait in the international arrivals terminal for 18 hours until I could be reunited with my planner. Sitting on that plane, somewhere west of Kamchatka, this plan sounded preferable to being refused entry altogether.

I'm happy to say that the plan went off without a hitch. The Narita agent was there as I deplaned, holding a new boarding pass and two passport photocopies—one to show the gate agent and one for my pocket. Arriving in Shanghai, Delta once again came through. The next agent was there, waiting for me. She kindly walked with me all the way to the passport control desk, where I'm assuming she explained the situation (in Mandarin) to the officer and produced the passport photocopy. This conversation lasted for about two minutes, ending with a longish monologue from passport control before they both nodded, he stamped the two photocopies, and waved us on. The Delta agent motioned me to the side, explained that they were allowing me entry, and that my passport would be brought to passport control along with the stamped photocopy so that the stamp could be duplicated in my book prior to sending the whole planner on to my hotel.

The next day, while I was in my hotel still adjusting to the time change, I heard a knock at the door. A bellhop had my planner for me, the passport was stamped, and everything else—including the cash—was undisturbed. That, ladies and gentlemen, was customer service.

In this month's issue of *PCB007 Magazine*, you won't find customer service stories quite as harrowing as the one I've just described.

Instead, our customer service coverage looks at the many facets of the industry by letting others tell their own stories. I am confident you will find something of value in at least one of those stories we tell.

Barry Matties files a dispatch from Houston, where The Ion's Joey Sanchez is cultivating networks of people to bring complementary skills together. Joey's philosophy is the core of customer-centric thinking. In addition, columnist Dan Beaulieu has been writing about customer service for years. We asked Dan to pick his five favorite columns on the topic and you'll get to read those here.

Speaking of columnists, Paige Fiet discusses manufacturing as a customer service ecosystem, and Todd Kolmodin keeps his eye on positivity and morale in the workplace. Furthermore, you'll find updates on solder mask legislation and regulation from Chris Wall, and an interview with American Standard Circuits' John Johnson on their customer-driven focus on ultra HDI. Throughout the magazine this month you will find short pieces telling customer service stories meant to inform and inspire.

Customer service is equal parts science, art, and inspiration. Once you find your groove, you know—and you'll know when you've fallen out of the groove as well. Delta Airlines demonstrated impeccable customer service for me, halfway across the globe. There is plenty of customer service success in our industry, too. As always, if you have story ideas, or your own customer service adventures to share, contact me at nolan@iconnect007.com. I'd love to hear from you. **PCB007**



Nolan Johnson is managing editor of *SMT007 Magazine* and co-managing editor of *PCB007 Magazine*. Nolan brings 30 years of career experience focused almost entirely on electronics design

and manufacturing. To read other columns or to contact Johnson, [click here](#).



Feature Interview by Barry Matties

I-CONNECT007

During the recent SMTA Houston Expo & Tech Forum, I had the good fortune to meet and interview Joey Sanchez, senior director of ecosystems at The Ion, a 300,000-square-foot space in the renovated historical Sears building in the city's Midtown section. Opened in 2021, The Ion is part of the 16-acre (12 city blocks) Ion Innovation District, which is currently under development. The facility is owned and managed by Rice University.

The Ion serves as a gathering place for entrepreneurs, students, corporations, and academics to connect, share ideas, learn, and collabo-

rate on innovation. There are many resources onsite for innovation, including prototyping labs with 3D printing, CNC mills, training courses, mentors, and meeting rooms that are open to the public. More than 250 companies occupy the floors above, including Microsoft on the top floor.

Hundreds of events are hosted each year at The Ion, including Cup of Joey, which was started by Joey Sanchez as a walk-in event every Friday morning. It's where people can meet, enjoy a cup of coffee, and make a connection with a wide array of people. I went to

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Joey Sanchez



A large and enthusiastic crowd at Cup of Joey.

my first Cup of Joey in March, where I connected with people from all parts of life and industry, including Alert Tech SMT, a Houston-based EMS provider.

During my visit, Joey Sanchez gave a tour of the facility to a very interested crowd that included an Italian trade agency and a venture capital group. He shared with the group that Houston is the fourth largest city in the country, but 89th in the country in density. He pointed out that Houston has the Johnson Space Center, a very large energy district, and a state-of-the-art medical center, each located in different areas of the city.

I asked Joey about the greatest challenge facing Houston today. “Creating density and connection is the biggest challenge,” he said, noting that the city is so vast—nearly the size of Rhode Island—that it can take hours to drive from one district to another.

It was this realization that crystalized Joey’s purpose “to connect people to a more fulfilling future” and to start Cup of Joey.

“I don’t know what that fulfilling future is unless I know someone’s purpose, and then I’m able to make that connection pretty seamlessly,” he said. “The Ion allows me to connect people on a daily basis, so I’m currently very fulfilled in my professional life. At home my purpose is very similar—to connect my wife and kids to a more fulfilling future.”

Here is more of my conversation with Joey Sanchez.

With that clear purpose, you set out to change the world, starting in Houston.

Cup of Joey is the catalyst for connecting people in the community and the foundation for innovation. It began with the pandemic, which

was hard on everybody for many different reasons. As a people person, I really wanted to be connected with people. As soon as the mask mandate was dropped here, I brought together a group at a local coffee shop. It didn't cost me anything because they just bought their own coffee. We talked about innovative ideas and how to build a better community. Cup of Joey was born, and we've been meeting every Friday for nearly two years.

The agenda isn't about a specific end product or a process, but about creating connection and finding opportunity through purpose.

You said it perfectly. That is my agenda, to connect people to a more fulfilling future. I think I can do this until the day I die. The goal is to not live for a job, but to live with purpose.

A purpose-driven life.

Exactly. If I can share that with a few people—my family, friends, and my community—and if Houston can be purposeful, then I think we have a better chance in the future.

Let's talk about customer service. In your presentation, you discussed Houston and its surrounding area. You mentioned that the region has technology and innovation silos, with miles between them.

Individual companies also have department silos—R&D, manufacturing, sales, etc.—and connections among them can be either nonexistent or not as strong as they should be. We may pass each other in the hall and never even know the people we work with. Does the Cup of Joey concept work within the four walls of a business?

Absolutely. It used to be called water cooler talk. I believe that Cup of Joey is not only a place to network, but a lifestyle that can enhance your family, community, and your company. All these entities need connection.

We have to connect with and service customers, and we need to do it with purpose. We attempt to do a good job at customer service, but we often fail to utilize all the connections and resources to improve customer experience. What's your advice for companies looking to strengthen their customer service?

Anyone working in the customer service realm needs to build real relationships. A relationship is a two-way street, where value is exchanged between the customer and the company. Build a relationship through real touch points. Check in with customers and find out what their real purpose is for using your product. Give them true value every single time you meet.

When people think of customer service, they naturally think of external customers. However, business comprises systems and processes that connect one to another. There's a handoff between the customer at one end and the supplier at the other end. We always hear that a company believes in 100% customer satisfaction;



Joey Sanchez speaks to a group at Cup of Joey.

however, we often forget about providing great customer service to our own internal customers, or we don't even recognize them as customers.

Very, very good point there. To identify external customers vs. your internal customers vs. your employees vs. your vendors and suppliers. It's the first step. Cup of Joey tries to systematize this idea of purpose and goodness. You can live the "Cup of Joey lifestyle" when you think about people more than process and product. People do business with people; they do not solely buy products or services. In this technologically advanced world, you tend to buy from vendors rather than people, so there's an opportunity for us to connect as human beings, not just with a physical product.

I think there are two points here. First is the person-to-person relationship, then there's the process of delivering great quality products and services, which we can improve through repetition and focus.

For sure. Those are the elements that every good business needs. But I've realized that a

business can disappear in a heartbeat and that people are the true asset. My personal mission is to connect people. Great teams are made when you bring together people who have different purposes to achieve one ultimate good.

Should corporations have chief connection officers?

I don't know. But I was hired as The Ion's senior director of ecosystems, which is essentially the same thing. My role is to bring in people. It's a mix of business development, community development, and product delivery. It's a community.

If someone is choosing to do business between two similar companies, the deciding factors are: Who do you like? Who do you have a relationship with? Who do you have a connection with?

Absolutely. You use that same mentality across every element of your life. That's how you pick a partner, a house, a neighborhood, and a car. It comes down to who you like.



Joey Sanchez explains the plan for Houston's downtown in this diorama.



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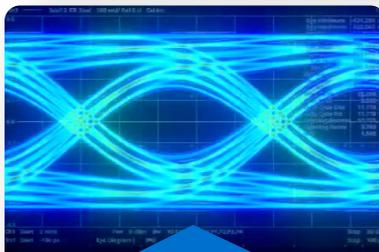
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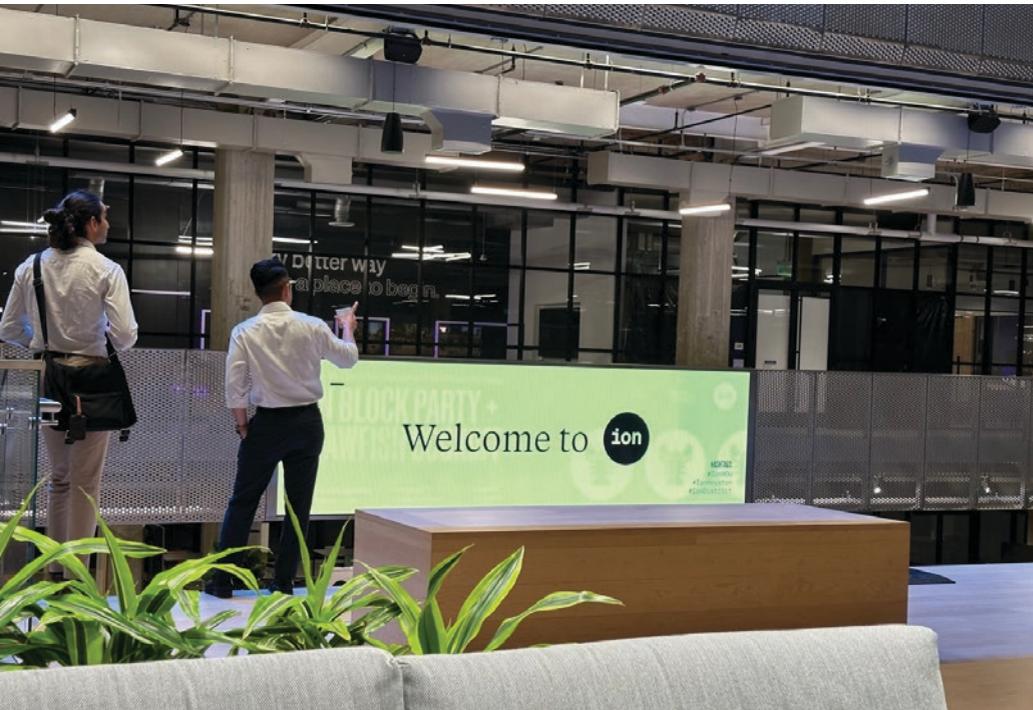
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ically connected. Now everyone is spread out, and we're trying to figure out a way to reconnect.

It's a challenge for businesses, individuals, family, friends, and the community. How do you open the door for connection? Silos can lead to loneliness and depression. Connecting to people is really a lifestyle, and business is the outcome of relationships.

If I oversaw customer service and wanted to re-imagine the department,

what advice would you give me?

Create a conversational-based customer service department. To have a good conversation, you must ask good questions. Feedback is key to customer service and product development. If you're not asking good questions, then you're not servicing your customer. If customers have already bought the product—tasted the sauce, so to speak—is that all there is? No, that should be the foundation of your next product launch or iteration. It's all based on communicating with your current customers.

Start with the truth.

The truth is relative; it's based on your customers' needs and wants. The key is to be customer-obsessed. If you don't know who your customer is personally and professionally, then you're dead in the water.

Thank you, Joey, for taking some time to meet with me today. I wish you all the best.

Thank you. PCB007

The service connection with customers is often limited to a single employee having a point-to-point connection, which can leave a business vulnerable. So, we try to form as many connections on different levels as possible. If you have meaningful, strong connections within your client base and provide great service, you can weather the storms, because, let's face it, every relationship goes through some rough patches.

When it comes to the importance of making connections, business is no different than life—the more connections you make, the more opportunities you have. Or it's the more identifiable network nodes you have that give you different routes you can take to avoid feeling stuck or alone. A customer service department that brings in an entire team, a whole army, will feel relied on and supported.

In life and culture, trends are shifting. Families used to comprise five or six people. Now families have one or two kids, at most. People don't have large networks anymore, like when brothers and sisters, aunts and uncles, and everybody used to live next to each other. Families and communities used to be phys-

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Dan Beaulieu's **Five Favorite** Columns on Customer Service

Dan Beaulieu has been an I-Connect007 columnist for at least 12 years. His weekly columns, now almost 800 of them, cover sales, marketing, business development and customer service, among others. They are a treasure trove of thoughtful commentary; he truly is an expert on customer service in the printed circuit board industry.

For this issue, we asked Dan to choose his five favorite columns on customer service. If you're new to Dan's columns, you'll see that he doesn't mince words. He tells it like he sees it—sometimes that's pretty, and other times it's not. But it's always valuable advice. We've excerpted his top picks here. Click on the icon next to the title to read the full column.

Customer Service Starts at the Top



All customer service starts at the top. It's a cultural thing. To have great customer service, you have to have respect for your customers. Everyone in the company, not just the customer service people, has to respect the customer.

Look, it's easy to pass everything along to the customer service people. (By the way, when I say customer service people I also mean inside sales people because I have found that in our industry, these terms are pretty much interchangeable.) So, for the record here, if a company wants to have great customer service, everyone in the company—the owner, the president, the sales manager, the plating supervisor, the maintenance person, the people in shipping, and the customer service person—must be completely focused on the customer. Everyone must live, eat, and



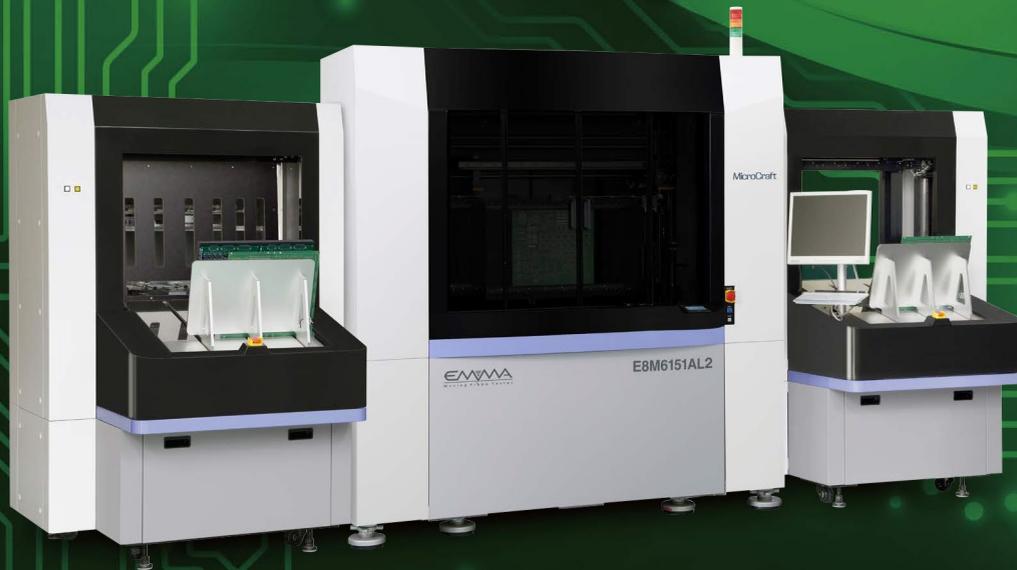
Dan Beaulieu

breathe customer service. Everyone should be staying up nights trying to figure out how to deliver the best possible customer experience on the market today, and the company leader should be personally leading that charge.

Remember that when customers judge how you treat them, you are not only competing against other board shops. You are also competing against the best customer service companies in the world, including Disney, L.L. Bean, Tiffany & Co. and Nordstrom. That's a lot of pressure!

Yes, great customer service comes from the top and filters all the way through the organization. But please be careful, because that sword cuts both ways. As the leader of a company, you have to make sure that at no time will you ever bad-mouth a customer. If you get angry

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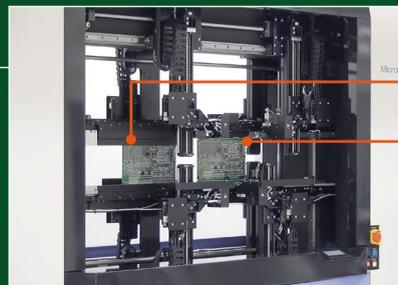
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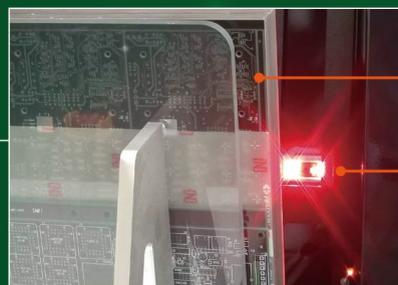


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or frustrated with a customer, or if you just don't get along with a customer, you never let it show. You never let anyone in your organization hear you criticize a customer. The fact is that anything that comes out of your mouth is multiplied tenfold when it hits the troops. If you are a company president and you publicly knock a customer, you are literally yelling to your people that they now have permission to knock that customer as well. You will have set that example and once that happens, there is almost no turning back.

Have you ever said something like this?

"My salespeople are too close to their customers. They need to be reminded of who they work for."

Or this:

"Look, I don't care what the customer wants. This is the way we do it here; this is our policy."

Or this:

"So what if we're late? Everybody is late once in a while. We're a board shop, and board shops screw up once in a while, so they are just going to have to understand that."

I hope you have never said any of these things or anything that even sounds like this. But if you have, then you'd better rethink your role in the organization because you are sending a terrible message to everyone who works in your company, particularly those who are working on the front lines: your customer service and salespeople.

The point here is that you can come up with all kinds of great ways to deliver solid customer service and you can teach them to your customer service people until you're blue in the face, but if the rest of the organization doesn't buy into it, you are wasting your time.

Delivering Amazing Customer Service



I'm on a journey to discover the best customer service ideas I can find. I have read several books and talked to numerous people on my search to find the best examples of not just good, but great customer service.

Great customer service is the key to successful sales growth. Customer acquisition is so expensive and time-consuming that we need to do all we can to retain those dear customers once we have gone through the blood,

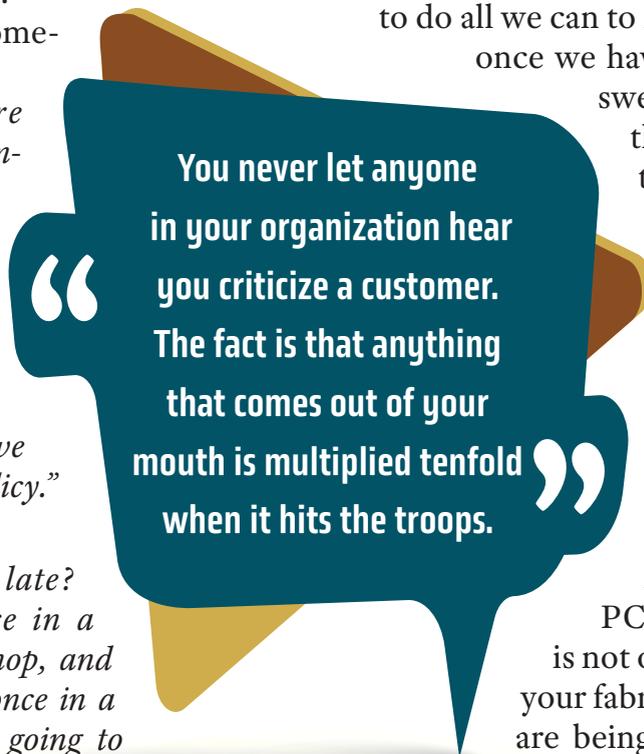
sweat, and tears of attaining them. The better your customer service and customer retention, the more successful your company will be.

The fascinating thing about great customer service—or poor customer service, for that matter—is that it crosses all markets, products, and technologies. If you are building

PCBs, your customer service is not only being measured against your fabricator competitors, but you are being measured against Disney, Nordstrom, and The Ritz-Carlton; there is some pretty stiff competition out there. Customer service is universal and should be treated as such.

One fact that I can never get out of my head is that when a customer is treated right, they will tell at least 50 people about it. But when a customer is treated poorly, they will tell 250 people about it. Wow! Those are some odds: 5 to 1 in favor of poor customer service. That alone should make us all realize how critical great customer service is to your company's success.

I have been reading a book by Shep Hyken called *Amaze Every Customer Every Time: 52*





LISTEN NOW!

Tools for Delivering the Most Amazing Customer Service on the Planet. This is an excellent resource when it comes to finding inspirational ways to amaze your customers.

In one of the most striking chapters in the book, Hyken talks about internal and external customers. The internal customer is your own company's team. He also references Herb Kelleher, the founder of Southwest Airlines, whose strongest philosophy was to put his associates first, even before his customers. Kelleher felt that if he could make his associates happy and delighted with the company, then they would delight their customers as well. He also uses this philosophy to show how, by amazing your employees, you will empower them to amaze your customers as well.

Getting Intimate With Your Customers



Relax, this is not what you think. This is about getting so close to your customers that you have a clear and concise understanding of what they need from a great supplier. You see, I am often asked for tips and ideas on how to create customers for life. Too often, we feel as if all that matters to our customers is price—and sometimes delivery.

Some of our customers will say, "All our suppliers are the same. You all do a pretty good job, so we don't have to spend time doing a differential analysis; we just go with the best price, and we feel good about that."

But is that all you have? Is that all you are to your customers? A blob of vendors delivering the same product, all doing "pretty good"? Is our success based on who buys the best lunches or belongs to the best country clubs?

In the words of the inimitable Peggy Lee, "Is that all there is?"

I absolutely refuse to buy this. I find this thinking abhorrent and refuse to settle for

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this type of reasoning. I shudder with disgust when I hear a salesperson say that the only thing his customers care about is price and there is nothing that can be done about it.

In your heart, you know that's not true. You really cannot figure out what else you can do? There is no way for you to shake things up? No way to be so much better than anyone else?

