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NOVEMBER 2019

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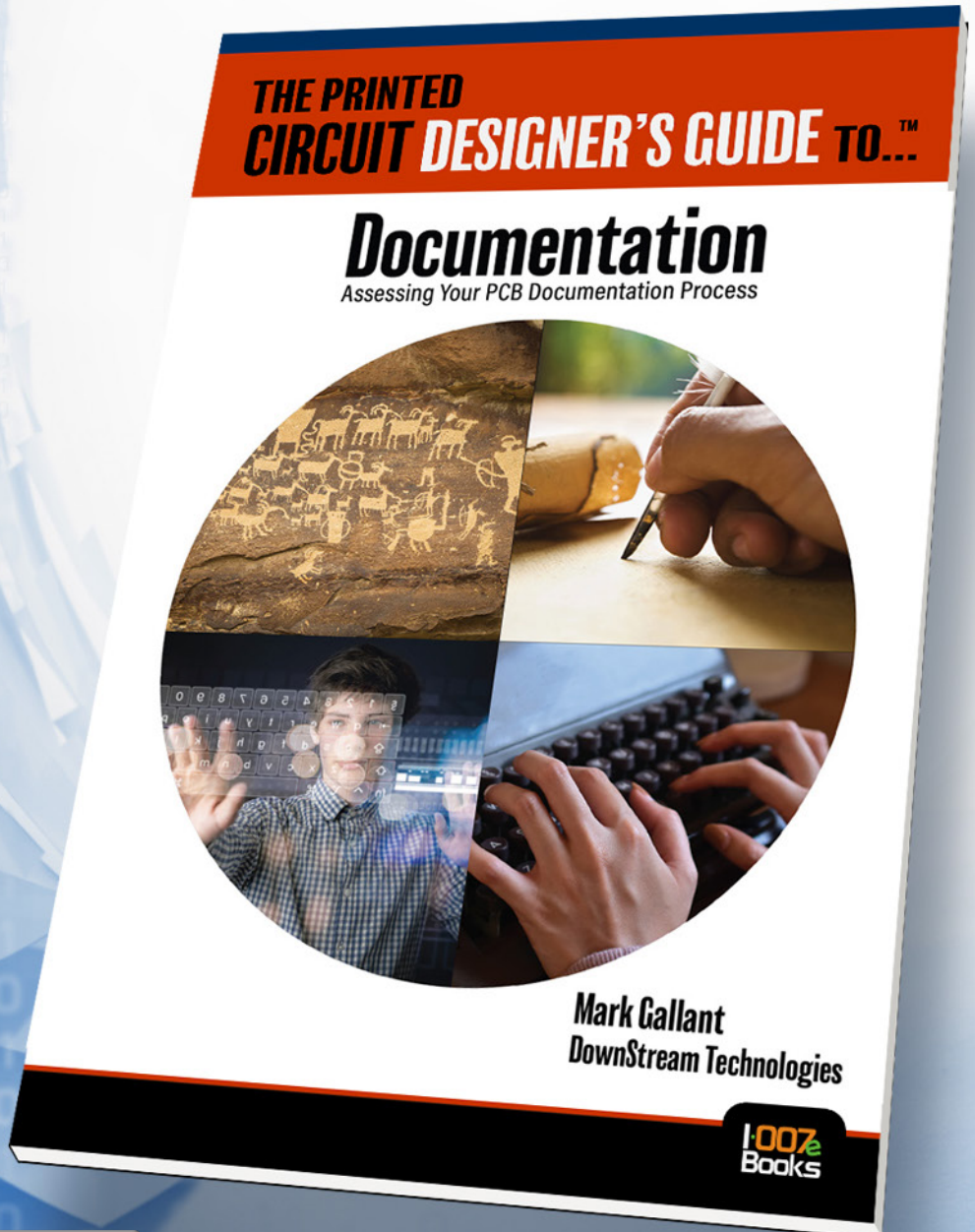

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From My Perspective

In this issue, we update your prescription, clarify your vision of the industry, and bring your own perspective into view. With each interview, try on another outlook and look at the industry from another point of view.

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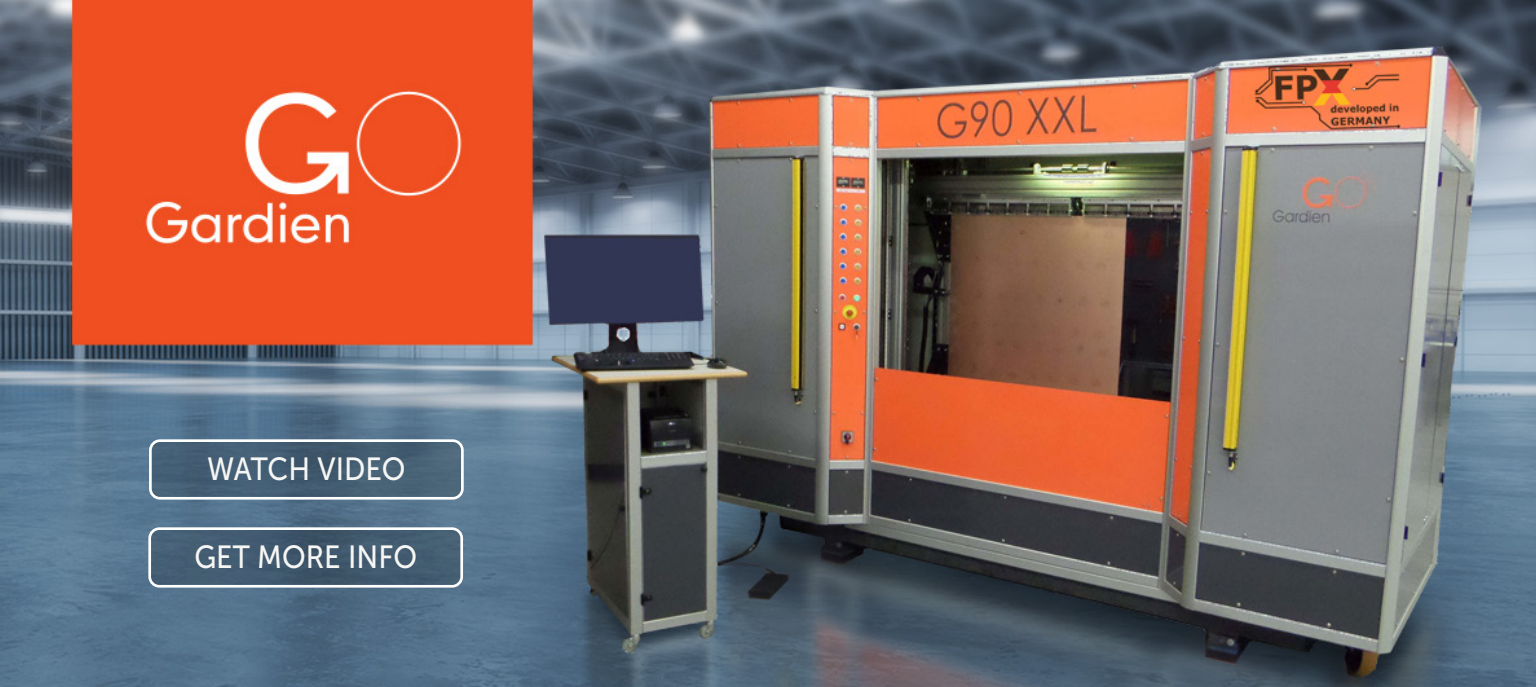

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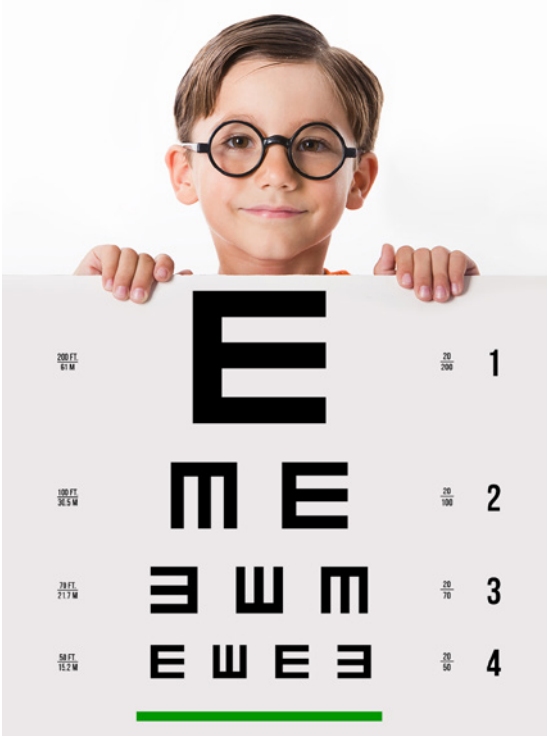
Clarity of Vision

Nolan's Notes

by Nolan Johnson, I-CONNECT007

I was eight years old; it was early in the school year, and I was attending a new school. My family had just moved across town—just a couple miles, but enough to change my world. I was still learning the names of my classmates and mapping out the school in my head. One day in my physical education class, Mr. Denley, the PE teacher, administered eye exams to the class. One after the other, kids toed the line, covered an eye with one hand, and mimicked the rotated "Es" on the eye chart with the fingers of their other hand. Then, it was my turn.



Oddly enough, those "Es" weren't very readable from the "line of truth." I knew I couldn't make out the chart from the back of the huddle of kids, but I had expected things would be clearer once I had a proper view. The unpleasant surprise grew into a minor grade school panic. I was mortified. Why couldn't I read the eye chart? Every kid in my class watched me struggle with incorrect guesses and saw me fail.

I said nothing to my parents; I just tried to forget that it ever happened. They never said anything, so I thought I had gotten away with it. However, a few days later, Mom pulled me out of school early. We drove to the local university and met some really cool college students who, I learned, were studying to be optometrists. They had me look through some weird machines and try on ugly glasses that they built up for me by putting a bunch of lenses together in a clamp. Those glasses weighed a ton! Next, Mom took me to a different room, and we played with the eyeglass frames that were displayed on the wall. Then, we went home.

About a week later, Mom and I drove out to the university again right after school. I sat in a big lab room that held about a dozen work stations. Each table had a crockpot full of sand on it and a vanity mirror. One of the students from my first visit greeted me, and we sat down at the table. He had a pair of frames and lenses, which he said were for me. He tested them on my face, and then heated the frames in the sand to bend them to fit me comfortably. Then, he leaned back a little and said, "Look around a bit. How do they work?"

I looked across the room. I was shocked by the details I could see. I blurted, "Mom, am I supposed to be able to see the wall sockets way over there?"

"Yes, Nolan, you are." I could feel the beginnings of tears welling up in my eyes.

"Do you suppose my batting is going to improve?" I asked.

"Yes, I suppose so," she almost whispered.

On the drive home, there was all this new information that I hadn't seen before right in front of me. I was so excited that I read every sign and license plate out loud. I'm sure

my mom was going nuts with all the random stuff I was blurting out from the back seat. But she just let me have my fun and celebrated my new perspective all the way home. And to the credit of my middle school classmates, my glasses were the topic of conversation that next morning.

In this issue, we update your prescription, clarify your vision of the industry, and bring your own perspective into view. With each interview, try on another outlook and look at the industry from another point of view. Let's see what else is out there.

We start with EIPC's Tarja Rapala-Virtanen perspective on changing PCB demands. Then, I-Connect007 technical editor Happy Holden catches up with Audra Thurston, a young and articulate PCB engineer who recently joined the industry after graduation. Next, I have a conversation with Sunstone's Nancy Viter and Sheri Kuretich on staffing trends and leveraging ISO 9000 to create a training knowledgebase.

I-Connect007 technical editor Pete Starkey submits a conversation: "Thomas Michels on the Importance of Investment and Cooperation," and I catch up with Zach Peterson from Northwest Engineering Solutions to discuss upcoming technologies in "Industry Set for Shift to True 3D Printing and Photonics." Then, the PCB007 China team updates us on the upcoming HKPCA Show, which has been renamed the 2019 International Electronics Circuit Exhibition (Shenzhen).

I-Connect007 technical editor Dan Feinberg covers how "5G Is Coming With Quantum-level Advances and Features," followed by an article from Rogers' Johnathan Rountree, titled "Chasing Down Materials for 5G and Beyond."

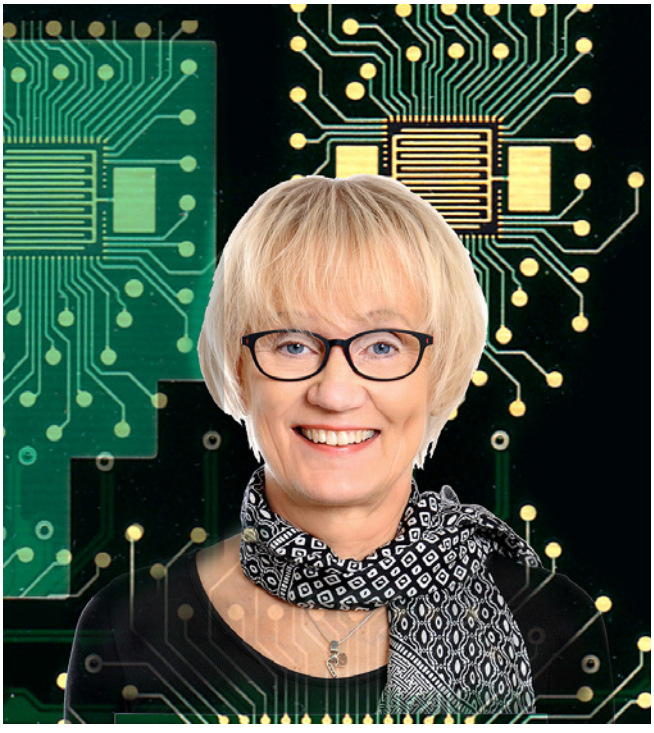
Wang Longji, a Chinese cultural icon as well as a PCB manufacturing pioneer, shares his perspective on the industry's growth in China in "The CPCA and China's Electronic Circuit Industry: Past and Future." We wrap up the features with a technical piece from Atotech's Rick Nichols, Sandra Heinemann, Robert Spreemann, and Gustavo Ramos, titled "The Viability of a Cyanide-free Immersion Gold Bath."

Todd Kolmodin takes a look at continuous innovation in his column, "Go to Bed Hungry," and Steve Williams sets out to improve quality programs in his column, "Making Quality Initiatives Fun." Marc Ladle sheds light on the preparation, application, and curing for solder mask in "UV Cure LED Energy Saver." Mike Carano concludes in his column "Changes and Concerns Regarding HDI Technology."

While we may not cause you to well up with tears or improve your sandlot baseball game, we hope you find some new perspective in these pages. **PCB007**

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

Tarja Rapala-Virtanen on Changing PCB Demands



Feature Interview by Pete Starkey
I-CONNECT007

Pete Starkey speaks with EIPC Technical Director Tarja Rapala-Virtanen about her perspective on changing PCB demands, including flex vs. rigid boards, and the impact of miniaturization, modularity, 5G, the automotive industry, etc.

Pete Starkey: Hello, Tarja. It's nice to have the opportunity to talk with you again, and I really appreciate you taking the time. Please give us a brief personal background to your present position.

Tarja Rapala-Virtanen: As you know, I have more than 30 years' experience in managing complex electronics projects in multicultural environments across Asia and Europe mainly as well as the U.S. During the last 10 years, I worked in China as the VP of technology for a global PCB company. I returned to Finland in the summer of 2018, and I'm still exploring the European landscape to understand it better. I'm currently the technical director of EIPC, the European Institute for the PCB Community. Through my knowledge network, and especially through my long Asia experience, I can bring value, a new perspective, and fresh ideas to my work with EIPC.

Starkey: You are already an enormous asset to the European PCB community, and we're very pleased to have you here. If you look at the European PCB industry from your perspective, what's the most significant change you've seen in the past few years?

Rapala-Virtanen: I'm still on a bit of a learning curve, but I do not see any significant change in the PCB industry. However, the demand for types of PCBs has changed. For example, the demand for flexible boards has grown while the demand for rigid PCBs has been steady, more or less; it may have increased a little bit, but what I see on the rigid PCB side is that the design features and requirements for next-generation PCBs are more challenging. Miniaturization will never end. The requirement for product tolerances is getting tighter and tighter both within the board and even at the lot-to-lot level. One driving factor for these requirements is increased modularity, which applies to the entire PCB supply chain. It's nearly everywhere; we see it in Europe and globally.

Starkey: Looking specifically at Europe, what sort of challenges are your European EIPC members currently facing?

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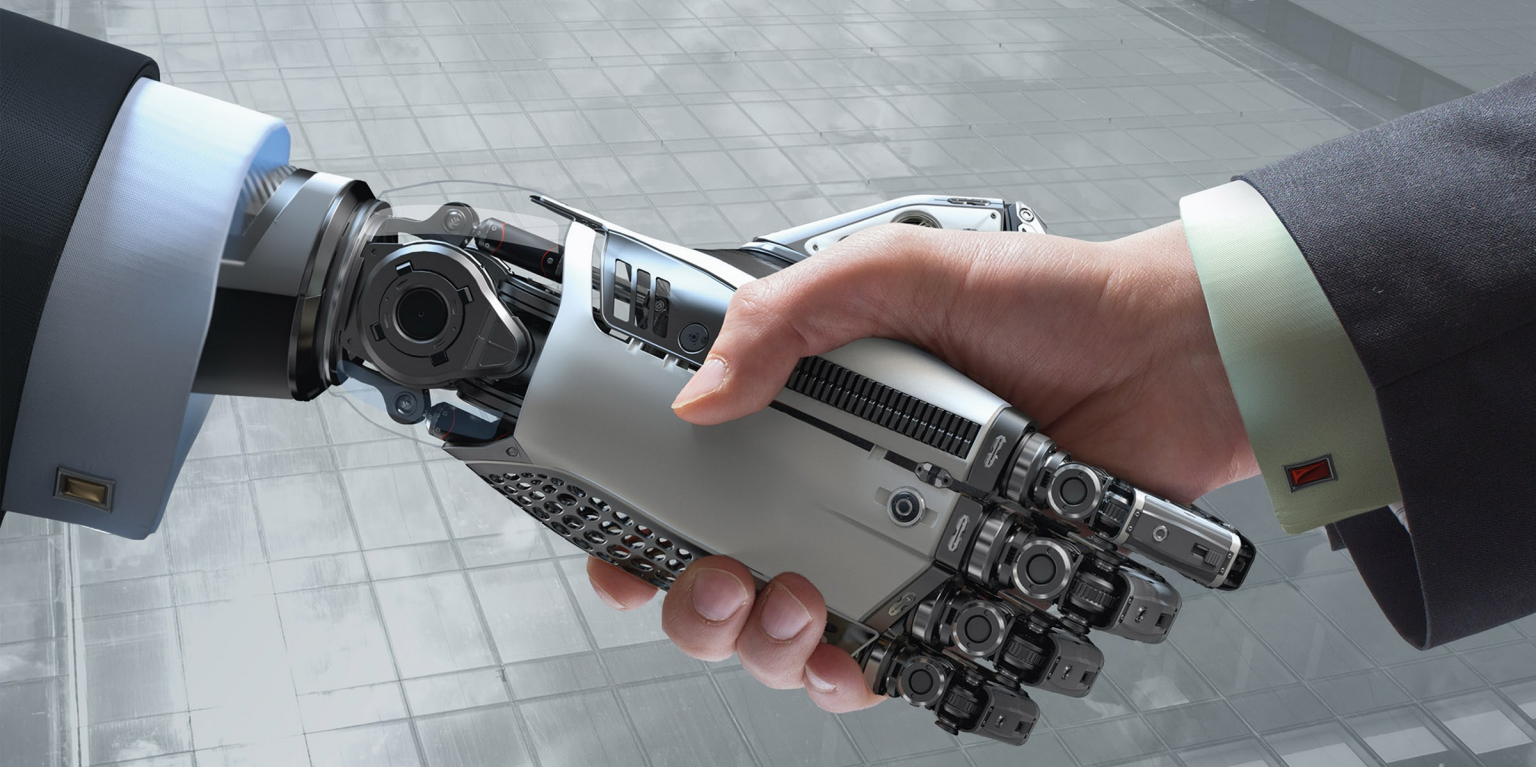

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Rapala-Virtanen: Global economic uncertainty and visibility present challenges. And we don't yet know what the demand for 5G will be or when it will ramp up. When will the volume come? And, of course, the trade conflict between the U.S. and China is also affecting us in Europe, although it could also lead to some possibilities for European companies.

All customers who are preparing for 5G are driving their stocks down, so that might affect short-term orders. Miniaturization and simultaneously increased data rates need new material and process solutions. And as I said before, modularity is increasing, which affects what will be the next-generation board types. For example, the manufacturing of chip-level packages is done in Asia. And embedding technologies are coming, which is a technology that some of the European companies are looking at.

In many of the market segments—including automotive, Industry 4.0, and IoT—I hear questions about future products. What are the material types as the data rates are increasing? What are the design features? What are the reliability expectations? These have to be fulfilled by manufacturers.

Starkey: You've already partly answered this question, but if we look to the future, how do you think the European PCB industry is going to change during the next few years?

Rapala-Virtanen: With 5G, Europe has to be ready to fulfill the requirements; thus, registration is one of the challenges as everything is becoming tighter and finer. We have to fulfill it at the product level, and we must understand the difficulties. High-frequency applications are also coming with new materials. So, how do we meet all of the reliability requirements throughout processing and enable the PCB to satisfy all the electrical requirements of the end product? As I mentioned earlier, we need to consider what IoT, Industry 4.0, and robotics will bring. Many designs are done in Europe because various OEMs are still located here, but where the boards will be done remains to be seen.

There is a lot of change on the automotive side as well. Power electronics are already there, but what new requirements will electric cars bring to the market, and what about reliability? We see that when some of the microvia boards are used in automotive, they require different reliability testing. So, it might take a longer time to get the products to the marketplace.

And one very important thing—we cannot forget about environmental impact, which has affected the whole supply chain. I think Europe has a strong position regarding green electronics. In the past, we have seen many innovative environmental solutions in designs, materials, and processing. And I cannot avoid mentioning what will happen with Brexit and all of the internal affairs in Europe. The German market has also had some challenges in the automotive industry recently, but we hope that they will bring some new, interesting solutions for next-generation products. All of these changes on the economic side may affect the future, including how it goes and how we see it.

Starkey: What is your area of greatest concern currently?

Rapala-Virtanen: My greatest concern is that, if Europe doesn't have the manufacturing capability available for next-generation products, when they do come, we will miss the opportunity for those new products in manufacturing. Therefore, we must have very close cooperation over the whole supply chain so that we can be ready. The time to market is very critical, and all of these points from design through manufacturing—including reliability testing and functionality—are linked together; we need this understanding so that we don't miss the opportunity.

Starkey: Tarja, many thanks for sharing your views with us.

Rapala-Virtanen: Thank you, Pete. PCB007

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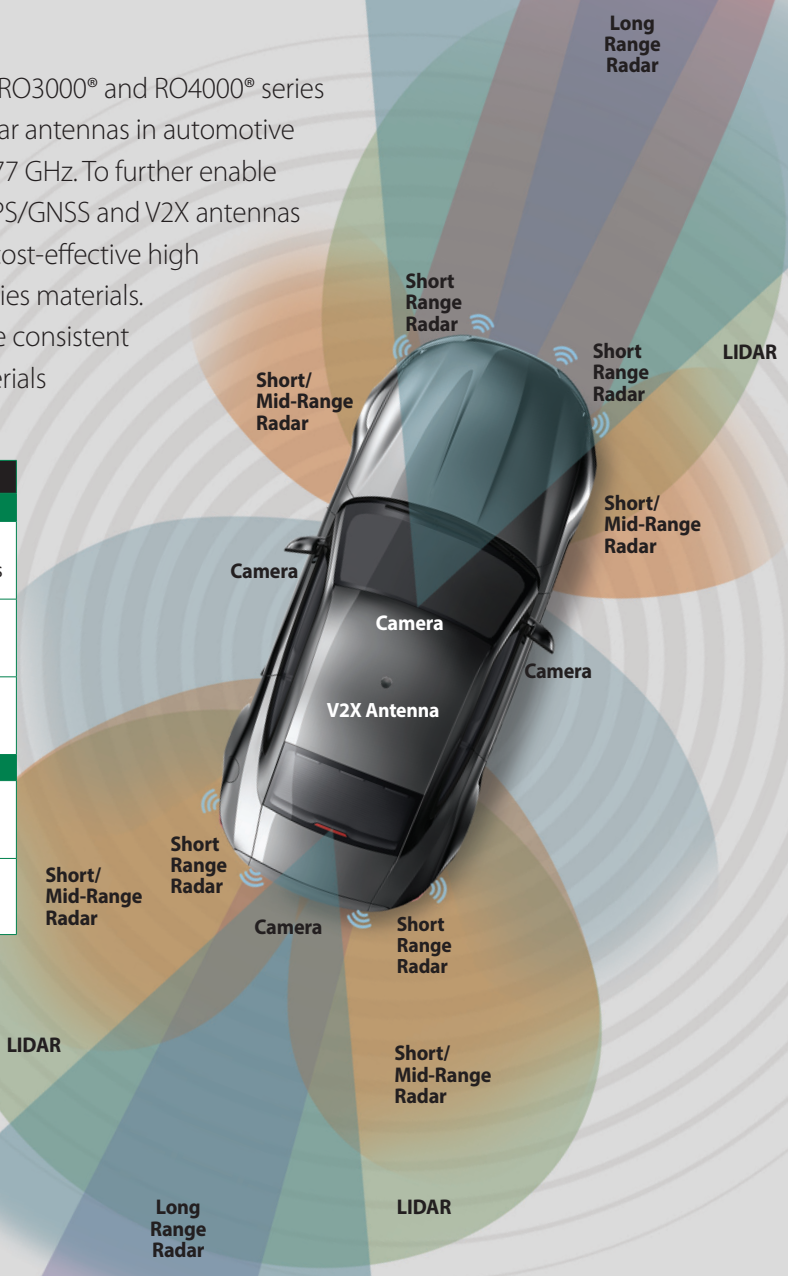

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A Young Engineer's Perspective on Joining the Industry

Feature Interview by the I-Connect007 Editorial Team

Audra Thurston, a process engineer at Calumet Electronics Corporation, talks about being an intern transitioning out of college and into the PCB industry. She gives her advice to other college students pursuing engineering and gives her view on the aging workforce and IPC student chapters.

Nolan Johnson: Audra, I'm interested to learn how you came to be a part of this industry. Who do you work for, and what is your role?

Audra Thurston: I came to Michigan Tech to get my chemical engineering degree. At that point, I didn't even know that a chemical engineer could work with PCBs; I thought you exclusively had to be an EE. But I learned that was not the case when I started looking for an internship in the area of Houghton, Michigan. I started as an intern at Calumet Electronics—about 20 minutes from Michigan Tech—the summer before I graduated. I came out of that internship with the desire to work with PCBs as a full-time career. Then, Calumet Electronics hired me after I graduated in 2018 to work as a process engineer, which is still my current role.

Happy Holden: What struck you about PCBs and led you to want to work with them?

Thurston: The industry keeps you on your toes, and if you stay in the industry, you will continually learn because of the pace of change in electronics is rapid. There are other career options for chemical engineers, such as paper making, but that wasn't as interesting to me because paper making probably isn't going to change much in the next 20 years compared to how much electronics is going to change in the next two years. I felt like I could be a part of cutting-edge technology.

Holden: There has never been a dull moment in my almost 50 years in the industry. And for younger people like you, it's going to be even more challenging and fast-paced.