I disagree. In fact, I vehemently disagree. I disagree with extreme prejudice.

While price matters, there is more to it. I want to share one solid idea to enamor your customers so much they will fight tooth and nail with their accounting department to pay extra for your services and products. These are ways to get intimate with your customers and keep you at the top of their approved vendor list.

Create a Co-company Partnership

Create a peer-to-peer relationship between your team and their team. Ask permission to bring the members of your team to visit their facility where your team will learn not only their needs but what it takes to make their jobs easier and more productive. For example, have your shipping person visit with their receiving person to find out how your product is received. Learning what your customer does with your product when it arrives will teach your shipping team how to better meet your customers' needs. Once your person sees how the product is received, he can ask the receiver how he can make his job easier and then implement those ideas into his shipping process. The same can apply to all levels of both companies: Engineers to engineers, quality to quality, accounting to accounting, sales to sales, and even sales to purchasing.

Get everyone working together so that both companies are completely in sync and operating as one cooperative and productive unit.

Now, before you pull out the tired "50 reasons why this is a bad idea and won't work," keep in mind that this idea has worked in

the past. Years ago, I was a regional sales manager and part of several

programs that were

based on this idea. Some

of you might remember

the old Digital

Equipment ship-to-

stock program which

was very similar to what I

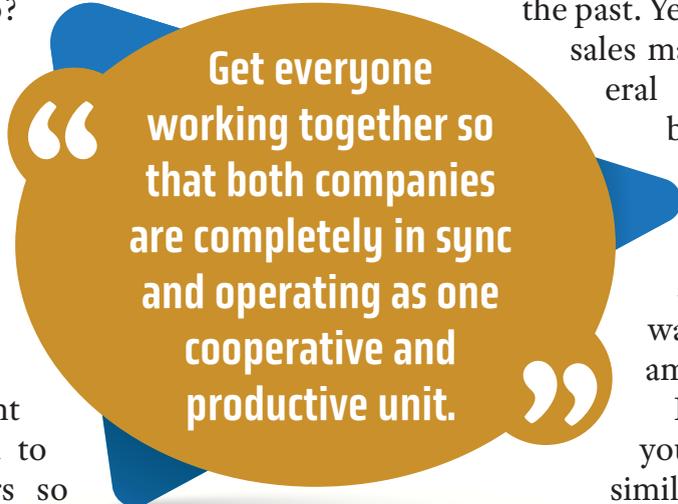
am proposing.

In fact, I'm sure some of

you are already involved in

similar programs with your

customers and can testify that this kind of thinking works.



Great Customer Service Stories



We all love wonderful customer service stories. For example, how about that time a Nordstrom employee gave a customer a refund for the snow tires he returned even though the company doesn't sell tires? Or when a Saturn representative personally brought a new seat to a Saturn owner in Alaska whose passenger seat had broken? Or have you heard about the waitress who paid two firefighters' breakfast bill one morning, and instead of the check, she wrote them a note thanking them for all that they do?

Again, we love those stories, especially when they have a kicker. Regarding the last story, the two firefighters found out that the waitress had a GoFundMe, trying to raise \$17,000 for a wheelchair accessible van for her quadriplegic dad. They shared her cause and helped raise more than \$85,000. It's a heartwarming story that almost makes you tear up. There are many more of these stories out there; things like this

happen every day. Stories of human kindness and great customer service are everywhere. In a way, customer service is where humanity supersedes business as usual.

I remember hearing the general manager of a quick-turn PCB facility talk about what his company did to get the boards out when I was a young man at an IPC Technology Market Research Conference (TMRC) meeting (remember those?). The company had a turnaround time of three days, which was unheard of back then. The general manager talked about getting in his car with a package containing some hot boards and chasing down the delivery truck because they didn't have the package ready when the truck made its regular stop at their dock. I heard that story over 30 years ago, and I'm still telling it to this day.

When I was a humble sales guy on the road, I made it a point to visit customers on snow days, if for no other reason than to embellish my reputation as a dependable and reliable salesperson who would do anything for his customers. I also made sure to show up at a customer's door when we messed something up, the boards were late or scrapped, and the customer was furious. I knew it would make them feel better if they had a person to yell at and a fresh butt to kick. Interestingly, these tactics worked every time. For instance, it is much easier to be furious at a hypothetical company figure than a real person standing in front of you.

The truth is that great customer service is unforgettable; the stories are eminently repeatable. And we repeat them to the point that they become legendary.

Never Get Mad at a Customer



Nothing is dumber than getting mad at a customer. What is the point? These days, when it is harder than ever to get a new customer and even harder to keep that cus-



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tomer amidst the barrage of competition coming from all sides, there is nothing more counterproductive than getting mad at one of your customers.

Look, I know customers can be demanding. They can be hard to deal with and sometimes even totally unreasonable. But that doesn't matter, because part of being in business is servicing your customers, providing them with whatever they want. Note that I said what they want, which is not always what they need, or what you think they need. No, you must give them what they want.

As the airlines are fond of telling us, in today's market, customers have many choices. (Actually, that isn't quite true; we have too few choices and are stuck with lousy airline service, but that's a column for another day.) In our case, in our industry, there are many choices our customers can make; if you don't believe that, just ask them. But our customers have many options when they buy their circuit boards. From the cheap guy down the street to the cheaper guy across the big pond, they have all the choices in the world and they exercise them freely all the time. Vendor loyalty is at an all-time low.

So, ladies and gentlemen, that is why you can never get mad at your customers. You must treat them like gold and make sure you are so valuable to them that they will never want to leave you. The trick is figuring out how to do that. How will you make sure that you keep your customers happy today and in the future?

Here are five ways to make sure you are so valuable, so loved by your customers, that they will never want to leave you.

1. Anticipate your customers' needs. Too many of us are sitting around waiting for the next demand to come down from our customers. This is wrong, and it turns us into victims. The better way is to learn everything about your customers, their end-products, their market, how they handle your boards, what they do with them when they arrive, and everything else they really need from you—and then give it to them.

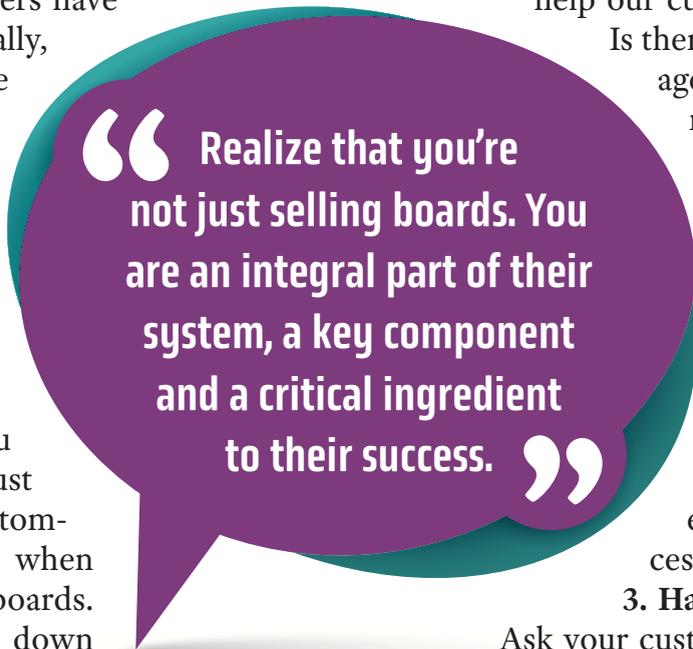
2. Realize that you're not just selling boards. You are an integral part of their system, a key component and a critical ingredient to their success. Our job is to figure out how we can help our customers be successful.

Is there a better way to package our boards that will make it easier for our customers? Can we help them with their designs? Maybe it's meeting with customers and their end-customers and listening intently enough to come up with ways to make everyone more successful.

3. Have regular check-ups.

Ask your customers if you can meet with them on a regular basis to make sure you are on the right track. Ask to visit face to face and find out how you are doing. Have a set of questions prepared so that you can develop a file on each customer that includes their special preferences so you can be outstanding and valuable.

This is a team effort. Don't just leave it up to the salespeople to talk to customers. Your customers belong to everyone in your shop so make sure that all your key people are on a first-name basis with your customers' appropriate counterparts. This could be the most important thing you have ever done. Customer service is a whole company effort. Every

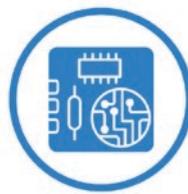


single person in your company is a customer service person and a salesperson. And it's your job as a leader to make sure that everyone in your company, from the guy in plating to the woman in drilling, knows everything they can about their customers.

4. Create a customer satisfaction team. Let it be one that does nothing but focus on the customers and the way your company can please them. This team should include representatives from every department in your company. They should meet at least once a week to work on ways to delight their customers. Can you imagine that? Can you imagine spending one hour a week focused on your customers and how you can make them love you? It's so simple, yet so rare. I don't know of a single company in our industry that is doing this today. So, you can be the first. Give it a try and you'll quickly be the most outstanding company in a virtual wasteland of customer delight. And yes, there is one more—always under-promise and over-deliver.

5. Call your customers. This is especially important if you run the company. They will take your call—you are the president, after all—and they will be anxious to talk to you. You will not only gain great insight into your customer and his needs, but you will impress him with your dedication to making sure he is delighted. The very action of picking up the phone and calling your customer will go a very long way toward letting that customer know how much you care. And once again, almost no one in our industry is doing this; you will be outstanding in the truest sense of the word.

Please give these ideas a try. This country is losing so many PCB companies that it is time we really stepped up to make sure our customers never even consider taking their business elsewhere. **PCB007**



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A Mini Manufacturing Ecosystem

The New Chapter

Feature Column by Paige Fiet, TTM-LOGAN

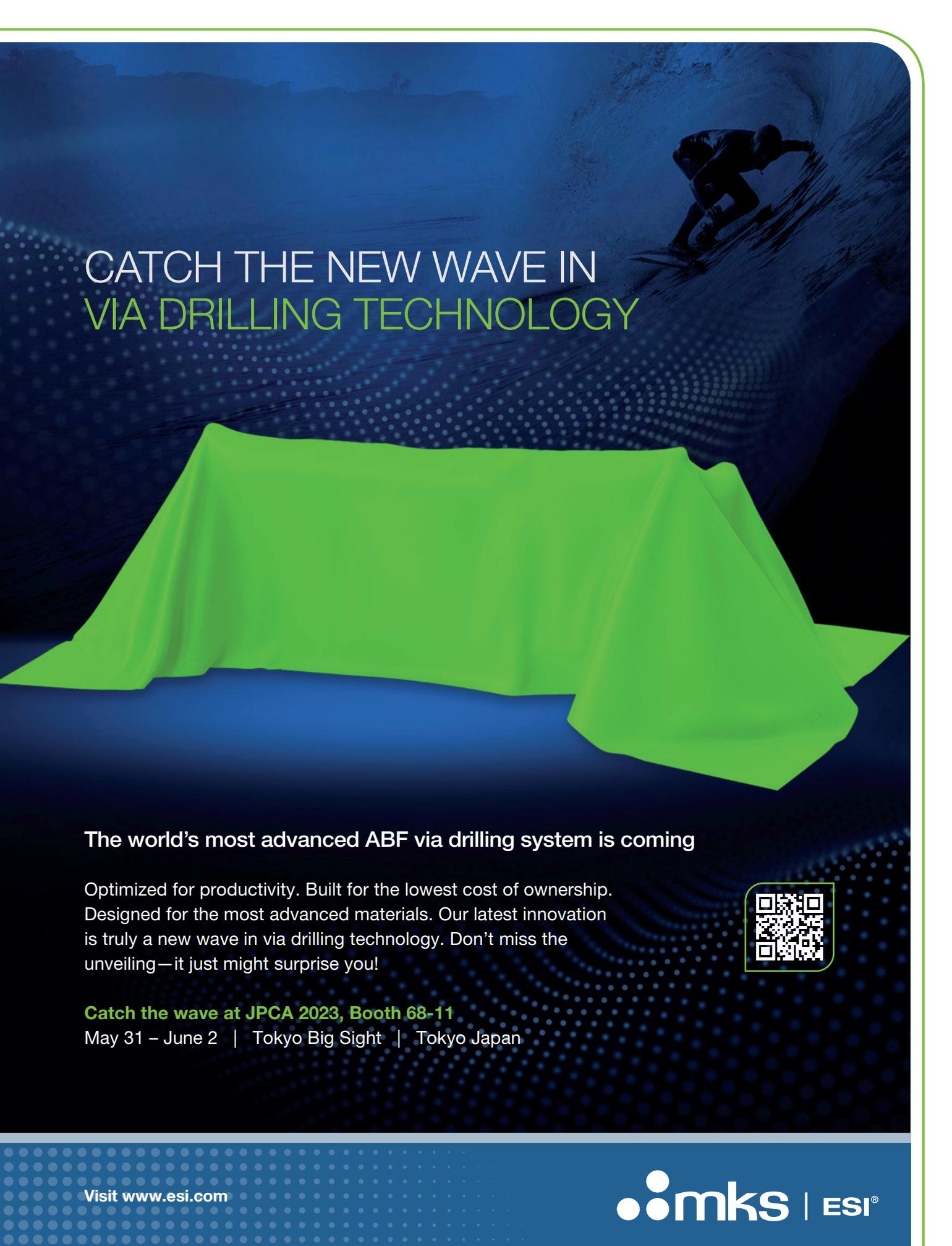
A manufacturing facility is set up like a miniature business ecosystem. Within it, a product is handed from one department to another, with more features and materials added in each step in the process. Most of the time, one process will greatly affect those that follow it. For example, targets created at an imaging step will verify proper registration in a drill step. Sometimes the effect can be negative, such as when too much warp in a panel at the lamination stages creates downstream issues for imaging.

Unfortunately, even processes within a department can cause headaches for subsequent processes. A thicker layer of solder mask on a panel may require a longer tack dry and

exposure time. An imaging defect in resist can cause troubles in etching, and the list goes on. But there are remedies. For instance, creating a culture where the next department is viewed as “the customer” can help achieve desired quality standards in all departments.

The first step in developing this type of culture is to open lines of communication. How does one department know the targets of other departments in the process if they never see what they do? Creating and maintaining an open dialogue that helps solve issues can allow, for example, each area of the manufacturing floor to get the tools they need to properly perform the job. Holding meetings with those who make up an entire department pro-





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vides time to discuss areas of mutual concern so both sides can understand the impact of their actions. They are a time to brainstorm a plan of action.

Promoting a team environment leads to better communication. Each department should feel part of a team working

toward a common goal for the entire facility, which should reduce competition across departments. (If there is competition, it should be within departments to continuously improve the quality of their own work.) Giving out small awards, like a gift card from a local business or a team T-shirt, increases team morale, promotes a stronger work culture, and achieves long-term goals. Teams should also participate in activities outside their day-to-day work activities, such as movie days, golf tournaments, and pizza parties. This helps build personal relationships, trust among teams, and better communication among colleagues.

Another important step is to establish cross-training among multiple departments. For many, it's helpful to talk about how a bent corner on a panel can cause an inkjet machine to flag an error for the wrong thickness, but few will understand it completely unless they see it done. If there's not enough time to fully cross-train an operator, then departmental trainings and presentations are the next best thing.

Site tours are a way to quickly show processes, too. Once an employee has spent a few months learning the business, a tour can show them the critical role their process plays. The tribal knowledge that is learned from working

in other areas of the manufacturing facility is priceless for everyone. It only takes a couple of people to understand all the steps in the process for a department to benefit and learn as a team.

The best way to maintain cross-training, communication, and team spirit is to have a unified leadership team. The operations and engineering teams should meet with all areas of the department to assist with this. Good leaders encourage all operators within a department (across areas and shifts) to learn about other processes in their area and to discuss opportunities for improvement. Leaders set the tone for everyone to feel part of the group—one unit working together toward a common goal.

A company culture that invites all manufacturing areas to improve their processes is a winning strategy for everyone. It starts at the top, with leaders who assist both individual departments and the entire facility in achieving long-term goals. Well-trained operators know what is required of their products before they leave their area and go on to the next department. In a sense, they act as the supplier serving its customer, and thus are important to the success of the business. Internal customers can be equally important. **PCB007**

“ Each department should feel part of a team working toward a common goal for the entire facility, which should reduce competition across departments. ”



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

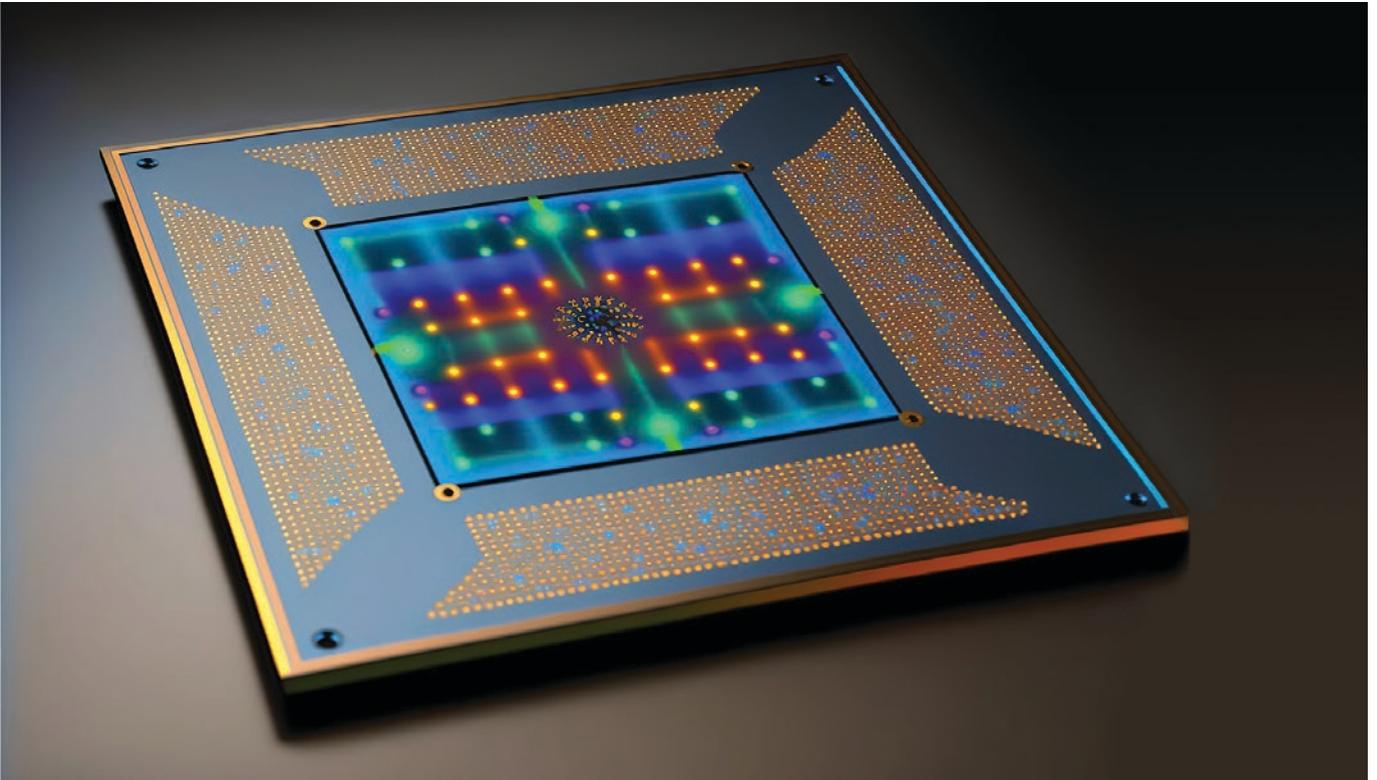
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A Focus on Ultra HDI

Interview by Nolan Johnson

I-CONNECT007

John Johnson is relatively new to American Standard Circuits, but definitely not new to the technology. In fact, he was hired to focus on business development for ultra-high-density interconnects. John explains more about the process and where it's taking ASC.

John, how do you define ultra-high density?

I define it as ultra-fine lines, small microvias, sub-4-mils; layer count can vary depending on what the needs are. It can be stacked microvias, multiple stacks up to four, maybe a little bit greater than four—any layer type of technologies.

What's the ASC technology roadmap to UHDI? What do you have and what do you still need? What are the customers asking for?

American Standard became a licensee of Averatek's technology—which is the A-SAP™ process—about a year and a half ago. During that time, ASC has been getting up to speed and running the technology, looking at business, and bringing in commercial opportunities.

Before joining American Standard, I worked for Averatek and had multiple years of experience with the technology; I spent time working on installations at a variety of printed circuit board manufacturing sites. When I came here, it was natural to get that process to the next level. We're now building a lot of test vehicles, prototypes, commercial orders that are quickturns with smaller requirements.

Now we are looking at adding ultra-fine vias. We've done some copper filling on 4-mil diameter through-holes as well.



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ASC has been using outside sources for laser. But as we get into this, it's beneficial to have our own laser in-house, so we've recently put in a purchase order to get a brand-new laser drill. We have quite a bit of capital acquisition right now. We've refreshed our strip/etch/strip line (SES), and our inner layer etch/strip line with vacuum etching technology.



John Johnson

sity board. It has a function in the boards of the future as well.

Are you seeing a higher percentage of that sort of implementation as embedded is specified more often?

The boards are getting smaller and it's natural when they can take those components off the surface and put it inside.

Of all these changes, which ones are directly related to UHDI? An additive process is critical to get those sorts of dimensions in a laser drill. Which pieces are necessary to support getting to UHDI?

In a sense, they all are necessary to getting there. We have been getting into other aspects where you have embedded capacitors and resistors. We've been working quite closely with the folks at Quantic in terms of the Ticer materials and the OhmegaPly® materials as well.

It all must come together because ultra HDI needs many different aspects. The Averatek process that we're using as our vehicle to get to ultra-fine lines is the cornerstone. But you can't do fine lines without ultra-fine vias. We've added copper filling ability for our microvias and we've been upgrading our plating lines. We're moving to insoluble anode technology with special brighteners and levelers to control the plating distribution better from surface to the via; there are many pieces that make ultra HDI.

You mentioned embedded components. Are you finding that sort of design decision going hand-in-hand with UHDI?