Thurston: I was working on research projects, trying to bring on new technologies, and helping Calumet Electronics get the capability of

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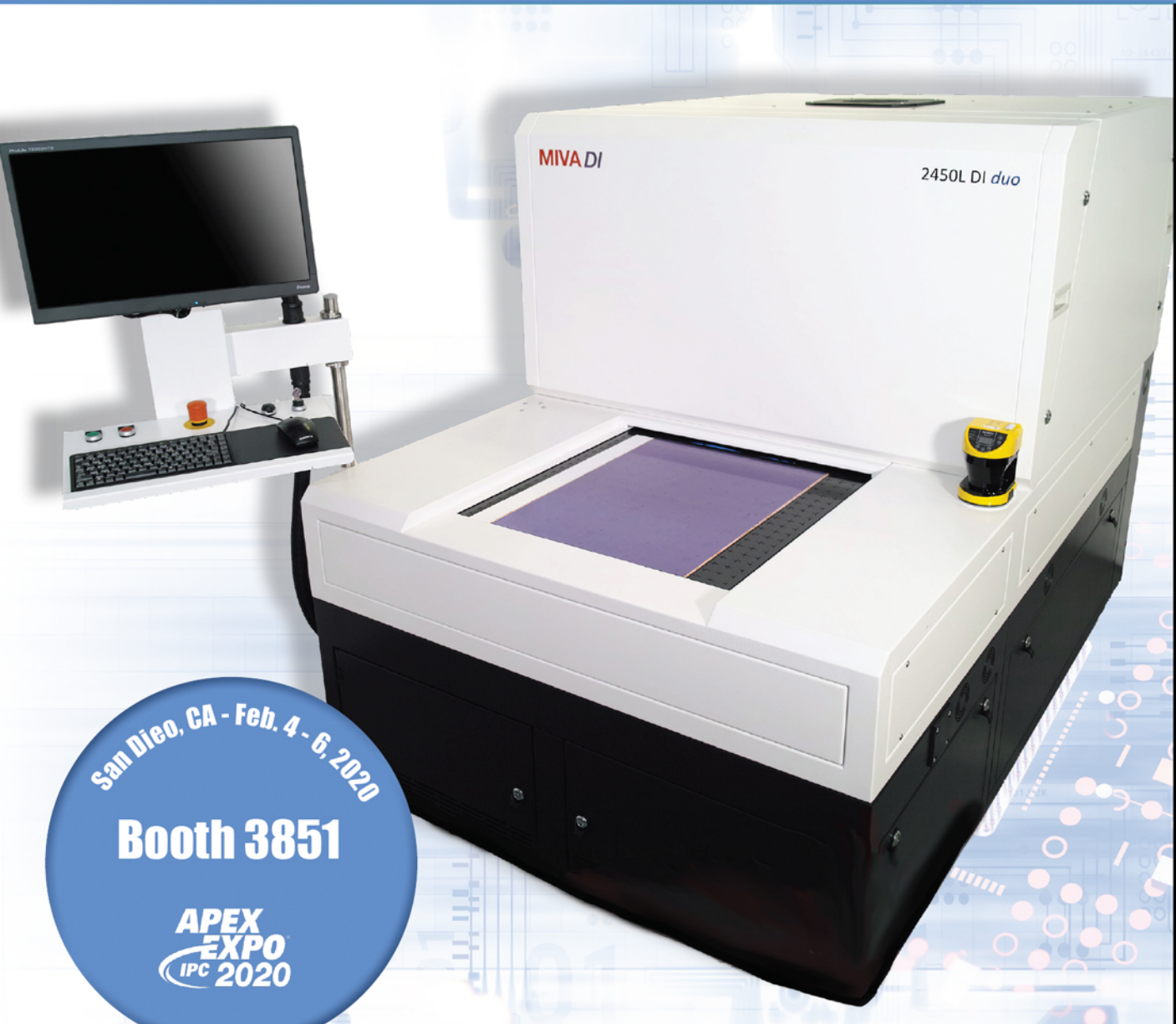

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copper-plated microvias as an intern. Seeing a production board go through the shop is run-of-the-mill now, whereas two years ago, it was something on which we were actively working. It's cool to see your project come to fruition.

Johnson: That is indeed a rapid turnaround for getting results from an intern project. What are some of the dynamics you see in our industry right now that stand out to you?

Thurston: One thing that stands out to me about this industry is that there are so many different parts of it. You have the PCB design side, which feeds into the manufacturing and assembly sides, which ultimately goes to an OEM to be in their product. Each of these areas of PCB design, manufacturing, and assembly is connected but still so separate. It's interesting that you need to have a general idea of all of those aspects of the process to succeed. For example, as a PCB manufacturer, we have to know a little bit about both design and assembly to help our end customers problem-solve and design their boards so that we can make them; it's a full product life cycle, and you get to be involved in all of that.

Holden: When you first started college, what did you think chemical engineers did? What would you have liked to know before you became an intern?

Thurston: I was influenced by where I went to school. In the Midwest, a big thing for chemical engineers is consumer products. Wisconsin has the Fox River Valley area where there's a lot of consumer and paper products being made. Naturally, Wisconsin is close to the Upper Peninsula of Michigan, so a lot of recruiters from consumer product companies recruit at Michigan Tech. As an impressionable freshman, if that's who you always see on campus, then that's what you think your options are. I always thought I would go into consumer products because that seemed to be the most marketed industry in the Midwest. The PCB industry could work on marketing more to students!

But the new IPC student chapters on college campuses are a great step in the right direction to involve students earlier because you almost have to reach them as freshmen and sophomores while they're trying to get their first internship in order for them to stay in the industry. If you're pursuing senior engineers, they probably already have their career trajectory mapped out and have had internships that influence where they want to go full-time, so it may be too late. It's about getting to people right when they start so that they are excited about this industry, take relevant classes, and find internships that will help them enter this industry; then, you can build on experience from there.

Johnson: Were you involved with IPC and the formation of the student chapters?

Thurston: I wasn't directly involved with that, but I was involved with the introductory PCB class that Happy was a part of at Michigan Tech. As a young engineer, attending that class was incredibly valuable because various experts from different companies taught the class about the industry, so listening to them was awesome. I learned a lot.

As far as the IPC student chapters, Michigan Tech has one, which started last spring. It hasn't been around long, but I hope it continues to grow. I want to increase my involvement as an outside advisor to lend some support, too, especially since I work in the nearby area. We're giving an informational session on

Calumet Electronics soon to try to spark some interest for internships next summer.

Holden: Did you interview with other companies in the Midwest your senior year?

Thurston: I did two interviews on site: one for a consumer products company, and another in the electronics business and based in Eau Claire, Wisconsin.

Holden: Eau Claire has a big board shop.

Thurston: That interview stemmed from my internship because I knew this was an industry I wanted to be in, so I talked to other electronic companies as well. Having that internship helped me get other interviews because a lot of chemical engineers don't know about the electronics industry as an option, at least in my experience, so having that on my resume set me apart.

Johnson: What advice would you give chemical, mechanical, and electrical engineers at Michigan Tech regarding the topic of PCBs?

Thurston: I would recommend young engineers to take a design class if they can; that's one thing I wish I would have done. It's funny because I didn't really like electrical engineering, so after I completed my physics requirements, I thought, "I'll never have to think about electricity again." But now, I wish that I had taken some design classes to understand the basics to build on in my career, even as a chemical engineer.

It's important to be a well-rounded engineer in any part of the electronics industry. You should know about PCB design, manufacturing, and assembly. Then, no matter where you are in the industry, you have a cohesive understanding of how things work because otherwise, it's difficult to give customers advice about whether a design or board is good or not, for example. Having at least a small understanding of design would make me a better engineer.

I would also advise young engineers to do an internship. I don't think there's anything more valuable than an internship because it will tell you whether you're going to like it or not. It's important to let chemical engineers know that there is a lot of chemistry in PCBs, so you would have the chance to have a hands-on experience that makes going to work fun.

Johnson: I know this sounds like a job interview question, but I'm curious where you see yourself and the industry in 3–5 years.

Thurston: I love the Upper Peninsula very much, so I picture myself still being in the area. I would also like to become more involved in processes across PCB manufacturing and have a better understanding of everything across the board, not just chemical-related areas. Right now, I primarily work in a couple of areas, but as you know, there are probably 50 different processes that go into one circuit board. I want to become a more well-rounded engineer and be involved with cutting-edge technologies. I have a chance right now to work on some of the technologies that we're pursuing, such as

one-and-one space and trace, so I'd like to continue that.

In the next few years, I think the industry is going to be figuring out new technologies but at a higher volume in North America. For instance, one-and-one is feasible in Asia right now because they have the technology and capacity, but in North America, we need to be able to have more than one source for those technologies and use them. It's not enough that one circuit board shop can do this technology; we need multiple circuit board shops to be able to do it, and in high volume, so that we can meet the needs of all of the customers that want to stay in the U.S.

Holden: What do you find is the most effective method of learning? And what can be improved to speed up the learning process for a breadth of topics?

Thurston: Offering more classes would help as would access to conferences. Conferences, especially where I am right now, are isolated, so they can be hard to attend. Having webinars available where you can pay to attend a class and do it on your own time without having to leave, take time off of work, and be absent from your responsibilities, would be useful for both young engineers and those who have been in the industry for a long time. Continuing education is going to make the whole industry better.

Many conferences have hands-on seminars too, where it's not sitting and listening to someone lecture, but having interactive sessions with your lecturer. It's hard to do demonstrations, of course, with chemistries and drill machines. But more interactive presentations are better. As much as I love college, sometimes lectures can be dry; I much prefer something hands-on and accessible.

I think the industry also needs to take some of the tribal knowledge out of PCBs. I haven't been in this industry for long, but it seems like a lot of knowledge is held by people that have been in the industry for 50–60 years. There are a lot of these tricks of the trade that aren't necessarily documented or written down, so it can be hard to find answers sometimes. Having a place where those with more experience could share their knowledge with young engineers like me would be awesome. I want that knowledge, and I'm sure other engineers my age do too. We want someone to teach us, but sometimes there's a disconnect between the people who have the knowledge and the people who want to be taught; I'd like to see a way for people to connect in that way and capture that knowledge into a white paper or forum.

Holden: I didn't choose to go into the printed circuits industry; it chose me. I was headed for chemical companies like DuPont or Dow. Instead, I ended up at Hewlett-Packard in the Bay Area, which had nearly 30

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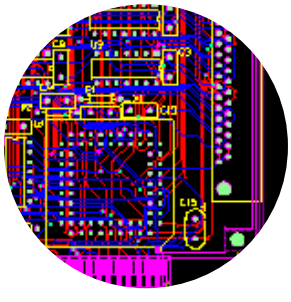

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printed circuit shops. The California Circuits Association was also in the area, where we met every month with a different speaker, which helped enormously. Even after the meetings, I would talk with these people, and I learned a lot. It would be great if we could have a virtual circuit board association that met every month, even if it was done electronically, because we're so spread out.

Thurston: That would be great, and then those established conferences would be a chance to meet in person.

Andy Shaughnessy: What surprised you most when you entered the industry?

Thurston: I was surprised by how much there is to learn and the rate of change, which is why I love this industry, but it can be overwhelming at times. For example, imagine you are plating copper onto a board, but then for your surface finish, you're plating ENIG onto a board. When you first get into the industry, you think, "I'm plating two metals, so it should be similar, and the problems I encounter should be similar too." But it turns out they are not similar at all. You might learn everything there is to know about plating, and then you try to learn ENIG, and you start from scratch. The same is true with the imaging of dry film compared to solder masks. The basis is the same—you're imaging something—and you have the same equipment, but when you troubleshoot one dry film, it's very different from troubleshooting solder masks.

Holden: I started out in process engineering for plating, so I joined the American Electroplater's Society, which had monthly meetings in the Bay Area. They had such valuable articles in their monthly magazine about electroplating that I would rip them out and put them in my binders, and I still use some of their modeling on electroplating distribution that nobody in printed circuits has ever seen. I also became a member of the IEEE. Unfortunately, where you are, it's not an easy place to reach, and if it's winter, we all stay away!

Thurston: We are pretty isolated up here, which is a big reason I am such a proponent of webinars.

Johnson: When it comes to your continuing professional education and growing into being an experienced engineer in this industry, what's your biggest concern for accessing resources?

Thurston: My biggest concern is the gray tsunami and that a lot of tribal knowledge is with people who are at or nearing retirement age; it seems like those people aren't bringing apprentices with them. I worry too many people will leave the industry, and we won't have filled that knowledge gap by the time they leave. Michigan Tech has about 7,000 students, but I am almost certain that I am the only person who chose to enter the PCB industry. There are not enough young people going into it to absorb that knowledge. You can't have a handful of young engineers absorbing all of the information from people who have been in the industry for 50–60 years; you need an equal number of people entering the industry as there are leaving. Eventually, I won't have access to tribal knowledge because those people will be gone, and it won't have been passed down.

And due to where we're located in Michigan, it is hard to access information. You can't meet other companies very easily for dinner to discuss PCBs because the nearest one is 500 miles away, which Happy pointed out. We're so spread out now that it can be hard to share information and strengthen the industry. Again, one solution could be webinars and attending conferences whenever you can for those face-to-face interactions.

Shaughnessy: Even your suppliers and supply chain are graying out.

Thurston: And we rely on our suppliers to be experts with their chemistry and have a fair amount of knowledge about PCB manufacturing. Across the electronics industry, we need to share knowledge from your base material and chemistry to the OEM designing the boards.

Holden: I've met all of the managers at Calumet Electronics, and they are fairly forward-thinking. Their business philosophy has helped the company a lot.

Thurston: Yes, I have great mentors here. Dr. Meredith LaBeau, the director of process engineering, is a huge proponent of continuing education. She helped me as an intern get into full-time engineering as well as continue growing in the role. And a lot of what I've been sharing has been informed by what I've seen and been taught at Calumet Electronics. The industry is aging, and that's something that people like Meredith and others in management are working to change by recruiting young engineers like me and starting classes, like the PCB course at Michigan Tech.

Holden: I'm hoping that we can continue to build the printed circuit and electronic manufacturing focus at Michigan Tech to introduce more undergraduate and graduate students and engineers, as well as those working on research projects.

Thurston: I agree.

Holden: What was your favorite course in chemical engineering?

Thurston: My favorite course was our unit operations lab, where the real world met the classroom. I became a chemical engineer because I wanted to do something in manufacturing, but I didn't know what. I knew that I didn't want to sit at a desk all day; I wanted the excitement of being on the floor and firefighting. Sometimes, I look back and think, "Why did I want to do this again?" especially when you have to scrap a bunch of boards and figure out why; that's no fun.

Holden: At Oregon State University, which both Nolan and I attended, our chemical engineering department had printed circuit and IC equipment in the unit operations lab.

Thurston: That's something that would be on my wish list, to try to get our chemical engineering department to have equipment like that because all of the people in the PCB class were electrical engineers; there weren't any chemical or mechanical engineers, but all three of those disciplines are needed. It would be cool to see that class grow to include all three types of engineers.

Holden: The reason we had printed circuit and IC equipment is because Merix and Intel would donate the equipment. So, we studied the McHale and TB conventional unit operations, but we went to labs. Instead of doing petroleum or chemical, we would do sputtering or photo deposition, which is the same principle but with different hands-on equipment.

Thurston: We had a distillation column and polymer reactions vessel, as well as some more minor projects. It would be cool to have something like an electroplating tank to start, and then hopefully, we could build from there.

Johnson: Thank you for speaking with us. You had some great insights, Audra.

Thurston: Thanks for your time. PCB007

Sunstone Circuits on Staffing Trends in the Digital Age

Feature Interview by Nolan Johnson
I-CONNECT007

Sheri Kuretich, human resources manager, and Nancy Viter, VP of operations, of Sunstone Circuits speak with Nolan Johnson about what they see from the perspective of a prototyping shop, the current state of the hiring market, and how they have used ISO 9000 as an information repository to pass technical knowledge from experienced employees to newer ones.

Nolan Johnson: What I wanted to talk to you both about is the passing of the guard, bringing in new people, recruiting your staff, etc. What are the current major trends?

Sheri Kuretich: The biggest change over the past five years is how we hire. We used to have a lot of walk-ins. People would drop off their applications often enough that we had a full folder, but now, we're lucky if we get two or three walk-ins each month. Today, the internet allows for online recruitment opportunities, and we receive a lot of responses that way from diverse candidates. We're currently hiring for a position where we're talking to people in completely different areas, but they have relevant experience to the circuit board industry, so it's pretty exciting when those individuals become a part of our selection pool. There aren't many circuit board shops left in the Pacific Northwest, so it's not that often that we have an applicant with direct circuit board experience unless we're open to looking into people in other geographical areas.

Johnson: Sunstone is located in Mulino, Oregon, outside of a metro area. Were walk-ins primarily local people?

Kuretich: Yes, or people that were in the industry in Portland, Beaverton, or further south and knew of us because they were in this industry at some point, but that doesn't happen very often anymore.

Nancy Viter: A lot of it is by word of mouth.

Johnson: So, there's a shift in how the local community interacts, and that also seems to line up with a need for more specific skills.

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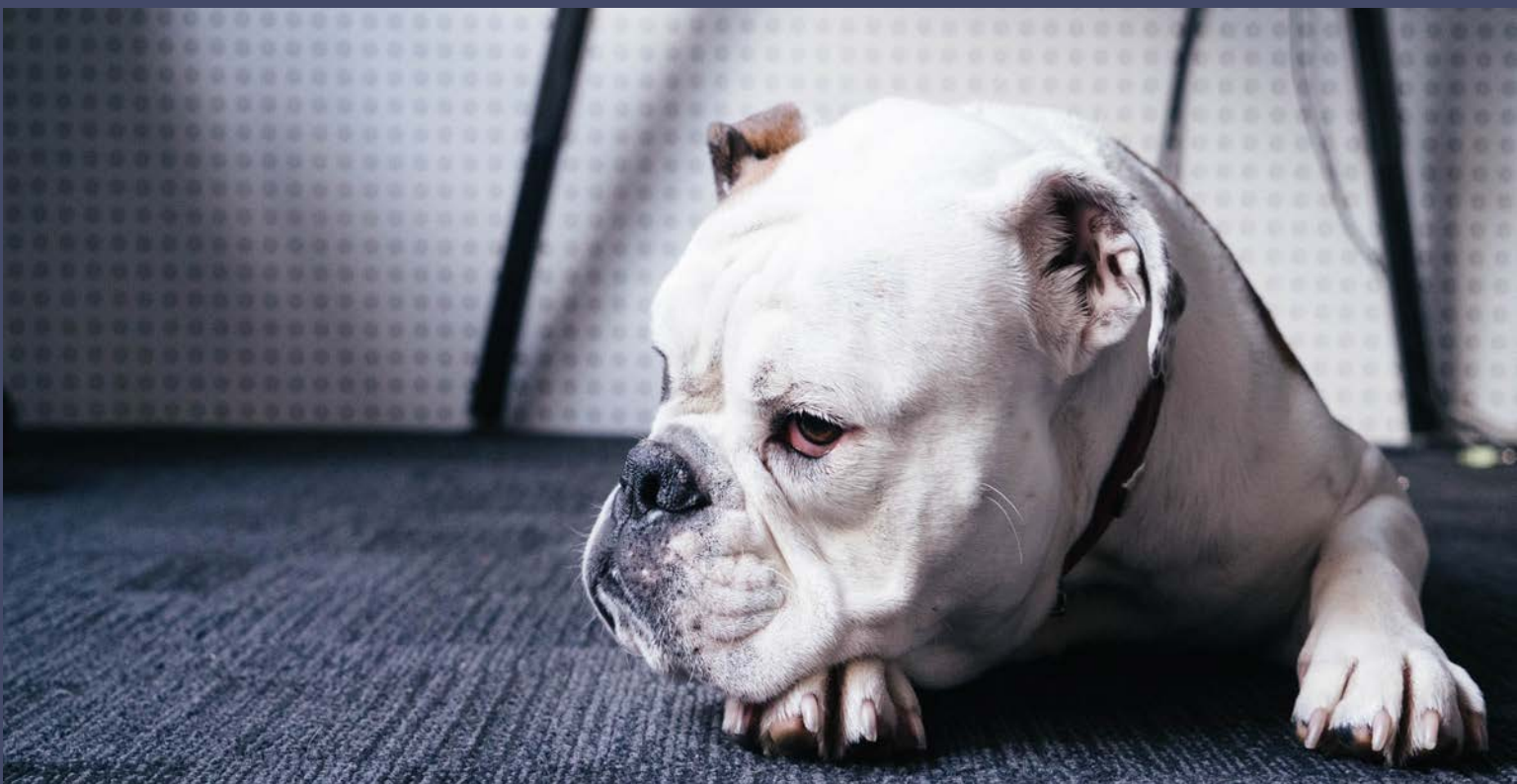

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Sheri Kuretich

Kuretich: Certain positions in any company might be more challenging to fill, since they may be more of a niche, and a lot of the jobs in a circuit board shop are very skill-specific. If we can get people with a manufacturing and production background who have an aptitude for learning the technology to build boards, that's great; we have been fortunate in that regard and gotten a lot of great referrals and excellent hires.

Johnson: Which is always a good measure of how you're perceived as an employer.

Viter: It has been interesting in the mechanical operations department. A couple of our newest hires were CNC operators, and rather than targeting just the PCB industry, we looked for some of the specific skill sets that may not necessarily be specifically PCB-related.

Johnson: How is that working out?

Kuretich: Very well. We had two new individuals start in our mechanical operations area that had finished up a CNC course at Clackamas Community College in Oregon City and sought us out. There was a referral by an employee, who sent them our way, and we felt good about it. They had the aptitude and passed the certifications. It's good to see that the local community colleges have those types of programs available; it's not all white-collar education. The students are ready to join the workforce, and they turn out to be great employees too. It's pretty exciting that the college is right in our backyard.

Viter: I'm on an advisory board there now to help reshape the curriculum for the electronics classes. I attended one meeting recently, and I'll attend another one soon to review the revised offerings. They are very interested in tailoring the classes to be relevant to today's electronics industry needs and are seeking input from the local businesses that would benefit from well-trained new hires. As a matter of fact, there were a few people at the meeting that used our PCB layout software, such as PCB123® and ExpressPCB®, which was satisfying to hear!

Kuretich: We recently conducted interviews for a technical customer service position. One of the individuals that we spoke with had used our PCB123 software as a student to design a board; he was so excited to be interviewing with us, and we were excited that he sought us out as well.

Johnson: Pardon the pun, but let's drill down a little bit on the students who trained in something close to PCBs. With the skill sets they're bringing, does that bring extra value to the company culture on the shop floor, and, if so, how?

Viter: Yes, and I'll use an eample. One of our CAD technicians didn't have PCB-related training; he had a great deal of experience working on computers, and, more importantly, he had a love for electronics and an insatiable curiosity. That is what we need in the industry to bring some life to it. When you bring somebody in who knows the other side of what these circuit boards go into, it sparks conversation and gets other people excited as well. It's important for our culture to give people a chance to get in the door and provide them with opportunities to evangelize (laughs).

Johnson: Helping to change the culture of a workplace is not something you can train; in that case, it's more about a personality, charisma, and attitude. Do you look for those qualitative features as well—someone who's driven to tinker and who understands academic training?

Kuretich: Yes. We also look for people with passion and natural curiosity that can bubble over and influence others as well in a positive way.

Viter: I was recently involved in what was called a "speed-dating program" at the Oregon Institute of Technology (Wilsonville, Oregon). Teachers and manufacturers joined together, and you had about 5–10 minutes to sit with different educators to help them to better understand our industry and how they might help students move in that direction starting in middle school or high school. I spoke with a robotics teacher from Molalla, Oregon, and one of the things that was disappointing to hear was that she's trying to build the program, but only three girls wanted to join. How can we bring more enthusiasm to opportunities like that and open it up for girls who are growing up and looking for industries to join?

Johnson: It's unfortunate that we have to have these conversations.

Viter: Exactly, but it is a fact of life. We want to show what's available out there for everyone. Manufacturing and these technical positions are real career options and a wonderful opportunity for all walks of life.

Johnson: Talking with people around the industry over the past year or so about staffing issues, there's a real age and knowledge gap, which has many in our industry worried. Now, we're trying to ensure that experience and wisdom are passed down. How is Sunstone tackling that challenge?

Viter: We have found that some of the newer people coming fresh out of high school haven't decided on a career for themselves yet, but they need money. They seem to be very fiscally responsible, and we have seen amazing work ethics from these folks; they also seem to be more relational, which is a big part of what makes them feel satisfied. They come in for a job and stay because they see the potential of a career in this circuit board industry, whether it's in marketing, quality assurance, process engineering, chemical analysis, CAD and engineering, environmental management, or even accounting or human resources. It's all here!


Nancy Viter

Related to that, we recently got our ISO certification. The natural inclination is to want to steer the auditor toward experienced people and not let them talk to the newbies (laughs). We found that some of the newer folks on a project were some of the best champions for speaking to auditors. I bring that up as an example because it's different than what you would expect and a pleasant surprise.

Kuretich: To add to that, some people in our workforce are starting to think about retirement, so we have been doing exercises through that ISO process to capture and document that experience and knowledge; it's been on our to-do list for quite a while, and ISO gave us a tool to start that process. There's a lot of "tribal" knowledge with our employees, and we want to make sure to capture and elevate the new people coming in so that it's not as painful when others leave.

Viter: I would imagine that you hear stories like this throughout the circuit board industry. There's a tremendous amount of tribal knowledge, and unfortunately, some things are not documented easily. It's almost an artisan craft (laughs) for some of the processes.

Kuretich: Yes, there are so many variables.

Viter: It's hard to document every one of those things. You have to pass on the craft, almost like a family business.

Johnson: Your point is well made. You can certainly look at the specifications and follow a recipe in the kitchen, but we all learn through experience exactly what "golden brown" means in any given recipe.

Viter: Exactly. We try to take out as much of the variability as we can in the process with

the new equipment purchases, but there are still people involved, and it often comes to a point where these people have to inspect it and understand the quality requirements. As you mentioned, what may be golden brown to you may be burnt to me. So, how do we capture that and figure out the right blend?

Johnson: You made a couple of interesting points. One is that the ISO 9000 process can be used to pass down knowledge from older generations to newer employees with respect to process knowledge. I haven't heard anyone else in my conversations cite ISO 9000 as an information repository.

Viter: Yes, that is interesting because for ISO 9001:2015, the big improvement is risk management—identifying the risks and mitigating them. Obviously, one big risk for us was losing critical knowledge, so that was a huge piece of our focus on our quality management system.

Kuretich: We uncovered the critical nature of this risk through our management review process and have started to document these items as well as put some plans in place so that our employees will be better equipped for the long haul. Everyone wins.

Johnson: Let's talk about that a little bit because your certification experience is fresh. Can you give me a couple of practical examples where the ISO process is going to help improve your information repository?

Micronic Mach-2 Nano Series drilling machine at Sunstone Circuits.

Kuretich: We created a process for our employee training records, which we have for every employee; they're accessible by HR and leadership, and they're a living document; as people are cross-trained, the documents are updated. Our recordkeeping is one avenue from my world that has been greatly improved; everyone got on board and recognized the value. We'll take it even further and use it in our performance review process, which is pretty exciting. The management review and the risks that Nancy talked about are eye-openers because 20–25 participants on that team are building the program, getting the paperwork, and sharing their concerns to get them all in one place.

Viter: It helps people take responsibility for looking at their process and assessing what the risks are and what is the likelihood that it will happen. If it is a likely thing, what is the catastrophic level if it were to occur? ISO requires a management review where all of the process owners come to the table, where we look at their KPI metrics and assess their current high-risk element—whether it's human resources, equipment, or organizational knowledge that they have determined as their most critical step to mitigate the risk. Then, as leadership, we apply a priority to those risks, recognizing that you can't do everything at once. Having everybody in one room together to discuss these matters helps so that we speak the same language and know where everyone else's pain points are.

For example, one concern was ensuring that everybody in the sales and customer support area used the same procedures and had one best way of doing things. In essence, when we speak to customers, we can't tell them two different things. As a team, we did a remarkable job getting those processes documented and training to them so that if something falls through the cracks, there is a place to go to say, "What did our process say, and how can we improve it?"

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Kuretich: Everyone has a voice, shares their concerns, and the information is located in one spot where management reviews them, assesses them, ranks them, and decides what to focus on first. It's powerful that we can share what we're most worried about. As far as being heard, at least they know what keeps me awake at night now; I'm not the only one going home with this concern. Now, everyone knows, and leadership is going to help us decide what we're going to focus on first.

Johnson: Do you see automation as something that is valuable on the shop floor at Sunstone?

Viter: I do. We were very excited recently to get a laser direct imaging (LDI) machine and take that risk off the table, for instance. All of a sudden, we have an image that is going directly onto the panel, which removes the need for several manual processes, reducing sources of error and headcount. So, we're looking for the type of automation that is a real benefit to our overall business.

Right now, we are researching drilling equipment, partly to address the industry trend toward smaller holes to add capacity and some automation. One of the drill machines that we're looking at right now has automated loaders, so you can put several different orders together, and it will load them as they go. That is an outstanding way for us to reduce some of the manual work of things and let folks focus on some of the more critical things that only humans can do.

For every piece of equipment, we look at how we can best utilize automation. Back in the old days, you didn't want anything that had autoloaders because they worked so terribly that you ended up spending half of your day fixing the alignment. But the industry has come a long way since then, and so has robotics. What used to be a big problem has been sorted out, and we have to take advantage of that where it makes sense and build that into the ROI.

Johnson: How important is data interchange to Sunstone's process? And by that, I'm referring to data formats such as CFX.

Viter: We have not even pursued that yet. That doesn't mean it's not a route that we want to analyze, because it has some tremendous opportunities, but it's not on the roadmap yet.

Johnson: When does it become something to pursue over where you are right now?

Viter: It's about having the appropriate resources and customer demand. In my perfect world, we would bring somebody into the shop with other industry experience, who has already gone through that piece and can help us be successful with that, but it's more about bandwidth. If we go back to the management review process, it's not yet at the top of the pile because there are bigger resource issues identified with labor being the biggest piece of our spend; we have more pressing projects around that. What type of things can we do that can help? Because it's continually getting more and more out of control, and whatever we decide to do, there has to be a great benefit for that aspect.

Johnson: I know that Sunstone completely rebuilt its enterprise resource planning tool to grow and move forward. And, within 24 months of completing that, you've implemented and passed an ISO 9000 certification audit. That's a lot of fundamental change in five years.

Viter: The extremes of data from one process to the next are terrifying. There's so much risk in losing data. There's a whole world that could stop us, which brings up fear. We need to make sure our infrastructure can do those functions seamlessly. With our quick turnaround, we still have the ability to do things the way we did 30 years ago if we have to (laughs), like running around the shop with a paper traveler and all of the information on a disc to go from one place to the next.

Johnson: So, you're saying CFX and data interchange is not a strong fix for a prototype shop.

Viter: Not at this time. Jamin Wilson was huge in our ISO endeavor, and I love speaking with him because he looks at things and says, "How

can we use automation to help in our inspection? How can we use automated intelligence to scan and understand a trace? Not with an AOI, but to take the guesswork out of everything." I love that because that's where we're going to see that push. The next generation is looking at technologies that are commonplace in other industries and asking, "Why can't we?" You have to keep pushing what's out there, figure it out, and be that voice that is going to take that risk.

Jamin Wilson, Sunstone Circuits.

Johnson: I think that is a great place to come back to one of my regular questions on this topic. What keeps you up at night?

Kuretich: Making sure we can get the right people applying to Sunstone and recruiting them through competitive wages and benefits is important. We want to have the right staff to support the needs of our customers and the right tools in place so that our employees can do a good job, be successful, and continue to learn and grow.

Viter: It all keeps me awake at night (laughs). I can't pinpoint anything more than that. We're working as a team to assess our specific risks so that we can address them together.

Johnson: Terrific. Thank you two for taking the time today.

Kuretich: Thank you, Nolan.

Viter: Thanks. **PCB007**

BMW i Ventures Invests in Flexible Circuit Tech with CelLink

BMW i Ventures has recently invested in CelLink, a San Carlos, Calif.-based manufacturer of flexible circuit technology that delivers high-conductance, large-area, lightweight, and low-cost flexible circuits through a proprietary combination of manufacturing processes, designs, and materials. The investment arm of BMW, aimed at finding advanced technologies and trailblazers for the Bavarian Group, participated in a $22.5 million Series B funding round alongside Ford Motor Co. and Robert Bosch Venture Capital.

The new funding is aimed at ramping up production of large-area flexible circuits for power and data transmission and will support CelLink's operations as it scales up existing production contracts and transitions several projects into full-scale production. CelLink will continue to ramp production in its first manufacturing facility through 2019, and the company intends to bring a new production facility online in the 2020-21 timeframe to meet additional demand.

"We believe CelLink's technology will transform wire harnessing from an old school, simple technology to a more advanced, integrated, multipurpose flexible circuit technology with more functionality and lower cost. Automotive wiring is finally becoming high tech," said Marcus Behrendt, partner at BMW i Ventures.

(Source: BMW i Ventures)


Thomas Michels

Thomas Michels on the Importance of Investment and Cooperation

Feature Interview by Pete Starkey
I-CONNECT007

Pete Starkey discusses industry drivers and challenges and the importance of investment and cooperation with Thomas Michels, CEO and managing partner of ILFA, a high-tech German PCB fabricator.

Pete Starkey: Thomas, can you describe your current position and the main characteristics of your company?

Thomas Michels: I run ILFA together with Christian Behrendt. ILFA is based in Northern Germany, and we have 180 employees. We concentrate on the aerospace and defense sectors as well as medical and sensors, and our products are mainly high-reliability rigid-flex and hybrid boards.

Starkey: Looking at the European PCB industry from your perspective, what's the most significant change you've seen in the past few years?

Michels: 2017 and 2018 were good years for the PCB industry and the electronics industry as a whole; in the last quarter of 2018, it started to weaken, and this has continued until today. The main drivers for this weak business are the automotive industry, and as a logical result, the industrial sector is also weaker due to the low business level. And people do not invest anymore. These are the two key areas that drive business in the wrong direction.

On the other hand, for prototypes and small series, business is not too bad if you are in a complex area. For example, autonomous driving, Industry 4.0, and 5G are part of our business in Europe. If you are running a factory in 4.0, you have a huge data transfer, and with the existing 4G systems, this is just not possible. This drives us, so we have a lot of projects with different complexities.

For ILFA, the average number of press cycles is 2.5, although we do up to 7. This is something that is challenging the PCB manufacturers because you have to invest significantly to fulfill this expectation. ILFA and other key companies in Europe have been fully digital for many years; nobody's working from artworks anymore because it would be impossible with the sort of boards we produce.

Starkey: You've already touched on it, but what sort of challenges are your customers currently facing?

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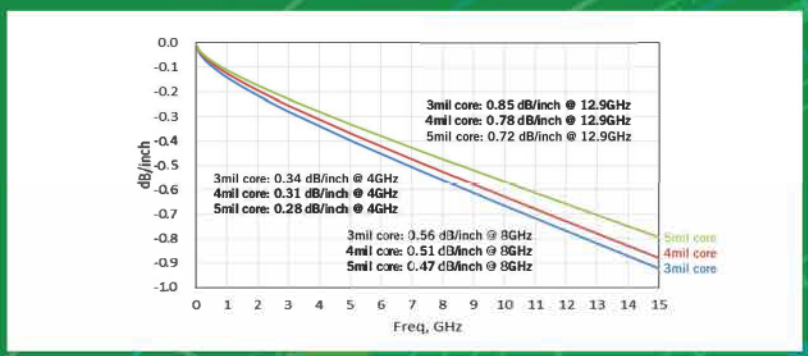
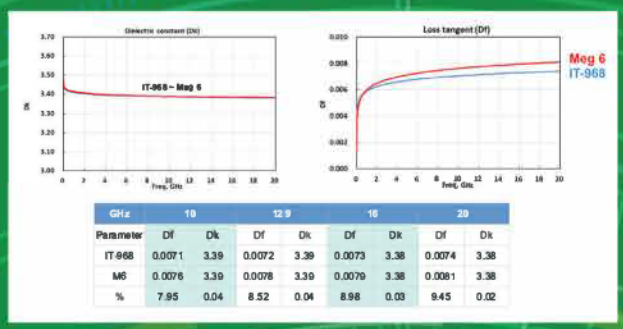


IT-968 SPP Comparison



GHz	10		12.9		16		20	
Parameter	Df	Dk	Df	Dk	Df	Dk	Df	Dk
IT-968	0.0071	3.39	0.0072	3.39	0.0073	3.38	0.0074	3.38
M6	0.0076	3.39	0.0078	3.39	0.0079	3.38	0.0081	3.38
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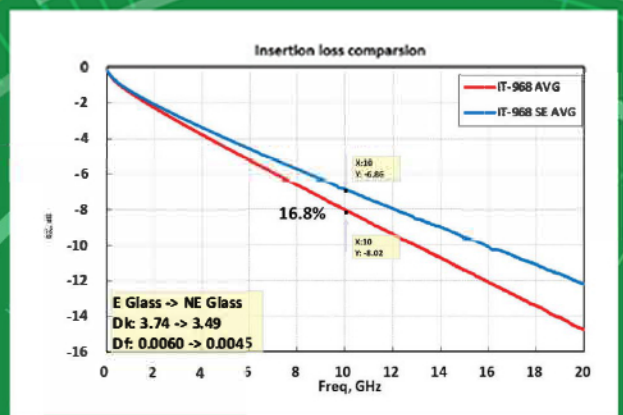
Tg (°C)	DSC	185	185
T-288 (w/ 1 Oz. Cu , min)	TMA	120+	120+
Td-5%(°C)	TGA 5% loss	390+	390+
CTE (%), 50-260°C	TMA	2.2	2.2
Peel strength (lb/inch)	1 oz	6	6
Water Absorption	D-24/23	< 0.1	< 0.1
Dk , 1 GHz 2-10 GHz	IPC TM-650 2.5.5.9 IPC TM-650 2.5.5.13	3.4 3.4-3.7	3.4 3.4-3.7
Df , 1 GHz 2-10 GHz	IPC TM-650 2.5.5.9 IPC TM-650 2.5.5.13	0.0032 0.0036-0.005 0	0.0028 0.0031-0.004 0

E-Glass vs Low Dk Glass



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Michels: As I just mentioned, the automotive and industrial fabrication industries are suffering from a lack of business. Nobody knows whether it is riding toward one direction or another. The other challenge is that there are a lot of projects for autonomous driving and 5G that OEMs have some ideas about, but they don't know all of the answers, so PCB manufacturers have to work much more closely than they used to work with the OEM. We are already in the design stage and a part of the project.

Starkey: Looking to the future, how do you think the European PCB industry is going to change in the next two to three years?

Michels: Let me first make one point clear: I hope nobody will disappear because we are such a small industry now that if we get any smaller, it could be dangerous. Meanwhile, OEMs understand that they need to have local support for the industry, and they honor this more and more. Besides this, the industry has to work together to avoid risk. I'm not scared at all if we do our homework. We must invest a lot. The companies who are not willing to invest 8–10% of their annual turnover, for example, will disappear over the next 5–7 years; they will die slowly.

We must invest a lot. The companies who are not willing to invest 8–10% of their annual turnover, for example, will disappear over the next 5–7 years; they will die slowly.

At ILFA, we started cooperating very closely on technology with a company called MOS Electronic—a German company that is also privately held where the shareholders are active in the management like ours are. This is a concept that others have to think about if they are not big manufacturers. We are complementary; they do certain things where we are not as strong, like heavy copper, and we do other things like rigid-flex where we are very strong. By working together, we give our existing customer base a better offering. From my point of view, we have to cooperate better in this small industry.

Starkey: I know exactly what you mean. In the present environment, it's very wise to adopt that strategy. What is your area of greatest concern right now?

Michels: My biggest concern is if we can find the right people with the right skills. The unemployment rate is very low in German-speaking countries, and we have a lot of big companies that offer very good salaries. This makes it very difficult for companies like ILFA and 100–180–250 people. We can't just offer the kind of packages that big companies do, which is a huge challenge for us. The second one is if we get all of the necessary investment finances. Because even though interest rates are close to zero, the banks have "short arms and deep pockets," and PCBs are not "sexy." The banks can be hesitant, which is another concern. But if we do our homework and work on cooperating with other companies to optimize our offering, if we invest sufficiently, the business is there.

Starkey: That's encouraging. You need to work hard on the relationships and make the right investments to secure that business.

Michels: Correct. For example, if we look at our own company, we have increased our business in 2019 by almost 10%, but we have lifted our technology level not one step but by at least two steps. Yes, we can do 4-layer and 6-layer boards, but that's not what we want to do; we have 40% rigid-flex and 40% hybrid containing ceramic, PTFE, and other materials with three, four, and five lamination cycles, copper filling, via plugging, etc., all in-house. This is the kind of business you have to do—either very fast or very complex—if you would like to survive in Europe.

Starkey: You have to become a specialist in a given technology, and then you have proportionately less competition. You're close to your customers, both geographically and in terms of working together. Customers know that they can rely on your support and that you will rise to their technology challenges to provide them with the best service.

Michels: That's exactly right. We have more than 10 people in our engineering department, so we work directly with the customer's design people to jointly develop the design. Most times, it's developing and optimizing the board with them and then building it. If you are reasonable with the price, then it's not the subject of a lengthy negotiation.

Starkey: I agree entirely. And reflecting on my own career in PCB fabrication, that's the sort of company I used to run; we weren't a manufacturer so much as a provider of a technical and engineering service to our customers.

Michels: And that's the importance of having the right people. Our company is already 40 years old, and we are able to offer this service, but we also have to find and invest in the right people and develop and keep the people. From my point of view, the PCB market worldwide is increasing at a minimum of 5% YoY with drivers like 5G, IoT, and autonomous driving, and it needs excellent, flexible European PCB specialists to help develop prototyping and medium volumes.

Starkey: Thank you for sharing your perspective with us, Thomas.

Michels: Thank you, Pete. **PCB007**

Würth Elektronik CBT, Taiyo America, Inc. Announce Successful Production of Inkjet Solder Mask

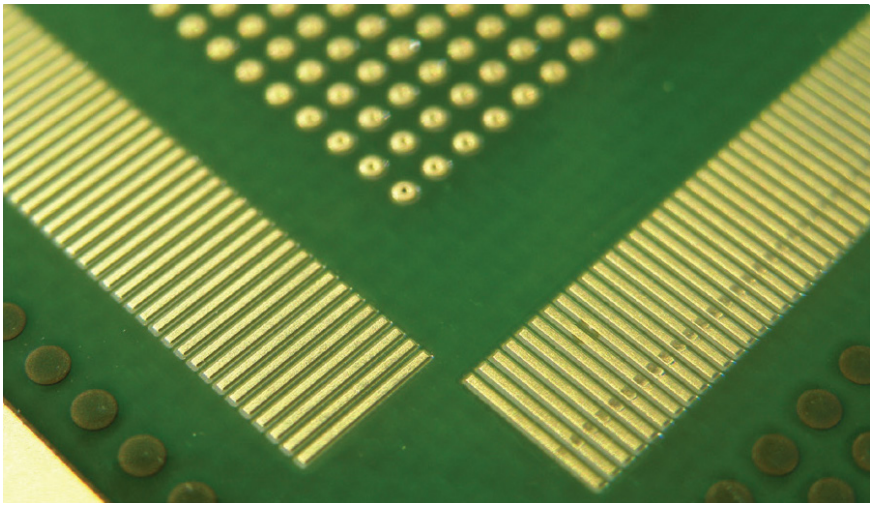
Würth Elektronik CBT, a leading European PCB manufacturer, and Taiyo America have announced that inkjet solder mask is in production.

IJSR-4000 JM03G is an inkjet solder mask product developed by the chemists and engineers of Taiyo Ink in Japan. The product is designed to meet all industry standards for high performance solder mask in the automotive, aerospace, defense, communications, medical and industrial market segments.

"We have been cooperating for over four years in the development of an inkjet process solution and the time and effort spent by both companies has finally paid off. We are pleased to have Würth Elektronik CBT as our first worldwide production customer for the IJSR-4000 JM03G," stated Zach Maekawa, president of Taiyo America.

Dirk Grether, a project manager at Würth Elektronik CBT, adds: "Together with Taiyo America, we pioneered a successful inkjet process. As one of the first producers, we were able to apply a functional 3D-surface designed PCB according to the customer's requirements. Also, beyond precision and functionality advantages, we offer our customers improvements in PCB protection–achieved by the gentle application of the functional surface, as well as by a reduction in the amount and type of chemicals used."

(Source: Würth Elektronik)



Industry Set for Shift to True 3D Printing and Photonics


Zach Peterson

Feature Interview by Nolan Johnson
I-CONNECT007

Nolan Johnson sits down with Zach Peterson, owner of Northwest Engineering Solutions, who predicts two things that would challenge the current status quo for the PCB manufacturing industry: true 3D printing and additive, including discretes as well as the substrates and traces, and a completely different approach with photonics.

Nolan Johnson: Zach, can you introduce yourself?

Zach Peterson: I own a company called Northwest Engineering Solutions, and we do a number of different things in the PCB and electronics industry. I also write for various companies and have a group of freelancers that handle design work. We do software, custom analytics tools, and technology research. The content that we produce for PCB companies and other startups is very high-level and forward-looking. And we always try to provide real, actionable advice that is within the context of what our customers do, which is important.

We want to offer solutions to problems that designers have, and the idea is that the designer could immediately implement that solution with one of our customer's products. And that's extremely important because if people are on the internet and have design problems, they have unanswered questions. Our goal is to do the research and help get those answers in front of the readers.

Johnson: So, while you might do some actual design work, that isn't your primary spot?

Peterson: That's right. As I said, I have a group of freelancers that I work with, and we do design. One guy that I have working for me is an RF designer; he has done a lot of wireless systems. Another guy I have working for me has done a lot of different designs for the solar industry; he worked in the solar industry for about 15 years, and now, he does freelance design work both for me and for other companies as well.

Johnson: What's your ideal customer?

Peterson: My ideal customer is a company that has a new product that they want to launch and needs to communicate their value to a target market, such as a software or hardware product, but they don't know how to do it. There's a lot of competition out there in content marketing, and we work with companies that are innovative and want to take a place

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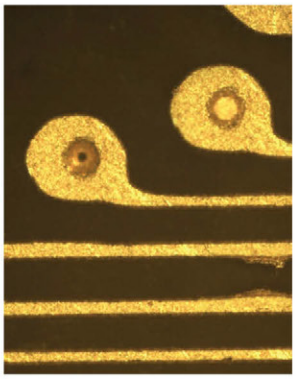
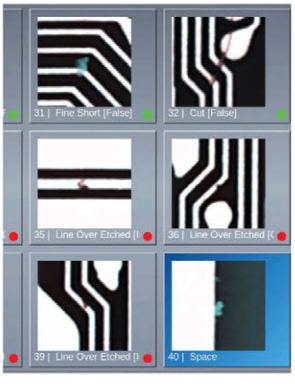
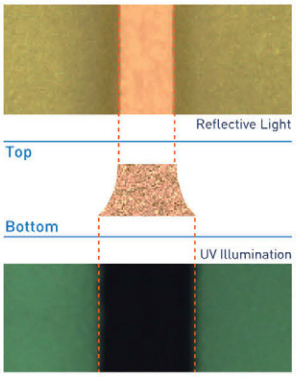


Laser Via (LV) Inspection



RMIV Pro



2D Metrology

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Nikki.Heng@orbotech.com I URL: www.orbotech.com/pcb

of leadership that they think they deserve. If you're another board house, and you're doing the same thing that 20 other board houses are doing, it probably isn't going to work out. Now, if you've taken the process that you use to communicate with customers, get your boards produced, and help build the industry and take it to new levels, that's also an ideal customer; I talked to a company at PCB West that does that.

Johnson: How long has your team been doing this?

Peterson: I'm actually a physicist by training. I've been a researcher for over 10 years, and I have a number of publication credits. I started out in optics and optoelectronics, so I have a broad research background that originally spanned into sensors and then optoelectronic devices, semiconductors, and nano-particle lasers. I left the academic side and moved to the corporate side two years ago and haven't looked back. It has been fulfilling to work with companies and to be able to provide real solutions that I know people are looking for. One of the things that happens in academia is you do a lot of research and writing, and maybe 10 people or 20 people will cite your work, and you're lucky to solve one problem for every 10 people. With producing content for electronics companies and small startups, it's gratifying to see them grow and see a larger engagement from their target audience.

It has been fulfilling to work with companies and to be able to provide real solutions that I know people are looking for.

Johnson: Looking at the industry, what are some of your key observations?

Peterson: Opening up into higher frequencies is huge. I think the highest, broadest commercially available product that runs at 10s of GHz that I've seen is car and UAV radar. Now, we're hitting close to 100 GHz in these systems, and that's not to say that there are things that run at much higher frequencies because there are. But we're talking about something you would buy as a regular purchase. And I think we're going to see the boundaries being pushed farther into the higher frequencies. Obviously, I have to be able to do mixed-signal and digital, but I'm more of an analog guy. I love analog design; that's why I have an RF designer around when I need one. A lot of the stuff I've been writing about recently has been on analog design.

The other thing that you're going to see from the manufacturing side is a move to greater connectivity within the factory. You're also going to see a greater move toward 3D printing and additive. I don't normally like to shout out specific companies, but Nano Dimension is an innovative company in the 3D-printing space. Others also do 3D printing for PCBs, but I find Nano Dimension's process interesting. In the future, you'll see more than just additive manufacturing for PCBs; you'll also see additive manufacturing for components, including semiconductor devices.

Currently, you can do conductive components, like you can do an electromagnetic coil; you can do an inductor or a capacitor by using the substrate as the dielectric. As the range of materials expands with any 3D printing system and starts to encroach on the organic semiconductor range of materials, which is a giant class of materials, you'll start to see low-temperature processes that are useful for 3D printing the actual semiconductor components. Eventually, we'll see a lithography process that's used to get down to small gate sizes. Now, you can 3D print transistors without having to use silicon, and you can do the board, transistors, and conductors all in one shot.

Johnson: Which starts to look a lot like true 3D printing.

Peterson: Yes. Currently, you can make the board and do flexible boards and all of the conductors, but not the components. Once you can do the components, then you can make fully functional boards right out of the factory with no problem, all day and night.

I'd also like to point out another trend that a lot of people in the PCB design industry don't consider. Coming from the optics side of things, we talk about this all the time because there's something called photonic integrated circuits as well as the related electric photonic integrated circuits. What you will see are fully functional consumer-level devices that run, partially or fully, on photonics.

People are working on integrating photonics at the board level, but not photonic integrated circuits or electric photonic integrated circuits. An EPIC microprocessor from Ayar Labs came out last year; it's a great start in this direction. I don't know what the price tag is, but it's far beyond my pay grade, so it's not going to be in a consumer-level device soon, but I think it's not a matter of if; it's a matter of when. You will see regular products that you buy off the shelf that run partially or fully on photonics.

Johnson: So, that's a technology shift that you're projecting.

Peterson: Absolutely. This has been going on in the research community for years. People have been trying to build the fundamental circuit building blocks from different photonic materials. You can do it with silicon, but there are a number of challenges; still, silicon is the best direction. All of the integrated circuits you buy are built with some type of silicon process, so you can easily adapt that to building photonic integrated circuits or electric photonic integrated circuits. The major challenge involves light sources and detectors that are integrated directly on silicon.

One route that may be promising is supersaturated doping to build light sources and detectors. Essentially, you shift the bandgap, or remove the indirect state and the indirect bandgap, and create a direct bandgap, silicon-based semiconductor via doping. The other option is to go the germanium route and bond germanium directly onto silicon, which has its own fabrication problems. Beyond that, if you can't do those things and instead integrate it directly onto the chip level, you have to use external components, which are bulky and create their own problems.

The major challenge involves light sources and detectors that are integrated directly on silicon.

It remains to be seen what's going to happen. A couple of months ago, I talked to the father of silicon photonics, Richard Soref; he's a nice guy, and he will show you on the back of a napkin how to build all of the fundamental photonic logic gates from silicon. Richard's breadth of knowledge is huge, and he was the one that told me he doesn't think III-V and II-VI semiconductors are going to do the job because they're incompatible with 1550-nanometer wavelengths; that's why the hardcore research and engineering community is looking more at silicon than at III-V and II-VI semiconductors.

Johnson: What is your take on the current state of the industry and the players? How accepting are they of the fact that there's going to be a shift in the technology all around them?

Peterson: It depends on who you talk to. For the more innovative manufacturers, the ones who are willing to be agile—and I use that word for a reason—adapt to change, and expand their capacity are going to dutifully manage their manufacturing capacity and balance. For example, "Do we manufacture more photonics boards or traditional boards?" They're going to do it once they start seeing the real demand for it; it will happen.

The PCB industry is demand-pull. A lot of what the industry does is respond to demand,

especially on the manufacturing side. Whereas on the software side for design, it's a technology push. They create the tools, put them out there, and let people do what they're going to do. Meanwhile, a manufacturer is not going to expand its capabilities into fully photonic, extremely complex boards with non-orthogonal interconnect geometry at the photonic level unless there's a demand for it, plain and simple. They're not going to do it because it carries such huge upfront costs.

Johnson: Are you observing anything that might be a little bit unusual or surprising?

Peterson: In terms of designers, one thing that I see as being surprising is the lack of new, younger talent coming into the industry, and I see you smiling and nodding your head. It's interesting because when I was teaching, most of my students were electrical engineers, and they all wanted to go into the semiconductor industry. The semiconductor industry, as far as the overall electronics industry, is sexy, and the manufacturing process is cool, but the PCB side is kind of seen as an overblown way of connecting wires together. I think there's a lack of understanding of the complexity that goes into a lot of boards. So, I'm a bit surprised by the lack of interest by the next generation of engineers in getting into the PCB side.

Johnson: One could say that it is a little bit scary if you go through a PCB facility, and there are open tanks, dangerous chemicals and fumes, and puddles on the floor where you have to wear rubber boots; that's not attractive.

Peterson: That sounds like the lab I worked in at university, so I'm cool with that. Whereas if you go to Intel or another semiconductor manufacturer, you're throwing on the bunny suit, which I wanted to do. I wanted to work in the metrology side at Intel or another semiconductor company because so much of what I had to do for my research involved microscopy; I used optical and electron microscopes all the time. I felt like I could do that and enjoy it, but I'm glad I didn't.

Johnson: Zach, thanks for your time.

Peterson: Thank you. **PCB007**

RoboSense Wins CES 2020 Innovation Award for Autonomous Vehicle Technology

RoboSense, a leading autonomous driving LiDAR perception solution provider, announced that it has won the CES 2020 Innovation Award the second year in a row for autonomous vehicle technology. RoboSense won this year's award for the first MEMS-based Smart LiDAR Sensor, winning in the Vehicle Intelligence and Self-Driving Technology category.

The RS-LiDAR-M1 is the first MEMS-based smart LiDAR sensor for self-driving passenger vehicles with its own embedded AI algorithm technologies and SoC (System on a Chip).

It goes beyond traditional LiDAR, providing full data collection and comprehension. As a ground-breaking product, the RS-LiDAR-M1 not only collects and interprets high definition 3D point cloud data, but also processes road data in real-time, with a built-in AI algorithm and SoC, while at the same time synchronizing high-precision positioning output; road traffic signage; lane markings, driving areas, road curbs, and obstacle detection; tracking; and classification. Also, it is the world's smallest MEMS-based solid-state LiDAR, providing a low cost, high stability, and superior manufacturability to meet automotive-grade and serial production requirements.

The RoboSense RS-LiDAR-M1 Smart LiDAR Sensor will be on display in the Innovation Awards Showcase at CES 2020. (Source: RoboSense)

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MilAero007 Highlights

Arlon EMD and U.S. Air Force Academy Establish CRADA ▸

Arlon EMD—a privately held, veteran-owned, specialty laminate manufacturer—has entered into an agreement with the United States Air Force Academy to collaborate efforts in researching and developing technology platforms for electronic materials, resin systems, and copper-clad laminate products.

Astronics Acquires Mass Transit Test Solution Provider Diagnosys Test Systems ▸

Astronics Corporation—a leading provider of advanced technologies for the global aerospace, defense, and other mission-critical industries—has acquired the primary operating subsidiaries from mass transit and defense market test solution provider, Diagnosys Test Systems Limited (Diagnosys).

Prototron Receives Mil-31032 and AS9100 Certifications ▸

Kim O'Neil, general manager of Prototron Circuits in Tucson, Arizona, discusses the company's recent MIL-31032 certification and how this experience prepared them for the AS9100 certification. He also explains why auditing is a good thing for any company's processes and highlighted some of the areas that the auditors inspected.

SMTAI 2019: Company Updates amd Future J-STD-001 Changes ▸

Nolan Johnson speaks with Graham Naisbitt, chairman and CEO of Gen3 Systems, and Andy Naisbitt, operations director, about how they just signed an agreement with a new distributor. Graham also discusses upcoming J-STD-001 changes and Gen3's shift to a more consultative customer model.

SMTAI 2019: To the Moon and Beyond ▸

W. Michael Hawes, D.Sc., gave a great keynote at SMTAI 2019 titled, "To the Moon! Orion's Next Giant Leap Into Deep Space." Dr. Mike Hawes is currently the VP for human space exploration and the Orion Program manager for Lockheed Martin. Barry Matties spoke with him afterward to discuss the technology innovations that empower the next-generation spacecraft to take astronauts to explore farther than humankind has ever ventured.

Raytheon to Provide Future Air and Missile Defense Radar ▸

Raytheon Company has been selected to provide the U.S. Army with its next-generation, 360-degree capable radar—the lower-tier air and missile defense sensor (LTAMDS). Raytheon will receive more than $384 million to deliver six production representative units of the advanced LTAMDS radar under an Other Transactional Authority U.S. Army agreement.

Nano Dimension Marks Major Sales Milestone ▸

Nano Dimension Ltd., a leading additive electronics provider, has reached a major milestone of selling more than 50 systems worldwide since the launch of its commercials sales in Q4 2017.

Boeing Building the Future of Space at International Astronautical Congress 2019 ▸

Boeing will participate in International Astronautical Congress (IAC) 2019 next week at the Walter E. Washington Convention Center in Washington, D.C., to celebrate our shared mission with NASA and global partners in this new age of space exploration and transformation.

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Industry Wind Vane: Future Development Through the 2019 HKPCA Show

Article by the PCB007 China Team

The annual HKPCA Show, which has been renamed the 2019 International Electronics Circuit Exhibition (Shenzhen), will be held from December 4–6 at the Shenzhen Convention and Exhibition Center. This year's exhibition will be jointly organized by the Hong Kong Printed Circuit Association (HKPCA) and the China Printed Circuit Association (CPCA) and will provide a more efficient business platform for all visitors. The PCB007 China Team interviewed a representative from the HKPCA about the exhibition, the industry's current situation, and future developments.

PCB007 China: From a global perspective, the demand for PCBs tends to be stable, and the growth rate is only in the single digits. As a unique industrial cluster, China has maintained a greater growth rate than other regions in the past decade. If we want to continue to make profits, the industry needs to find a new entry point or move to a new market. Specific ways might include merger and acquisition, an increase in capital to establish companies, production expansion, and plant building. This is not only an optimistic expectation for future market growth from PCB companies, but also a necessity for the industry to move toward the advantages of large-scale development. What do you think about this trend, and how can HKPCA guide the future layout of the industry?

HKPCA: The global economy slowed down in 2019, and the whole market is relatively weak. This year, the total output value of the circuit board industry is expected to decline slightly. Companies need to consider their technical capacity. The way of circuit board companies making profits by order volume has been gradually eliminated, the demographic dividend has been reduced, the environmental protection policy has been tightened, and large circuit board factories will face the risk of closing down. Therefore, we need to avoid blind expansion of business scale. Today, only companies with certain technical abilities or companies that closely follow the market trend can have development.