That technology has been around for quite a while, probably since the 1980s. It's not necessarily part of ultra HDI as we describe it today, but back in those days, it was a very high-den-

It's a key method for space savings there.

Yes. There's a lot of interest these days for package substrates, which is nothing more than ultra-high density; we are looking toward that side of the business as well.

We all know that UHDI has a lot of value in Mil-Aero, DoD, but your UHDI work is not necessarily in that space. What non-DoD sectors are you working in?

All sectors, actually. We are working with DoD customers, but in some cases, they are working on new designs that are needed. Essentially, finer pitch components are really the push.

If you look at a 0.5-millimeter BGA, we have customers that are struggling to get those routed. They need to go to 2-mil lines and spaces or finer to route them.

However, 0.5 millimeter won't be around long; we will get down to 0.35 mm and 0.3 mm. That will drive the industry crazy because you must have finer lines and spaces throughout. Then you get to a point where you can only build these stacked microvias so high before reliability becomes a factor. When you look at these aspects, military will need UHDI; they cannot go offshore for this technology, so they're the greatest U.S. market we'll have.

The same requirements are in the chip scale packaging substrate side of the business, but there are other applications that are all over—semiconductor testing, for example.

You have all these different technologies. Medical is a huge application. The one neat thing about the A-SAP™ technology is it allows for materials other than copper and nickel. You can make circuits out of gold on the surface of a flex, for example. You can have products that are biocompatible. And that's really an interesting part of the market that we're looking at right now.

Speaking of markets, are you finding that customers are seeking you out, or are you actively marketing to get the word out? What's the marketing dynamic in offering this?

We have a situation today where our sales team has been actively pushing for work, but customers come to us because they see our marketing. Averatek is part of our relationship; they have been actively looking for customers for us, as well. It's all coming together, and it's really getting quite busy.

What about prospective customers who want to use this technology, but need to know there's a second source? Is there anyone else in your space?

It's true that there are specialties we have that others don't. There are other licensees of the A-SAP technology, though, and they're great shops. They have their own capabilities and their own focus in how they're implementing the ultra-high-density interconnects in their operations.

We believe that we have the mix of technologies that are needed; we can incorporate it not only in rigid, but also rigid-flex and flex. That focus helps.

We've looked at the ultra-thin foils, and they have a place, but I think we see the technology

going much further below 25-micron lines and spaces; 15 micron is pretty much the rigor for package substrates. So, you need to be able to get there, and just using ultra-thin foils makes it a lot harder to get into that arena.

Does this change the CAM process? How significant a change is the CAM process, the interaction with the customer to get the design data ready to go, for ultra HDI?

There are design rule changes that they need to think about, in terms of intermixing the tool-kit that's out there today for design. You obviously have filled microvias. You have via-in-pad plated over. You have all these things that, when you put them on the surface of a board,

require a lot of plate-up. Those multiple plate-ups don't play well with ultra-high density externally in a board.

They must think about putting that on the first layer, or further in the package. You can have that externally without any issue, as long as you don't

have all the multiple plate-ups.

You can still do it with the multiple plate-ups, but the cost goes up dramatically, and it makes it much more difficult to get good yields. That's what we're advising our customers to do—look at it from that standpoint.

There are other things like solder mask and final finish concepts they need to think about; you have to use aspects such as solder mask-defined pads rather than copper-feature-defined pads. Those are some of the things you have to look at with final finish.

It sounds like the best way to start a sale for UHDI work is to get involved at the design start.

Absolutely. We like to do that anyway with our customers. Any manufacturing plant trying to build high density boards today really needs to



“ It's all coming together, and it's really getting quite busy. ”

be very involved with their customers' design teams and help guide them through that process. It will make it a lot easier for both parties, and result in a board that's more cost-effective in the long haul.

Do you see substrates in ASC's future? Is that a direction you think you want to head?

Yes, we do. We have some testing going on in that realm, and package substrate demand won't be filled by the U.S. market—it's just too large; Asia will always have that market. But there are areas where IP becomes a concern, where it's defense-oriented, where they need that source stateside, or at least in North America. From that perspective, that's really where we will have a play in the marketplace for package substrates.

How close are you to doing package substrates?

We're starting to build some demonstrators.

Do you find you need to hire toward new skill sets for the UHDI work, or can you move existing staff to this area?

We're moving people over. Ironically, the technology behind A-SAP™ has been in the industry now for a while. To do ultra-fine lines requires discipline and handling and special techniques for that. But once you have that in place, you can get someone off the street and train them. You can take someone that has been building boards in our facility and bring them in. I've recently brought in two gentlemen to work with me to get to that level of expertise, and it's going along quite well.

How has offering the Avertech process, being able to move toward UHDI, changed the dollars per board metric? So many PCB shops are finding themselves squeezed down into single-digit margins. Pricing is just razor-thin.

If you go into ultra-high-density interconnects with the same mentality that this industry has

had for the last 30 years, you're making a mistake because there is a learning curve. You cannot give it away and you do yourself a disservice if you do. At some point, we need to have a technology and a market that we can make money on.

The North American printed circuit board operations need to do more R&D, and you need profitable businesses to fund R&D. Ultra-high-density interconnects is one of those businesses. If we give it away now, like the song says, "When you ain't got nothing, you got nothing to lose." We won't help our customers or the defense infrastructure. We have to charge more for that type of technology.

Final thoughts?

What you see with American Standard is that we have capabilities here that are really exciting, separate from ultra HDI. We're building 34 layers and a lot of metal carrier work. We do quite a bit of multilayer flex. We can do book binders, rigid-flex.

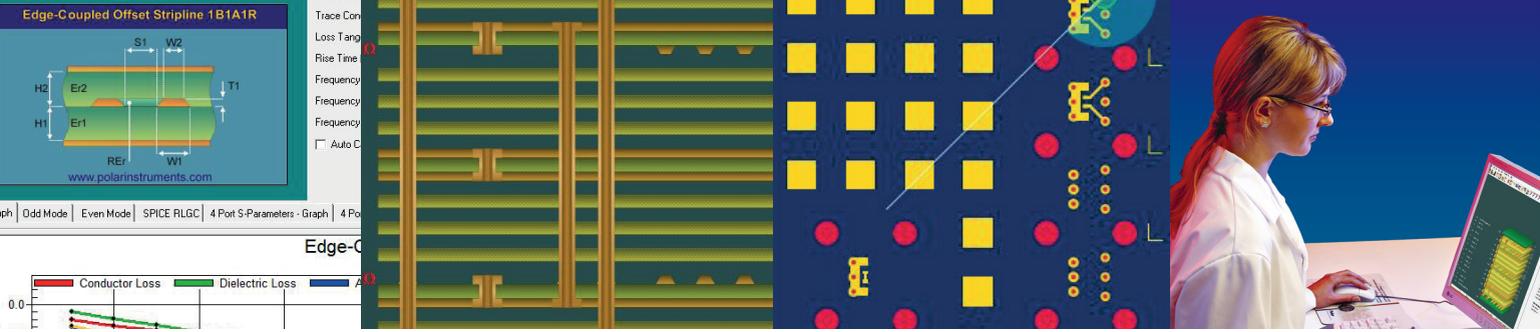
I've run my own operation for a lot of years, and I'm really impressed. We had a lot of great technology back in the day. But our technology now is awesome. To be able to walk into ultra HDI or ultra-high-density interconnects is a lot easier from that perspective.

When do you think you will be doing full production?

It will be soon because the demand is there, and we need to fill the demand. I would say by the second quarter, we'll probably be in what I would call a low volume production area, where we'll have customers that are actually building all their projects. As that grows, we'll get into higher volume later. It just makes sense all the way around.

That's a great place to finish. Thanks for talking with us, John.

My pleasure. PCB007

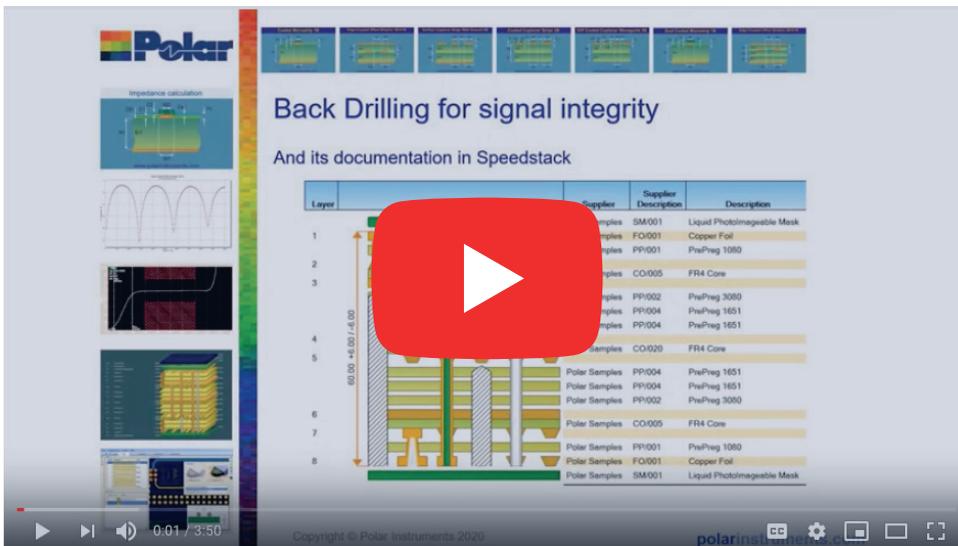


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What's an Annular Ring?

Connecting the Dots

by Matt Stevenson, Kevin Beattie, and Karla Thompson, SUNSTONE

Let's learn about annular rings, because a greater understanding can help ensure that your PCB designs successfully become physical boards. The annular ring is the space between the drill hole and the edge of the pad—a specified minimum gap around the drill hole. Don't get the impression that an annular ring is a separate part. The term is used to describe the portion of the copper pad that remains after

a hole is drilled through the pad. The annular ring of a pad is measured from edge of hole to edge of pad.

Annular rings serve a variety of purposes, and improperly sized annular rings can cause serious PCB concerns. In addition to causing shorts, small or nonexistent annular rings can create significant manufacturing delays and board reliability issues.

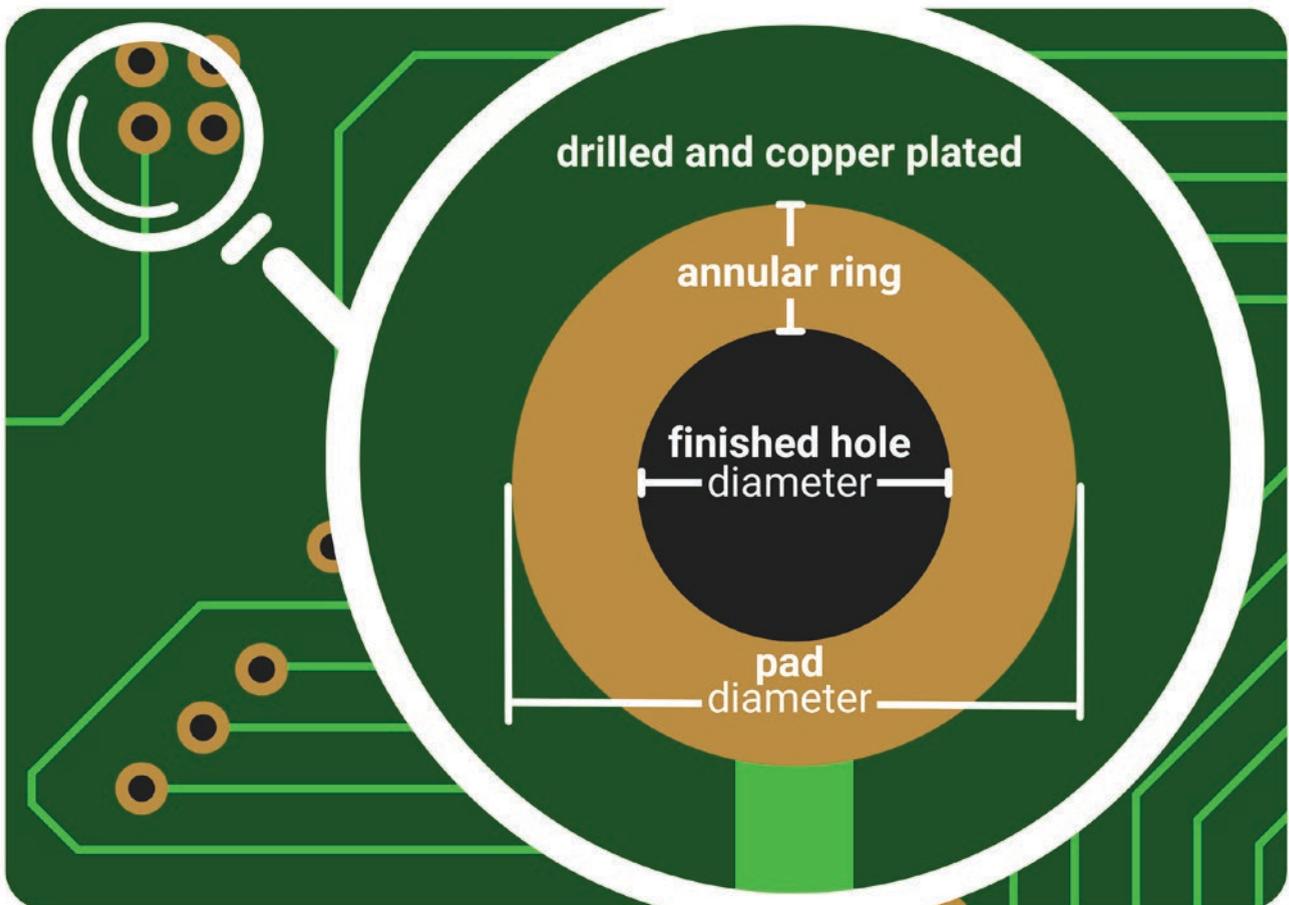
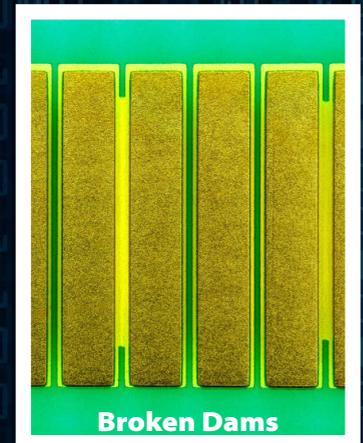
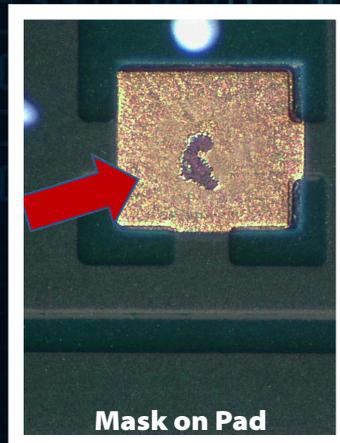
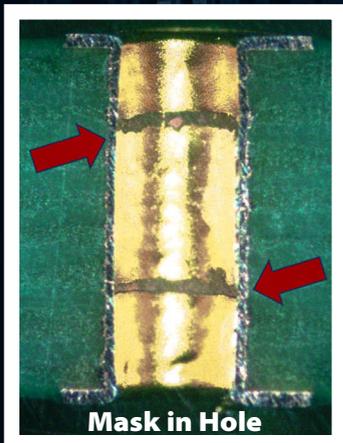


Figure 1: Magnified graphic illustrating a typical annular ring.

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What does an annular ring do?

One of the most important aspects of an annular ring is that it keeps a through-hole within the boundaries of a pad. This is crucial for solid construction and connectivity between leads, pads, and traces. An annular ring prevents a plated through-hole from shorting to the ground layer as well. On the outer layer of a PCB, the annular ring helps ensure solid construction of the entire board.

Planning for properly sized annular rings gives the PCB fabrication process room for drift—within tolerances.

In order to plan for sufficiently sized annular rings, these are the recommended pad sizes:

Inner and outer layer pads should be at least 18 mil larger than the finish hole size, though via pads only need to be 10 mil larger (typically the non-via holes are drilled larger than the finished hole size, where vias will be drilled at the finished hole size).

If the design includes any pad to trace junction minimum requirement or a higher IPC inspection class requirement, that will need to be accounted for in the pad design. For example, an 18-mil pad and a 2-mil junction should actually have a 20-mil pad. These sizes should end up creating a 9-mil annular ring target for leads and a 5-mil annular ring for vias to allow for process variation and still meet the requirements.

If you have all the needed numbers from your PCB manufacturer, you can use the following equation to calculate your minimum pad sizes.

$$L = a + 2b + c$$

Where:

- L is the required via land size
- a is the internal diameter of the drill hole
- b is the minimum annular ring size
- c is the fabrication allowance or allowed drift for the drills

What happens when annular rings are too small?

It is easy to see why annular ring size can be a problem. Many times, designers want to use the largest through-hole drills to save cost. At the same time, they want to pack their designs tightly so that the required PCB can be smaller. However, larger drill holes mean larger annular ring requirements. Good design requires being aware of the needed trade-offs.

That's because an annular ring that is too small can cause manufacturing and quality issues. One of the most common is breakout, when the drill hole crosses over the edge of the pad. Breakout can be a serious issue because it can lead to shorts and poor connection between the lead and the pad.



Figure 2: Example of annular ring that is too small.

Too-small annular rings can also cause longevity issues for a PCB. While the PCBs may work great at first, the small annular ring could cause a failure somewhere down the line.

Usually, though, when annular rings are too small, the PCB will encounter shorts or just simply won't work. There have been instances where small annular rings caused an "unintended thermal fuse situation"—that's right, the PCB caught on fire.

How common are undersized annular rings in PCB manufacturing?

Ideally, a PCB design will be reviewed for issues like undersized annular rings before it hits the manufacturing floor. This review helps ensure the PCB can be created within IPC specifications. IPC-A-600 covers the acceptability of printed boards, while IPC-6012E governs "rigid printed boards." They both define different classifications for minimum annular ring requirements.

For example, in IPC-A-600, the different classes define requirements as follows:

- **Class 3:** No breakout, though holes are not centered in the pads; the annular ring measures 2 mil or more.
- **Class 2:** 90° breakout or less, with the conductor junction measuring 2 mil or more.
- **Class 1:** 180° breakout or less, as long as the conductor junction is not reduced by more than 30%.

Note that only Class 3 requires some amount of leftover annular ring. A quality-focused manufacturer will do everything it can to meet that requirement.

Unfortunately, undersized or absent annular rings are very common in PCB designs. We sometimes see as many as 30% of jobs in the queue put on hold for annular ring issues. This can delay production for hours while the designer and manufacturer work to resolve the issue.

You can avoid annular ring problems in your PCB designs by carefully considering the drill size and pad sizes you want to use. This can certainly affect cost, but it may be worth the difference. Note that your PCB design software probably has configuration settings for minimum annular ring widths. Make sure these settings match IPC-A-600 Class 3, and you should be ready to go.

Another option you can use to avoid annular ring issues and reduce the chance of breakout is to add teardrops to your pads and traces. This can be a very effective method for reducing annular ring issues.

It's important to remember that annular rings play a crucial role in PCB functionality and reliability. Poorly planned and undersized annular rings are a leading cause of PCB manufacturing delay. By realizing these important facts and by planning ahead, you can keep annular rings from derailing your PCB manufacturing plans, budgets, and timelines. **PCB007**



Matt Stevenson is vice president at Sunstone Circuits. Download *The Printed Circuit Designer's Guide to... Designing for Reality* by Matt Stevenson.



Kevin Beattie is a production manager at Sunstone.



Karla Thompson is a CAM manager at Sunstone. To read past columns, [click here](#).

Customer Service Starts With a Quality Product



Feature Interview by the I-Connect007 Editorial Team

Sibor Circuits is located in the high-tech hub of Ontario, Canada, where CEO Simon Etherington is in the unique position of finding more U.S.-based military contracts than in his own domestic market. But those jobs provide stability and, with great customer service, open the door to less complex contracts.

Barry Matties: *Simon, what is your forecast for the printed circuit board and electronics manufacturing industry? What markets should we pay attention to?*

For several years, we've been reinvesting in automation and making sure that our certifications ran parallel with looking for opportunities to keep work domestic. The market for more sophisticated circuit boards, especially for military and aerospace products, will become a key driver for domestic manufacturing in North America.

Matties: *It seems like military armament inventories are dwindling. Do you see an uptick in military contracts?*

It's taking me longer to acquire jobs than I'd like, and there are probably several reasons for that. Even though we're a Canadian company, 95% of our sales are U.S.-based. We have had more success doing U.S. military work than Canadian. I'm diligently working on getting more domestic Canadian military work. You have to earn those opportunities and the path is not short.

Matties: *It's who you know. Is that what you're saying?*



Simon Etherington

Yes. We're about to improve our website so that it runs a program that reaches out and finds customers; it will help, but this is definitely still a "who you know" business.

Nolan Johnson: *It sounds to me like you are specifically targeting military work.*

I am because I know that it's a stable job; it won't go offshore, and as long as I do good work, I'll keep the job. That's the reason that I like the military now.

We've seen it with certain types of military and medical products as well where we've built some very sophisticated, large flex boards. There are some things that we do in processing that really make a difference in quality. I also think there will be a number of sophisticated commercial boards that are likely to stay here. Much of the military product is made from commercial product. Did the military buy military-qualified components? No, they're commercial components, and you come to a crossroads. If you can make the high layer-count sophisticated boards very well, then I suspect the customer will ask us to do some of the less difficult work as well because our service is that good.

Johnson: *So, the point in your spear is to get in on the DoD military work and then let your customer service excellence speak for itself.*

Yes, and military will probably work out quite well for us because of their need for engineering excellence. We're bound to do well once we get our hooks into an account. **PCB007**

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My **Journey** From Atomic Lattices to Circuit Boards

Material Insight

by Preeya Kuray, AGC MULTI MATERIAL AMERICA

Editor's note: Welcome to our newest columnist, Preeya Kuray, a materials scientist who will be writing about the impact of global affairs on PCB R&D in America, as well as the growing intersection between the PCB and chip packaging industries.

Although I fell into the PCB world somewhat accidentally, I remember the exact moment I knew I wanted to become a materials scientist.