PCB007 China: A hot topic in the industry right now is PCB smart factories. New construction, reconstruction, and expansion are the problems to face. Right now, cooperation in project demonstration, development, and standard

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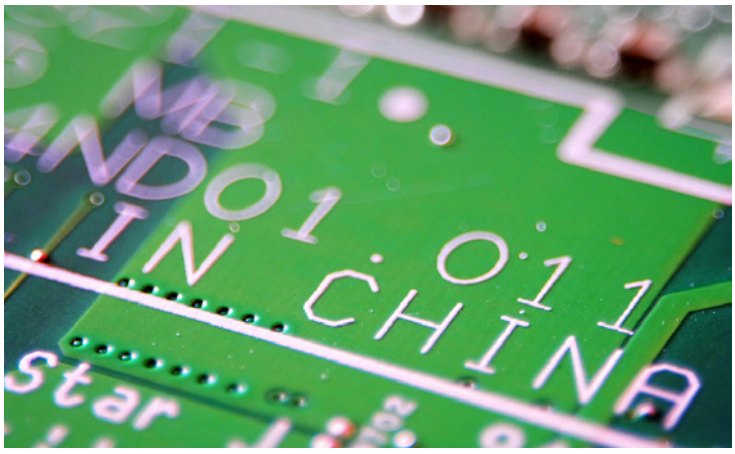
setting has achieved certain results. How can HKPCA help companies to solve common problems in this respect, carry out in-depth exchanges and cooperation in the field of smart manufacturing, make full use of their advantages and specialties, and continuously strengthen the promotion of various collaborative projects?



HKPCA: For PCB smart factories, smart logistics are the core, and the industrial internet of things (IIOT) is the means. The standardization of material loading and unloading in warehousing and equipment communication is fundamental. There are different [HKPCA] committees to coordinate various activities. We hope that through annual exhibitions, quarterly publications, and technical seminars, members can understand the current market and trends and further explore various technological innovations. Every year, we interview major manufacturers and equipment suppliers in Hong Kong and South China to collect data and make market research reports. We hope to provide members with reliable information and assist them in planning business development and technology upgrading. We also have an industry standards group to focus on the development of international PCB manufacturing standards and actively communicate and coordinate solutions with relevant industry organizations.

PCB007 China: The stability of the supply chain is very important for the development of the industry. The localization ability of key products, a stable and healthy supply of raw materials, and the improvement of the smart logistics field all affect the development of PCBs in the future. At the same time, tariffs and new trade agreements are also very important factors in the change of international trade dynamics. How can the association lead such changes and help the industry to develop healthily and sustainably?

HKPCA: Due to the formation of the buyer's market, the continuous shortening of the product life cycle, the increasingly fierce market competition, the rapid development of information technology, and other factors, the supply chain presents an increasingly important trend. HKPCA has been committed to providing a diversified communication platform for the industry, sharing the latest market information, and helping the industry to appropriately develop the relevant supply chain and technology to meet the needs of PCB products. With the increase of trade barriers and tariffs, the development of the supply chain will become more localized with an increase in international trade costs.

PCB007 China: In the field of technological innovation, additive processes will be a significant pursuit in the future. There are many innovations in the industry, including materials, equipment, and process reform. What are your expectations for the future?

HKPCA: To meet the processing requirements of 40/40-µm products and below, the production of high-density circuits will gradually develop to meet the technical direction of carrier boards. With the demand for thinner end products, the overall thickness of HDI products is getting thinner and thinner, and the thickness of the innerlayers is also becoming increasingly thinner. Regarding the material characteristics of mSAP boards, we mainly consider the Tg, CTE, Dk, and water absorption, as well as matching the degree of new materials to improve yield.

Also, to meet the development of new technology, some equipment manufacturers pro-

vide mSAP key process equipment at this stage, which can guarantee the contactless production of the key process and the smooth and even surface of electroplating, improve the uniformity of electroplating, and ensure the stability of high-frequency and high-speed signal transmission. In the future, in the new technology fields of mSAP, SAP, and SLP, these factories will continue to develop the whole process of contactless production equipment.

PCB007 China: The 2019 International Electronics Circuit Exhibition (Shenzhen) serves as a wind vane into the industry's development. Please tell us about this year's show.

HKPCA: The exhibition attracts leading and new manufacturers in the industry every year, and the exhibitors are enthusiastic about participating. The number of exhibitors increases every year, and the exhibition scale expands every year, reaching record highs. This year, the exhibition will exceed 67,500 square meters—covering Halls 1, 2, 4, and 9, as well as part of Hall 3 of the Shenzhen Convention and Exhibition Center—with nearly 600 exhibitors and 3,500 booths. The exhibition has already attracted nearly 120 new exhibitors at home and abroad and will show the latest equipment and cutting-edge innovation technologies in the market.

Exhibitors are looking forward to finding more potential customers through the exhibition, gaining an in-depth understanding of the needs of customers in the local market, and meeting more professionals at home and abroad to open up business opportunities and contacts for development. At the same time, they hope to grasp the latest trends in technology and market information exhibition.

PCB007 China: What will be some of the exhibition highlights?

HKPCA: There will be many highlights in this exhibition, including more space for exhibitors to launch new products, technologies, and solutions at the conference covering the entire industrial chain, which will bring more surprises to visitors this year.

Also, activities, such as the welcome dinner and Golf-ko Open games, will be held to help exhibitors get to network with industry professionals. This year's international technology conference invited Mr. Liu Zhe, chief engineer of ZTE technology research, to give a keynote speech, sharing the challenges and demands of 5G high-frequency technology on PCBs. Other distinguished guests include Dr. Hayao Nakahara of N.T. Information, Dr. Jiang Xugao of Prismark, and Mr. Lin Dinghao of KINSUS. Exhibitors can participate in the conference free and listen to the insights of technical experts and industry leaders.

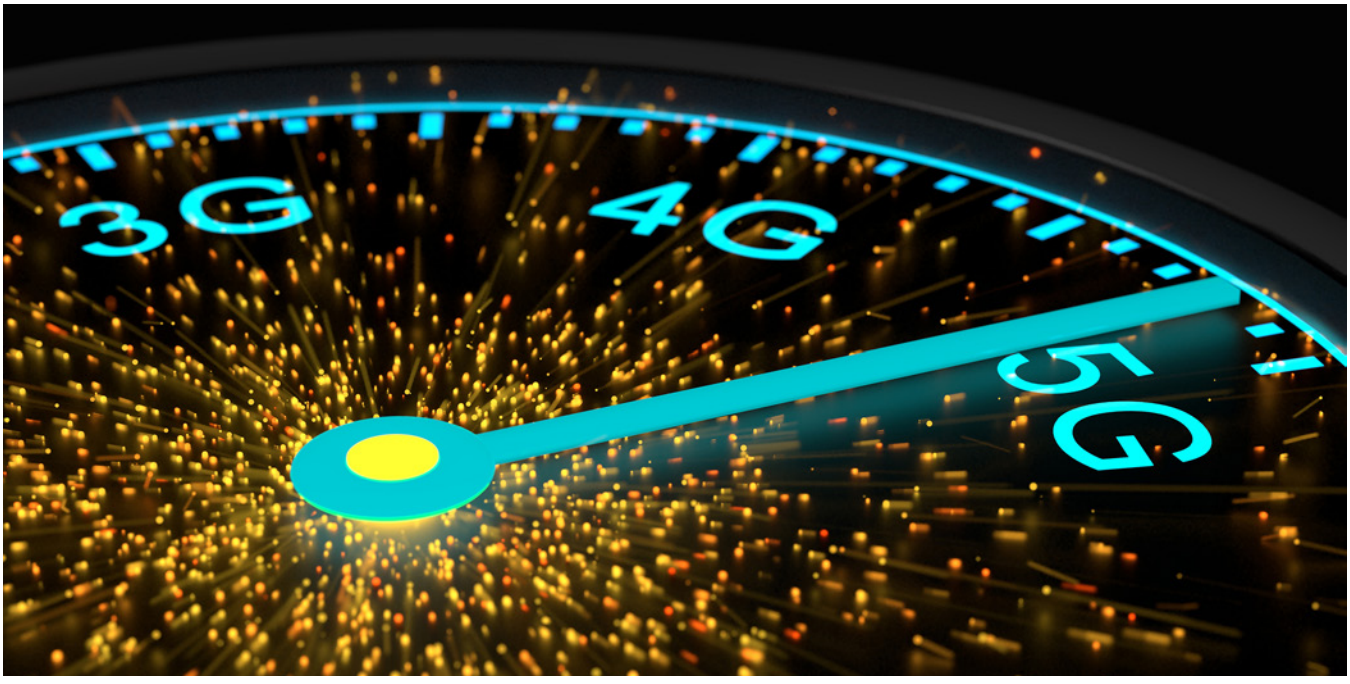
PCB007 China: This year's themes are "Convergence, Innovation, and Navigation." What do attendees have to look forward to regarding these themes at the exhibition?

HKPCA: By partnering with the CPCA to jointly organize the exhibition, we're able to provide a more efficient business platform for all visitors. The show will continue to be an influential industry exhibition, with a one-stop exhibition covering the whole supply chain of innovation within the circuit board and electronic assembly industry. Global industry professionals will gather to discuss new technologies, such as 5G, big data, and smart factories, create new ideas and business opportunities, and continue to promote the continuous development of the industry. PCB007

More Information

Please visit hkpcashow.org, and follow the official WeChat account of the exhibition to get the latest information. Register before the exhibition to enjoy multiple benefits:

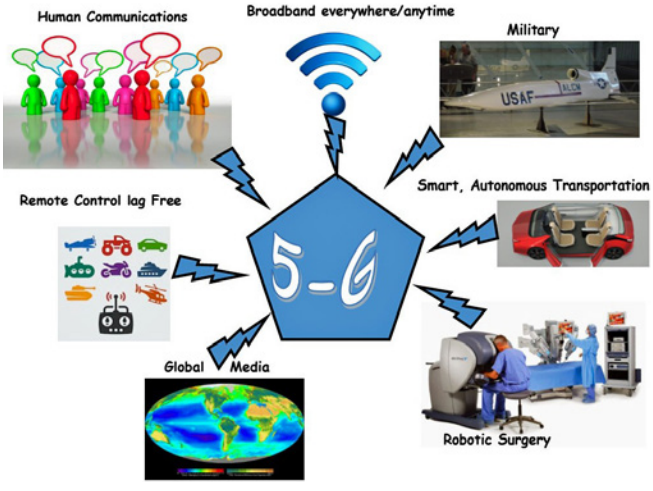
- Free Shenzhen metro/bus pass
- Each company inside Guangdong Province with a group of more than 30 people can enjoy free bus transfer
- Visit the exhibition and win electronic gifts
- The quantities are limited, first come, first served; organizer has the final say



5G Is Coming With Quantum-level Advances and Features

Article by Dan Feinberg
I-CONNECT007

I am sure that, by now, all of you have heard about 5G (the fifth-generation of mobile phone and data communication standards). I am also relatively sure that many of you think that this means neat, new cellphone features, and perhaps more texting and selfie abilities. While that may be true, getting a new cellphone for those reasons would be like getting a new car because you want a different color.



The many uses of 5G.

First, you may want to familiarize yourself with what came with the first four generations and what they have given us over the last 35–40 years. If you want a detailed primer on the various generations and what they enabled, you might want to review our previous article on that topic.

Generations of Mobile Communication Networks

Mobile communication networks are grouped into generations. The first-generation (1G, although not named as such) was an analog system introduced in the early 1980s. The second-generation (2G, for example, GSM) was digital and made short messages (or short message service, SMS) available for the wide public in the 1990s. It originally intended to support phone calls but was later augmented

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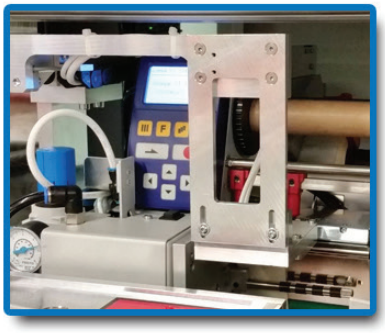

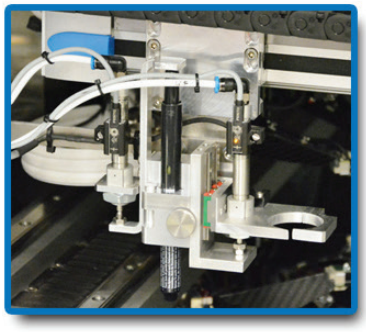

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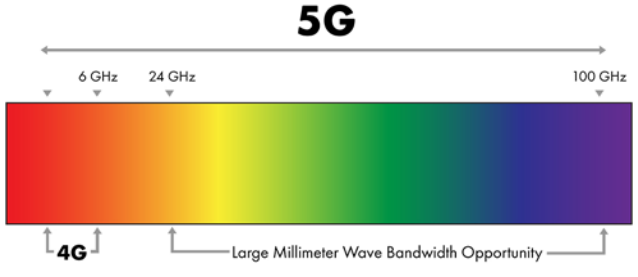
to also allow data transmission. In addition, it greatly increased security, making your calls much more difficult to hack.

The third-generation (3G) was aimed at both telephony and data transmission in its design and became widely deployed in the early 2000s. The fourth-generation (4G and 4G LTE, or long-term evolution, and improvements to the original 4G have continued to become available) dating to the 2010s was built for data transmission and supports telephony only through data packets (voice-over-LTE and voice-over-internet protocol, or VoIP). Each new generation introduced higher data rates and new features to the public.

5G Advantages

5G is truly a giant leap; it makes possible quantum-level advances and features. Obviously, it will be much faster than its predecessors and far more efficient. But what difference does "faster" mean for voice communications? Will you even notice if you hear the voice/response of whomever you are speaking with one or two milliseconds faster? Of course not. In fact, you will probably notice that the new phones will be labeled as +5G, meaning that the cellular phone communications are still using 4G, and the rest may be 5G, depending on advances made in the next few years. However, 5G will be used by the affected industries and devices to enable much faster response times using enhanced speed and bandwidth. Upload and download speeds will be significantly faster.

On a cellphone or an online-connected device, the advances that the average user will notice will include: being able to video chat in 4K or higher resolution with no noticeable lag; being able to download a file, program, video, game, etc., in seconds rather than minutes (remember, before 3G, this often took hours); and a real-time response when using augmented reality (AR), which adds to the real world rather than replacing it like virtual reality does. You will be able to stream movies in high resolution on your mobile device and game with a portable device in real-time.



5G bandwidth spectrum.

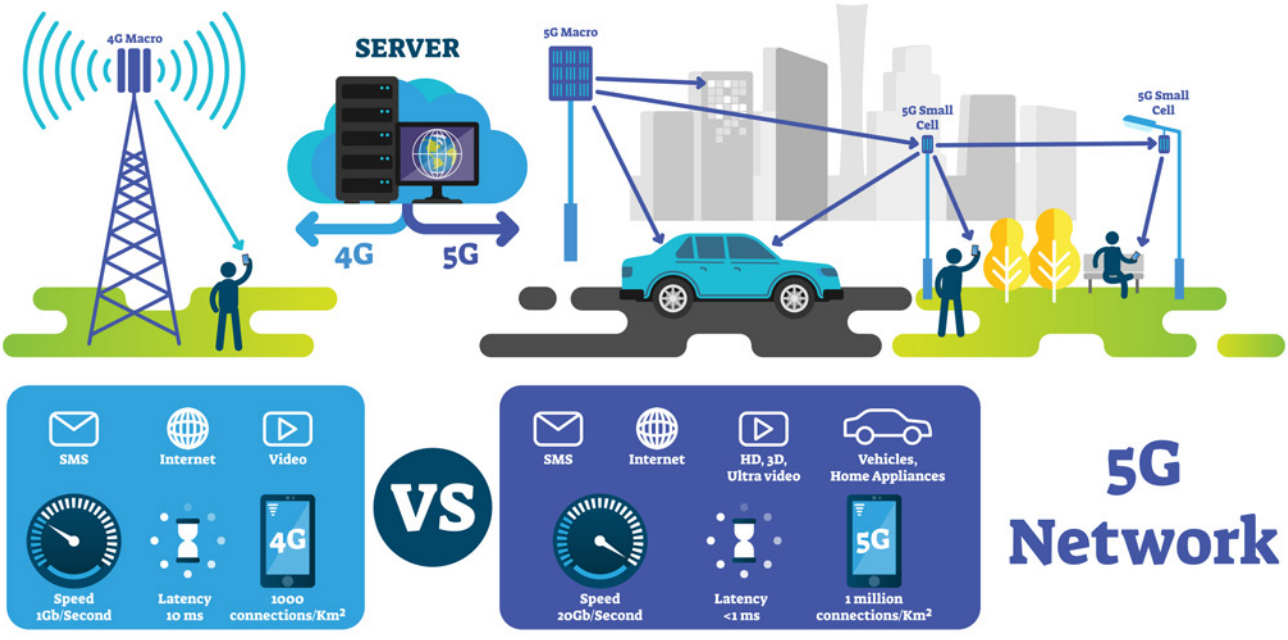
However, 5G is not just the next generation in mobile communications; because it has a far higher level of ultra-fast data transmission, it also will power a wide range of industries from AR-enabled service and self-help repair calls to healthcare, including enabling long-distance robotic surgery, education, and let's not forget autonomous transportation, entertainment, and so much more, all with mission-critical reliability and availability.

Think about what real-time data transfer, command, and response communications can mean to the military. In our industry, the availability of ultra-low latency information exchange within the factory and even across different manufacturing locations globally will result in huge economic and technical change. It will allow moving from wired to wireless connections in many industrial environments. This will reduce installation costs and increase the flexibility of production processes across multiple manufacturing segments and locations.

5G Technology

Let's get "techy" for a little bit with some commentary regarding the bandwidth that makes 5G function and the differences from 4G. 5G uses bands in the 30–300 GHz range, which are rarely used today, while current 4G networks operate on frequencies below 6 GHz. Range testing of 5G has shown results approximately 500+ meters from the tower.

Using small cells, carriers using the millimeter-wave band for transmission using 5G can improve the overall coverage area. With beamforming, and by using small cells to focus the signal, it has been reported that there will be improved coverage with the expected 5G low latency. Remember, low latency is one



The changing mobile landscape from 4G to 5G.

of 5G's most important features (more on this later). This makes the technology suitable for applications that require rapid responsiveness and no lag, such as those mentioned earlier. 5G technology can demonstrate latency as low as one millisecond with reported realistic estimates in the range of 1–10 milliseconds. 5G is reported to be 60 times faster or more, and perhaps up to 120 times faster, than present average 4G latency.

While researching data for this update, and looking at the new standards defining 5G, it seems that, theoretically, data rates can hit 20 Gbps download and 10 Gbps upload; in other words, those are very fast data speeds. Now, remember that these impressive numbers are theoretical rates. We can expect that the specifications of 100 Mbps download and uploads of 50 Mbps are being expected, but we will see.

Key Features

The possibilities are almost endless with 5G, so let's look at the key features. 5G technology:

- Has a reported latency of only one millisecond (latency is the time it takes for the data to go from the point of transmission to the point of origin), which is a significant improvement
- Can increase the number of devices connected by 10x to 100x; therefore, this opens up the possibility of having 50,000 million connected devices simultaneously
- Has very high levels of network availability
- Has a very low chance of network overload
- Will make it possible to have 99.9% coverage
- Will enable an internet of things (IoT) device to have a 10-year, low-power life
- Will provide greatly increased speeds up to 10 GB per second
- Will lower energy consumption; it is reported, but not yet verified, that 5G will reduce energy consumption in the network by up to 90%
- And 5G devices should be compatible with the newer security standards

Along with these key features, many more will most likely be announced in the coming year.

The Future of 5G

Overall, we can expect that 5G in the real world will give us the aforementioned low latency, be efficient, and reportedly be able to switch to a low-energy state within millisec-

onds of detecting a lack of use. 5G networks will be able to communicate with devices moving at very high speeds reportedly up to over 300 mph between the base station and the moving device. 5G will be able to support many more devices than 4G in the same area without overload.

It is reported that 5G will be able to support up to one million devices per square kilometer. You might think that there would never be that many people on their cellphone in a single square kilometer, but we are not just talking cellphones when talking 5G; we are talking about the myriad of devices of all types—such as transportation, entertainment, military, medical, etc.—that will be communicating with each other in the next quarter of a century. For those of you who were around at the time, think back to the devices that communicated with each other back in the 70s, look at where we have come, and then imagine what is to come.

Possible Costs and Risks

Nothing is free, however, and there are some significant costs and possible risks associated with the introduction of 5G. First, there is a need to invest many millions of dollars in physical infrastructure. Many of the advances enabled by 5G are possible due to the much higher frequencies used. These higher frequencies mean a much shorter range per transmission point as well as less ability for the high-frequency signal to penetrate walls and windows with that ability in decline as the distance from the transmission point (the call tower) increases. This will require many more cell towers in closer proximity to each other and the communicating device; even tens of thousands more cell towers and signal transmission and reception points will be needed. You will see cell sites in places you would never have dreamed that they would be.

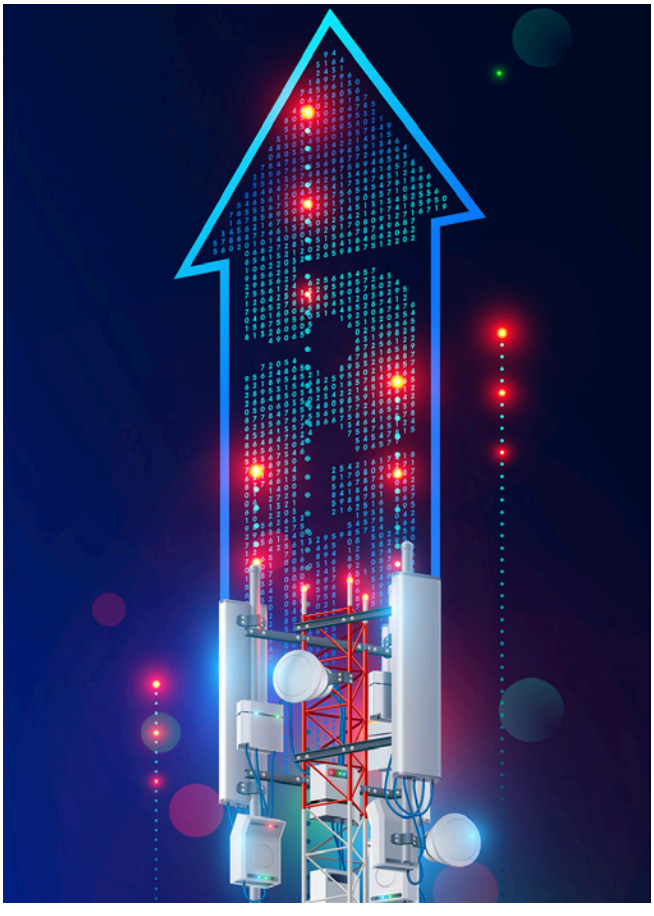
In fact, this expansion has already started. Some existing cell towers are already being converted to 5G or are being converted to 5G + 4G combo towers. If you are in an area where your usually reliable signal is now experiencing dropouts or lost connections, it just might be because your favorite/most-used cell tower is in the process of being converted (a cost some of us seem to be already inadvertently paying).

Cell towers have increasingly become part of the agricultural landscape. This one is housing a bird's nest.

There is also the possibility of health issues caused by higher exposure to RF radiation; this is a controversial topic, with significantly differing opinions. Where I live in Southern California, and where new cell sites are obviously under construction, this specific discussion is taking place on social media, in local web-based discussion groups, and at local meetings with strong feelings on both sides. Let me quote a recent article on 5G [1]:

"One of the biggest concerns people have about 5G is that the network's radio frequency will be unsafe, expose people to radiation, and cause cancer. The fears aren't completely unfounded. A 2011 report from the World Health Organization suggested that cellphone radiation should be listed as "possibly carcinogenic to humans." In 2016, a study funded by the U.S. government showed a link between radio-frequency radiation and cancers in rats. And popular phones like the iPhone and Galaxy handsets may exceed the level of radio-frequency radiation allowed by the FCC.

On the other hand, after years of research and review, the FCC chairman circulated a proposal to deem cellphones as safe, including ones that use 5G. There's no doubt that we now have decades of exposure to RF radiation with no real evidence of decreased health issues caused by it; however, the 5G network will involve the installation of millions of extra antennae, to be placed closer to homes, schools, hospitals, etc., as well as thousands of transmitting satellites, which are also being deployed in space.



Is 5G just a trap? Opponents have strong opinions on the matter.

While the link between cancer and cellphones may be overstated, let's not forget that as of the last few years, since the last studies, there are now millions of wireless headsets in use. Each of these is a tiny, but very close to the head, RF transmitter/receiver. Also, people spend so many more hours per week holding their phone against their head while talking and using Bluetooth headsets, which use RF to communicate. Low-power signals still add up.

In my opinion, I would stick with a wired headset, just in case. Generally, they have better signal quality, a more reliable connection, and no RF, even if they are much less convenient. I remember all of the talk from the '50s and '60s on how smoking cigarettes was safe. Is close RF, even low-power RF, the cigarette of the early 21st century? Something to consider.

Conclusion

In any case, there is no doubt that things are changing, the use of portable devices in all aspects of life is increasing, and the abilities granted by 5G technology will increase that rate of change exponentially. Overall, I would expect positive progress, and that most of this change will be for the good of humankind. **PCB007**

Reference

1. Lynn La, "No, 5G Won't Replace 4G (and Other 5G Myths Debunked)," CNET, September 15, 2019.

Chasing Down Materials for 5G and Beyond


Jonathan Rowntree

Feature Interview by Nolan Johnson
I-CONNECT007

I spoke with Jonathan Rowntree from Rogers Corporation about the impact of 5G on technology, materials, and more.

Nolan Johnson: Jonathan, thanks for your time. What's your background?

Jonathan Rowntree: After graduating in the U.K. as a chemical engineer, I have been very fortunate to have a career spanning several industries, and I spent the last 21 years based in the U.S. in the electronic materials industry. During that time, I worked in both the semiconductor packaging and electronics assembly markets with roles of increasing responsibility across engineering, operations, technology development, sales, and marketing. Before joining Rogers five months ago, I held several business leadership roles for a thermal materials and adhesives, sealants, and coatings business serving telecom, industrial, and automotive electronics end markets. In my new role as general manager of Rogers Corporation's Advanced Connectivity Solutions (ACS) business, I am still learning a lot about the low-loss RF CCL products and applications, but the industry and customers are very familiar.

Johnson: What's the most significant change you've seen in the past few years?

Rowntree: One significant change has been the swift commercialization of 5G wireless communication. Three years ago, there were no 5G standards; many people were asking, "Why do we need 5G?" and questioning the necessity of 5G and validity of 5G use cases. Many people also doubted the technology readiness of 5G, from access network technology to 5G devices. For example, mmWave 5G was perceived by many people as "mission impossible." Fast forward to October 2019, 62 operators have deployed 3GPP-compliant (Third Generation Partnership Project consortium) 5G technology in their networks. And 71 vendors have announced 172 3GPP-compliant 5G devices, at least 38 of which are already commercially available. South Korea has more than three million 5G subscribers, while China has activated 86,000 5G base stations and has 10 million pre-ordered 5G smartphones.

Johnson: Those are big numbers; the scale of this is huge. What challenges are you and your customers facing?

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Rowntree: One big challenge is to build adequate capacity to support the rapid and massive 5G rollout, not only in 2019 but also in 2020 and beyond. Our ACS team predicted the large capacity needs for 5G a couple of years ago and took action to get the capacity ready. This included buying production assets from Isola, building more presses and treaters in our global supply network, and increasing the productivity of our existing presses and treaters. Our current and planned capacity expansions are more than sufficient to meet the surging demands from 5G.

One big challenge is to build adequate capacity to support the rapid and massive 5G rollout, not only in 2019 but also in 2020 and beyond.

Another big challenge is having the right RF laminates and bondply materials to meet new and more demanding design needs for 5G. We are very happy we completed a lot of voice of the customer (VOC) work a few years ago and developed new products based upon predicted material requirements. We have built a broad product portfolio to meet customer design needs for multiple 5G applications at both sub-6 GHz and mmWave frequencies.

Johnson: What do you think is going to change in the next few years?

Rowntree: One big change is the industry will need even higher-performance RF materials. For example, materials will be needed with tighter Dk tolerance under higher operating temperatures and higher humidity and thinner low-loss RF materials with multiple thicknesses. The second big change is RF customers will need more design support from RF CCL suppliers, such as substrate-integrated-waveguide design and electrical property characterization at mmWave frequencies.

Johnson: What's driving that change?

Rowntree: One thing driving the change is the application requirements from more advanced wireless technology. For example, the higher number of transceiver channels, wider bandwidth, and higher frequencies of 5G will drive up operation temperature as well as the range of temperature variation. Another thing driving the change is many more applications at mmWave frequencies, such as 5G, automotive radars, and satellite communications, etc.

Johnson: How should the industry get ready for that change?

Rowntree: From an RF CCL supplier perspective, the suppliers should continue to develop and launch higher performance RF products to provide better and broader solutions and enhance design and testing support for more complex designs at higher frequencies. At Rogers, we have a strong and exciting innovation pipeline with several launches planned for 2020 that will fulfill these increased requirements.