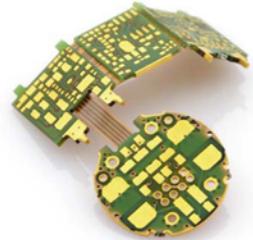
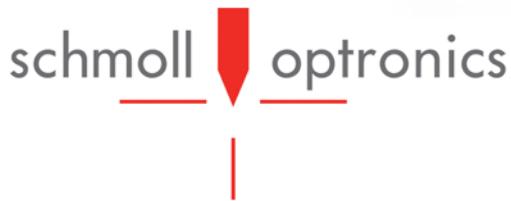
At an undergraduate engineering information fair, I saw the breadth of research possible within the materials science discipline: superconductors, synthesizing gold nanoparticles for cancer cell detection, and organic photovoltaics. It was all endlessly fascinating, and my curiosity drove me to ask what was possible, and more importantly, what was next. I didn't

know the answers, but I knew that I needed to be a part of it.

Ten years later, after completing my PhD in materials science engineering, I found my current industrial R&D role: designing next-generation buildup films for HDI and chip packaging applications at AGC Multi Material America. Now I can put my passion and experience in materials science into practice for the PCB world, working toward answering questions like these: If the chemical structure of Component X is changed, how will this impact the overall buildup film properties? Will Additive Y bolster or completely dismantle my dielectric constant? Will incorporating Chemical Z enhance copper peel strength while still maintaining low moisture absorption?



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These are the kinds of questions that reverberate through my mind daily. I have learned that creating competitive buildup films is a fine balancing act, akin to walking a tight rope: gain one property, potentially lose another. At the end of the day, you're faced with the difficult choices of figuring out what's important. What do customers *truly* care about, and what can we let go of?

As a newcomer to the PCB field, my job is not only to create new materials but to learn as much as I can from the PCB veterans, those who have been in this industry for the past two to four decades. I am often regaled with stories from my senior colleagues on what it was like working in the PCB industry in the 1990s vs. today. I've learned that in the '90s, North America led PCB production with 1,500 operating board shops and production valued at \$11 billion. Today, there are less than 200 board shops in the United States, and production is valued to be only about \$3.5 billion.

What happened? How did we get here, and where are we going? These are the questions I hope to address in this column. How did the industry shift from North America to Asia over

the last 30 years? What are the implications of Biden's Defense Production Act, and how will it impact the PCB supply chain? What does the growing integration between chip packaging and PCB technologies mean from both an economic and scientific perspective?

I look forward to investigating these hot topics and sharing the knowledge I acquire from the PCB veterans and pantheon, lacing in bits and pieces of my own perspective as a materials scientist new to the field. Together, I hope to answer the pressing questions: How did we get here? And more importantly, *what's next?* **PCB007**

Resource

1. "Comparing PCB Industry in China and the United States, How Small and Medium-sized Enterprises Can Do Better," PCBA Manufacturers, Sept. 27, 2022.



Preeya Kuray, PhD, is a materials scientist at AGC Multi Material America.

The Mindset Behind the Customer Experience



Brian Wallace, CEO/consultant with HR Strategies Now in Houston, Texas, shares a couple of thoughts on the importance of understanding the connection between customer experience and the employees' mindset.

"Customer experience drives more business and revenue, but that's only part of it," he says. "It's really all about helping leaders understand how to position their employees to deliver a great customer experience. It's more than connecting with the customer and delivering that experience; it's about making sure that your employees are properly geared to do that. That's an important issue."

Wallace says there are several key elements at play to achieve this. "First, have solid hiring practices so you hire employees with a mindset to be

well positioned to engage with customers. Second, create a safe and innovative work environment where employees can come to you with ideas or challenges they're experiencing with their customers. This will help them figure out a way to exceed customer expectations. Last, make sure that your leadership team continues to promote that mindset and helps manage that customer experience."

A pivotal point in determining whether businesses succeed or fail rests in the quality of their middle management, in particular—those people who translate strategy into operational activity and interact with employees. It's a very dynamic and powerful thing to have leaders who understand the connection between customer experience and their employees' mindset. If employees are not working under good leadership, they'll find something else. Today, they have the agency to go look for a good culture.

The 7 Core Principles of Customer Service



Source: MBA Knowledge Base (www.mbaknol.com)

Electrodeposition of Copper, Part 4: Addition Agents

Trouble in Your Tank

by Michael Carano, IPC CONSULTANT

I've spent a good part of my career working on disciplines such as process control and technology management, and troubleshooting complex issues in electronics manufacturing. I also spent quite a bit of time formulating chemical processes and understanding the underlying principles of what makes these processes function the way they do. Everything is connected. It's all about the entire process and its various constituents.

When I first started on this, there were no microvia designs, and most through-hole ratios were easily manageable at 6:1 to 8:1. However, that began to change with the advent of more complex interconnect designs and the requirement of much higher reliability. Soon, we

began using insoluble anodes, periodic pulse reverse plating, and new solution additives, and looking differently at solution agitation.

Adding to the complexity of high-end, high reliability printed wiring boards were organic addition agents and their functions related to the physical properties of the electroplated copper deposit. These addition agents are often referred to as leveling agents and brighteners.

The Critical Role of Addition Agents

It is no mystery that without these specially formulated additives, the grain structure and physical properties of the electroplated copper would be less than stellar. You also can



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assume that without additives, the copper deposit would not be able to withstand the high temperature and mechanical stresses subjected to the board during assembly and service in harsh use environments.

What functions do these additives perform? Are they simple? The short answer is “no.” As stated earlier, the complexity of circuit board designs today, and certainly in the future, requires new and improved plating additives, as well as methods to control them. Traditional through-hole via (direct current) plating parameters and chemistries are not optimal for these more complex structures. Worse yet, metallization of boards with blind and through-hole vias require trade-offs in plating conditions and chemistries to achieve acceptable results on through-holes and in the blind vias.

The additives, which are sometimes referred to as brighteners (for the cosmetic effect on the copper), are formulated with multiple components that can be blended into a single container or added individually as needed. (The

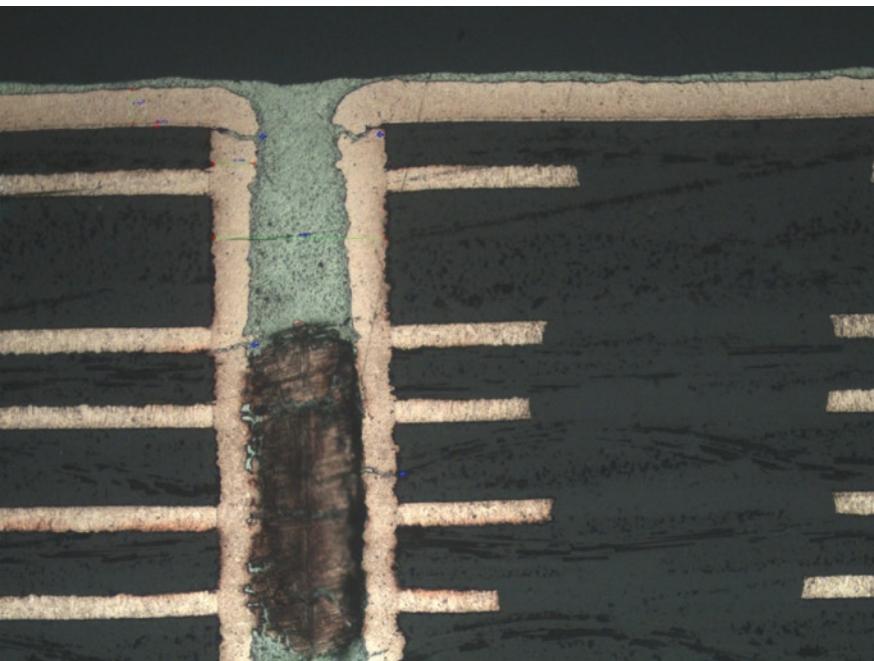


Figure 1: Barrel cracking and corner crack due to brittle copper deposit. Also, note the rough nodular deposits in the via.



Figure 2: Rough spots due to poor leveling of the copper.

latter is recommended for tighter control of the process.) So, what are these components, and what functions do they perform?

In the absence of these organic additives, copper grains grow preferentially on surface defect sites. The copper then grows along preferred copper crystal planes. The plated copper does not exhibit the fine-grained equiaxed structure that is beneficial in providing ductility and tensile strength to the deposit. Under these conditions, the plated copper is dull (matte) and brittle or non-ductile. This causes the plated copper to fracture when stressed, due to the deposit's poor ductility. In general, additive-free or low-additive plating solutions typically produce deposits with columnar structure, which can lead to cracking in solder float tests (Figure 1).

Copper grows faster on protruding topographies (high spots on the surface), as well as high spots in the via caused by poor drilling. These high spots typically form because of higher primary current density (Figure 2). The primary current distribution is mostly dependent on the board

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geometry and position in the plating cell, as well as on the absence of properly formulated organic addition agents or low concentration of the addition agents. Fortunately, the function of the organic addition agents, when at the optimum concentration in the electrolyte, mitigates primary current distribution and shifts the plating to secondary current distribution. These addition agents suppress plating on the high-current density areas, which then shifts more of the copper deposition to low-current density areas, such as through-hole and blind vias.

As the defects in Figure 2 show, the plating is primarily being attracted to high spots on the surface, which then adversely affects

uniform plating distribution. In summary, organic addition agents are complex and perform critical functions related to the plating process. It is very critical for the process engineer to understand the role of organic addition agents and how they affect plating quality and reliability. **PCB007**



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

To read past columns, [click here](#).

The Most Important Thing About Customer Service

Barry Matties talks to Marge Laney, founder and CEO of Alert Tech SMT, about the importance of this one simple tool in effective customer service.

In your 40 years in business, what do you find most important about customer service?

Communicating with your customers is most important. The reason why we've been so successful in our short time in contract manufacturing is that we're very customer-oriented and transparent. Before I was in contract manufacturing, I sat on the

other side of the table as an OEM, and I noticed that people didn't communicate. When you sent files or a message, you weren't sure whether you'd hear back. As an OEM, we were very involved in dealing directly with very large retailers and understood the importance of good customer service. We brought that culture into our contract manufacturing business, surprising everybody. "Wow, you people are great," customers said. "You communicate with us, and you care about our products." Culture is important. When we bring in a customer, there's mutual respect and a good partnership. I don't want it to

come down to looking for the cheapest deal. No, it has to be a good fit.

As hard as we try to provide good customer service, there are always bumps in the road. How do you overcome those?

For me, customer service means talking about those challenges up front. It's easy to have a good relationship when things are going well. But when things don't go so well, that's when you find out who you really are and what your relationships are really about.



Marge Laney

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MilAero007 Highlights



Nathan Edwards to Lead USPAE as New Executive Director ▶

Effective May 1, 2023, Nathan Edwards will transition into the role of executive director of the U.S. Partnership for Assured Electronics (USPAE). Currently serving as director of government development, Edwards will replace Chris Peters who will continue with the organization as a senior advisor, providing continuity and focus on special projects. As executive director of USPAE, Edwards will be responsible for establishing and growing the organization to help ensure the U.S. government has access to trusted, secure, and resilient electronics supply chains.

BAE Systems, Microsoft Join Forces to Equip Defence Programmes with Innovative Cloud Technology ▶

BAE Systems and Microsoft have signed a strategic agreement aiming to support faster and easier development, deployment and management of digital defence capabilities in an increasingly data-centric world.

Fresh PCB Concepts: PCBs for Harsh and Extreme Environments, Part 2 ▶

Designing a PCB for a non-demanding environment can be a daunting task. There are many issues to consider, especially as you make certain decisions. But when I think about some of the challenges unique to extreme environments, I am amazed at the robust technology that is available. There are also negative effects of altitude, vibration, shock, and heat that plague the electronics systems that we rely on every day.

Panel Discussion: CMMC and Cybersecurity ▶

The electronics manufacturing sector faces unique challenges when it comes to cybersecurity, given the highly sensitive nature of the information that it handles. With the introduction of the Cybersecurity Maturity Model Certification (CMMC) framework, businesses will soon be required to meet specific, more stringent cybersecurity standards to bid on Department of Defense contracts.

Inmarsat Government Completes Cross-country Demonstrations of L-TAC Service ▶

Inmarsat Government, the leading provider of secure, global, resilient, mission-critical telecommunications to the U.S. government, announced it successfully completed cross-country, multi-site demonstrations of Inmarsat's L-band Tactical Radio (L-TAC) service.

Lightning Speed Laminates: Optimizing Thermal Management for Wireless Communication Systems ▶

The term wireless communication has been around for many years, and it can mean many different things. The wireless communication between your mouse and your computer is very different than the wireless communication between a satellite and its ground station. The PCBs that are used for wireless communications are as diverse as the term. As a general statement, a more complex wireless communication system will require a more complex PCB.

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Positivity Boosts Employee Morale

Testing Todd

Feature Column by Todd Kolmodin, GARDIEN SERVICES USA

It's just another day at work until you get that call or text from your manager or supervisor: "Hey, can you come to my office?" I can already guess your first thought: "Uh-oh, what did I do wrong?" It's unfortunate that this is the standard reaction in today's workplace.

As managers and supervisors, the fault rests with us. Something has gone wrong, and we go into reactionary mode. In an instant the "sweep" is on to find out "who done it." Routinely, it is a blame game; conducting a root-cause analysis to find the primary cause is just an afterthought. But it's too late; employees are already in defense mode and more unlikely to cooperate or play an active role in finding the solution. "Take the hit and move on," managers say. Productivity may suffer, and employee morale degrades or drops another notch.

How many of you are nodding your head in the affirmative right now? "Firefighting" is a skill most of us have and we're quite good at it. Unfortunately, firefighting always results in some damage. Managers and supervisors are not perfect, but we must realize that how our employees perceive us can affect their morale.

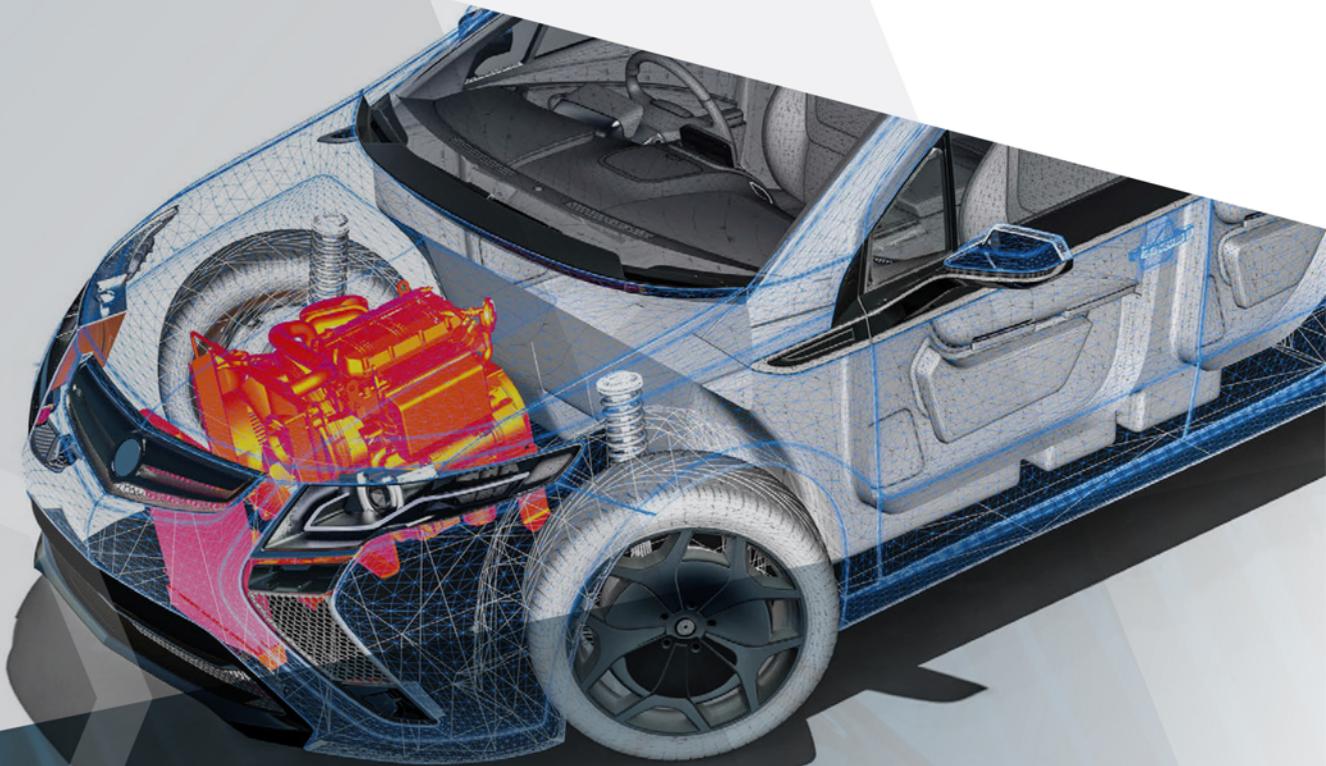
We need to take a strong, proactive role when working with our employees to solve issues. Yes, we all make mistakes, but we also do great things. Why are we so quick to point out the negative? Focusing on one wrong move or mistake among 50 successful tasks doesn't make sense, does it? Think about how it feels when customers complain about quality. You may provide a perfect, on-time product 99.9% of the time, only to be grilled about that 0.1% miss. We are all guilty of playing the





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blame game, and no one volunteers to be the one blamed.

Building morale is a process, just like any other process. To be successful, it must be consistent. The first building block to boosting morale is to be a mentor. If there is a problem, first review the situation. Don't jump to conclusions. Before looking for someone to blame, look for possible systemic problems. Many times, it is not the fault of an employee at all, so try to eliminate all the possibilities before blaming anyone. If an employee is at fault, it may be an anomaly, so it's always better to start with a mentoring attitude rather than a disciplinary tone.

When was the last time you met with an employee to say, "Great job"? (Crickets...) That silence, my friends, is a huge morale killer. Employees want to feel involved and empowered during their tenure. Negative reinforcement never works. If we already know how to fight fires and take time to blame someone, we can make time for positive reinforcement as well.

Many times, when we fail, it is due to a lack of information or misunderstanding the results. Look differently at FAIL: "first attempt in learning." Rather than jump to conclusions, we need to view it as a mentoring opportunity. Of course, there may be times when it is obvious that an employee deliberately did something wrong or made a mistake. However, we should not immediately jump to that conclu-

sion. Remember, they are part of the team. Make them feel like it.

Another obstacle is when the workplace atmosphere is less than optimal, and employees seem afraid of management. Again, this is our fault. If they just see and experience us dealing out disciplinary actions or negative reinforcement, can you blame them? If all they see is negative, fear ensues. You may be the greatest person in the world, but if employees don't perceive you that way, then FEAR—"false evidence appearing real"—gets the better of them.

We need to correct this and make the workplace positive for all employees. Leadership, mentorship, understanding, and positive reinforcement play a significant role in nurturing employee morale. When one-offs or anomalies occur, remember how FAIL and FEAR play a significant role in the scenario. Try to find the positive while navigating the negative. Employees should never fear their supervisors or managers. If they do, you are doing something wrong. Teamwork is so important today, so be that kind of a player. **PCB007**



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



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Next-generation Electroplating Systems

Happy's Tech Talk #19

by Happy Holden, I-CONNECT007

Electroplating has always been at the core of printed circuit fabrication. It was the first process I was assigned to as a young engineer at Hewlett-Packard in 1970. Of course, the copper-plating process was copper pyrophosphate, an alkaline solution—a very temperamental bath from MT Chemicals Inc. Soon after I mastered the chemistry and control of this plating solution, I had the opportunity to test and introduce PC-GLEEM from LeaRonal, Inc., a new sulfuric acid-based copper sulfate copper-plating chemistry. We never switched back.

The technical editor at *CircuiTree* was Karl Dietz, who wrote many Tech Talks about acid copper plating. At that time, electroplating systems were primitive and simple. I will focus on the equipment changes, because Karl covered most of the plating chemical changes in his columns.

Electroplating

The plating cell itself has gone through multiple upgrades to accommodate different chemistries and via constructions. The first innovation I ever saw was in 1971, when Nathan Pritikin (of the Pritikin diet) introduced me to a box plater at his PCB shop in Galena, California, and Peter Pellegrino demonstrated his flo-motion plating manifold—a fluid manifold with numerous outlets to distribute the plating electrolyte at

such a velocity and volume that it allowed a much higher current density and ion distribution even down into the plated through holes—that could plate one-mil of copper (in the hole) in 15 minutes. Since then, most of the innovations have come from plating equipment vendors and the rapid growth of multilayer and high-density interconnect PCB. Some areas of focus are discussed here.

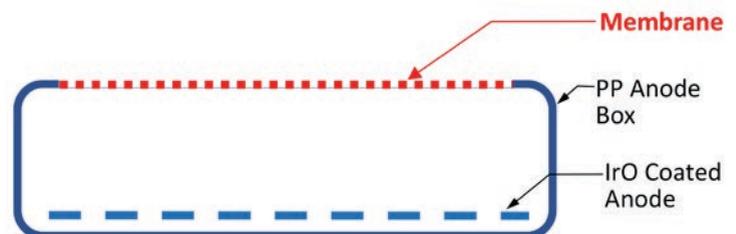
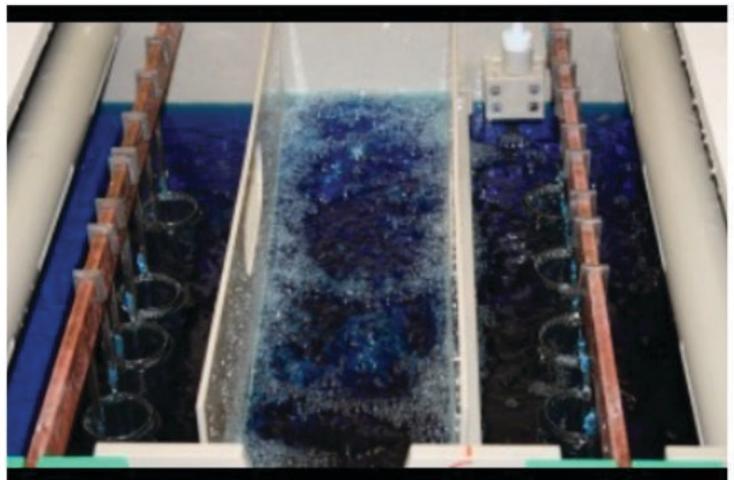


Figure 1: The use of an anode box to contain a semi-permeable membrane improves the consumption of additives when employing an insoluble anode for electroplating copper¹.