Johnson: What about your part of the industry keeps you up at night?

Rowntree: The raw material supply chain used to keep me up at night, but thanks to the great collaboration between RF CCL manufacturers and raw material suppliers, the whole supply chain of RF CCL doesn't seem to be having as many bottlenecks anymore. One recent example is the tight allocations of low Dk glass, which is impacting the high-speed digital CCL market. The RF CCL supply chain will need to continue their close collaboration to ensure there are adequate capacity and inventory levels to support the growth of high-speed and 5G applications into the future.

Johnson: Jonathan, thanks so much for talking with me.

Rowntree: You're very welcome. PCB007

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Electronics Industry News and Market Highlights

Raytheon, WEYTEC Team to Co-develop the Next-generation Air Traffic Control Workstation ▶

Raytheon Company has signed a teaming agreement with WEY Technology (WEYTEC), a global leader in advanced data visualization and operator control solutions, to co-develop the next-generation air traffic controller workstation called Multi-Platform ATC Re-Hosting Solution, or MARS.

Combination of Techniques Could Improve Security for IoT Devices ▶

A multi-pronged data analysis approach that can strengthen the security of IoT devices—such as smart TVs, home video cameras, and baby monitors—against current risks and threats has been created by a team of Penn State World Campus students pursuing master of professional studies degrees in information sciences.

Wearable, Washable Textile Devices Are Possible With MXene-coated Yarns ▶

Producing functional fabrics that perform all the functions we want, while retaining the characteristics of fabric we're accustomed to, is no easy task. Two groups of researchers at Drexel University believe they have a solution.

Tunable Optical Chip Paves Way for New Quantum Devices ▶

Researchers have created a silicon carbide (SiC) photonic integrated chip that can be thermally tuned by applying an electric signal.

Soft Robot Programmed to Move Like an Inchworm ▶

Engineering researchers from the University of Toronto have created a miniature robot that can crawl with inchworm-like motion. The underlying technology could transform industries from aviation to smart wearables.

WWII Meteorologist Turned Material Scientist Shares Nobel Prize in Chemistry 2019 ▶

The Air Force Office of Scientific Research congratulates John B. Goodenough, professor in the Cockrell School of Engineering at The University of Texas at Austin, for recently being awarded the Nobel Prize in Chemistry 2019. Goodenough is the eldest recipient of a Nobel Prize at age 97.

Meet Ari: The Smart Bike That Helps You Catch Green Lights ▶

With more bikes than ever taking to the city streets, researchers have designed an e-bike that could help riders cruise the "green wave" while also improving trust between humans and machines.

Digital Platform Experimentation Project Uses Quantum-inspired Computing and Deep Learning Technology ▶

Fujitsu Limited, the Singapore Management University (SMU), and the Agency for Science, Technology, and Research (A*STAR)'s Institute of High-Performance Computing announced the launch of the Digital Platform Experimentation Project.

Global Market for Counter Unmanned Aircraft Systems to Exceed $2B by 2024 ▶

Frost & Sullivan's recent analysis, "Global Counter UAS Market: Forecast to 2024," reveals that heightened demand for commercial unmanned aerial systems (C-UAS) by the military for expensive, technologically advanced, multiple-sensor systems is driving innovative C-UAS market growth opportunities.

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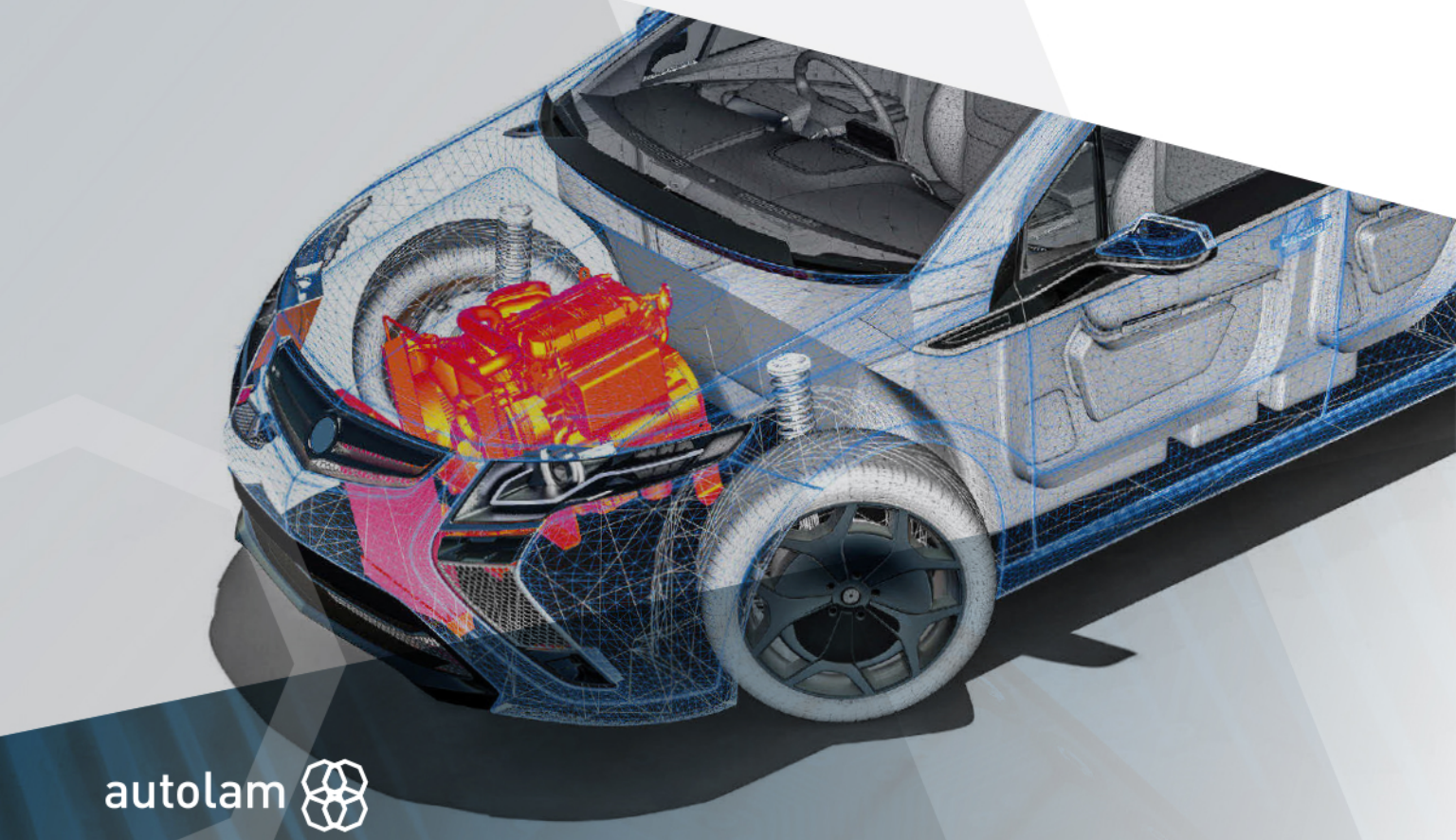

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The CPCA and China's Electronic Circuit Industry: Past and Future

Article by Wang Longji
CHINA PRINTED CIRCUIT ASSOCIATION

Wang Longji is the honorary secretary-general of the China Printed Circuit Association. He is a senior engineer and an industry leader and used to be the production manager of the first imported PCB manufacturing line in China. Mr. Wang is also a well-known child actor and a "national treasure;" one of his most famous characters was San Mao in "The Winter of Three Hairs."

"If you want to have great achievements, you need to end your anxiety first." I often wonder: what is the purpose of living in this world? What is the meaning of human life? After thinking seriously about it, I realize that the meaning of life is to constantly encounter difficulties on the way and solve them. This is true for people, and running a business can use the same philosophy. If we do not meet difficulties and are not able to solve them, whether people or enterprises, life will be meaningless.

Over the past two years, great changes have taken place in the pattern of our manufacturing industry and the external environment. These changes have brought pains, but I believe right now is the best opportunity for the development of the industry. In this article, I will review the development of the China Printed Circuit Association (CPCA) and China's electronic circuit industry in the past 30 years as well as the future of the industry landscape in China.

Wang Longji

Arduous Pioneering

Fifty years ago, I entered the printed circuit industry (renamed the electronic circuit industry in 2015) when it was still in its infancy in China. At that time, our predecessors—professors like Yao Shouren, Li Shihao, Gu Changyin, and Wang Tiezhong—were leading young people to study hard in the lab on single-sided, double-sided, and multilayer printed circuit boards (PCBs).

The earliest professional "circuit workshop" in China was in the Shanghai No. 20 Radio Factory, which consisted of less than 40 people, and all of the circuit boards were produced manually. I also returned to Shanghai from the Fuzhou Military Region. Fortunately, I did not go to the Film Bureau or Shanghai Film Studios (I could return to the literary and art circles at that time),

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but instead, went to the circuit workshop in the Shanghai No. 20 Radio Factory. Since then, I have fallen in love with this industry.

In the 1960s—without information, equipment, and technology—we manually produced single-sided PCBs for seven-tube and eight-tube semiconductor radios. At that time, the width of the line was about 0.8 mm, and the aperture was over 1.0 mm. They were the simplest, low-level PCBs, but they made headlines in major domestic newspapers at that time.

In the 1970s, we produced PCBs for the National 905 Computer B. At that time, the minimum line width/spacing was 0.5 mm, the minimum borehole diameter was 0.8 mm, the double-sided panel had only 22 gold-plated plugs, the maximum size of the plate surface was only 12 cm x 8 cm, and six layers made up the maximum multilayer PCB. Back then, the metal holes were completely manual work; there was so much manual work. We worked day and night. Even during the Spring Festival, we continuously worked 72 hours throughout the night before Lunar New Year's Eve.

Lu Zhiyang, Wu Kedong, and I set up a "three-in-one" innovation team to reconfigure the whole factory. Without any information or references, we relied on our passion for printed boards to guide us. We designed and manufactured equipment and processes by ourselves. We successfully developed semi-automatic printing presses and ferric chloride regeneration equipment and etchers. The semi-automatic continuous production line of point-to-line connection, which was suggested by the former factory director Sha Ancai, was realized. For this reason, the Ministry of Electronics and Shanghai Economic Commission held an unprecedented on-site conference on technological innovation at our Shanghai No. 20 Radio Factory.

In the early 1980s, the localization project of color TV sets successfully introduced 21 production lines from abroad. More than 10 young people from Shanghai No. 20 Radio Factory went to Japan in two batches for 61-day internships. A fully automatic, one-sided PCB production line was introduced by the Panasonic Corporation of Japan, and the first one-sided PCB production line in China was completed. A brand new PCB introduction workshop had been established. At that time, materials were all imported; even the pens and double-sided adhesive paper for repairing boards had not yet been produced in China.

Three Hairs was the name of a popular comic character played by Wang Longji in the 1949 movie adaptation of *The Winter of Three Hairs,* the story of a street urchin with a bald head save for three thin strands of hair.

Forming the Association

In the 1980s, domestic PCBs developed rapidly, especially from local state-owned enterprises to school-run workshops and then to township enterprises—for example, there were the following: Shanghai No. 20 Radio Factory, Dalian No. 14 Radio Factory, Hangzhou Sanlian, Shantou Goworld, Shennan Circuits, Wujin Electronic Accessories Factory, Qiandeng Suhang Electronic, Hebei Hangling, etc. We all found that the industry was developing in a disorganized way, and each company was charting its own path. Product standards, process specifications, environmental protection, and quality assurance were unreachable by these companies.

Led by Shanghai No. 20 Radio Factory and 15 units of the Ministry of Electronics, the CPCA was established in 1990 mainly for three

reasons: to make communication between the enterprises and the government more effective, help the government understand more about the enterprises' difficulties so that the government could support and help enterprises in time, and better standardize industry behaviors. Enterprise officials hoped to have a platform on which to speak. At that time, there were just over 100 PCB, special equipment, and special materials enterprises in China. The annual output value of the largest Shanghai No. 20 Radio Factory was only 670 million yuan, and the total output value of the whole country was only 2.35 billion yuan.

With the establishment of CPCA, our industry had its own home and association. We were all heartened and encouraged. We made *Printed Circuit Information*, the only magazine that had an official domestic publication number in the whole industry. Through overnight negotiations with the Japan Printed Circuit Association (JPCA), the Association Connecting Electronics Industries (IPC) in the U.S., the European Institute of Printed Circuits (EIPC), the Korea Printed Circuit Association (KPCA), the Taiwan Printed Circuit Association (TPCA), and the Hong Kong Printed Circuit Association (HKPCA), we won the right to host the 11th World Electronic Circuits Conference, which was successfully held in Shanghai with the active support and participation of all the people. And we promoted CPCA from the second-level branch to the first-level national industry association.

We also co-sponsored with the JPCA, IPC, and EIPC to establish the World Council of Electronic Circuits (WECC) in Germany. The WECC promotes exchanges between nations in the industry. We strengthened our contacts with our Japanese counterparts, including communicating with non-government experts, and cooperated with Fujioka, Nagashima, and Endo Yu from the JPCA to accelerate the rapid improvements of Chinese enterprises.

In the early 1990s, through the relationship of friends, we borrowed 500,000 yuan of cash (this was a huge amount at the time, with which we could buy five or six houses) and established Guanglian Company, so that the association had space for activities. We also established Yingzhan Exhibition Service Company in which to hold exhibitions. In the beginning, the facility was less than 3,000 square meters; now, it reaches 55,000 square meters. With the establishment of the association complete, we cooperated with government departments to solve the problems regarding the use of auric cyanide, the termination of production license, and the formulation of environmental protection standards in the industry.

After China's accession to the World Trade Organization (WTO), there was a serious inversion of national tariffs. At that time, the imported dry film was only 8 yuan per square meter in our

Mr. Wang speaks in 2008 at ECWC11 which was hosted by CPCA and held in Shanghai, China.

industry, and the tariff was 9 yuan. Imported electronic grade fiberglass cloth, for example, was subject to a 36% tariff. Chinese companies could not survive under these restrictions. Through careful and repeated consultations, we became the association that solved the problem of tariff inversion in a very short order.

When enterprises faced difficulties in environmental protection, such as inaccurate reports in the discharge of sewage, we rushed to the scene to investigate and solve them as soon as possible. We also focused on academic, educational, environmental protection, and standardization work, including the following:

- We established the first Chinese College of Electronic Circuits, Yuncheng College of Electronic Circuits Technology, which was officially approved by the Ministry of Education; after its establishment, nearly 1,000 freshmen have been sent to the enterprises
- Professor He Wei, director of the CPCA Education Committee and professor of Chengdu University of Electronic Science and Technology, sent dozens of senior talents to our industry and helped to set up several national laboratories
- The CPCA Science and Technology Committee organized the spring and autumn international information/technology forums every year and identified a group of senior engineers and a large number of workers in different grades

Mr. Wang sits for an interview in 2015 with Edy Yu, I-Connect007 China editor.

- The CPCA Material Branch organized the spring tea event every year to discuss the development trend of the materials
- The CPCA Environmental Protection Branch actively participated in the preparation of relevant standards, investigated the facts of corporate governance, and communicated frequently with government authorities
- The Standardization Committee formulated or participated in the formulation of a number of industry, enterprise, and national standards; joint standards have been worked out with the JPCA, and a number of JPCA and IPC standards have been translated

We also actively supported and stimulated the social responsibility of enterprises, including giving portable B scan ultrasound machines to remote areas, expanding buildings for Hope Primary School in impoverished areas, setting up the Hope Primary School Excellent Teachers Award, organizing activities for Hope Primary School, and supplying books and pens. Over the years, association membership grew from over 100 when it was founded to nearly 900 today.

Scaling New Heights

The reform advocated for by Deng Xiaoping allowed us to step out of the country and integrate into the world, and the industry experienced tremendous changes. In the years since, millions of employees in our industry, over generations, have devoted themselves to help become the world's largest producer of PCBs and electronic circuits. The supporting functions are basically fully equipped.

In 2006, our PCB output surpassed that of Japan for the first time, accounting for 27% of the world's total; Japan's output accounted for 26%. Today, China's output of CCL is over 70%, and the output value is over 60% of the world total; the output of PCB is over 60% and the output value is 52.4% of the world total. The production of special equipment and materials also ranks number one in the world.

Today, China has the ability to produce PCBs with various advanced technologies. We can

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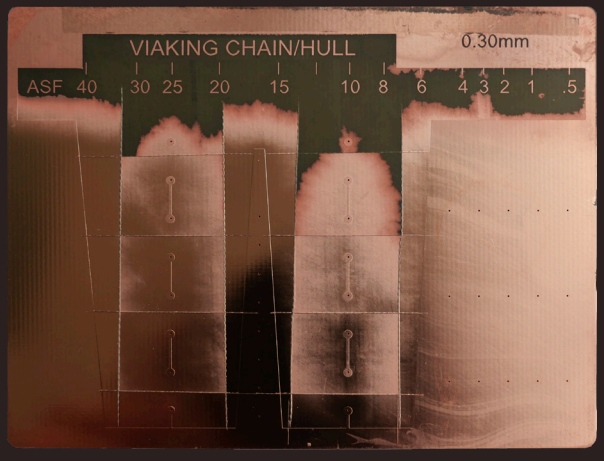

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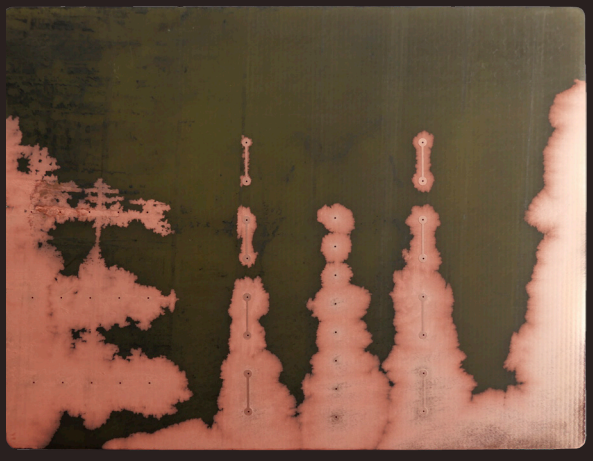

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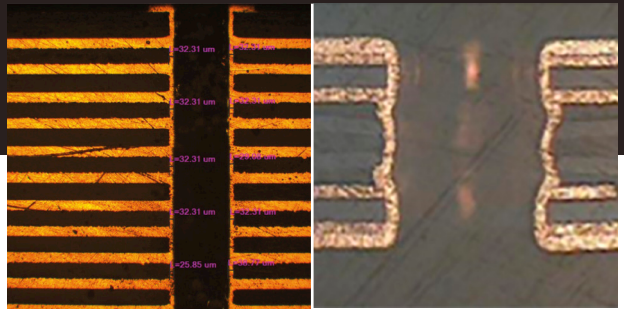
Hull Cell daisy chain results using Cupracid® AC plated @ 1A for 10 min



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produce the world's top 100-layer PCBs. We can support 10 billion instruction-per-second computers. We now have more than 200 national enterprises with a production value of over 100 million yuan in China. Among the top 100 companies in the world, more and more companies are from China, and the total output value has increased more than 100 times compared to 30 years ago.

We now have more than 200 national enterprises with a production value of over 100 million yuan in China.

We are happy to see the emergence of a large number of outstanding national enterprises with advanced international-level management teams and entrepreneurs with a global vision; they have foresight, are focusing on R&D, promoting modernization, and taking on social responsibilities. Many great national entrepreneurs have emerged, included Mo Shaoshan, Yan Haizhong, Huang Zhidong, You Lei, Liu Shufeng, Chen Rongxian, Gen Tongzhang, Wen Yonghe, and others. Experts and scholars have sprung up as well, such as Lin Jindu, Wang Houbang, He Wei, Gong Yonglin, Zha Chunfu, Zhu Datong, Liang Zhili, Yang Xingquan, Ma Mingcheng, and Wang Hengyi.

Now, how do we satisfy the needs of our industry and have sustainable development and structural reform on the supply side? China needs to adjust our thinking to address how to improve our ranking in the world so that China can become an innovative electronic circuits powerhouse rather than a manufacturing specialist. Throughout China's 40 years of domestic development and international exchanges, some colleagues in our industry have worried about the use of domestic special equipment and materials.

Today, we are in a critical period of deepening supply-side reform throughout China, and we have a long way to go. Every Chinese colleague in our industry must share the same dream, and not just making your own profit. We must cooperate and work hand-in-hand with the world. We must try our best to improve localization.

For some key equipment or materials, we should recognize that there is still a certain gap when compared with Japan and other advanced countries. Fortunately, these gaps are shrinking rapidly, and most of the domestic equipment, instruments, and raw materials can meet our demand. We should support national suppliers as much as possible.

For China to become strong, we must have our own substantial economy as well as technologies and products. The upstream and downstream of China's electronic circuit industry chain must be closely united. We need to have mutual trust, understanding, and support and strive for self-reliance. Enterprises must be more independent, increase the ability of R&D and innovation, and solve problems jointly. China must work hard to create an electronic circuits industry that is advanced and trusted.

We know that chips and integrated circuits are first-level assemblies, and many other devices—including mobile phones, computers, televisions, computers, etc.—are third-level assemblies. Our PCB assemblies are second-level assemblies and play an important, irreplaceable, and indispensable role as a link between the former and the latter. Where there is information, modernization, automation, and intelligence, there must be a PCB.

The world's PCB technology needs further development and upgrades, and China has a responsibility to be one of the leaders. There is still a long way to go. Although it is not easy to create a complete "made in China" supply chain, the industry has brilliant prospects. We must persevere, step by step, train our internal skills, and be confident and ready to meet the takeoff of China's electronic circuit industry.

The past 30 years have been brilliant, and looking forward, we will bravely scale new heights. **PCB007**

Wang Longji is the honorary secretary-general of the China Printed Circuit Association.

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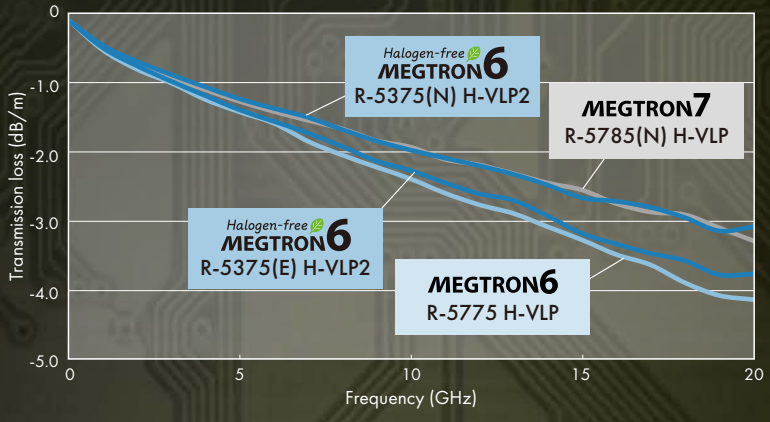

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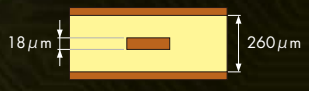

Line length	200mm , 100mm
Line width	125μm
Impedance	50Ω
Inner Cu treatment	No-surface treatment
Core	0.13mm
Prepreg	#2116 56% x 1ply

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The Viability of a Cyanide-free Immersion Gold Bath

Article by Rick Nichols, Sandra Nelle, Robert Spreemann, and Gustavo Ramos
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A key discussion topic within the electronics industry in recent years has been about the impact of real estate pressure on lines and spaces. However, looming in the background is a very real issue that will not go away by simply being ignored. The monster in the closet is environmental awareness.

The Tianjin chemical blast in August 2015 sensitized the Chinese authorities to the use of cyanide in production. As a consequence, the authorities have introduced licensing with regard to the use of cyanide. In turn, this has motivated Chinese PCB manufacturers to ask suppliers for a competent cyanide-free immersion gold solution (CNF Au).

To achieve authenticity, the gold data for this article has all been generated in a 19-liter production simulation tank (Figures 1 and 2). Beaker testing can potentially result in non-representative findings. To ascertain the relevance of any data generated, statistical tools will be applied where suitable.

Background

Although the main drive of this article is a benchmarking exercise, due to the application complexity, some of the elements studied need to be considered on their own merit. In the field, electroless nickel chemistries are normally combined with complementary immersion gold chemistries to provide a robust and reliable system. This article has maintained this approach, in that the immersion gold baths that will be compared to the CNF

Figure 1: 19-liter lab setup for Au bath.

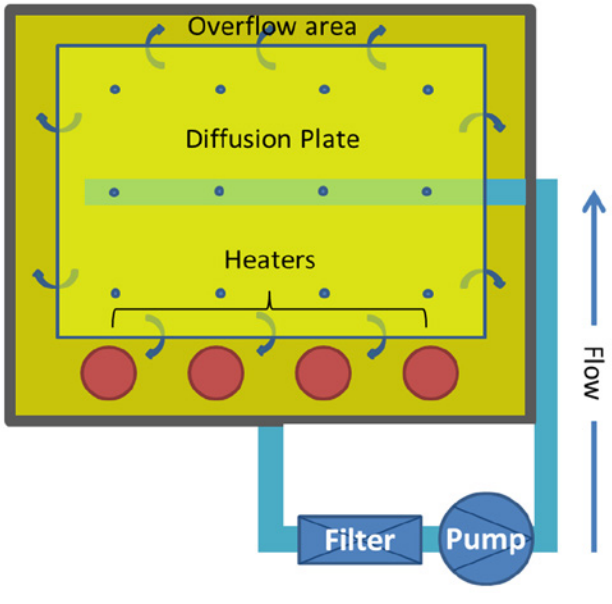

Figure 2: Diagrammatic plan view of gold plating cell.

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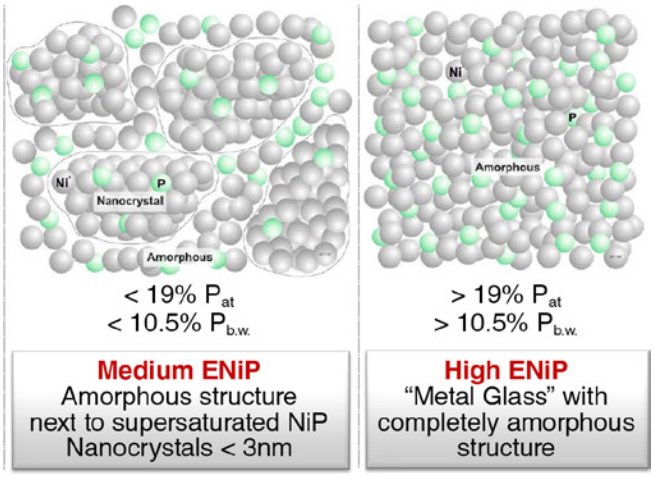

Figure 3: Impact of phosphorous content on crystallinity [1].

Au are purpose defined. Where comparisons are made, CN Au1 will be used on high-phosphorous (HP; P > 10%) nickel and CN Au2 will be used on mid-phosphorous (MP; P = 7-10%) nickel. In essence, the CNF Au bath will be compared against specialist golds.

At approximately 10.5% phosphorous content in the electroless nickel, the crystal structure of the layer changes from nano-crystalline to amorphous [1]. In doing so, the availability of atoms to promulgate the immersion gold process is reduced (Figure 3). This is an explanation as to why the corrosion performance is better for HP nickel but is also why specialty application-orientated immersion gold baths are required for products.

CNF Au General Characteristics

The initial goal will be to establish some basic characteristics for the CNF Au bath. All of the basic characteristics were established by plating on an HP nickel. The basic characteristics will be judged according to age, time, temperature, and agitation.

Impact of Metal Turnovers on Gold Deposition

Cyanide is used as a key complexing agent specifically for gold and is in place to prevent plate-out. Cyanide alternatives are judged by their relative stability because instability is directly related to cost; in the case of gold, that's a significant cost!

Metal turnovers (MTOs) are an accepted lifetime scaler in the electronics industry. MTOs refer to how many times the metal at makeup is added back through replenishment. For example, if the makeup of the bath is 1 g/l gold, 10 MTOs will be achieved when 10 g/l of gold has been added back to the bath. Figure 4 demonstrates that the gold thickness over a lifetime is statistically stable. While stability is a key attribute for immersion gold, cost concerns also require that the distribution of thickness be narrow.

The coefficient of variance (CV%) is a representation of distribution. In this testing environment, a coefficient of less than 10% is considered good. Figure 5 demonstrates that there is no statistical difference in CV% between the beginning of the lifetime and the end of the lifetime. For this article, the IPC 4552A methodology was not used, as the pad sizes that were measured varied significantly in size.

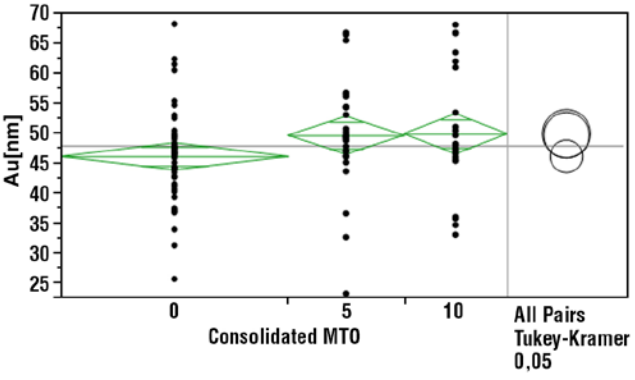

Figure 4: ANOVA, the impact of metal turnovers on gold deposition.