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Plating Cell Construction

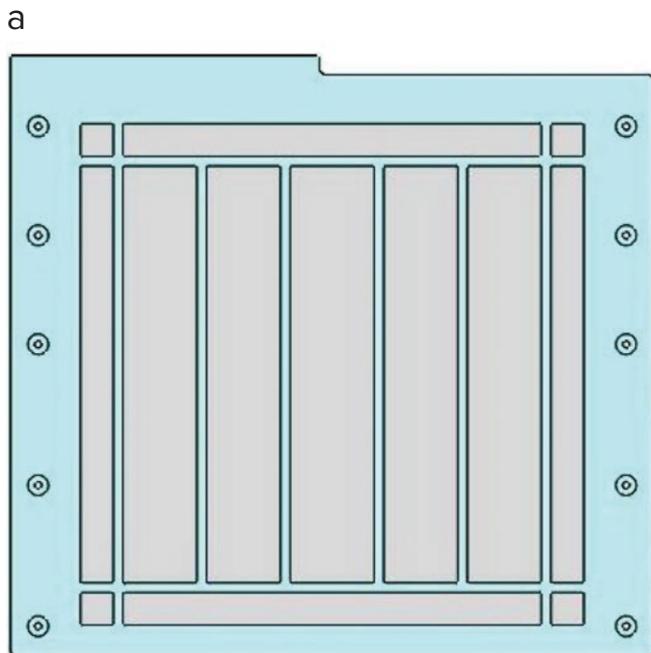
The basics have not changed much, but several innovations have been added. These include:

Anodes and Cathodes

One of the biggest innovations is the insoluble anode, constructed out of titanium or iridium oxide-coated titanium electrode and the anode membrane (Figure 1). Soluble, phosphatized copper anodes can introduce particulates and limit the ability to control plating distribution. Insoluble anodes are known to eliminate the particulates, provide considerable anode area, and the anode can be shaped to match the plated part. When matched with solution inductors and anode membranes, they limit additive breakdown and consumption normally seen with the soluble anode surface.

Segmented Anodes

Another innovation is the segmented anode (Figure 2). It showed much better control of



current distribution, especially when the cathodes (boards) are moving on a vertical or horizontal conveyor.

Solution and Work Agitation

Eductors for high-solution agitation began with flo-motion manifolds in the mid-1970s. The performance progress has been increasing ever since, particularly with new fluid nozzles providing better solution distribution without the introduction of air. Higher laminar flow equates to higher solution exchange and fluid dynamics, especially in confined spaces or blind vias. Work agitation has improved with the Z-axis added for better fluid distribution and reduction of entrapped micro-bubbles. Fluid dynamics is controlled by improved pumps, filters, and integrated support equipment (Figure 3).

Transport Systems: Vertical Conveyors and Hoists

Laser distance units were first employed by Hewlett-Packard's PCB facility in Loveland,



Figure 2: The use of segmented anodes, in conjunction with separate DC or pulse-plating power supplies, allows much finer control of cathode current densities and distributions. This is very important for newer copper via filling chemistries and for apparatus that employs conveyORIZED cathodes (panels).

(Source: Atotech² and Ludy³)



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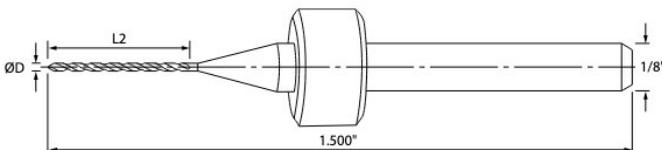


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4 Facet Point Geometry

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

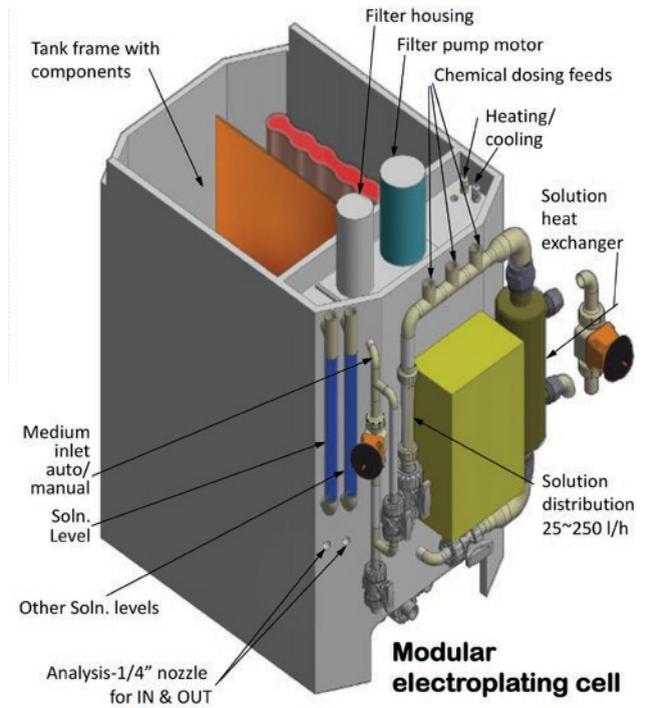
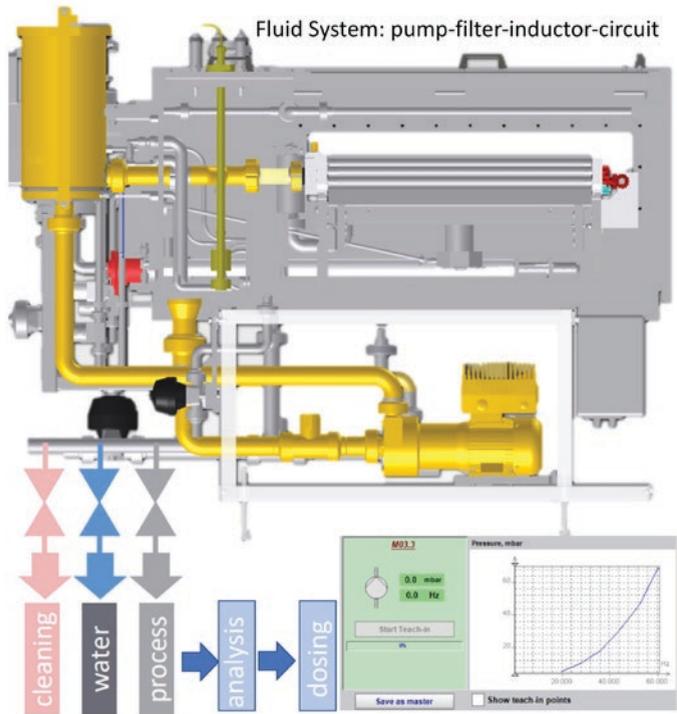


Figure 3: Advanced plating cells have been engineered with advanced filtration and solution agitation to ensure the best via filling, as well as cooling and chemical analysis and dosing. (Source: Atotech and Ludy)

Colorado, in 1975. By driving the hoists with variable-speed motors and using the HP laser surveying system to measure the precise location of their various hoists, they could accelerate and decelerate to the exact center of process tanks. This saved precious minutes in hoist travel times and ensured that none of the hoists collided.

Automated Racking

Robotic and articulating plating flight bars are now employed to rack PCBs into the plating carriers and ensure that a good electrical contact is made. Figure 4 shows some of the many simple robotic arms used to rack PCB panels. The articulated flight bars allow hoists to carry two sets of cathodes but move them closer in non-plating cells to save space.

Control Systems, Sensors, and Chemical Dosing

Programmable logic controllers (PLCs), with their associated networking capability

and display graphics, have emerged as the most popular control system. With their associated sensors and monitors, they are the workhorses of the control field. As seen in Figure 5, they can control PCB panel movements, as well as power supplies, pumping and filtering, chemical sequencing, temperature and analysis, and displays and warnings.

Modular Power Sources and Rectifiers

Modern current and voltage sources with digital control and modular design are now common. The modular system design can use identical rectifier modules, and the increase in output power through parallel or serial operation of the individual modules provides flexibility for plant expansion, production changeover, and process changeover. Redundancy is also guaranteed in the event of a component failure.

In the course of modularization, multichannel systems are installed, anodes and anode groups are switched on and off, and specific monitoring options for contacting anodes and



Figure 4: Articulating robotic arms provide racking and panel handling. (Source: Ludy)

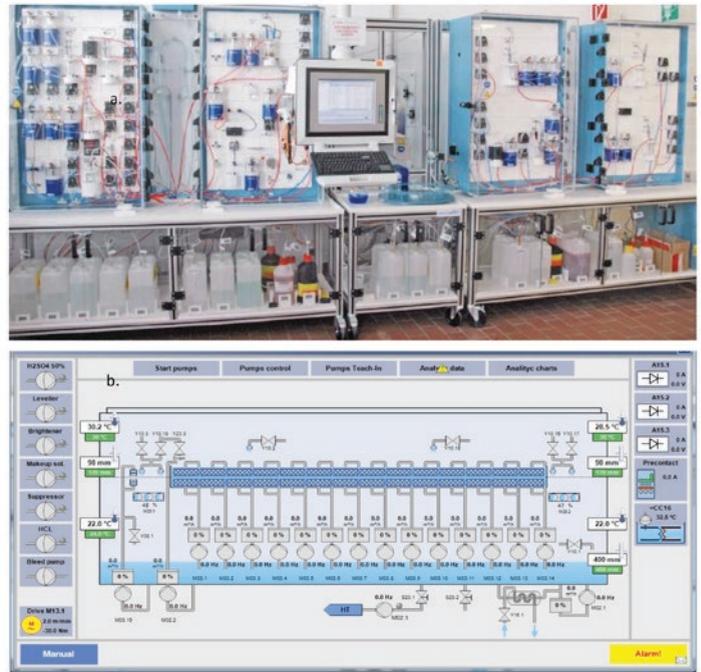


Figure 5: Modern PLCs provide networking, sensory and analytic control, and real-time displays. (Source: Atotech)

anode groups are provided. The use of a complex digital control system results in increased control accuracy, lower residual ripple, an extended control range, and higher efficiency. This all operates under the control of PLCs with integrated ProfiNet interface for data exchange with the plant control system for diagnosis and remote maintenance and improved energy efficiency.

tion (Figure 7). This means that the exhaust air is clean and dry, and no additional wastewater is produced. Thermodynamic synergy effects regarding waste, heat, evaporation, and condensation are the result. The necessary exhaust air volumes can be kept small, and thus the necessary purification is kept to a minimum by flow-optimized extraction.

Ventilation and Effluents

Modern electroplating systems can reduce exhaust air from the process by up to 80% by having tank covers that are programmed to open when the transport drops a load into it. This leads to fewer emissions released into the environment (Figure 6).

By using heat pumps to warm rinse waters, the evaporation loss is replaced by water recovered from ventila-

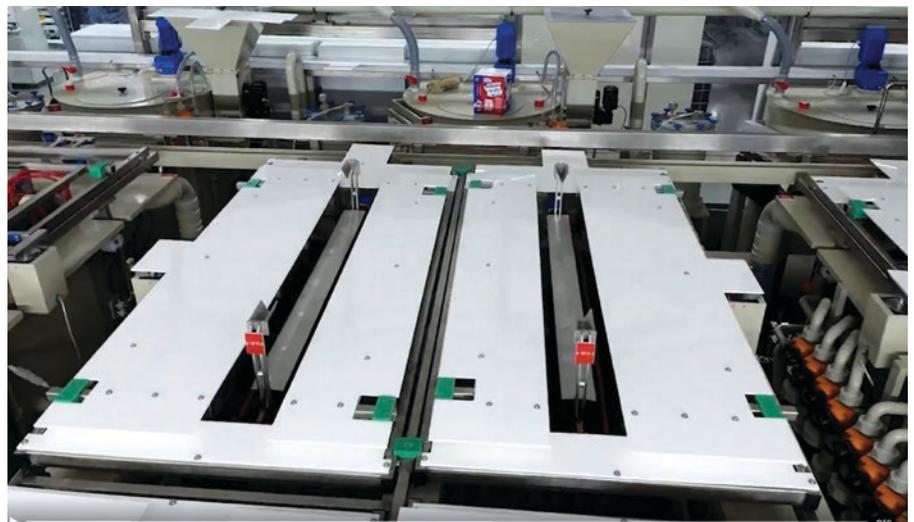


Figure 6: Process tank covers can reduce exhaust air by up to 80%. (Source: Ludy)

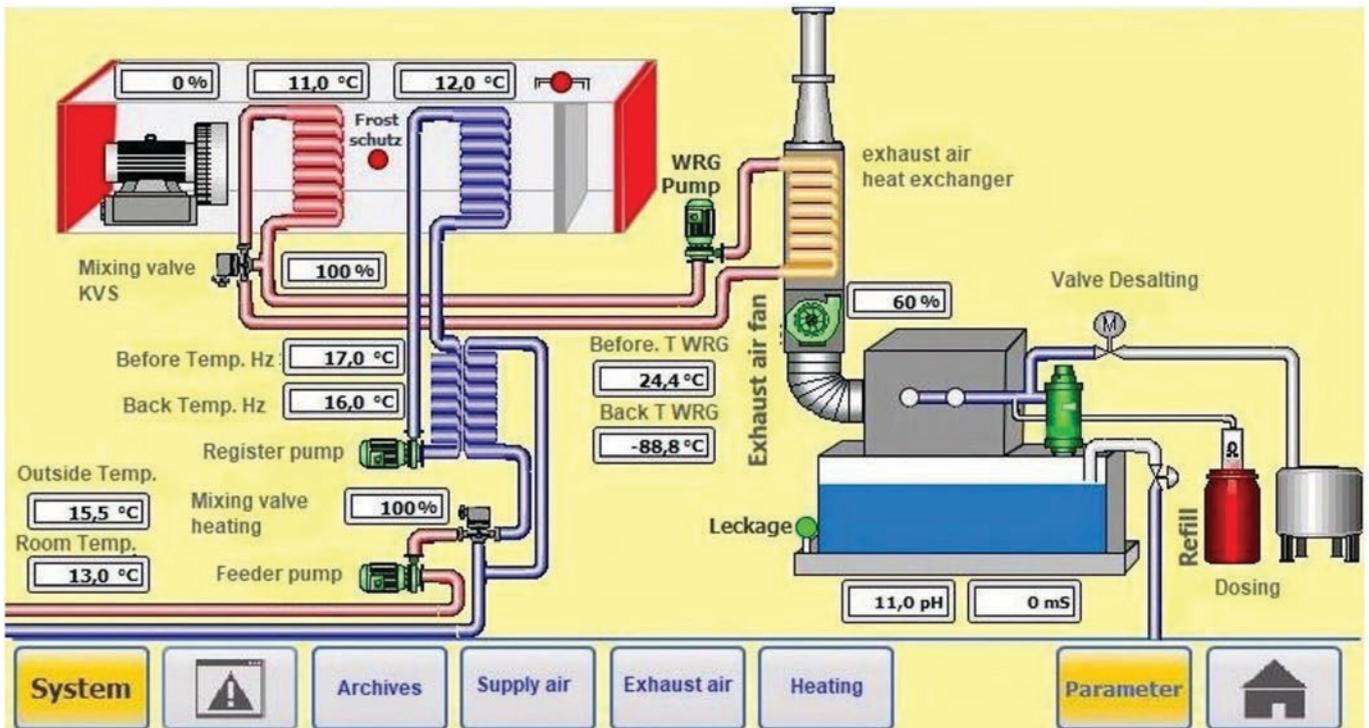


Figure 7: Heat pumps can be used to cool appropriate plating and processes, and heat other processes and rinse waters. (Source: Ludy)

Drying

As seen in Figure 7, the heat pumps can be very efficient in cooling the many power supplies and process tanks, and that energy, along with a principle of Raleigh wave ultrasonics³, can be used to dry the PCBs efficiently, including all the vias and cavities.

Electroplating Simulations and Dynamics

Newer understanding of Faraday's principles and boundary layer dynamics has led to the anode effect model based on number, spacing,

and distance to the cathode, as seen in the first equation.⁵ The second equation introduces the diffusion model for electrodeposition⁴.

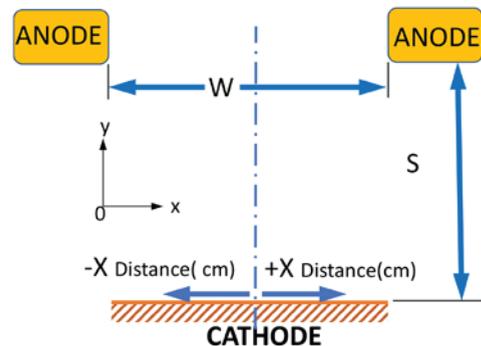
Predictive Maintenance

For predictive maintenance, parameters such as voltage, current draw, vibrations, temperature, acoustics, and switching frequency are measured, recorded, and stored. This is in addition to the operating hours of the device. Depending on the device, the data is stored in a database and used to predict maintenance

$$\frac{J}{J_{\infty}} = \sqrt{\frac{\cosh^2\left(\frac{\pi X}{2 S}\right)}{\cosh^2\left(\frac{\pi X}{2 S}\right) + \sinh^2\left(\frac{\pi W}{4 S}\right)}}$$

Plating current density

Equation 1



Diagram

$$j = n_e \cdot F \cdot \frac{dn}{dt} = n_e \cdot F \cdot D \cdot A \cdot \frac{(C_o - C_{cath.})}{\delta}$$

Where : j = Coulombs flow in time, t
 n_e = Number of electrons picked up per ion
 F = Faraday Constant
 $\frac{dn}{dt}$ = Number of ions discharged during time, t
 D = Diffusion coefficient
 A = Cathode area
 C_o = Diffusion boundary ion concentration
 $C_{cath.}$ = Ion concentration at cathode surface
 δ = Diffusion layer thickness

Role of Organics in General: Effect on D and δ
 Role of Organics Specifically: Increase δ and/or decrease D to minimize effect of local $[C_o - C_{cath.}]$ variations.
 Role of Leveler Specifically: Increase δ and/or decrease D selectively at points of high current density.

Equation 2

options. For each device, the standard values for the existing measuring channels are stored as set point parameters.

New innovative evaluation modules record and evaluate the target and actual values. This enables the calculation of the statistical probability of failures, depending on the frequency and length of the violations of the standard. This evaluation is self-adaptive and improves with an increasing number of data sets.

Various evaluations can be made available to the user in a device list, whereby the percentage probability of an event (i.e., regular maintenance and preventive inspection) is displayed accordingly.

Conclusion

The sophistication of electrodeposition through both chemistries and equipment and analytical techniques, have improved so much that, today, electrodeposition is employed in semiconductor fabrication for through-silicon vias and IC packaging for through-glass vias in the micron geometries. Each new generation of electronics further erodes the line between wafer and PCB fabrication. The overall requirement for a plated copper deposit is a thinner deposit, but one with consistent higher ductility, improved thickness distribution and throwing power, and the elimination of surface defects. **PCB007**

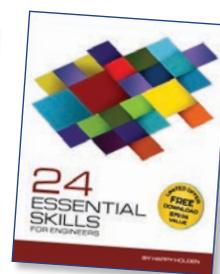
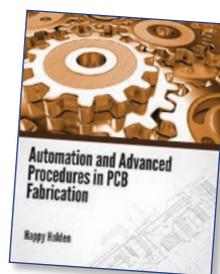
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Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa Westwood, Merix, Foxconn, and Gentex. He is currently a contributing technical editor with

I-Connect007, and the author of *Automation and Advanced Procedures in PCB Fabrication*, and *24 Essential Skills for Engineers*. To read past columns, [click here](#).



Taking the **Fight** to Capitol Hill

American Made Advocacy

by Travis Kelly, PCBAA

If you're not at the table, you're on the menu.

That's one of the reasons why, in his State of the Union address, President Biden's praise for an emerging manufacturing renaissance was so welcome. He said, "If we invent it here, we should also make it in America."

He sounded a lot like a microelectronics CEO.

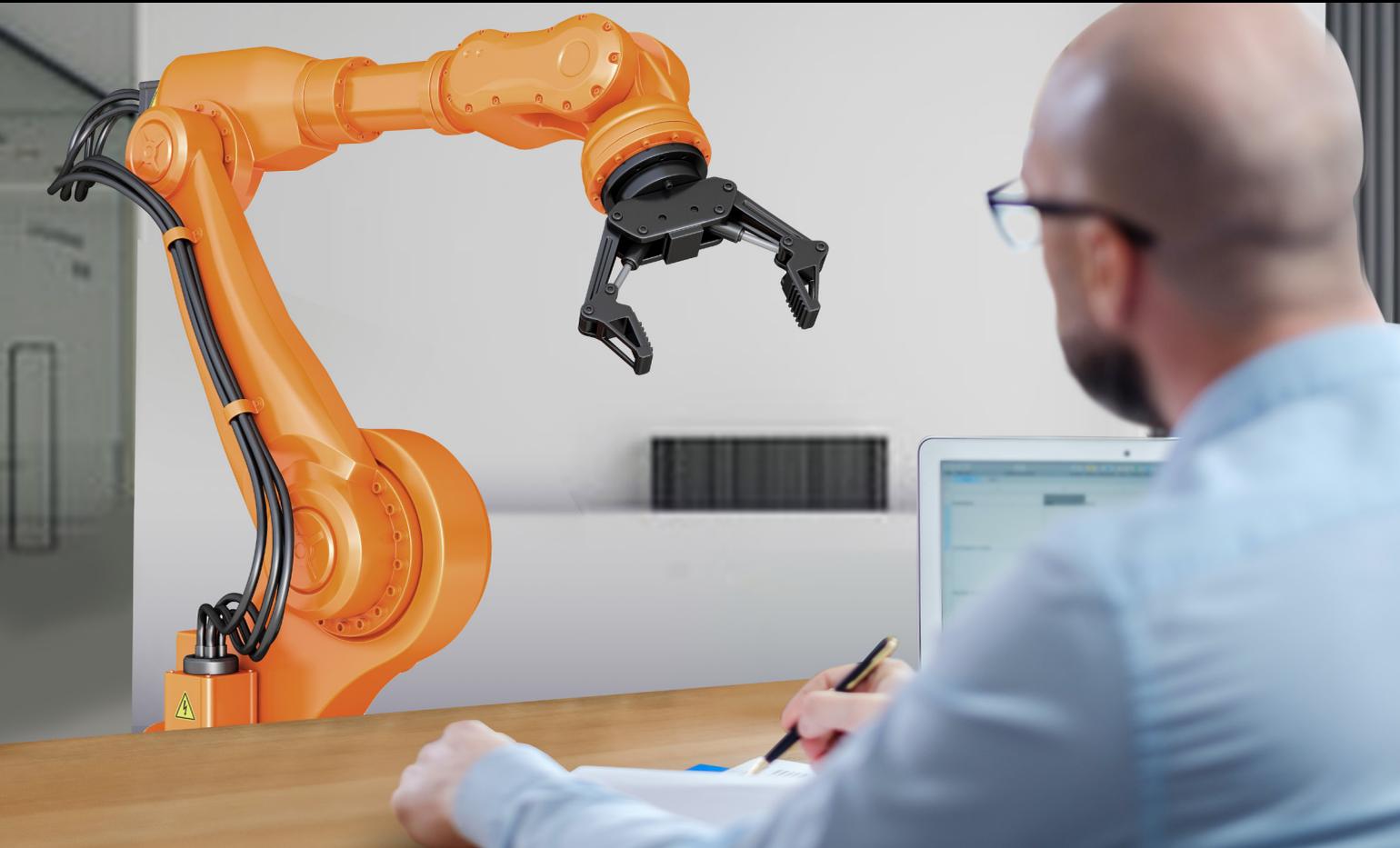
Two decades ago, the United States had more than 2,000 companies designing and manufacturing printed circuit boards to satisfy 30% of the global demand. Today that number is less than 150 companies, representing only 4% of PCB production.

A refreshed bill from Reps. Blake Moore (R-UT-1) and Anna Eshoo (D-CA-16) aims to address this atrophy with direct government funding and tax credits that will make American printed circuit boards cost competitive with foreign sources.

Next month, the PCBAA will gather in Washington to meet with lawmakers and lobby directly for this important legislation. This conference is the culmination of a multifaceted campaign we have been leading for more than two years.



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There is no substitute to for in-person advocacy, and here's why we're taking our fight to the halls of Congress:

- **The environment is ripe for reshoring.** Challenges to supply chains that began during the COVID-19 pandemic have lingered and, coupled with a tight labor market, created a challenging environment for high-tech manufacturing. Businesses are securing their sourcing and building new arrangements closer to home. New factories are under construction from Arizona to New York, and businesses are recognizing that dependence on any one region is not sustainable. Governments all over the world are competing for a share of this rebalanced portfolio.
- **The competition for lawmakers' attention is fierce.** Every day in Washington our elected officials are inundated with requests for support and appeals to action. Our system empowers individuals and organizations alike to engage in the political process, and from corn growers to clothing importers, tens of thousands avail themselves of this option during every legislative session. With so many diverse interests competing, it's important to connect the faces of your stakeholders to the arguments you're making.

Some might argue that in our new "virtual" work environment, the need to show up is out of fashion, but I strongly disagree. Sitting across the table, shaking hands, telling the story; there is no replacing that kind of connection and the results it can bring.

If anyone still doubts the value of direct engagement with lawmakers, you need only look to the CHIPS Act. Far from a safe bet when it was first proposed, the CHIPS (Creating Helpful Incentives to Produce Semiconductors) Act took nearly three years to go from an idea to signature by the President. During those three years our colleagues in the semiconductor industry worked tirelessly in Washington to make it happen.

That understanding led to nearly \$52 billion in government investment and more than \$400 billion in private funds that followed the government's strong signal.

Now it is time to finish the job.

It took almost three decades to shrink our PCB manufacturing base. We're not going to reverse that trend overnight, but we must act. Now is the time to sit with our elected officials and explain that "chips don't float."

A truly secure, robust, and resilient supply chain includes semiconductors, substrates, and printed circuit boards manufactured in America.

We owe it to our shareholders, employees, and customers to make this vision a reality. That's why I am going to Washington, D.C., next month. If you care about American manufacturing, I hope you will join us. **PCB007**

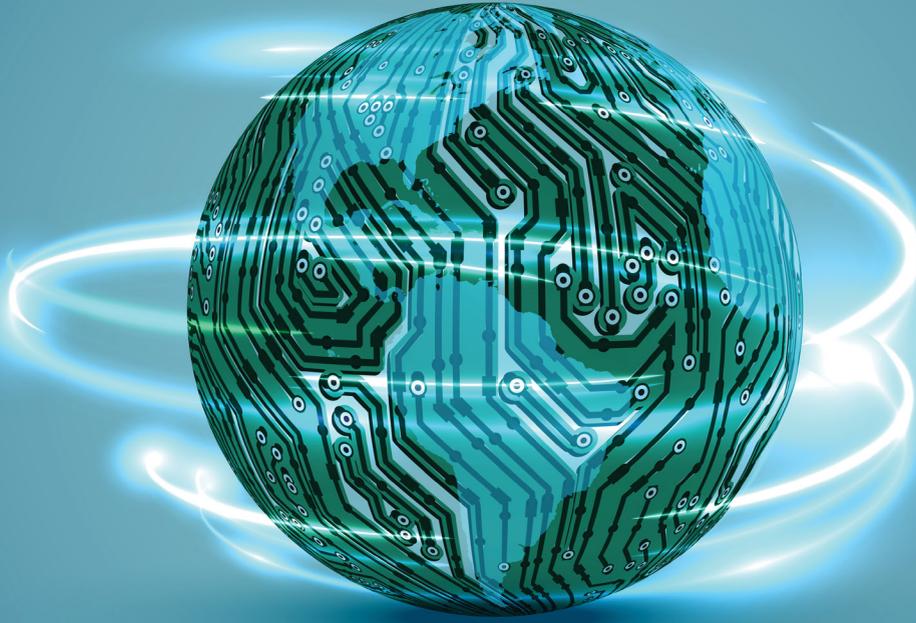


Travis Kelly is CEO of Isola-Group and current chairman of the Printed Circuit Board Association of America. To read past columns, [click here](#).

“Some might argue that in our new “virtual” work environment, the need to show up is out of fashion, but I strongly disagree.”



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Rex Rozario on the set of the upcoming biopic "Midas Man," the story of the Beatles' manager, Brian Epstein.

The **Birth** of the Printed Circuit Board

Interview by Barry Matties and Nolan Johnson

I-CONNECT007

Every industry has a beginning, and we are lucky to have Rex Rozario here to share the story of how the printed circuit board industry got its start. I-Connect007 chatted with Rex recently about how he became involved with circuit board inventor Dr. Paul Eisler.

Barry Matties: *Let's start at the beginning, Rex. My understanding is you were there when circuit boards were first being manufactured.*

You're correct. Fortunately for me, when I left university, my first job was with a company called The Telegraph Condenser Company; they had just acquired the first license from Paul Eisler. He developed the printed circuit in

a shed in London, circa 1940; they were single-sided boards. He had the patents in 1948 and issued five licenses. We (The Telegraph Condenser Company) were the first to get a license.

Eisler later joined Technograph and worked there for some time. Eventually, Technograph and Telegraph merged.

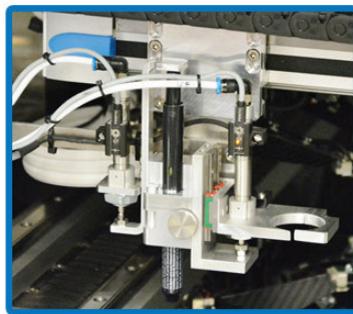
Matties: *Would you say you were the first company to produce a licensed printed circuit board?*

Technically, we were the first company in the UK to manufacture PCBs. Eisler sold one license to the UK and four others to the U.S. We could appoint other people as well, if they wanted to manufacture under our license.

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Matties: So, how did you get involved?

Whilst studying for my degree at university, I was lucky to obtain a work/study job in my spare time in a development lab with Daly Condensers Ltd. (UK) where I learned all about manufacturing electrical condensers. This gave me the opportunity, after obtaining my university degree, to apply to the UK's largest condenser manufacturer, The Telegraph Condenser Co., which employed me as a development technician. Three weeks into my new job, I took a pre-arranged vacation for two weeks. When I returned, I was met by a senior director and was marched into the office of the managing director who was already addressing five men. The managing director informed us that Telegraph had just obtained the first license in the world from the inventor Dr. Paul Eisler, who was also engaged by Telegraph as a consultant. I was invited to join the five specialists which Telegraph had tapped to form this new team with Dr. Eisler. We were given 5,000 square feet of a surplus building to further develop and introduce printed circuits to replace manual wiring. This was circa 1953.

In the beginning, we had to shop around for everything, from the base laminate to the copper foil. We did all that within our team, and then suddenly the printed circuit developed in the UK went from a single- to a double-sided board. For the double-sided, we used eyelets until through-hole [electroless copper plating] came along.

Matties: You were along for the journey the whole way.

I was just lucky to be there.



Dr. Paul Eisler “The Inventor of the Printed Circuit” with Rex Rozario in 1990.

Matties: How were the designs for the circuit boards developed? Were you doing them in-house?

Yes, we did the design in-house; we didn't have any idea about laminates, but we knew the copper foil was around. We actually used wallpaper, and then impregnated it with resin. That's how it started. There was nothing available

in the market. It was all sorts of looking in the dark, really, and hoping it would do the job. Eventually, a laminator took over—they manufactured the laminate, they went into fiberglass, and so forth. I think one of Eisler's motivations was that he looked at the round wires and he moved them onto a printed circuit so that you could assemble something very large into something very small and not have the wires around.

Matties: In your career, Rex, what was most surprising to you?

The surprising thing was that I was picked to be part of this team. When I met the manag-



ing director that day, long ago, he invited me to join the printed circuit board team. Of course, I hadn't a clue what he was talking about. I asked the other five chaps, "What's he talking about?" They didn't know. "He's talking about a printed circuit, but we don't know exactly what that means." Luckily, Paul Eisler joined us, and we were on our way. Paul was with us for about a year, I think.

Nolan Johnson: How long did it take before you were making circuit boards for others?

The first customer was in the radio trade in the UK. We had to convince them that changing from wires to printed circuits would be better for them. If they would design the circuitry, then we could manufacture the printed circuit for them. So, we had to go to every customer and more or less convince them all to change from the old-fashioned ways of manufacturing to using printed circuit boards. The radio trade was the first to pick up circuit boards; of course, they were very basic single- and double-sided boards.

Johnson: Was it difficult to get your customers to adopt this new idea?

Yes, because they are very suspicious of any change. Of course, the printed circuit was something that just came out of the blue. But once they picked it up, then we had lots of competition, as well. So, there were a number of small companies under licensed manufacturing.

Matties: Eventually you started your own facility.

Yes, in 1968, I moved to Devon, England, and felt confident enough to start my own manufacturing company, Graphic Electronics (later changing the name to Graphic PLC, which is still in operation).

Matties: Are you doing anything in electronics that we should be aware of now?

Rex Rozario's Many Accolades:

- Founding member of the Printed Circuit Association, now graded as the Institute of Circuit Technology
- Honoree Fellow of the Institute of Circuit Technology
- Past Director of the IPC (USA)
- Fellow of the Metal Finishing Association
- Fellow of the Institute of Directors (UK)
- Fellow of the Royal Society of Arts
- Past President of the World Electronics Circuits Council
- Past Chairman of the Federation of Electronics Institution
- Fellow of the Sales and Marketing Institute

Not really. I'm getting to the age now... I should have retired a long time ago.

Matties: You aren't just interested in electronics, you were also involved in the early days of the music scene in London.

Well, you wouldn't believe this, really, but I also had sidelines while I was still doing printed circuits. I got into the music industry and my drum tutor was a guy called Jim Marshall, the maker of the now world-famous Marshall amplifiers. We had to more or less push him to develop an amplifier that gave us that very solid bass sound.

I had my own jazz club at one point. A group would come and practice there. It turned out to be the Rolling Stones! In fact, the drummer, Charlie Watts, lived near me until he passed away two years ago. (I had known Charlie back when we were teenagers.) When I got married, I told my wife I'd give up music. I focused on the electronics industry, and I'm very pleased that I did. I am now, however, involved in making a film about the Beatles' manager, Brian Epstein. It's called "Midas Man" and we



Rex on the set of "Midas Man" chatting with a cast member while Blake Richardson, the actor playing the part of Paul McCartney, makes the shhhhh sign behind him.



Jacob Fortune-Lloyd (center) who plays the lead role of Brian Epstein, meets with Rex during the movie production.

just finished the final episodes. That will be released later this year.

Another interest of mine is restaurants. I'm partnered with the Lymptone Manor, one of the best Michelin-starred restaurants in Devon, England. Our chef, Michael Caines MBE, is one of Britain's most celebrated and influential chefs. I have a few other restaurants around, so that's another hobby. [Related content: [Rex Rozario's Next Big Thing](#)]

Matties: *What advice would you give to a young person entering the electronics industry today?*

The opportunities are limitless. Really, it depends on your personal interest. I mean, everything that happens now is still electronics. There are so many possibilities. So, I'll just generally say: Stick to electronics, even the basics, and then take it from there.

Matties: *Well, Rex, it sure is great to catch up with you. Thanks for sharing your stories with us.*

Thank you. PCB007



Chef Michael Caines with Rex at Lymptone Manor.

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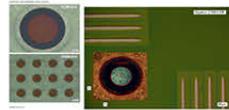
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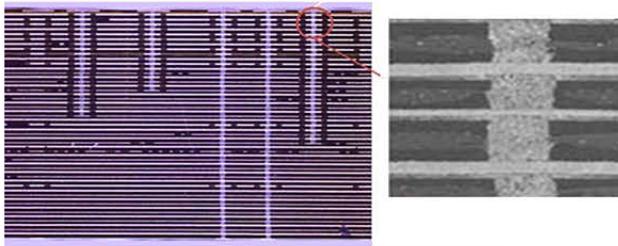
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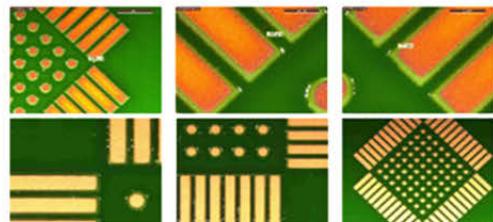
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The Challenges of Thin Material Transport

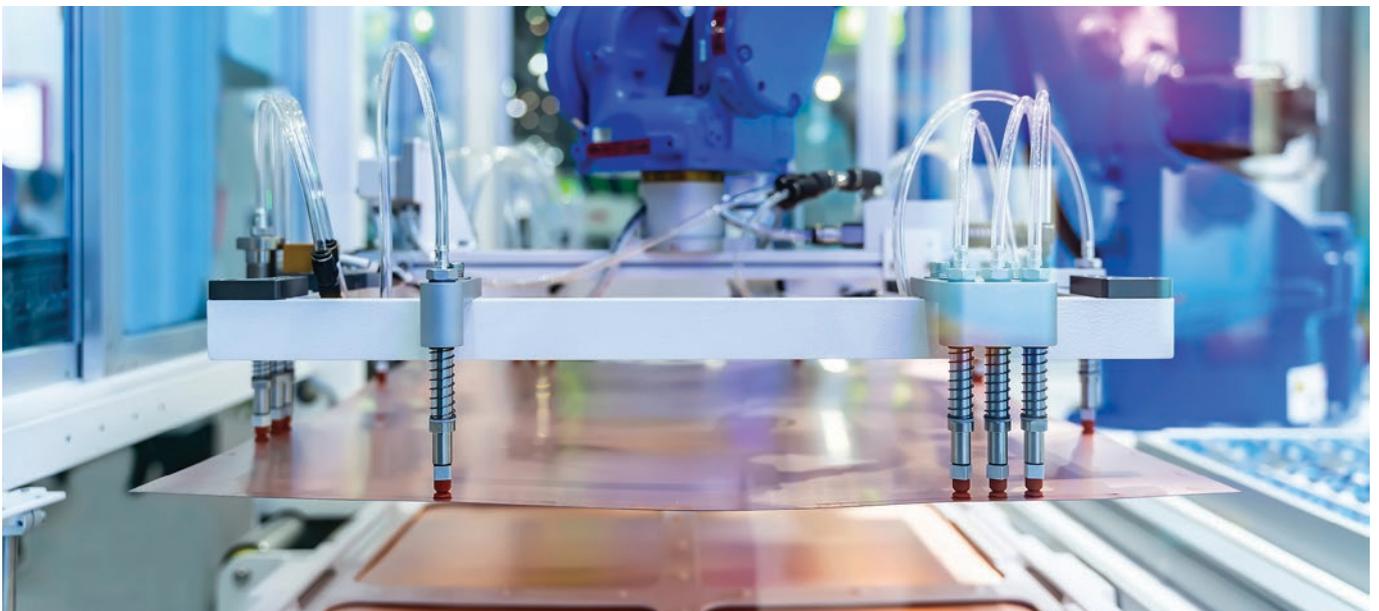
The Chemical Connection

by Christopher Bonsell, CHEMCUT

In wet processing, the transport of thin materials and substrates (<1 mil in thickness) can be a rather tricky process. These materials are vital in manufacturing flexible circuits, but often this flexibility adds new challenges. Most of these materials are easily damaged, and in some cases require well-trained personnel to handle them. You would think that this could be easily remedied with conveyorized equipment, but that is not entirely the case. Transporting thin materials through a conveyor aids the process to a degree, but once you get to the wet-processing stages—cleaning, developing, etching, and stripping—there are risks for error if you do not have the right tools or equipment.

Thin material transport in wet processing is challenging because, for it to perform, the con-

veyor needs to have open spaces. In PCB fabrication, the goal of all wet processes is to have a liquid interact with the surface of your product. Most often, this is done with spraying. If you want interaction from both top and bottom sides of the PCB, there must be gaps for that spray to come through and reach the product. If the conveyor were a simple, flat conveyor belt that pulled the board through, you could make the product go from one end of the conveyor to the other, but it would receive no etching on the bottom side. Even if the belt were porous, this would still leave shadow marks behind, because the point of contact between the board and the conveyor would remain the same throughout the process. The conveyor needs enough gaps in the bottom side, and it also needs to change points where it touches





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Figure 1: Standard wet processing conveyor.

the board. That is why wet-processing conveyors are designed this way today (Figure 1).

Gaps are required to conduct normal wet processing, which creates some difficulties. Any gap in the conveyor provides a chance for a corner to dip downward. The thinner the material, the more likely this will happen, especially when a liquid is sprayed onto the top of it. When this happens, it can cause that edge or corner to fold or “crinkle.” This happens because of the uneven movement among all parts of the panel. Once a corner drops down into a gap, that part of the board loses velocity in the forward direction, while the rest of the board keeps a consistent forward velocity as the conveyor moves along.

The Leader Method

Although these complications can be a significant obstacle, they do not stop flex PCB manufacturers from using wet processes. The leader method has been commonly used for many years. With it, a rigid board is taped (using chemically resistant tape) to the leading edge of the thin material that needs to undergo a wet process. This ensures that the leading edges of the flexible circuit do not drop into a gap and thus form an error. Since this drooping issue is the main problem of thin material transport, the method tends to provide consistent results. Despite this, most manufacturers of flexible circuits want to get away from using leaders because of the manual labor needed to apply and remove the

tape. The process takes time and is prone to human error, which creates further potential for panels to get damaged.

The Leaderless Approach

If leaders are not desired, the next solution must come from the conveyor design. Frequently, the solution is to provide greater conveyor density—meaning fewer gaps in the conveyor and less like-

lihood for an error to occur. The main downside is that the etch rate on the bottom side can be inhibited by the conveyor since it is harder for spray to reach the panel.

Surface tension is another issue that comes with leaderless transport of thin materials. Often in wet processing equipment, rollers ensure the chemicals in each wet processing section are contained within their modules and don’t leak into other modules. Sometimes with thin material, the liquid on the panel creates enough surface tension to cause the panel to stick to the rollers and wrap around it. To avoid this, use either lightweight rollers or rollers with reduced surface area.

Conclusion

If you wish to move away from using the leader method, know that wet processing of thin materials and substrates is a complex process that requires specialized equipment. While specialized equipment can aid in the transportation of these materials, it is not enough to guarantee error-free wet processing. Although there are some restrictions, I foresee leaderless thin material transport soon becoming an issue of the past. **PCB007**



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



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Chemical Legislation and Restrictions on Solder Masks

Article by Chris Wall

TECHNICAL DIRECTOR, ELECTRA POLYMERS

Ever since liquid photoimageable solder masks (LPISMs) were introduced, their UV exposure speed has been a key factor in their performance. The LPISM is coated onto the PCB, dried, and then selectively exposed with UV light via a phototool, or more recently, via direct imaging using LED or lasers. The exposed areas polymerise and become insoluble in the developing solution. The polymerisation is initiated by one or more chemicals called photoinitiators, which are components of the LPISM.