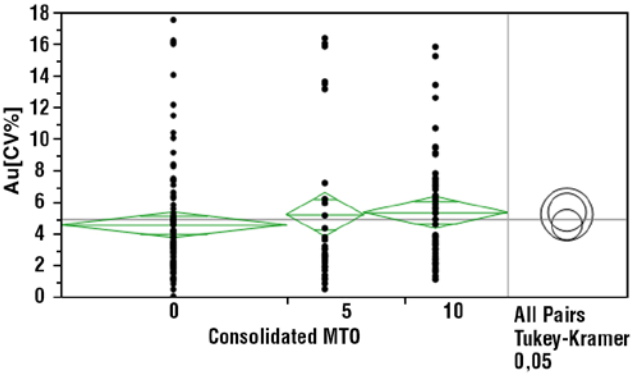

Figure 5: ANOVA, the coefficient of variance vs. MTO.

Impact of Dwell Time on Gold Deposition

Timeway allowing, the dwell time is a tool for controlling the gold thickness specified by the end user. With thickness control in mind, a linear relationship between the thickness and plating time is advantageous.

Figure 6 demonstrates that a statistical relationship exists between dwell time and deposition thickness for the gold and is essentially linear; it displays the confidence intervals for pairwise comparisons of least squares means using Tukey-Kramer HSD. The statistical significance is verified by the fact that the All Pairs Tukey HSD comparison circles are distinct and do not overlap each other. Given the fact that we could see larger comparison circles, the difference is underlined in its significance.

Impact of Temperature on Gold Deposition

While the dwell times are used to configure timeway programs, the temperature is used for fine-tuning (Figure 7). Specified gold thicknesses can be achieved in this way. Within the range tested, no statistical variation exists in the deposition thickness. The temperature range tested for this article was not broad enough to give a signal, but the optimum temperature of 68°C is significantly lower than the running temperature of comparative cyanide-containing baths that operate at >80°C.

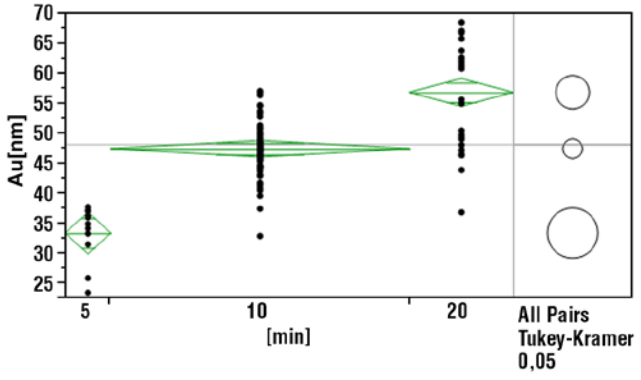

Figure 6: ANOVA, the impact of the dwell time on gold deposition.

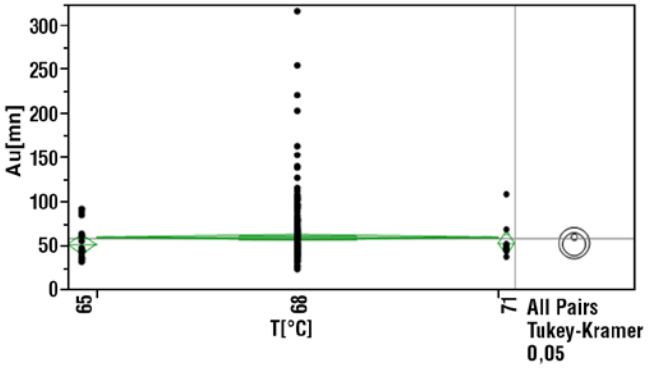

Figure 7: ANOVA, the impact of temperature on gold deposition.

Impact of Bath Turnover on Gold Deposition

Solution turnover is essential for filtration and can also be beneficial for cosmetic consistency. Production equipment often does not have the versatility to comply with supplier-recommended agitation. Figure 8 shows that the flow rate of 50 L/h and 250 L/h have no statistical impact on the gold thickness.

Wetting Balance Result

Wetting balance testing is a method to evaluate wettability. Wettability is influenced by ageing, and the degree of degradation is of concern to manufacturers. In Figure 9, this deterioration can be seen. The degradation is expected and comparable to cyanide-containing immersion golds on the market.

Nickel Corrosion Results

Nickel corrosion is currently peaking in interest in the industry at present, with both fabricators and OEMs being involved. In Figure 10, all of the gold types and nickel types have been compared. The technique used was before IPC-4552A discussions; however, many of

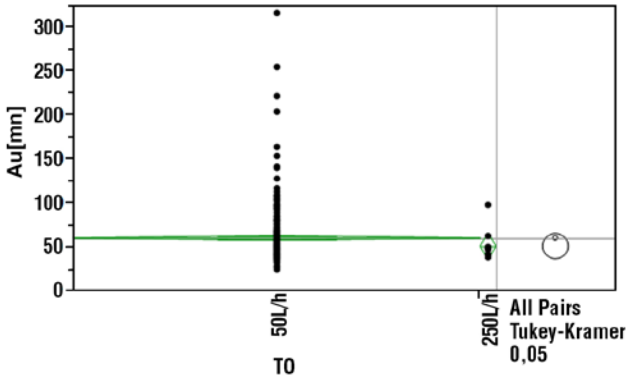

Figure 8: ANOVA, the impact of bath turnover on gold deposition.

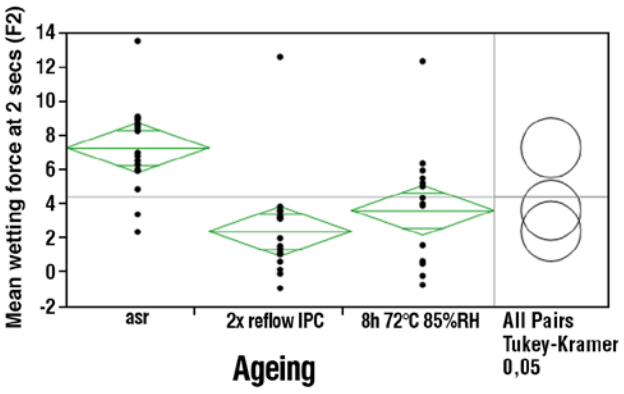

Figure 9: ANOVA, wetting balance force after two seconds by ageing.

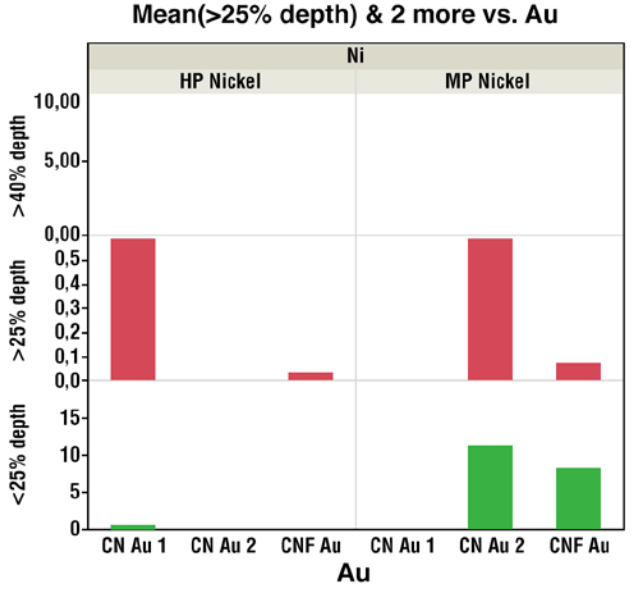

Figure 10: Corrosion by internal evaluation techniques.

the newly introduced rules governed this evaluation. The key difference was not the type of immersion gold but the type of nickel. Please note that the cyanide-containing gold is dedicated to specific nickel types.

Performance Benchmarking

The general performance characteristics indicate that the CNF Au bath is a potentially viable immersion gold bath. The performance of the CNF Au bath is predictable, and the stability is as good as or better than production-qualified cyanide alternatives. In the field, immersion gold can be realistically expected to have a lifetime of over 10 MTOs, not less than 10 MTOs, as is the case for CNF Au. However, "the proof of the pudding is the eating." In this section, the CNF Au will be compared using quality indicators that cover wire bonding, soldering, and corrosion.

Aluminum Wire Bonding

Aluminum wire bonding is an expected performance criterion for any electroless nickel immersion gold (ENIG) process. Wire bonding is generally regarded as a reflection of the compatibility of the gold and nickel in the system. Whether this is true or not, it is definitely an analog representation of functionality. Bonding performance is measured by the force required to break the wire and the location of the break (fracture mode). The ideal pulling mechanics are described in Figure 9.

Aluminum wire bonding utilizes wedge-to-wedge bonding as opposed to ball bonding. This is important for understanding the fracture mode as described in Figure 10 but requires no further discussion in the context of this article.

Heraeus 25-µm gauge aluminum wire was used in this exercise. This has a breaking load of 14.9–15.2 g (according to the supplier). And according to DVS 2811, the average pull strength should exceed 50% of the breaking load [2]. Therefore, the pass criterion is approximately 7.5 g.

Figure 11 represents the pull strength for all the immersion gold types that were tested.

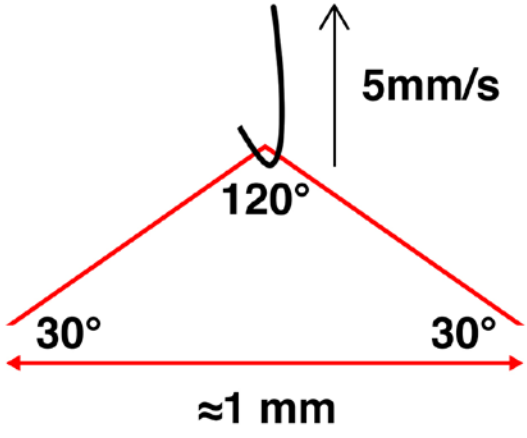

Figure 11: The pulling conditions applied to test wire bonding in this article.

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The one-way analysis graph shows that all the golds achieved the same pull strengths. The one ANOVA analysis of variance has been included to show that there exists a statistically supported variance. The significance is confirmed by the Prb > F function of < 0.0001. The scale of the diagram was, in this instance, too small for the statistical significance to have been borne out by the All Pairs Tukey-Kramer analysis. According to this result, the pull strength result for CN Au 1 on the HP nickel was marginally better.

In practical terms, Figure 11 acts as confirmation that the cyanide-free gold bath (CNF Au) performs comparably to the cyanide-containing baths independently of whether the related nickel diffusion barriers are HP nickel or MP nickel.

As previously mentioned, the pull strength is only one aspect of wire bonding reliability. The other aspect is the fracture mode or break location. Essentially, only fracture modes 1 and 5 are of true concern and are considered failures. Fracture mode 3 represents the perfect result, while failures 2 and 4 may be indications that bonding parameters need to be optimized. In reality, fracture modes 2 and 4 are the most common as the welding process always entails a degree of wire thinning. It can be seen that in Figure 12 that the status quo for CNF is maintained while the cyanide-containing immersion gold variations both show a small degree of wedge lift for the first bond.

The minimal amount of level 1 fracture modes for CN Au1 and CN Au2 could be attributed to the wire bonding parameters, so in reality, the performance of all the immersion gold baths should be considered as equal. Although the results for the cyanide-containing gold baths were achieved by plating on dedicated electroless nickel baths, the results for the CNF Au were a conglomeration of results plated on HP nickel and MP nickel. To evaluate whether the electroless nickel has a defining impact, a one-way analysis was carried out, isolating the results for the CNF Au only. These results are shown in Figure 13.

Mode 1	Wedge lift first bond
Mode 2	Neck break first bond
Mode 3	Wire loop break
Mode 4	Neck break second bond
Mode 5	Wedge lift second bond

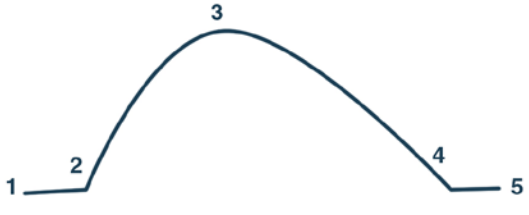
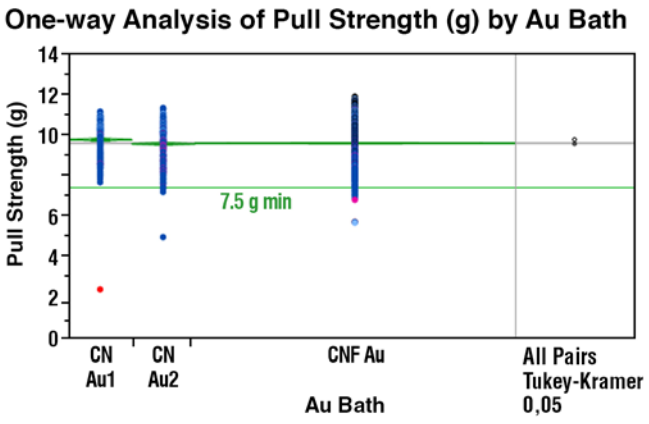


Figure 12: Description of fracture mode used in this article.



One-way Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Au Bath	2	17,7138	8, 85691	9, 2775	<,0001
Error	4255	4062,0956	0,95466		
C. Total	4257	4079,8094			

Figure 13: ANOVA, the pull strength for all immersion gold types in the study.

The pull test result for the MP nickel is statistically superior to that for the HP nickel; however, the disparity is so low that it can be overlooked. The type of nickel has no veritable impact on the pull strength for the CNF Au. In Figure 14, the fracture modes are evaluated. The results in Figures 13 and 14 contradict themselves if the differences were significant. The fracture modes for both nickel types can be regarded as the same.

Solder Joint Reliability

Solder joint reliability (SJR) is a measure of the formation of the intermetallic compound (IMC) and can be evaluated by physical shock

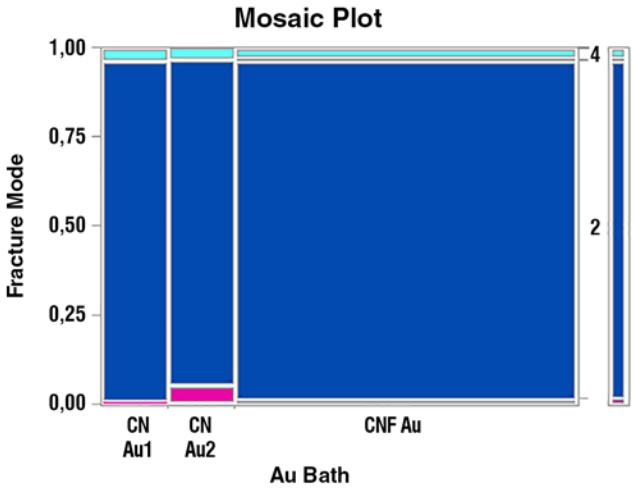


Figure 14: The impact of the gold type on the fracture mode for CNF Au.

Ball type	Shenmao SM Ball PF684-S
Alloy	SAC 305
Ball Diameter	450µm
Flux Type	Kester Taky Flux TSF 6502
Reflow Profile	TSF 6502 LF Linear Profile
Reflow Atmosphere	Air
PCB Type	TV3v4, SMD BGA,SRO380
IMC creation time	4 hours

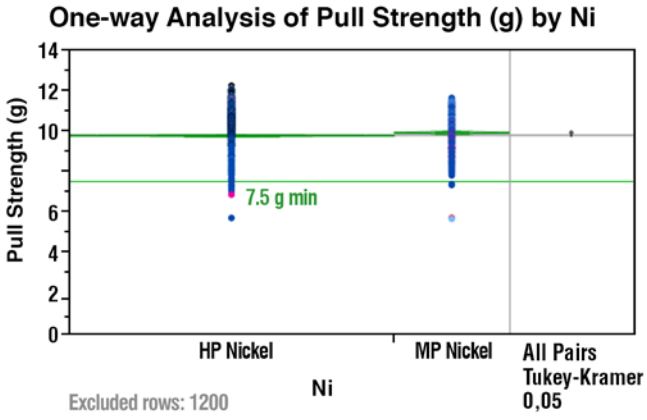
Table 1: Solder conditions for the solder joint reliability testing.

testing. This article does not dwell on the mechanisms that are involved in IMC generation, as the topic is far too complicated to be sidelined as an incidental. Ultimately, the SJR should demonstrate high forces accompanied by high ductility. The target is to simulate accelerated shock-related wear and tear.

The results of cold ball pull (CBP) testing and ball shear (BS) testing will be discussed in this section of the article. In Table 1, the solder assembly conditions for this article are represented.

Cold Ball Pull Testing

As outlined in Figure 15, the pull force is applied in the z-axis at a speed of 5 mm/s. Because SJR testing is performed on attached solder balls, the test vehicle is a solder defined (SMD) ball grid array coupon (BGA). The forces that are associated with SJR are related to



One-way Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Ni	1	11,5240	11,5240	11,6570	0,0006*
Error	3056	3021,1372	0,9886		
C. Total	3057	3032,6612			

Figure 15: ANOVA, the impact of the nickel type on pull strength for CNF Au.

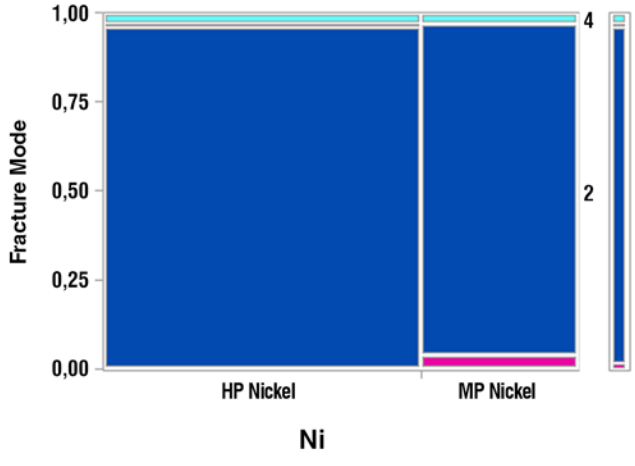


Figure 16: The impact of the nickel type on the fracture mode for CNF Au.

the contact area exposed by the solder resist openings (SROs).

A fracture graded as 4 in Figure 16 is a bond failure with probable low pull strength and poor fracture characteristics. These are considered catastrophic failure and would be investigated further in the field. For SROs that are 380 µm in diameter, the expected pull strength

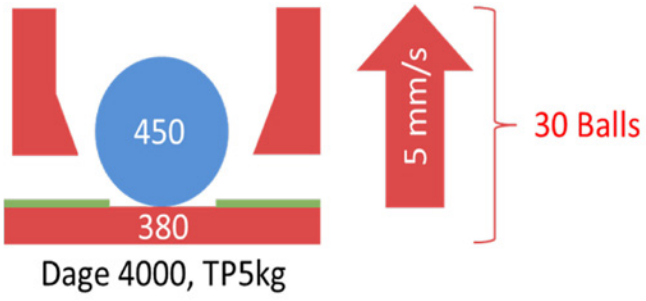


Figure 17: Physical conditions for the cold ball pull test.

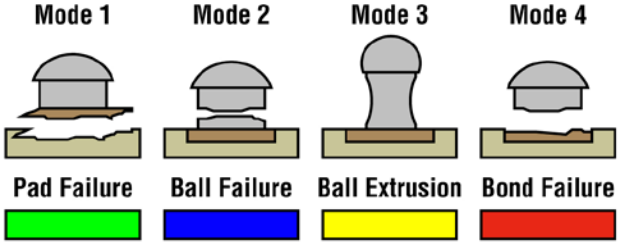


Figure 18: Failure classification for the cold ball pull test.

would be approximately 1,000 g. Figure 17 shows that the means for all the results are very similar. The fluctuation for the CNF gold is greater, but the data set is also bigger.

Despite the pull strength being very similar in the fracture modes, they are different (Figure 20). The CN 1 plated on HP performed the best with 80–90% mode 2 fractures. Mode 2 failures represent fractures that occur above the intermetallic compound.

Interestingly, it can be seen in Figure 18 that two distinct performance levels have occurred. There is a disparity between CN Au1

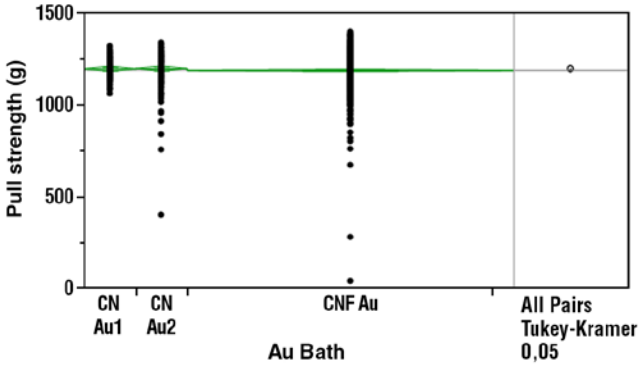


Figure 19: ANOVA, comparison of the CBP pull strength for the gold types.

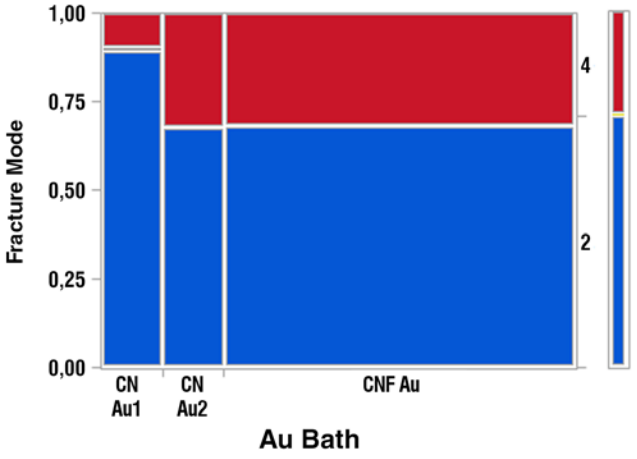


Figure 20: A comparison of the CBP fracture modes for the gold types.

and the other two immersion gold types. The disparity may be linked to the nickel types on which they are plated, as they are also distinct. In Figure 19, the types of nickel that are used are also evaluated. The results are statistically different, identified by the probability value; however, the difference is minimal in practice.

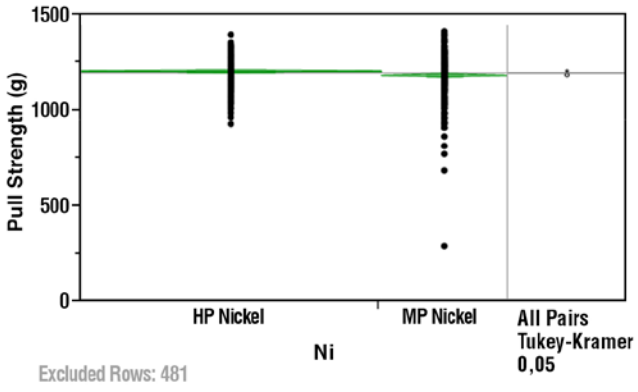
The impact of the nickel was not evident in terms of pull strength but is significant in terms of fracture mode. The result for the HP nickel is superior to that of the MP nickel. The impacts of the nickel-plating solutions were probably the key contributors to the skewed results in Figure 18.

Ball Shear Testing

As the name implies, ball shear testing differs with regard to CBP because it employs a horizontal lateral force. Additionally, the force generated is greater due to the speed of the transducer. Figure 21 represents a diagrammatic version of the equipment setup.

Ball shear testing is an alternative to CBP that really focuses on the IMC formation. The fracture mode is determined by the amount of the IMC that remains after the shear (Table 2). SJR performance is affected by multiple factors.

The shear strength for ball shear testing, similar to CBP, is affected by the SRO area. Further, the test can have an expected minimum average value for a 380-µm SRO. This value



One-way Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Ni	1	100214,4	100214	12,1337	0,0005*
Error	1020	8424392,0	8259		
C. Total	1021	8524606			

Figure 21: ANOVA, comparison of the CBP pull strength for the nickel types.

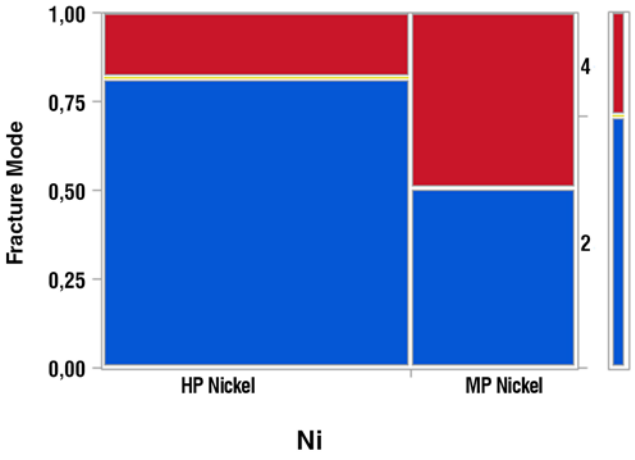


Figure 22: A comparison of the CBP pull strength for the gold types.

Mode 1	Pad pull-out
Mode 2	Intermetallic fracture < 5%
Mode 3	Intermetallic fracture < 25%
Mode 4	Intermetallic fracture < 95%
Mode 5	Intermetallic fracture > 95%

Table 2: Failure classification for the ball shear test.

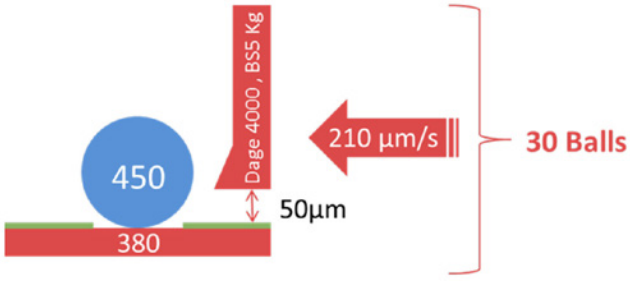


Figure 23: Physical conditions for the ball shear test.

is approximately 750 g. It is demonstrated in Figure 22 that all the results conform to expectation.

More importantly, for benchmarking purposes, the results are similar. The instant visual message relating to Figure 23 is the dominance fracture mode type 2, shown in blue. The inference is that the SJR has a high degree of ductility.

The fracture modes in Figure 25 indicate that the CNF Au performed worse than both of the cyanide-containing gold baths. However, due to the difference in population size, the resolution became too poor to show the distinctions. The actual variations in the results are represented in Table 3.

The results are visible on the top line of the row that represents each gold bath. The total population count is also shown in the table.

Contingency Table

Fracture Mode

Count / Total % / Col % / Row %	2	3	4	5	Total
CN Au1	180	0	0	0	**180**
	13,02	0,00	0,00	0,00	**13,02**
	13,29	0,00	0,00	0,00	
	100,00	0,00	0,00	0,00	
CN Au2	180	0	0	0	**180**
	13,02	0,00	0,00	0,00	**13,02**
	13,29	0,00	0,00	0,00	
	100,00	0,00	0,00	0,00	
CNF Au	994	18	7	3	**1022**
	71,92	1,30	0,51	0,22	**73,95**
	73,41	100,00	100,00	100,00	
	97,26	1,76	0,68	0,29	
Total	**1354**	**18**	**7**	**3**	**1382**
	97,97	**1,30**	**0,51**	**0,22**	

Table 3: The fracture mode data for the gold baths.

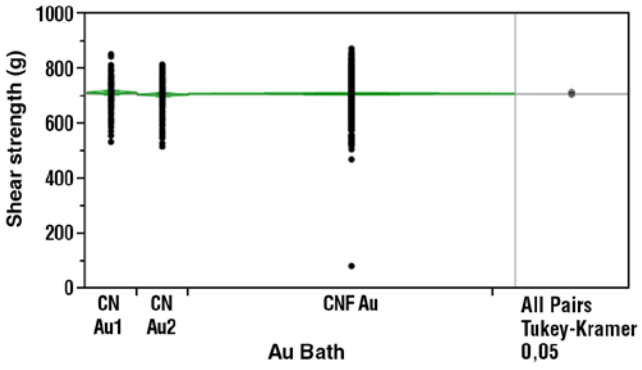


Figure 24: ANOVA, a comparison of the shear strength for the gold types.

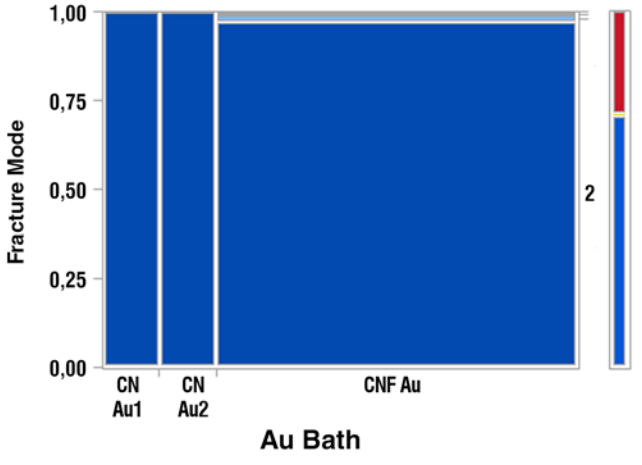


Figure 25: A comparison of the ball shear fracture modes for the gold types.

The result for the CNF Au gold bath is worse than that for the cyanide-containing baths. The determining decision factor is the type 4 and type 5 fracture modes as these types of fracture modes indicate brittleness. However, the population size may have influenced the outcome.

It is worth considering that the total percentages for fracture mode 4 and the percentages in Table 3 are below 1%. Ultimately, the ductile types fracture mode 2 represent over 97% of the results. To complete the circle, the impact of the nickel was evaluated. The shear strength can be seen in Figure 24.

The shear strength for the nickel types is comparable and a statistical difference between the averages that cannot be identified. In Table 4, as with Table 3, differences are observable but are once again, the resolution is too low to show the actual numerical classifications. Both nickel baths generally display high ductility. The brittle fracture modes for both the nickel types are below 1%.

Contingency Table

Fracture Mode

	2	3	4	5	Total
Count					
Total%					
Col%					
Row%					
HP Nickel	890	8	3	0	**901**
	64,40	0,58	0,22	0,00	**65,20**
	65,73	44,44	42,86	0,00	
	98,78	0,89	0,33	0,00	
MP Nickel	464	10	4	3	**481**
	33,57	0,72	0,29	0,22	**34,80**
	34,27	55,56	57,14	100,00	
	96,47	2,08	0,83	0,62	
Total	**1354**	**18**	**7**	**3**	**1382**
	97,97	**1,30**	**0,51**	**0,22**	

Table 4: The fracture mode data for the nickel baths.

Solderability

Solderability is the reflection of the functionality of a final finish in assembly as opposed to after assembly. Solder flow or wettability is required to secure components and potentially saving money by minimizing the volume of solder paste.

This article will address two of these evaluation methods; although these are proprietary, they remain topical for this article. The tests are the solder indicator (SI) test and the solder spread (SS) test. These are described in Figure 26 and Figure 27. In both test methods, solder paste is applied in a specific pattern, or location, from where it can flow during reflow.

In the case of the SI test, the solder is expected to close the gap in the solder and is scored accordingly, depending on how far it flows, and, of course, in which direction. Less than 2 is poor, indicating dewetting, while 10 is excellent but rarely achieved.

In the case of the SS test, a limited volume of solder paste is applied, and the coupon is reflowed. After reflow, the angle will be measured to assess flow potential. The lower the angle, the better, but around 20° is regarded as the critical value.

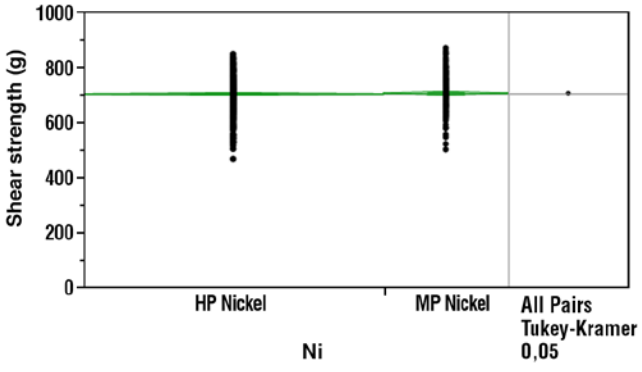


Figure 26: ANOVA, a comparison of the shear strength for the nickel types.

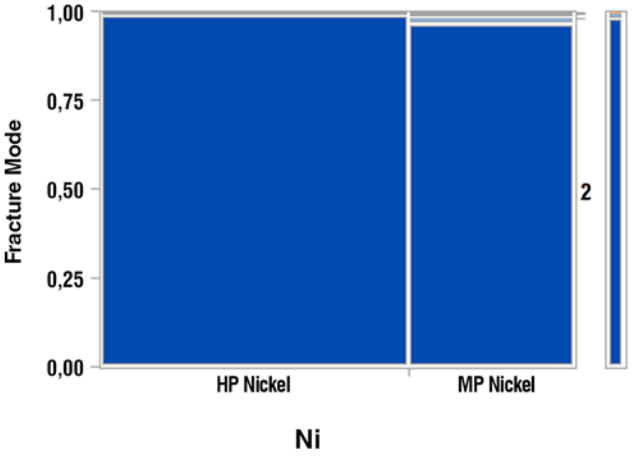


Figure 27: A comparison of the CBP fracture modes for the nickel types.

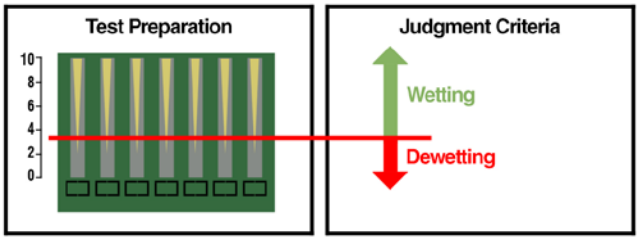


Figure 28: Solder indicator preparation and judgement.

The results for both solderability methods are shown in Figures 28 and 29.

The results for the CNF Au are better than the CN-containing gold types. The spread of the CNF Au result is greater, potentially because the CNF Au is plated on both HP nickel and MP nickel.

The one-way analysis to verify the significance of the results for the gold is represented

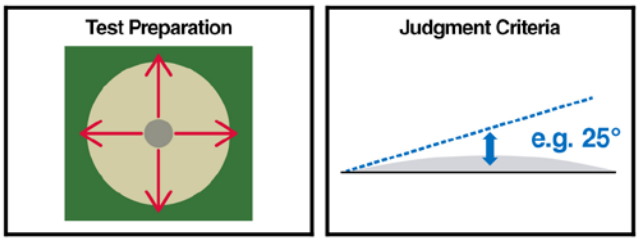


Figure 29: Solder spread preparation and judgement.

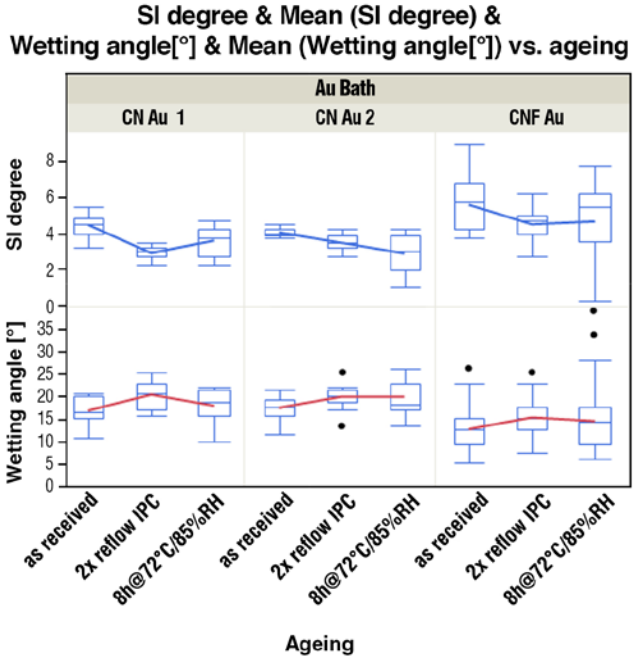


Figure 30: The impact of ageing on the solderability of the gold types.

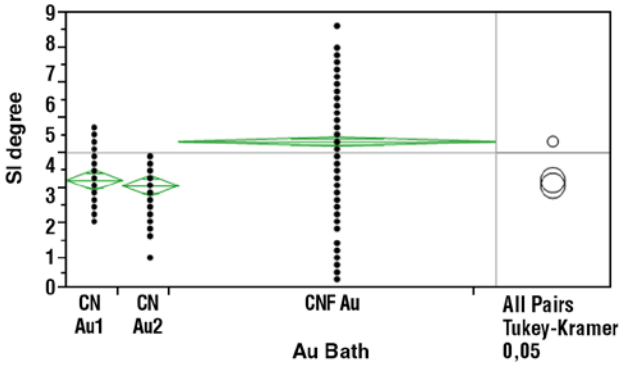


Figure 31: ANOVA, analysis of the solder index value of the types of gold bath.

in Figures 31 and 32. Figure 31 confirms that the CNF Au gold bath performs better than the cyanide-containing gold baths. Figure 32 confirms that the CNF Au gold bath performs

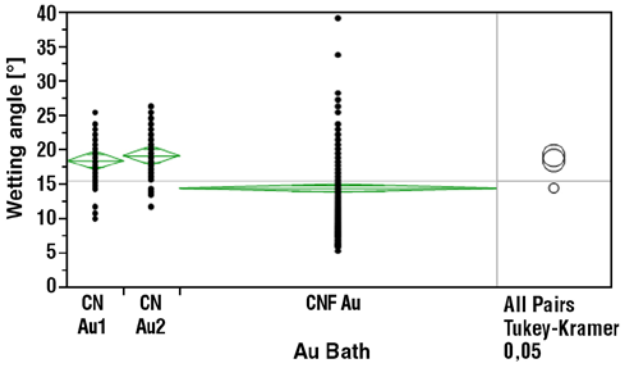


Figure 32: ANOVA, analysis of the solder spread value of the types of gold bath.

better than the cyanide-containing gold baths. The impact of the nickel type can be seen in Figure 33. The HP nickel performs similarly or better than the MP nickel despite the negative impact of the CN Au 1 result in Figure 29.

Conclusions

Many of the benefits of CNF Au are described in the introduction of this article. This article highlights how the test results were generated using a production simulation tool. In doing so, the results are more poignant to the field and industrial practice.

One of the key items of interest is the stability of the CNF Au bath. This has been a major vexation to many cyanide-free development efforts of the past. This article has demonstrated that the performance over a lifetime measured in MTOs is stable, predictable, and controllable. The indications are also that the CNF Au is a drop-in replacement for cyanide-containing immersion gold in existing ENIG setups. This process readiness has been demonstrated by the compatibility of the CNF Au bath with both HP nickel and MP nickel.

Where possible, this article has shown statistically that cyanide-free immersion gold can be a viable competitor to cyanide-containing immersion golds. The benchmarking demonstrated that no discernible differences could be found between the cyanide counterparts and the cyanide-free bath. It is also realistic to suggest that the compatibility of the CNF Au and the HP nickel is something to consider for the highest reliability ENIG production. **PCB007**

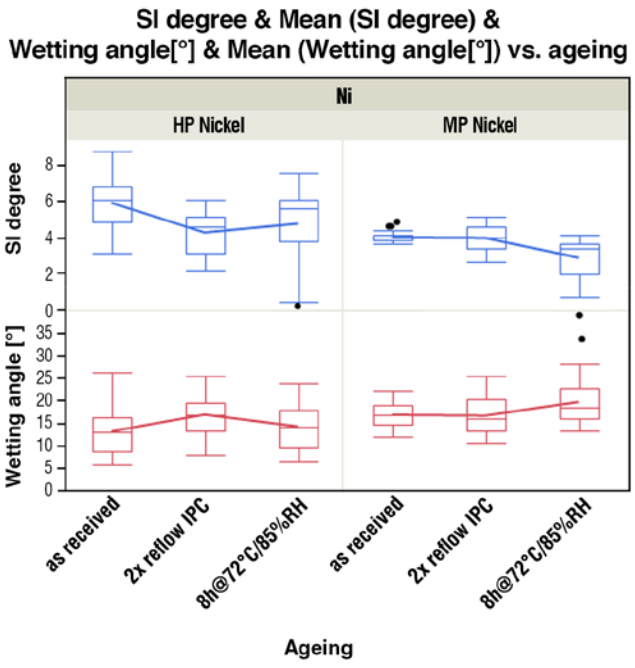


Figure 33: The impact of ageing on the solderability of the nickel types.

Acknowledgements

Without the hard work of the chemists and material scientists in Berlin, this article could not have been done.

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This paper was first presented at SMTAI 2018 and published in the technical proceedings.

Rick Nichols is a global product manager for surface finishing at Atotech Deutschland GmbH.

Sandra Nelle is a product manager for surface finishing at Atotech Deutschland GmbH.

Gustavo Ramos is global product director for selective finishing at Atotech Deutschland GmbH.

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Go To Bed Hungry

Testing Todd

by Todd Kolmodin, GARDIEN SERVICES USA

Another decade is coming to an end, so, forward thinkers, take this time to review the past, evaluate past decisions, and hopefully make prudent decisions to move forward in the ever-changing marketplace in which we exist. There has never been a Magic 8 Ball to predict what is going to happen, so we all do our best to calculate, look over the fences, and aim to remain in this competitive meat grinder we call "the market." One thing I have learned in my 33 years in the electronics field is that you have to go to bed hungry. Tomorrow is a new day and possibly the beginning of a new era, so you will need to be sharp and eager when the sun rises.

We exist and compete in dynamic markets both abroad and in the Americas, and we see some of the same challenges in both theatres. For some perspective, I talked with Masayuki Komatsu, director of operations in our Japanese market. We discussed some of the challenges the Asian markets are facing. It's not surprising that the same trials and tribulations are being felt there.

A strong opener is the increased trade friction between the U.S. and Chinese markets. This is having an impact on the Japanese market as well. Japanese OEMs are pulling some development back to Japan, while relocation to Southeast Asia is still increasing by others. As in the Americas, competition is fierce. Company closures, acquisitions, and takeovers increase the stress on the markets. Labor shortages are problematic in Japan, and manufacturers are recruiting foreign workers to fill the gaps. Unfortunately, the language barriers come into play, and effective communication becomes troublesome. This is not so different in North America. Unemployment is historically low, and many manufacturers struggle for skilled labor as the time to market is crucial, and the grooming time for new employees has to be accelerated to keep them competitive.

Complicating matters in the Asian and North American markets is the age of manufacturing tools. Communication from Asian customers strongly indicates concern about equipment


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age and the ability to perform and produce products under the current and projected demand models. Are the equipment and technology evolving as fast or faster than the product being developed?

Komatsu-san continued by stating a strong point in the Asian markets has been in the automobile industry. The push for electric and self-driving cars has put a tremendous boost in the camera and sensors markets. Much of this market has been lost in North America due to the mechanization and automation of this manufacturing sector, including inspection and test. As this technology is definitely going to move forward and evolve, the need for higher-precision flying probers and four-wire Kelvin equipment is going to increase.

The push for electric and self-driving cars has put a tremendous boost in the camera and sensors markets.

The Americas and Europe feel the same squeeze. Margins are disappearing with the technology, and challenges are increasing. Standard fixture testers of the '80s through the 2000s are basically obsolete. The density, pad size, and spacing of today's designs make that era of fixture technology cost-prohibitive to maintain any favorable margin. Fixture testers to compete with this technology need to be quad and octal density and preferably automated. Labor burden, plus the tooling cost of fixtures for this type of equipment, require automation and large volume to be effective. We do not see this in the Americas. Therefore, flying probe technology is the solution for the prototype and mid-volume markets. Reducing dedicated tooling costs and labor burden and implementing automation are the three building blocks to success.

However, with these guidelines, new challenges remain. Flying probe testing is not accepted in all manufacturing scenarios. Some military, medical, and aerospace contractors still shy away from the use of flying probes; these are the high-reliability markets and may still require fixture testers, as they provide the true parametric test. But these designs also follow today's development curve and are complex. With most of the North American fixture testers limited to double-density grids, the requirement of multipass fixtures materializes. Now, tooling and testing costs rise without the proper feedback to the sales/marketing teams, which results in diminished margins. And we all know the effects of long-term margin loss.

I have seen that the Asian, American, and European markets all feel challenges. We may thrive in separate markets/niches, but the overall challenges are the same: labor, equipment, and margins. The larger challenges in North America are the ability to stay ahead of the manufacturing curve. Effective equipment and automation to handle the new designs of today and tomorrow are key. For Asia, it's labor and margins. Automation is mandatory with the volumes found in the Asian markets. Automated fixture testers in octo-density configurations run 24/7, whereas none of this technology is used in the Americas.

As volumes increase in the North American markets due to regulations or OEM preference, the flying probe will be overwhelmed at some point. We will see a time where this precision fixture technology will be required in the Americas to compete and maintain margins. And as Komatsu-san commented earlier, the trade frictions are apparent now. If they increase, the Asian markets may become less viable for volume manufacturing, and the push will be back to the Americas.

Remember to go to bed hungry, my friends; the hunt begins early. **PCB007**

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

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Supplier Highlights

Helfried Weinzerl Steps Down as President/CEO of Bürkle North America ▸

Bürkle North America announced that its board of directors has appointed Kurt Palmer as president & CEO, replacing Helfried Weinzerl who is stepping down after seven years. This leadership appointment is effective immediately.

Amphenol Printed Circuits Recognizes Panasonic as a Qualified Vendor for Flexible Laminates ▸

Amphenol Printed Circuits has qualified Panasonic's Felios Flexible Laminates and will now increase usage on new part numbers.

Ventec to Unveil autolam Based Material Solutions for Automotive Electronics at productronica 2019 ▸

At productronica 2019, Ventec International Group Co. Ltd. (6672 TT) will launch "autolam"—a base material solutions set specifically curated for the diverse and unique requirements of automotive applications.

Chemcut Representative TriChem Technologies Expands to Illinois ▸

TriChem Technologies will now represent pre- and post-sales support of Chemcut wet processing equipment in Illinois.

Perfect Point Announces Release of New FPC & Adhesive Based Material Endmill ▸

Perfect Point and Jinzhou have recently released the newly designed "SR111RE" single flute endmill specifically engineered for processing of FPC, rigid-flex builds and adhesive layers. Perfect Point has solved an industry challenge in cutting/milling soft materials. The modified helix and other geometry improvements on the SR111RE prove to be effective at heat mitigation by more effectively evacuating debris.

Isola Names Travis Kelly President/CEO ▸

Isola, designer and developer of copper-clad laminates and fabrication materials for multilayer printed circuit boards, has appointed Travis Kelly president and chief executive officer. Kelly most recently served as global chief operating officer at Cerberus Operations and Advisory Company (affiliate of Cerberus Capital Management).

The Plating Forum: Update on IPC-4552 ENIG Specification Revisions ▸

George Milad's columns will cover PCB plating, IPC specifications, and more. In this debut installment, he gives us an update on the IPC-4552 ENIG specification, including Revision A and B.

Nano Dimension Releases Record Q3 Results ▸

Nano Dimension Ltd. has released selected preliminary unaudited estimates of financial results for the third quarter of 2019 and reported record quarterly revenues of approximately $2.2 million for the third quarter of 2019, up by 32% year-over-year.

Unimicron, Nan Ya 4Q19 Revenues to Grow on ABF Substrates ▸

Taiwan-based Unimicron and Nan Ya PCB have both seen revenues for the third quarter of 2019 reach high levels thanks to robust shipments of ABF substrates, and the growth momentum is expected to persist into the fourth quarter of the year.

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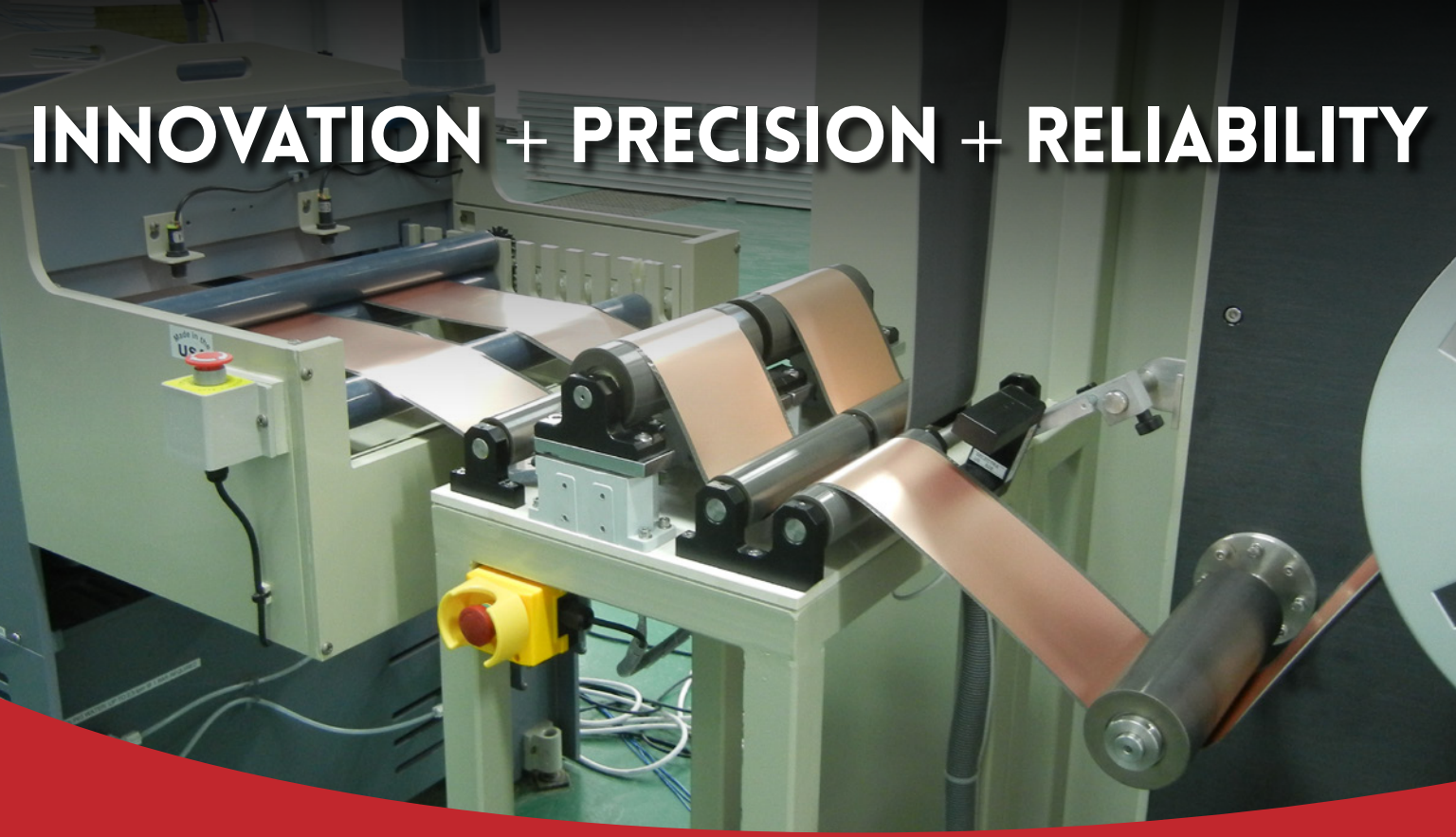

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Making Quality Initiatives Fun

The Right Approach

by Steve Williams, THE RIGHT APPROACH CONSULTING

How do you overcome resistance and gain employee buy-in when implementing a new initiative, especially one that is generally seen as dry and boring, such as a quality management system? Follow Law 2 from *Quality 101 Handbook: The Biggest Little Book on Quality You'll Ever Need.* For the sake of continuity, Law 1 states, "Never fear an unexpected customer visit." If every employee lives and breathes the quality system every day, there will never be a need for an audit-prep panic. In this column, I will focus on Law 2.

Law 2

Law 2 claims, "When things are fun, things get done." Here are a few additional reasons to make quality initiatives fun.

Fun, you see:

- Is free
- Enhances communication and builds relationships
- Makes people want to perform well at work
- Energizes creativity and problem-solving abilities
- Pleases customers, team members, and co-workers
- Makes boring tasks easier to do
- Breaks down enormous undertakings into manageable tasks
- Allows people to relax and perform better while under audit/customer pressure

Create an Environment of Excitement

I am a firm believer in making work as fun as possible, and this is the perfect situation for that approach. A quality management system is not a topic often associated with being interesting, much less fun. But a cultural change as significant as this presents the opportunity to smooth the transition by creating an environment of excitement around the change. The key is to foster ownership in the effort with every employee, and one of the best ways to engage people is to make it fun.

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Further, there are many benefits to making quality initiatives fun. For example, customers notice employees who:

- Enjoy their job
- Like their company
- Embrace the quality policy
- Believe in the culture
- Talk the talk and walk the walk

1. Choose a Battle Cry

First, develop a battle cry. Your battle cry should be a common theme for the quality system and be memorized along with your quality policy. To develop a battle cry, you could hold an internal contest. Once established, you could print your battle cry on T-shirts (Figure 1), which you could wear during major audits/customer visits; you could also give these items out as ISO rewards.

Whatever you decide to call your "battle cry" (e.g., your slogan, mantra, or call to action), this technique provides a central theme around which to unite your workforce and "rally the troops" around. The creativity of your battle cry is only limited by your imagination. One I have used very successfully in the past is, "Say what you do, do what you say, and prove it!" The Ford Motor Company's famous battle cry, "Quality is job #1," is recognized around the world and served as a rallying point for employees as the company pulled itself out of some difficult times. This slogan was born out of Ford's implementation of Total Quality Management in the early 1980s, which now associates the name Ford with quality automobiles. These are the types of messages this technique should try to capture.

Figure 1: Battle cry T-shirt example. (Source: Quality 101 Handbook)

2. Publicize Your Battle Cry

Second, capitalize on the battle cry everywhere you can, such as on T-shirts, posters, signage, plaques marketing promotions, business cards, etc. Make it fun by rewarding employees for being able to recite it by memory on demand. Hold an internal contest to come up with a logo, mascot, or another symbol of the battle cry. Integrating your battle cry into the workforce daily vernacular is a major step in creating a culture of living and breathing the quality system. These activities empower the workforce and facilitate buy-in, which will be the most effective and cheapest advertising you will ever find.

3. Hold Rallies

Third, you can fully engage and energize the entire workforce by holding company-wide rallies, much like the pep rallies you remember from your high school years. The managers could become the quality "cheerleaders," and much like the high school functions, could lead audience participation "games" created around the quality system. This is a perfect forum to communicate the status of key milestones of the implementation plan, bring in guest speakers, and encourage open dialog on the system.

And don't be afraid of employee questions. The willingness to openly address concerns, challenges, and rumors will go a long way in building the trust that a significant change like this will need to be successful. Publically reward even the smallest successes of individuals or teams during these events. Nothing generates perpetual momentum like recognition and acknowledgment that the new thing is a good thing.

QUALITY BULLETIN

Subject: **Top Ten Reasons Change Fails**

Number: QB1
Date: May 19, 2013
Originator: SUW

1) Unrealistic goals
2) Making change an option
3) Small failures out of the gate
4) Underestimating the power of vision
5) Not involving those affected by the change
6) Outsourcing the change management process
7) Leadership does not "walk the walk"
8) Undercommunicating the vision
9) No change in reward system
10) No follow-through

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Distribution: Everyone

Figure 2: The top 10 reasons change fails. (Source: Quality 101 Handbook)

What Not to Do

When analyzing all of the reasons that organizational changes fail, one thing stands out and needs to be acknowledged; most of the failure modes can be traced back in some way, shape, or form, to leadership. Avoid following the top 10 reasons change fails list (Figure 2), and you will remove major obstacles.

Conclusion

Manufacturing strategy is complex, and each industry has its own unique set of products, processes, and challenges. While there is no paint-by-numbers way of implementing a quality management system, there are certain principles, tools, and methodologies that should be a part of any successful program. **PCB007**

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

Pacifier Biosensor Could Help Monitor Newborn Health

Wearable biosensors that non-invasively monitor health and fitness are growing in popularity among adults. But adopting this technology for use with babies is difficult because the devices are often bulky or have rigid surfaces that could harm infants' delicate skin. Now researchers reporting in ACS's journal *Analytical Chemistry* say they have developed a pacifier-based biosensor that tracks real-time glucose levels in saliva. It could ultimately help diagnose and treat di-abetes in the smallest of patients.

Continuous glucose monitoring in newborns, available only in major hospitals, usually requires piercing the infant's skin to reach interstitial fluid. Joseph Wang, Alberto Escarpa and colleagues wanted to develop a baby-friendly biosensor in the form of a pacifier that could collect saliva and analyze it for biomarkers.

A pacifier biosensor could someday be used to non-invasively monitor glucose in the saliva of infants. Credit: Adapted from Analytical Chemistry 2019. DOI: 10.1021/acs.analchem.