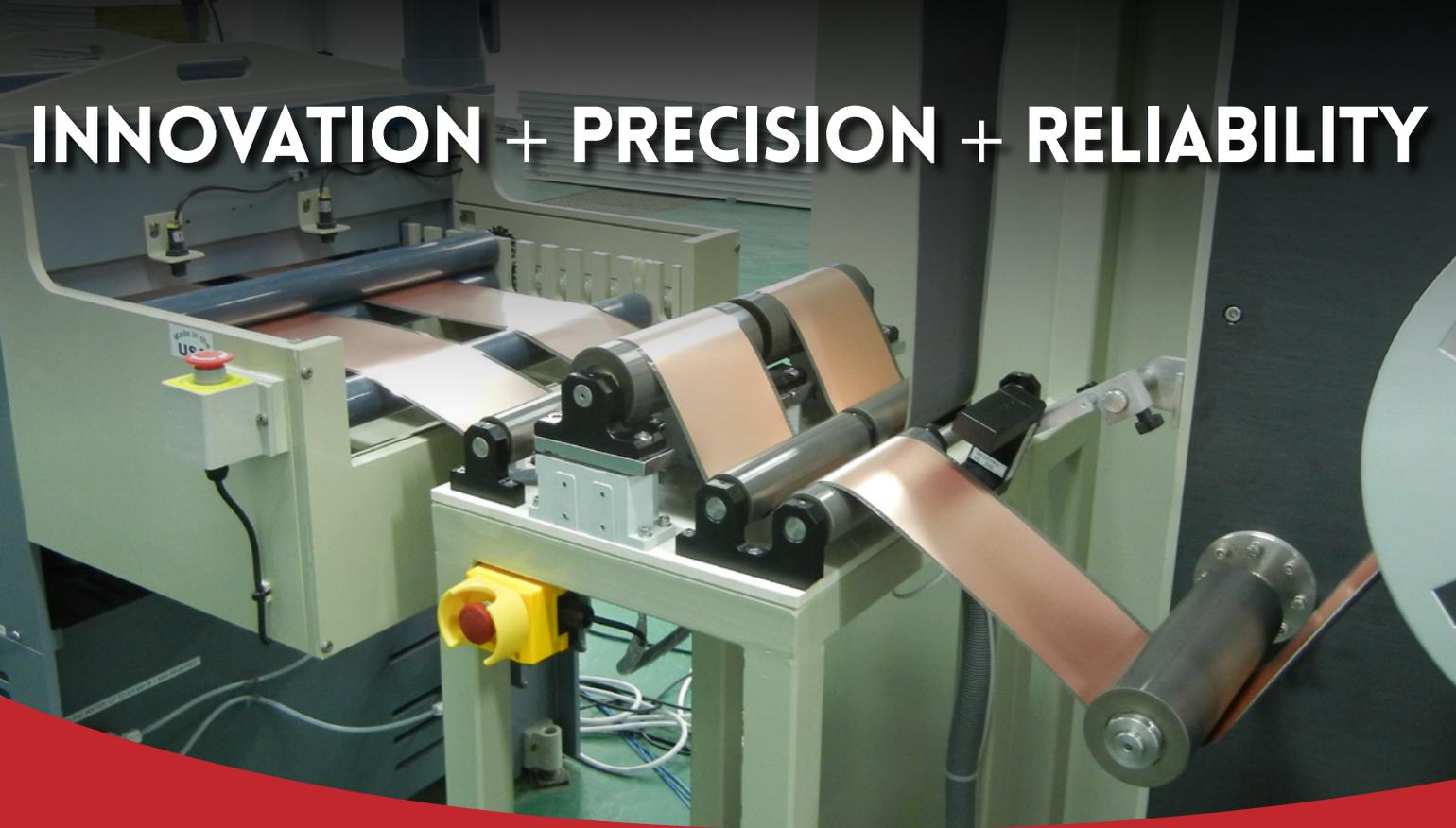
REACH

REACH (Registration, Evaluation, Authorisation, and Restriction of Chemicals) is a European Union regulation that was adopted in 2006 and came into force in 2007.

Under REACH, manufacturers and importers of chemicals must register the substances they produce or place on the market in Europe with the European Chemicals Agency (ECHA). The registration process requires manufacturers and importers to provide information on the properties, uses, and potential risks of the



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substances they produce or import. Generally, REACH applies to all individual chemical substances on their own, in mixtures, or in articles. However, some aspects of REACH only apply to quantities of one tonne/year or more.

The REACH regulation establishes a process for identifying and controlling substances of very high concern (SVHCs). As part of this process, the European Chemicals Agency (ECHA) maintains a list of substances that are being evaluated for potential inclusion in Annex XIV (the “Authorization List”), called the Candidate List of Substances of Very High Concern (SVHCs).

UK REACH

In the UK, the government created UK REACH, which adopted all the provisions of REACH as they were at the time of Brexit. Under the European Union (Withdrawal) Act 2018, the EU REACH Regulation was brought into UK law on Jan. 1, 2021, and is known as UK REACH. EU REACH, and related legislation, were replicated in the UK with the changes needed to make it operable in a domestic context.

The REACH statutory instruments that made these changes can be found on legislation.gov.uk.

The key principles of the EU REACH regulation were retained in UK REACH, which regulates chemicals placed on the market in GB. The UK REACH and the EU REACH regulations operate independently from each other. You must ensure you comply with both regulations, where necessary.

Candidate List

The Candidate List includes substances that have been identified as having properties such as being:

- Carcinogenic, mutagenic, toxic to reproduction (collectively termed CMR)
- Persistent, bioaccumulative and toxic (PBT)
- Very persistent and very bioaccumulative (vPvB) or that are considered to be of equivalent concern

After a substance is added to the Candidate List, ECHA evaluates it based on the data submitted and potentially renders a decision on the proposed restrictions or authorisation requirement. After completion of this evaluation, the proposed restriction or authorisation requirement is brought forward at the REACH Committee, where representatives from Member States and European Commission decide whether to adopt the measure.

Once a substance is added to the Candidate List, manufacturers and importers of “articles,” such as PCBs, are required to provide information to their customers and downstream users about the presence of the substance in their products, if the substance is present above 0.1 weight% (of the whole article).

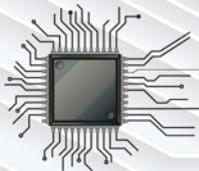
Annex XIV (the ‘Authorization List’)

Once a substance is added to the Candidate List, it means that it is being considered for inclusion in the “Authorization List,” which lists those substances that can only be used under specific conditions, such as that the risks are adequately controlled.

Once a substance has been added to the Authorization List, there will be a period of 18, 21, or 24 months from the date of inclusion for manufacturers or importers to apply for authorization to continue manufacture or import of the substance the latest application date (LAD). If this is granted, it will be authorized



“ The REACH regulation establishes a process for identifying and controlling substances of very high concern (SVHCs). ”



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for use for a further period. At the same time, a sunset date (SD) will be notified, which is 18 months after the LAD. This is the date after which the substance can no longer be used or placed on the market without an authorisation. A candidate list is included¹.

Registry of SVHC Intentions Until Outcome

Member States (or ECHA at the request of the European Commission), may propose a substance to be identified as a Substance of Very High Concern (SVHC) by preparing a dossier in accordance with the requirements set out in Annex XV to REACH. An evaluation process is included².

The Registry of SVHC Intentions until Outcome aims to make interested parties aware of the substances for which an SVHC dossier is planned to be submitted to ECHA.

Photoinitiators subject to, or likely to become subject to, usage restrictions:

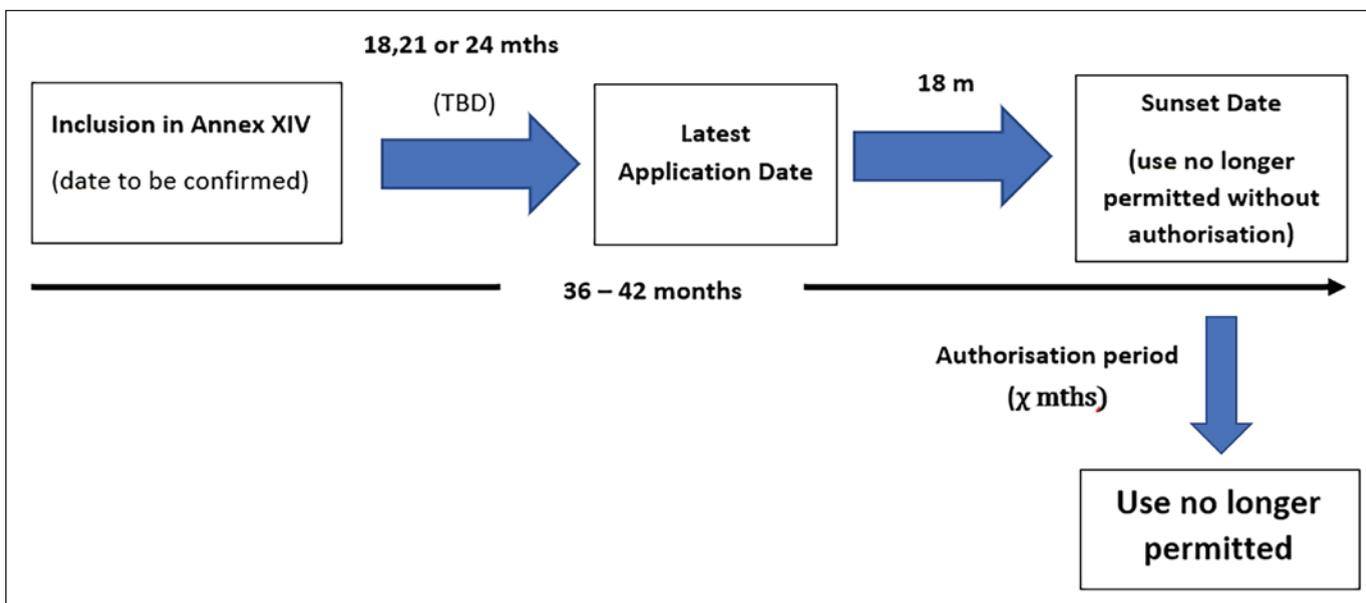
- 907: (2-methyl-1-(4-methylthiophenyl)-2-morpholinopropan-1-one)
This photoinitiator, when combined with one or more other photoinitiators, gives exceptional photospeed. For this reason,

it has been used by manufacturers of LPISMs all over the world, however, it has been on the Candidate List since 2020 and has recently been prioritized for inclusion in the Authorization List.

- 369: (2-benzyl-2-dimethylamino-4'-morpholinobutyrophenone)
This photoinitiator was introduced previously as a potential replacement for 907 but is now grouped with 907 for inclusion in the Authorization List.

Other components of solder masks subject to, or likely to become subject to, usage restrictions:

- TGIC (1,3,5-tris(oxiranylmethyl)-1,3,5-triazine-2,4,6(1H,3H,5H)-trione)
A thermal curing agent used in solder-mask hardeners; added to Candidate List 18-Jun-2012
- Melamine (1,3,5-triazine-2,4,6-triamine)
Thermal curing agent; added to Candidate List 17-Jan-2023
- Diphenyl (2, 4, 6-trimethylbenzoyl) phosphine oxide (TPO)
Photoinitiator; recently added to the Registry of SVHC intentions until outcome



Timeline for permitted use of 907 and 369.

**Draft 11th Recommendation of Priority Substances to be included in Annex XIV of the REACH Regulation
(List of Substances Subject to Authorisation)**

Draft Annex XIV entries									
#	Substance	EC number	CAS number	SVHC-relevant intrinsic properties*	Latest application date pursuant to REACH Art. 58 (1) (c) (ii)**	Sunset date	Review periods	Exempted uses or categories of uses	Exemptions for PPORD
1	Ethylenediamine	203-468-6	107-15-3	Respiratory sensitising properties (Article 57f – human health)	Date of inclusion in Annex XIV plus 18, 21 or 24 months	Latest application date plus 18 months	None	None	None
2	2-(4-tert-butylbenzyl) propionaldehyde and its individual stereoisomers	-	-	Toxic for reproduction (Article 57c)	Date of inclusion in Annex XIV plus 18, 21 or 24 months	Latest application date plus 18 months	None	None	None
3	Lead	231-100-4	7439-92-1	Toxic for reproduction (Article 57c)	Date of inclusion in Annex XIV plus 18, 21 or 24 months	Latest application date plus 18 months	None	None	None
4	Glutaral	203-856-5	111-30-8	Respiratory sensitising properties (Article 57f – human health)	Date of inclusion in Annex XIV plus 18, 21 or 24 months	Latest application date plus 18 months	None	None	None
5	2-methyl-1-(4-methyl thiophenyl)-2-morpho linopropan-1-one	400-600-6	71868-10-5	Toxic for reproduction (Article 57c)	Date of inclusion in Annex XIV plus 18, 21 or 24 months	Latest application date plus 18 months	None	None	None
6	2-benzyl-2-dimethyl amino-4'-morpholino butyrophenone	404-360-3	119313-12-1	Toxic for reproduction (Article 57c)	Date of inclusion in Annex XIV plus 18, 21 or 24 months	Latest application date plus 18 months	None	None	None
7	Diisohexyl phthalate	276-090-2	71850-09-4	Toxic for reproduction (Article 57c)	Date of inclusion in Annex XIV plus 18, 21 or 24 months	Latest application date plus 18 months	None	None	None
8	Orthoboric acid, sodium salt	237-560-2	13840-56-7	Toxic for reproduction (Article 57c)	Date of inclusion in Annex XIV plus 18, 21 or 24 months	Latest application date plus 18 months	None	None	None

Timeline for Permitted Use of 907 and 369

For 907 and 369, if no authorisation is obtained, they will no longer be authorised for use 36 to 42 months after they are added to Annex XIV.

Status of 907 in Electra Products

In preparation for this date, Electra has been working hard to develop LPISM products of equivalent performance that do not contain 907. These materials are available for evaluation through your local contact.

Action Required

To date, nothing has changed with regard to the obligations of solder mask users with respect to 907. The substance has been on the Candidate List since 2020 and PCB manufacturers should already be notifying their customers of its presence (if appropriate) in the boards they supply to their customers.

If they are not and they are uncertain if the solder mask they use contains it, they should contact their solder mask supplier and ask for confirmation. If the solder mask is being

imported from outside the EU (and/or UK) they should also ask for confirmation that all the component substances are registered under REACH (and UK REACH).

Looking forward, solder mask users may wish to consider looking at solder mask products which do not contain 907 and they should contact their solder mask suppliers for alternatives. **PCB007**

References

1. Preparation of Draft Annex XIV Entries for Substances Recommended to be included in Annex XIV, European Chemicals Agency, echa.europa.eu.
2. Substances of Very High Concern, echa.europa.eu.



Chris Wall is technical director at Electra Polymers.

Leadership 101: Be a Heretic, Not a Sheep

The Right Approach

by Steve Williams, THE RIGHT APPROACH CONSULTING

True leaders drive change. They are not afraid of swimming against the current. Managers, however, drive the status quo. Their mentality, “It’s the way we have always done it,” feels safe and comfortable.

Balloon Factory

One of my favorite authors is Seth Godin. In his book, *Tribes: We Need You to Lead Us*, he uses the metaphor of a balloon factory to describe a business environment that maintains the status quo. It’s a workplace full of workers—the balloons—who are fearful of sharp objects like pins, needles, and porcupines. They don’t like changes in temperature, or for that matter, changes of any kind. Godin’s point is that many workplaces are too concerned with maintaining the status quo, even though everyone there thinks it “sucks.” Still, they freak out when a

“unicorn” shows up at the door, which is anything that disrupts the status quo of the balloons at the factory.

The average factory in our business is fraught with anxiety and short-term fixes that perpetuate the status quo. The average manager spends too much time and energy putting out fires instead of moving the business forward, and “firefighting” is extremely exhausting.

Does this sound familiar? If not, good for you, but you are probably in the minority.

Sheepwalking

When we say that people behave like sheep, we are saying they blindly follow the status quo because it is the “way we have always done things.” It’s called “sheepwalking.” I would bet a boatload of beer that at some point in your career, a boss told you something like, “Be a good soldier and just do what I say. You have to be a team player and take one for the team.” Many times, we do things we know are not right simply because we don’t want to rock the boat, cause issues, or put a bullseye on our backs. I don’t blame the sheep for their behavior; I blame leadership.

A personal story: Chris Kyle is my true-life hero who wrote the book *American Sniper: The Autobiography of the Most Lethal Sniper in U.S. Military History*. Chris’s father once gave a speech in which he described three types of people in the world: sheep,



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wolves, and sheepdogs. I had two sons in the military, one who later became a police officer, and I felt so strongly about his message that I got a tattoo of a sheepdog.

‘Never Hire a 5.0’

Another one of my favorite management consultants is Tom Peters, author of the book *In Search of Excellence*. At one of his appearances in the early '80s, he said something that has stuck with me throughout my career. When talking about hiring leaders, he said, “If you are looking for a needle mover, never hire a 5.0.” It wasn’t until I was well into my leadership journey that I began to understand and embrace his advice. Tom’s point was that people who strive to be perfect don’t color outside the lines. They follow the rules and don’t think outside the box. In other words, they live by the status quo. Now don’t get me wrong, 5.0 GPAers are critical to running successful businesses. But they are not the visionaries who will bust through the status quo and lead the organization to bigger and better things.

Another personal note: When I began my undergraduate program, I was caught up in being a perfectionist and wanted to finish with a 5.0 GPA. I was a typical Type A overachiever, and along with that came the stress and pressure to be perfect. About halfway through the program, I received my first “B,” making my goal of a 5.0 out of reach. Once that happened, it was like a boulder was lifted from my shoulders, and I was able to enjoy the process. This was a critical revelation and instrumental in later helping me balance business school, work, and family. I now gladly embrace my “perfect imperfection.”

When I said earlier that I don’t blame the sheep, it’s true. In fact, I blame the leadership, and this includes leaders of our educational system. I believe that from elementary school through

university, indoctrination is the norm and critical thinking is often squashed. Teaching and graduating sheep is a lot easier than developing students to think for themselves and question the status quo. I believe the reason we rank so low in world academic achievement is because we graduate so many sheep—well-educated, but compliant rule-followers, nonetheless.

‘Heretics’ are the New Leaders

What is a heretic? In this context of leadership, it is a person whose opinions, ideas, and perspective are in direct opposition to the current organizational norms. They challenge everything and don’t accept business as usual. In that sense, truly great leaders are heretics: they challenge the status quo, develop solutions, and drive change. Being a heretic is not for the weak. They are often (almost always) ridiculed, criticized, and not taken seriously at first. Heretics don’t follow; they lead. To quote Seth Godin:

“Leaders go first:

Everyone will think it’s stupid!

Everyone says it’s impossible.

Guess what? Everyone works in the balloon factory and everyone is wrong.”

One of the greatest heretics of all time, and another personal favorite, was Steve Jobs. He had the incredible vision to create products that people didn’t even know they wanted



until they saw them. Designing products that were beautiful, simple, and intuitive shattered the cookie-cutter products of Apple's competition. Remember spending Saturday afternoons in the record store? Now, remember your shock when Jobs introduced iTunes? We suddenly had the opportunity to buy only the songs we wanted instead of an entire album. It was not universally accepted at first but talk about a revolution in the music industry.

Henry Ford was another heretic who went against the grain with his vision of a motorized automobile. Had he asked people what they needed to improve their transportation, they would have told him, "A faster horse." Just

think where we would be today without these two heretics.

Leadership is hard, but what's harder is finding the strength to become a heretic—to drive radical change in the face of massive resistance and inspire others to break norms and do the same. **PCB007**



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

Knowledge: The Heart of Great Customer Service

Barry Matties asks David Thomas, master IPC trainer at EPTAC, about his views on customer service. David says that the more you understand the work and technology that goes into your processes and products, the better you can serve your customers.

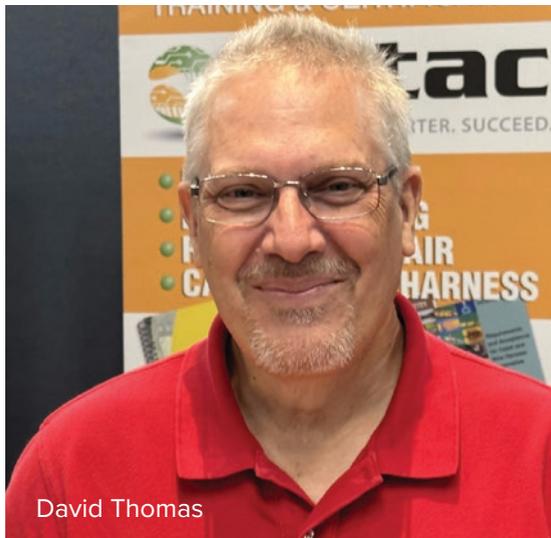
There are a lot of approaches to customer service, but I'm a firm believer that content knowledge is the foundation of great customer service. Service is a process, but understanding technology certainly is a benefit. What are your thoughts on that?

There are cases that I've personally experienced in which someone knows how to speak the language, but they don't know how to apply it, and vice versa. They may come in and talk about something. They think they're speaking as an educated person but are saying something completely wrong. For example, they need to know the basics, from the difference between a resistor and a diode, to how a resistor pack, timer, and an EPROM operate. If you go to a conference or talk with a customer, you need to have basic knowledge so that

you're on the same page as them. They should be able to see that you're not the person putting the solder to the application.

What advice would you give someone who's looking to retool their customer service department or their approach to customer service?

First, gain knowledge on the things you're working with. You can often gain a good understanding by taking, for example, a basic soldering class. Even if you don't use that knowledge, at least you have it. You were there, you did it, and you saw what it takes to do it. You have a better understanding. I find that many engineers who are at the design level want something done to a certain degree, but they have no idea what they're asking for. It makes no sense at all because they aren't there, trying to put it together. Customer service improves when people speak the same language and have a good understanding, whether it's the engineer and whoever is doing the work, or a customer and a company.



David Thomas

How Health Smart Are Smartwatches?

The Doctor's In

by Henry Crandall, UNIVERSITY OF UTAH/IPC STUDENT BOARD MEMBER

Sure, smartwatches are state-of-the-art and snazzy, but what do they really tell us about our health? Do their growing reams of data on us impress or carry clout with actual health care professionals? Let's dive into watches, from start to future.

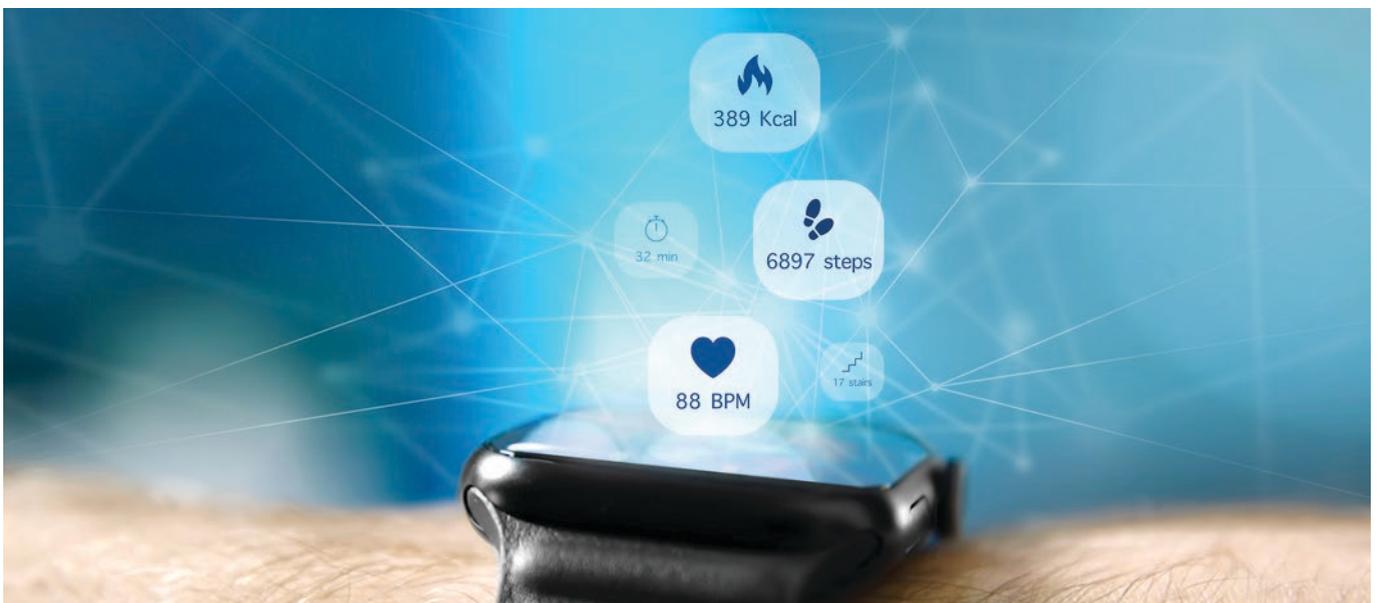
The Past

Watches have come a long way since their humble beginnings in the 15th century. Back then, they were nothing more than miniature clocks worn around the neck or kept in a pocket. It wasn't until the 16th century that a Swiss watchmaker invented the wristwatch, primarily for women to wear as a fashionable accessory. Wristwatches gained popularity among men in the late 19th century, thanks in part to soldiers using them during the Boer War in South Africa for timing military operations.

During the next century, watches continued to evolve with innovations like the electric watch and quartz watch; it wasn't until the 21st century that the watch indeed became "smart." With the advent of Bluetooth and touchscreens, watches incorporated features like notifications, GPS, and fitness tracking. Now, smartwatches are more than just a way to tell time; they're mini computers we wear on our wrists. So, after almost 600 years of technological advancements, how "smart" are our watches today? How smart are our watches at telling us about our health?

The Present

Smartwatches are the latest technological innovation in the world of health and fitness. These wrist-bound devices are jam-packed with features that make tracking your health



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and wellness easier than ever. Engineers have designed sensors for smartwatches to measure a wide range of metrics, from basic activity tracking to more advanced biometrics like heart rate, blood oxygen levels, and even electrocardiograms (ECG). Let's take a closer look at some of the most common sensors.

- **The accelerometer** is one of the essential sensors found in smartwatches, which measures your body's movement and helps track your steps and distance throughout the day. Other sensors include a gyroscope, which measures your wrist's rotation, and a magnetometer, which measures the earth's magnetic field and helps determine your orientation. Combining these sensors enables a watch to detect your activity, whether it's walking, running, cycling, etc.
- **The heart rate monitor** is another ubiquitous smartwatch feature. These sensors use photoplethysmography (PPG) technology to detect changes in your blood flow, allowing them to measure your heart rate. That green light that periodically lights up on your watch? That's a PPG measurement. Keeping track of your heart rate allows your watch to estimate patterns like stress levels, calories burned, and sleep quality.
- **Blood oxygen sensors** are also becoming common in smartwatches. These sensors use pulse oximetry to measure the oxygen saturation levels in your blood. A smartwatch with a blood-oxygen sensor can provide users a better understanding of how their oxygen levels fluctuate throughout the day and night. Algorithms can then use this data to estimate restfulness and help avoid overtraining.

There are some newer features on the way as well. Some smartwatches can incorporate temperature sensors, which measure the skin's temperature on your wrist. These sensors can detect changes in your body temperature and are primarily used for tracking women's health.

Smartwatches also have apps and digital solutions that act like a one-stop shop for all the health data recorded by your smartwatch. Within these apps, powerful algorithms can combine data from various sensors to provide in-depth analysis and long-term monitoring of health trends.



“Smartwatches also have apps and digital solutions that act like a one-stop shop for all the health data recorded by your smartwatch.”

The Future

With the introduction of ECG sensors, smartwatches began to blur the lines between wellness tracking and medical-grade instrumentation. Now, some watches can detect arrhythmias or regular heartbeats and notify you to visit a doctor.

Building off the successful implementation of ECG, smartwatch designers have circled blood pressure and glucose monitoring as the next major innovative features, promising critical new tools for patients with diabetes and high blood pressure. Who knows? Maybe someday they will analyze our blood (looking at you, Theranos) or tell us whether we have contracted COVID-19. Either way, the future of smartwatches is so bright that it even outshines those green PPG sensors.

It's important for users to remember, however, smartwatches are not hospital-grade equipment, and tech companies are quick to note their products are not intended to make a medical diagnosis. It doesn't mean the data is useless, but users should know that some doctors might scrunch their noses at smartwatch data.

The sophistication of health-tracking features in smartwatches is evolving rapidly.

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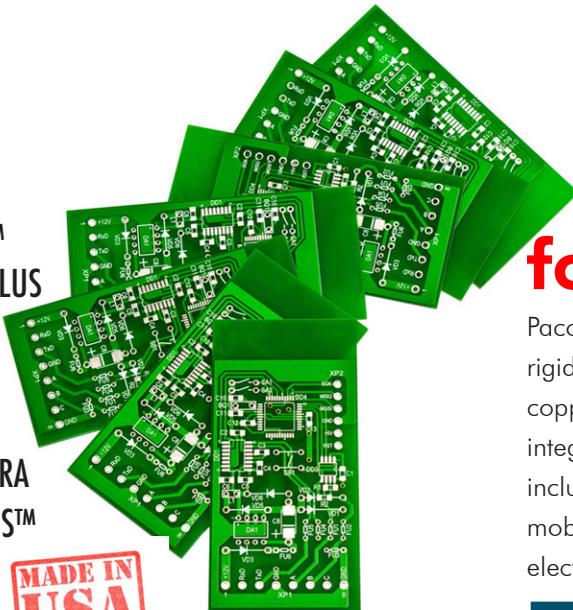
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Medical instrumentation that once was confined to hospitals or clinics is now finding a new home in smartwatches. These devices provide users with unprecedented insight into their health and wellness, allowing them to make better informed decisions about their lifestyle and seek medical treatment when necessary. As technology advances, smartwatches will become even more valuable tools for doctors and patients alike, helping us to live happier, healthier lives. Say what you will about how smart our watches are today; they have

certainly come a long way from the humble pocket watch. **PCB007**



Henry Crandall is the IPC Student Board Member. He is a graduate of University of Utah and is currently pursuing a PhD in electrical engineering as the Advancing Research in College Scientists Graduate Fellow. To read past columns, [click here](#).

Garry and Christina: Proving Mentorship Works

A new engineer walks into a reception at IPC APEX EXPO... in other words, there are many ways to connect with one another in the electronics manufacturing community. Here's the true story of how a mentor and a mentee met, discussed IPC standards, chaired a committee together, and won top IPC awards.

Christina Trussell of Blue Origin was new to her career and eager to learn. Garry McGuire of NASA Marshall Space Flight Center was an established contributor to dozens of IPC standards. After they met at an IPC APEX EXPO Newcomers' Reception, the two built a strong mentor/mentee relationship. Christina is an Emerging Engineer (EE), and they both have leadership roles on the 7-31FS IPC/WHMA-A-620 Space and Military Electronic Assemblies Addendum Task Group.

Coincidentally, they also celebrated two big wins at the IPC annual awards ceremony this year, with Garry taking home IPC's highest honor, the IPC Raymond E. Pritchard Hall of Fame Award, and Christina emerging as a Rising Star.

Let's start with your first meeting. How did that go and what was your expectation?

Christina: The first time I attended IPC APEX EXPO, I went to the Newcomers' Reception. While I was there, I had a question regarding the IPC/WHMA-A-620S and I had no idea who to talk to about it. I saw John Mitchell, president and CEO of IPC, greeting every-

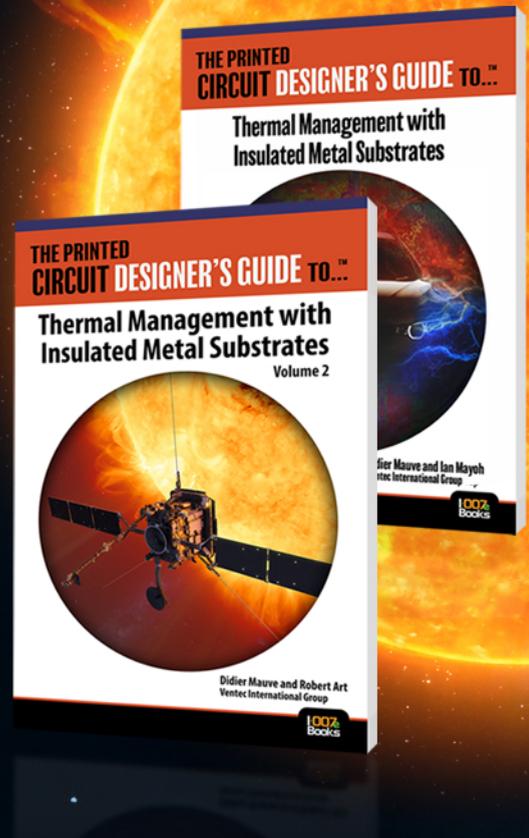
one and I decided that talking to him would be the best way to find an answer to my question. I was able to speak with John about my question, and he directed me to Teresa Rowe, who eventually introduced me to Garry. When I met Garry, he gave me such a great answer to my question that I asked him if he would be my mentor.

Garry: Teresa Rowe approached me and said she knew an engineer who would be a great candidate for me to work with in the Emerging Engineer program. Christina and I met shortly thereafter. The COVID shutdown affected our ability to conduct face-to-face activities, but we did make it to several IPC meetings, and we had many more virtual meetings.

To read the rest of this article, which appeared in the Spring 2023 issue of *IPC Community*, [click here](#).



Companionship at its Best



This must-read sequel to Ventec's book series on Thermal Management describes the applications, IMS products and support services to help you understand and overcome thermal management challenges.



Download Now

I-007eBooks



North American PCB Industry Sales Up 11.6 Percent in March

IPC announced the March 2023 findings from its North American Printed Circuit Board (PCB) Statistical Program. The book-to-bill ratio stands at 0.91.

IPC Issues Call for Participation for High Reliability Forum

IPC is now accepting abstracts for the High Reliability Forum, the international conference focusing on Class 3 and safety critical electronics for mil-aero, automotive, medical, and long-life applications that are subjected to harsh use environments.



The Shaughnessy Report: A Strong Start

Do you remember when you started working at your current job? What sort of onboarding process did you



undergo? If you've been with the same company for decades, you likely didn't see much of an onboarding process at all! If you're lucky, your boss took you out to lunch on the first day. Were you assigned a mentor? Were you welcomed with open arms into your new work family, or were you basically tossed in the pond and told to sink or swim?



Tamara Sites

Tamara Sites Joins I-Connect007 Sales and Marketing Team

Tamara Sites, a sales professional with strong ties to companies in the electronics manufacturing sector, has joined the I-Connect007 sales and marketing team, effective April 1. She most recently worked on growing the IPC CFX community, part of IPC's Factory of the Future initiative. Tamara will now focus her attention on increasing partnerships between I-Connect007 and companies serving the printed circuit board industry supply chain, with a particular emphasis on developing new business.

The Chemical Connection: Chemical Control for Wet Processes

As I've mentioned in previous columns, etching can be the most complex process in the wet processing stages because there are many factors that contribute to your etch rate. Without keeping these contributing factors steady, your etch rate will vary and, therefore, so will your product quality.

Punching Out: Seven Drivers of Market Success

Throughout my years in electronics mergers and acquisitions, I have seen some companies succeed and others fail. A variety of factors determine the success of a company, from great leadership to a strong corporate culture and luck. I define a successful company as one that is profitable and receives attractive offers in the market, whereas a failing company doesn't generate money, is shunned in the market, and often shutter.



Tom Kastner

The Doctor's In: Everything You Need to Know About Getting a PhD

When it comes to advanced degrees, the PhD is often a misunderstood and undervalued option. In a world where MBA programs have strong name recognition, and master's degrees can seem relatively easy to obtain, the PhD is frequently overlooked. In fact, many people couldn't even tell you what the initials stand for. As someone who has embarked on this journey, I am eager to share the insights I've gained along the way. I'll cover the value of a PhD, the requirements for earning one, and some advice for successfully completing the program.

CMK Hits the Gas on Automotive PCBs



Mike Meyer

Guest Editor Kelly Dack recently spoke with Mike Meyer, senior business development manager for CMK Americas, which specializes in manufacturing PCBs for the automotive sector. In this interview, they discuss CMK's latest developments, trends in the global automotive market, and why they plan to expand their facility in Thailand.

NAMM 2023: It's All About That Bass

The use of AI in the music industry seems only natural. If you're trying to create a piece of music that is similar to one you already have, AI can do that for you. Just give it some basic instructions and let it go to work.

Spring Issue of *IPC Community* Now Available for Download

It's another home run for this collaboration between IPC and I-Connect007. Detailed information on how shipping costs will affect your business this year, efforts in Mexico to make a play on the world stage of electronics manufacturing, the impact of IPC-1791 for defense manufacturers, an image gallery from WHMA's 30th annual conference, and so much more.



For the latest news and information, visit PCB007.com

Career Opportunities



Find industry-experienced candidates at jobConnect007.

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

In addition, your ad will:

- be featured in at least one of our newsletters
- appear on our jobConnect007.com board, which is promoted in every newsletter
- appear in our monthly [Careers Guide](#), emailed to 26,000 potential candidates

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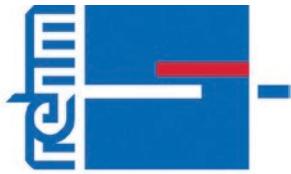
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I-Connect007
GOOD FOR THE INDUSTRY



Career Opportunities



THERMAL SYSTEMS

Sales Engineer SMT North Mexico

Rehm Thermal Systems, a leading German manufacturer of reflow soldering systems with convection or condensation and drying and coating systems, has produced energy-efficient manufacturing equipment for the electronics and photovoltaics industry since 1990. We also offer tailor-made applications related to the soldering, coating and hardening of modules.

Responsibilities:

- This position is responsible for expanding our customer network and maintaining existing customer relationships in the Northeast Mexico region. The Sales Engineer would work closely with the German headquarters and the General Manager Rehm Mexico to implement the sales strategy.
- A candidate's proximity to Monterrey, Mexico, is a plus.

Qualifications:

- An Engineering degree or comparable qualification with a strong technical background is required.
- Sales-oriented attitude, good communication skills and willingness to travel frequently within Mexico is essential.

We offer innovative products, a great dynamic work environment and exciting training opportunities in our German headquarters.

To learn more about Rehm Group please visit our website at www.rehm-group.com.

Please send resumes to: Mr. Luis Garcia at luis.garcia@rehm-group.com.

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Europe Technical Sales Engineer

Taiyo is the world leader in solder mask products and inkjet technology, offering specialty dielectric inks and via filling inks for use with microvia and build-up technologies, as well as thermal-cure and UV-cure solder masks and inkjet and packaging inks.

PRIMARY FUNCTION:

1. To promote, demonstrate, sell, and service Taiyo's products
2. Assist colleagues with quotes for new customers from a technical perspective
3. Serve as primary technical point of contact to customers providing both pre- and post-sales advice
4. Interact regularly with other Taiyo team members, such as: Product design, development, production, purchasing, quality, and senior company managers from Taiyo group of companies

ESSENTIAL DUTIES:

1. Maintain existing business and pursue new business to meet the sales goals
2. Build strong relationships with existing and new customers
3. Troubleshoot customer problems
4. Provide consultative sales solutions to customers technical issues
5. Write monthly reports
6. Conduct technical audits
7. Conduct product evaluations

QUALIFICATIONS / SKILLS:

1. College degree preferred, with solid knowledge of chemistry
2. Five years' technical sales experience, preferably in the PCB industry
3. Computer knowledge
4. Sales skills
5. Good interpersonal relationship skills
6. Bilingual (German/English) preferred

To apply, email: BobW@Taiyo-america.com with a subject line of "Application for Technical Sales Engineer".

apply now

Career Opportunities



BLACKFOX

Premier Training & Certification

IPC Instructor Longmont, CO

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

IPC instructors will primarily conduct training at our public training center in Longmont, Colo., or will travel directly to the customer's facility. It is highly preferred that the candidate be willing to travel 25–50% of the time. Several IPC certification courses can be taught remotely and require no travel or in-person training.

Required: A minimum of 5 years' experience in electronics manufacturing and familiarity with IPC standards. Candidate with current IPC CIS or CIT Trainer Specialist certifications are highly preferred.

Salary: Starting at \$30 per hour depending on experience

Benefits:

- 401k and 401k matching
- Dental and Vision Insurance
- Employee Assistance Program
- Flexible Spending Account
- Health Insurance
- Health Savings Account
- Life Insurance
- Paid Time Off

Schedule: Monday thru Friday, 8–5

Experience: Electronics Manufacturing: 5+ years (Required)

License/Certification: IPC Certification—Preferred, Not Required

Willingness to travel: 25% (Required)

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**Prototron
Circuits**

Sales Representatives

Prototron Circuits, a market-leading, quick-turn PCB manufacturer located in Tucson, AZ, is looking for sales representatives for the Southeastern U.S. territory. With 35+ years of experience, our PCB manufacturing capabilities reach far beyond that of your typical fabricator.

Reasons you should work with Prototron:

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

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

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Career Opportunities



Regional Manager West Region — Two Positions

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

DETAILS OF FUNCTION:

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

QUALIFICATIONS:

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

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

fernando_rueda@kyzen.com

apply now



Technical Marketing Engineer

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

Requirements:

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

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

Send Resumes to: resumes@ema-eda.com

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Career Opportunities



MACHINES FOR PRINTED CIRCUIT BOARDS

Field Service Engineer

Location: West Coast, Midwest

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

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

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

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

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

Must be able to travel extensively.

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Technical Service & Applications Engineer

Full-Time – Flexible Location

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

Responsibilities

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

Skills and Qualifications

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

Benefits

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

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Career Opportunities



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

- Engineering
- Quality
- Various Manufacturing

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

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

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

For additional information, please visit our website at www.arlonemd.com

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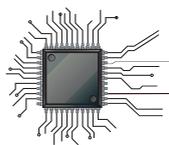
Are You Our Next Superstar?!

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

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

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Career Opportunities



MivaTek

Global

Field Service Technician

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

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

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

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

More About Us

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

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eptac

TRAIN. WORK SMARTER. SUCCEED.

Become a Certified IPC Master Instructor

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

Qualifications and skills

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

Benefits

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

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Career Opportunities



American Standard Circuits

Creative Innovations In Flex, Digital & Microwave Circuits

CAD/CAM Engineer

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

ESSENTIAL DUTIES AND RESPONSIBILITIES

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

ORGANIZATIONAL RELATIONSHIP

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

QUALIFICATIONS

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

PHYSICAL DEMANDS

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

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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.

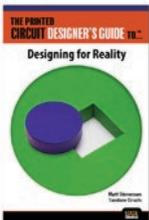
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NEW PODCAST! *On the Line with...*

...is available now on Spotify and coming soon on all major podcast platforms. In this podcast, we speak with industry experts to get the latest insights and perspectives on the most relevant topics in the electronics industry today. The first series of On the Line with... features conversations on sustainability.



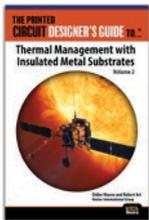
I-007eBooks The Printed Circuit Designer's Guide to...



Designing for Reality

by Matt Stevenson, Sunstone Circuits

Based on the wisdom of 50 years of PCB manufacturing at Sunstone Circuits, this book is a must-have reference for designers seeking to understand the PCB manufacturing process as it relates to their design. [Read it now!](#)



Thermal Management with Insulated Metal Substrates, Vol. 2

by Didier Mauve and Robert Art, Ventec International Group

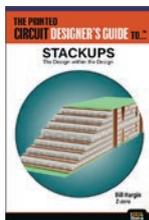
This book covers the latest developments in the field of thermal management, particularly in insulated metal substrates, using state-of-the-art products as examples and focusing on specific solutions and enhanced properties of IMS. [Add this essential book to your library.](#)



High Performance Materials

by Michael Gay, Isola

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



Stackups: The Design within the Design

by Bill Hargin, Z-zero

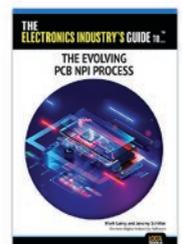
Finally, a book about stackups! From material selection and understanding laminate data-sheets, to impedance planning, glass weave skew and rigid-flex materials, topic expert Bill Hargin has written a unique book on PCB stackups. [Get yours now!](#)

THE ELECTRONICS INDUSTRY'S GUIDE TO... *The Evolving PCB NPI Process*

by Mark Laing and Jeremy Schitter, Siemens Digital Industries Software

The authors of this book take a look at how market changes in the past 15 years, has affected the process for new product introduction (NPI) in the global marketplace.

Learn how to streamline the NPI process and better manage the supply chain. [Get it Now!](#)



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

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

EDITOR | COLUMNIST COORDINATOR: **MICHELLE TE**
michelle@iconnect007.com

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

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

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

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

SALES MANAGER: **BARB HOCKADAY**
(916) 365-1727; barb@iconnect007.com

BUSINESS DEVELOPMENT: **TAMARA SITES**
tamara@iconnect007.com

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

ART DIRECTOR/PRODUCTION MGR.: **SHELLY STEIN**
shelly@iconnect007.com

MAGAZINE LAYOUT: **RON MEOGROSSI**

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

CREATIVE TECHNOLOGIST: **BRYSON MATTIES**

COVER: **SHELLY STEIN**

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PCB007

MAGAZINE

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