Researchers made a pacifier with a nipple that contained a narrow channel designed so that when an infant sucked on the pacifier, small amounts of saliva would be transferred through the channel to a detection chamber. There, an enzyme attached to an electrode strip would convert glucose in the fluid to a weak electrical signal, which could be detected wirelessly by a cellphone app. Researchers haven't yet tested the device with babies, but they conducted a preliminary analysis with adult type 1 diabetes patients. Using the pacifier, the team detected changes in glucose concentrations in the patients' saliva before and after a meal. The device could someday be configured to monitor other disease biomarkers, the researchers say. (Source: ACS)

UV Cure LED Energy Saver

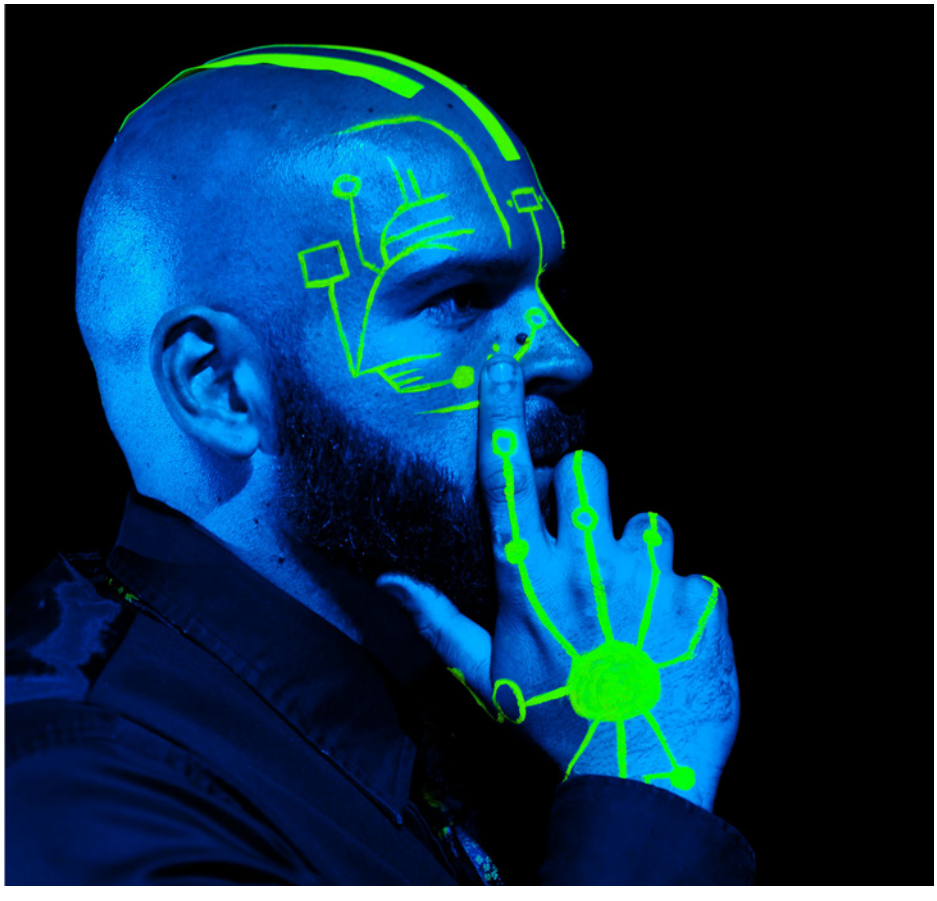
Ladle on Manufacturing

by Marc Ladle, VIKING TEST LTD.

The solder mask (also known in some regions as solder resist) that protects the surface of the circuit boards we make has to stand up to a very wide range of process conditions. The same type of solder mask is typically expected to perform just as well in a superheated lead-free solder levelling process as it is in a chemically aggressive chemical nickel gold finish. Thankfully, the material has a wide process window, and with some care, it can usually handle everything that is thrown at it.

The normal application process involves first cleaning the circuit board surface. This could be abrasively cleaned, using an abrasive brush process, or if you are very old like me, you may remember scrubbing the copper surface with a pumice compound in a butler's sink. Currently, the more common cleaning processes would involve chemical cleaning the surface with a micro-etch solution to create a good key to which the solder resist could adhere.

The methods of application for the solder resist are just as varied. The liquid types of solder mask could be applied by screen printing, spraying, or curtain coating, to name a few. Each of these processes has its own advantages and drawbacks. The resulting coverage may vary a lot in thickness and surface finish, depending on how it was applied. The corporate tastes of the companies that purchase circuit boards mean that there is also a wide range of colours that need to be applied, which adds a further element of variation.



I would like to concentrate on the most common type of solder mask material, which is the photoimageable type. It contains photoreactive elements in the ink that link together to form strong bonds when exposed to UV light. This allows a phototool or UV laser process to be used to selectively expose the

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mask. The photoselective process means that the whole surface of the production panel can be covered in the solder mask material.

Once the solder mask is applied to the production panel, it has to be surface-dried to enable it to be handled and allow contact with the phototool without creating cosmetic damage. Now, the ink can be selectively exposed to UV light to create the final pattern required by design. After the exposure process, the PCB is then run through a developing process that uses a chemical solution to dissolve the unexposed areas of solder mask where they are not wanted on the final design.

So far, so good. The vast majority of modern printed circuits are manufactured by this type of process. What happens next depends on the final metal finish of the circuit. For metal finishes, such as HASL or solder leveling, the level of UV exposure received during photoprocessing is enough. There is no further aggressive chemical processing usually involved, and the solder mask will be robust enough to achieve a long service life after receiving a final oven bake to fully dry it.

The reason I have taken this preamble through the processes of applying, exposing, and developing is to illustrate that there can be a lot of variation in the thickness, colour, and surface finish of the solder mask. When all of these components are considered together, it means that there can be a considerable range with regards to what is required from the final curing process to achieve the desired result.

For the more aggressive processes, more UV exposure may be needed. I have always called this process a UV bump, but it is just a blanket exposure to UV light at a process point following the development of the image. This is required because the photoimage exposure only creates enough crosslinks of the photoinitiators to stop them from being washed away by the developer solution. If you expose too hard at this stage, there is a tendency for the crosslinks to extend beyond the exposed edge, which can make the final feature size a little hard to control. There is also a risk of embrittling the mask, which could lead to failure during the heat process.

UV bump is not a new idea. Many years ago, I used a standard solder mask exposure machine to give a healthy second dose of UV light following the solder mask develop process. It was a bit of a pain bringing the panels back into the printing room after they had exited via the developer, but for the circuits I was making at the time, it was enough to ensure the mask would stand up to the electroless nickel or immersion tin chemistry.

An easy simplification of this process is to use a conveyorized dedicated UV cure machine that can be attached to the end of the developer or used following final thermal bake of the solder mask. To achieve enough exposure energy to run the process, 1 m per minute for a single vapour lamp is usually needed. If you want to go faster, you need more lamps.

Mercury vapour bulbs have a few negative issues. They degrade over time, which means the process has to be regularly adjusted to ensure that the exposure energy remains the same. They also are power-hungry, as they produce a lot of heat. Further, they require a long warm-up period and need to be shut down carefully to ensure the bulbs are not damaged prematurely.

UV LED is a useful step in the right direction (Figure 1). Modern LEDs are capable of outputting high power, and they are certainly a lot more efficient than the vapour lamp process. Each LED outputs a distinct light wavelength. Different LED wavelengths can be mixed to give an array, which is useful for the UV cure

Figure 1: UV LED conveyorized machine.

process. The length of the array can be manufactured for pretty much any width, which removes the need for any type of reflector or lens to cover the width of a typical process conveyor.

LED may appear to be the ideal solution, but there can be a problem with their use due to the way that solder mask materials work. The wide spectrum output of the traditional vapour lamp includes some Infrared wavelengths, which are also often required to complete the cure process by heating the solder mask. The LED with its distinct single wavelength output cannot match this aspect of the vapour lamp.

The good news is that the two processes can be combined pretty easily. A hybrid machine with a single vapour lamp and one or two LED arrays will still save more than 50% of the power consumed by a conventional machine. Maintenance is also reduced, and there is very little degradation of the LED output over time, giving a more consistent process.

Like so many parts of the printed circuit manufacturing process, the solder mask materials and basic production methods are stolen from larger and better-funded industries. In time, solder masks may be "tuned up" to better suit the defined wavelength output of LED machines.

A further advantage is the more adjustable nature of the LED system where certain wavelengths can be increased or reduced. Typically, LEDs output at 365-, 385-, 395-, 405-, or 415-nanometer wavelengths. With a careful design of the LED array, it is possible to control the intensity of each wavelength (Figure 2).

Figure 2: UV LED array.

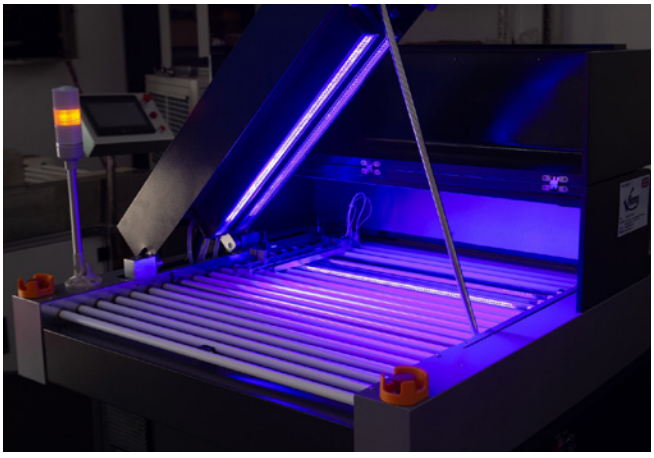

Figure 3: UV LED double-sided.

This may become useful when attempting to cure different colours, particularly white solder mask, which is very reflective. The thickness of the solder mask can also cause some problems due to a lack of UV light penetration to the full depth of the material.

A cure machine using only UV LEDs can work with some solder mask materials, but it is important to make a realistic trial before machine purchase to ensure that it will meet all of your process requirements. If it works for you, the advantages are a nearly instant start-up and shut-down time and energy savings of more than 80% compared to a vapour lamp process (Figure 3). The maintenance of an LED-driven machine is also greatly reduced, as the diodes typically last for many production years and do not require changing every few months. LED process is also completely suitable for the reduction of ionic contamination, which is an increasing requirement for certain types of circuit manufacturing.

If you can make it work for you, changing to an LED-driven process is an easy decision. The power savings alone will ensure a quick payback on investment, and a well-designed system will add a new and improved level of control to the process. **PCB007**

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

Changes and Concerns Regarding HDI Technology

Trouble in Your Tank

by Michael Carano, RBP CHEMICAL TECHNOLOGY

One does not have to look too far back to point out some significant changes that have taken place in our industry over the past few years. Processes, materials, equipment, and board designs continue to change. If I was to pick one to focus on for this column, it would be in the ever-increasing trends toward higher circuit density. This relates to finer lines and spaces, smaller diameter blind vias, and even multilevel stacked and staggered vias. All of these changes will continue to place significant pressures on bare PCB fabricators to increase their investment and onboard new and critical skill sets.

What Is Driving These Changes?

The semiconductor packaging industry is driving changes to higher density for both the bare board as well as IC substrates, system integration, SiP, and very-large-scale integration (VLSI). Increased device complexity has been a primary driving factor for future designs. To keep the component package size small, component lead spacing was decreased. Further increases in semiconductor integration (VLSI), requiring more than 196 I/Os, can drive packages to even closer perimeter lead spacing such as 0.5 mm, 0.4 mm, 0.3 mm, and 0.25 mm. The array package format has become standard for high I/O count devices. To support these requirements, wiring density is increased.

Looking at the latest data from various roadmaps, one can easily see the following:

- Finer lines and spaces
- Increased use of blind via technology
- Stacked vias

What challenges are bare board fabricators facing? Look at the first bullet point. The average minimum line width and spacings as specified by OEMs are shown in Figure 1.

As the line width and spaces become finer and tighter, several opportunities for change present themselves.

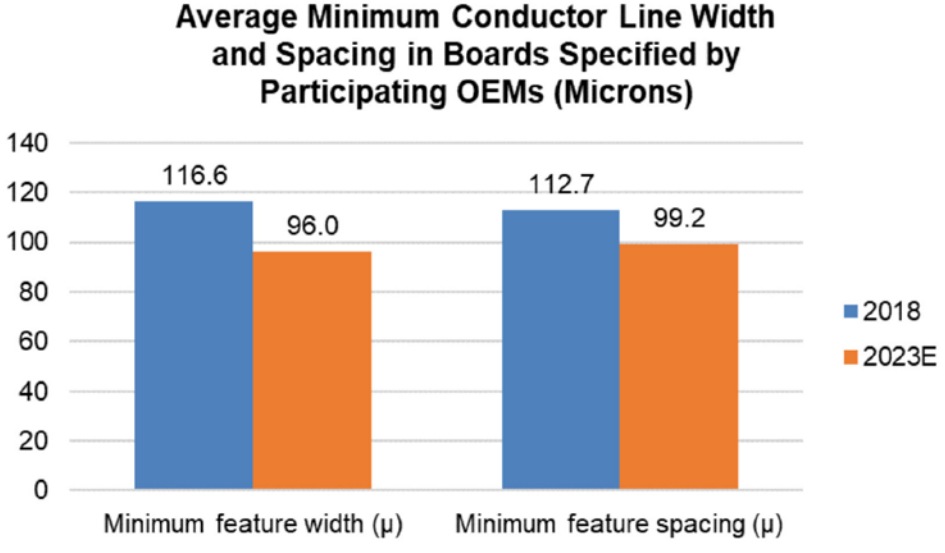

Figure 1: Minimum line width and spacing. (Source: IPC)

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3. For fine lines, consider SAP (semi-additive processing either with thin dielectrics, such as resin, film, or etched-off copper from laminate) or subtractive etch to reduce copper foil thicknesses
4. Improved rinsing modules especially for tight spacing and very small vias
5. Horizontal equipment set-up for thin material transport
6. Critical control of fine-line imaging and etching

These six areas are crucial for the fabricator to consider to be successful in meeting these new requirements. And with respect to the requirements for finer lines and spaces (along with minimal undercut from etching), semi-additive or modified semi-additive technology takes center stage. The issue currently acting as a significant roadblock is the lack of expertise in this area. Yes, there is some semi-additive processing in the industry, but certainly not enough to achieve what one would call "critical mass." For technology implementation to be successful, it must be widespread. That is where there are many sources of the technology, both from the process supplier side as well as the fabricator.

Stacked and Staggered Blind Vias

Perhaps the most significant change over the past few years is the proliferation of the use of blind vias, including multilevel blind vias. Further, many designers require these multilevel vias to be stacked (Figure 2).

In Asia, the use of stacked vias is considerably higher. While this design has many advantages in supporting technology, including IoT, sensors, and AI, the ramifications related to the thermal reliability of these vias have been called into question. There has been much research lately fostered by HDPUG (HDP User Group) as well as the IPC Technology Solutions Committee and its subcommittee, which is the TSL-MVIA Working Group. In a nutshell, it is this that keeps that me awake at night. With so many moving parts to this technology related to these complex board builds, a solution remains elusive.

The use of stacked and copper-filled vias has proliferated over the past three years. This is driven primarily by the need to increase routing. Thus, the move from staggered multilevel vias to stacked and filled vias for many of these designs. However, what was not anticipated was the latent defect shown in Figure 3 [1].

Essentially, as Figure 3 depicts, there is a hidden defect that is not normally detected by in-circuit testing. This defect, described as a weak interface between the electroless copper deposit and target pad, manifests itself most often during convection reflow assembly; however, that is too late, or the defect leads to a failure when the interconnect device is in service. Regardless, this is a critical situation that requires all hands on deck to fully understand the root cause or causes of this latent

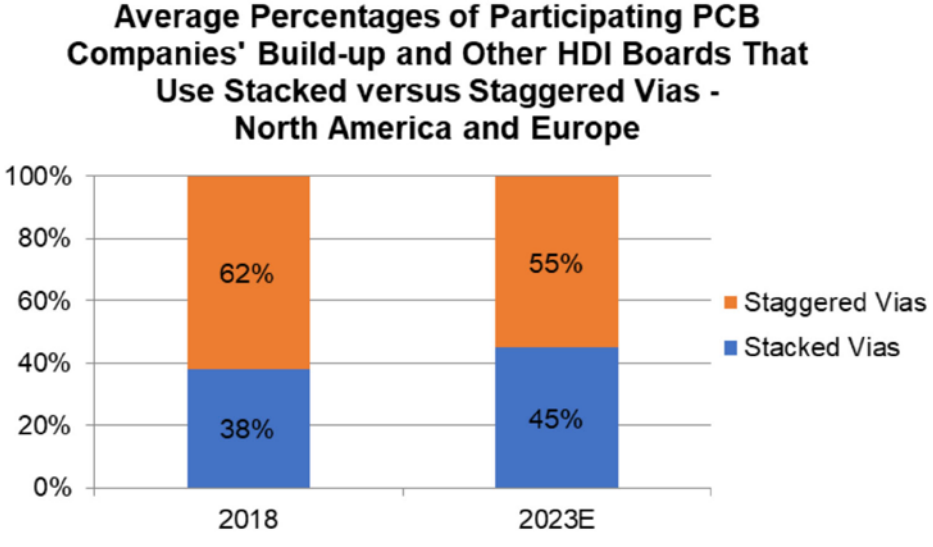


Figure 2: Increased used of stacked vias. (Source: IPC)

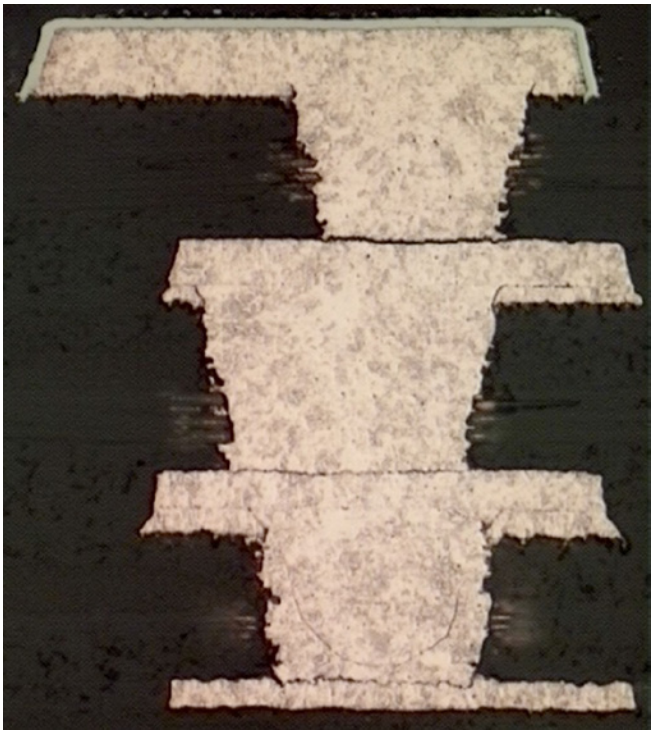


Figure 3: Note the separation of the plated copper at the interface with the capture pad. (Source: IPC TSL-MVIA Committee)

defect and mitigate it once and for all, but this is easier said than done.

What Does the Supply Chain Need Going Forward?

For HDI technology to be successful, including ensuring long-term reliability, nothing short of full cooperation among materials, chemical, and equipment suppliers; major PCB fabricators; and key OEMs is required. While there are various consortia (HDPUG, iNEMI, IPC, and other organizations), this is only a loosely coordinated effort.

Part of the reason for the reticence of some firms to join the effort relates to sharing information or that they feel they have already solved the problem. This is dangerous thinking. Industry leaders need to bond together in a coordinated effort; then we can make great strides in mitigating these issues and providing more guidance so that complex HDI technology becomes mainstream.

Reference

1. Jerry Magera, "IPC Technology Solutions White Paper on Performance-Based Printed Board OEM Acceptance—Via Chain Continuity Reflow Test: The Hidden Reliability Threat—Weak Microvia Interface," IPC High-Reliability Forum and Microvia Summit, 2018. **PCB007**

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

iNEMI Publishes Organic PCB and Power Conversion Electronics Chapters from the 2019 Roadmap

The International Electronics Manufacturing Initiative (iNEMI) has announced the publication of the Organic PCB and Power Conversion Electronics chapters of the 2019 roadmap.

Both of these Technology Working Group chapters identify key technology developments anticipated and required within the supply chain to meet product needs between now and 2029 in their respective technology areas. The chapters also identify any potential gaps between product sector needs and technology capabilities.

New products will require, for example, advanced packaging and heterogenous integration, new materials, and innovative architectures. Organic PCB developments must comprehend these changing market demands. Power conversion electronics topics include device-level considerations through power supply technologies that are needed to either extend or improve within the roadmap time horizon.

Now Available: The 2019 Roadmap is now available on the iNEMI website. It is free to iNEMI members.

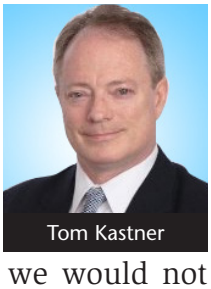
(Source: iNEMI)

Editor Picks from PCB007

1 AT&S and Chongqing University Collaborate on Research and Education ▶

It represents a milestone for AT&S as a first high-end IC substrates manufacturer in China partnering with one of the universities affiliated to the Ministry of Education of China in research and education excellence.

2 Punching Out! SMTAI 2019 ▶


Tom Kastner

My firm goes to a lot of trade shows—at least one each month—because it is a great way to meet business owners as well as their trusted advisors. Trade shows are also an excellent way to hear industry information that otherwise we would not hear. Tom Kastner shares his experience from SMTAI 2019.

3 Happy Holden Previews His AltiumLive Frankfurt Keynote ▶


Happy Holden

Andy Shaughnessy interviews Happy Holden, who gave a keynote speech at this year's AltiumLive event in Frankfurt, Germany. Happy gives a preview of his presentation, which focused on smart factories and automation, and why AI might improve PCB design and fabrication in the future.

4 Nano Dimension, CBTP Collaborate in Additive Manufacturing Research ▶

Nano Dimension Ltd., a leading additive electronics provider for electronics, has signed a multi-year Memorandum of Understanding (MoU) with Chungbuk Technopark (CBTP), in South Korea, for research collaboration in the field of additive manufacturing of electronics.

5 Flexible PCB Maker Zhen Ding Likely to Revise 2019 Revenue Forecast Upward ▶

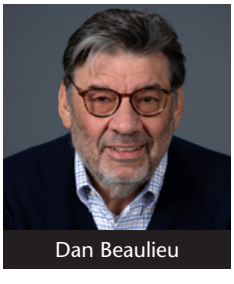
Flexible PCB specialist Zhen Ding Technology is expected to revise its revenue forecast for 2019 to growth from flat as projected earlier, having posted strong sales for September and the third quarter.

6 Communication, Part 1: How to Qualify a Board Shop ▶

Mark Thompson

In Part 1 of this six-part series for "Fab Fridays," Mark Thompson, CID+, engineering support at Prototron, and CA Design CTO Bob Chandler discuss ways that PCB fabricators and designers can better communicate, starting with how to qualify a board shop.

7 It's Only Common Sense: The Modern Salesperson ▶



Dan Beaulieu

It's a new world, and the modern salesperson has to keep up or get run over; that's just the way it is. Dan Beaulieu shares five steps that every great, modern-day salesperson—from age 24 to 74—should be doing to be successful today.

8 Become an IPC Emerging Engineer Now ▶

IPC's Emerging Engineer Program provides a unique opportunity for engineers early in their careers to receive education and mentoring for professional development.

9 Standards: Why We Have Them and Live by Them ▶

Have you ever designed a board but received feedback that it couldn't be manufactured unless changes were made? Or maybe you've designed a complex board and sent it to the factory only to find out that the manufacturer didn't build the board to your expectations? NCAB Group explains how PCBs are becoming more complex, factory options are growing, and expectations for product life cycles are becoming longer.

10 Printed Circuits Installs New Notion n.jet Direct Solder Mask and Legend Printer ▶

Rigid-flex circuit board manufacturer Printed Circuits has purchased and will install a new Notion Systems n.jet direct solder mask and legend ink printer.

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Full product training will be provided.

This is a fantastic opportunity to become part of a successful brand and leading team with excellent benefits.

Please forward your resume to jpattie@ventec-usa.com and mention "Technical Sales Engineer—Chicago" in the subject line.

apply now

Career Opportunities

FREEDOM CAD SERVICES

Sr. PCB Designer–Mentor Xpedition

Freedom CAD is a premier PCB design service bureau with a talented team of 30+ dedicated designers providing complex layouts for our enviable list of high-tech customers. Tired of the commute? This is a work-from-home, full-time position with an opportunity for additional compensation for overtime work at time and a half.

Key Qualifications

- EXPERT knowledge of Xpedition VX 2.x
- Passionate about your PCB design career
- Skilled at HDI technology
- Extensive experience with high-speed digital, RF, and flex and rigid-flex designs
- Experienced with signal integrity design constraints encompassing differential pairs, impedance control, high speed, EMI, and ESD
- Excellent team player who can lead projects and mentor others
- Self-motivated with the ability to work from home with minimal supervision
- Strong communication, interpersonal, analytical, and problem-solving skills
- Other design tool knowledge is considered a plus (Altium, Allegro, PADS)

Primary Responsibilities

- Design project leader
- Lead highly complex layouts while ensuring quality, efficiency, and manufacturability
- Handle multiple tasks and provide work leadership to other designers through the distribution, coordination, and management of the assigned workload
- Ability to create from engineering inputs, board mechanical profiles, board fabrication stackups, detailed board fabrication drawings and packages, assembly drawings, assembly notes, etc.

apply now

ROGERS CORPORATION

Advanced Connectivity Solutions

Senior Development Engineer

Rogers Corporation is seeking a senior development engineer accountable for the development of more complex products and processes, the establishment of sound technical bases for these developments, and effective interaction with technology, process, and platform innovation; operations; sales and marketing; and process engineering personnel to commercialize these developments.

Essential Functions:

- Design and conduct experiments and interpret the results
- Report on projects in both written and verbal formats at all levels of the organization
- Perform technical troubleshooting of new products and processes; act as new product/concept incubator for new technologies and platforms, identifying opportunities for improvement and incorporation design for manufacturing requirements resulting in a viable, scalable product
- Provide ongoing process and manufacturing support to newly launched products as applicable
- Provide support in terms of analytical equipment maintenance, methods development, material analysis, and documentation of new process or products
- Manage capital projects for the purchase and installation of new process or support equipment; train employees in new processes

Required Education and Experience:
Ph.D., Ch.E., M.E., or material science, or B.S. or higher in a technical discipline with accomplishment in product development and project management.

Rogers Corporation provides equal employment opportunities to minorities, females, veterans, and disabled individuals as well as other protected groups.

apply now

Career Opportunities

Field Service Engineer
(Location Negotiable)

Are you passionate about delivering an exceptional user experience? Come work as a field service engineer at the industry's leading inspection company that offers great benefits with opportunities to advance while learning alongside accomplished business leaders.

The Company: Koh Young is the leading 3D inspection solutions provider in the electronics manufacturing industry. With is new offices in Atlanta and Guadalajara, it helps its customers optimize their printed circuit board assembly process.

The Position: Deliver technical services–including installation, support, and maintenance–to elevate the user experience. Location is flexible, but OH, IN, IL, MA, MI, FL, CA, or Toronto are desired.

The Reasons: An opportunity to apply leading-edge inspection technology to products you know and use every day. A great environment that supports its team and treats everyone like family.

Join the industry's leading provider of
true 3D inspection solutions

Interested? Submit your resume below.

apply now

Gardien Is Hiring!

The Gardien Group, a leading solutions provider in the PCB industry, is looking to fill multiple openings in their China, Japan, Taiwan, and United States service centers.

We are looking for electrical engineers, operations managers, machine operators, and sales executives. Prior experience in the PCB industry is beneficial but not essential. Training will be provided along with excellent growth opportunities, a benefits package, and periodic bonuses.

Our global teams are from diverse cultures and work cohesively as a tight-knit unit. With performance and initiative, there are plenty of opportunities for professional growth.

Gardien is an equal opportunity employer. Employment decisions are made without any regard to race, color, religion, national or ethnic origin, gender, sexual orientation, age, disability, or other characteristics.

Interested candidates, please contact us with your resume and a cover letter. Kindly note that only shortlisted candidate will be contacted.

Apply at careers@gardien.com.

apply now

Career Opportunities

Assistant Department Manager, Operations, Carson City, NV

This is an entry-level professional management trainee position. Upon completion of a 1-2-year apprenticeship, this position will be elevated to facility/operations manager. Primary functions during training: shadow incumbent staff managers to learn and understand the operations and personnel of the operations department. This position will train and learn, develop, implement, and coordinate strategies related directly to the manufacture of Taiyo products. Additionally, this position will be learning all about the facility, environment, and health and safety functions. Eventually, this position will be responsible for the administration, security and maintenance of the facility and warehouse

Required Experience/Education:

- 4-year college degree in industrial engineering or another similar science discipline combined with work experience in ink or coatings manufacturing
- Ability to read, analyze, and interpret common scientific and technical journals, financial reports, and legal documents
- Ability to respond to inquiries or complaints from customers, regulatory agencies, or members of the business community
- Ability to develop and implement goals, objectives, and strategies
- Ability to effectively present information to top management, public groups, and/or boards of directors
- Ability to apply principles of logical or scientific thinking to a wide range of intellectual and practical problems
- Knowledge of governmental safety, environmental, transportation regulations/laws

Preferred Skills/Experience:

- Bilingual (Japanese/English)
- Toyota Production System (TPS)

Working Conditions:

- Occasional weekend or overtime work

See complete job listing for more information.

apply now

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

apply now

Career Opportunities

INSULECTRO

Technical Account Manager Chicago/Minneapolis

Insulectro, the largest national distributor of printed circuit board materials, is seeking a talented sales superstar for a Technical Account Manager role based out of either our Chicago or Minneapolis office. This role will focus on maintaining the existing customer base and developing new business within the assigned territory in both the printed circuit board and printed electronics industries. We are looking for the perfect fit of education, experience, and attitude that matches our company culture and enhances the service level to our customers.

Qualifications:

- A self-motivated business professional who is driven to succeed with a minimum of 3 years outside sales experience in the PCB or PE industry
- Proven sales/business development record
- Excellent communication and interpersonal skills
- OEM and electronic assembly experience is a plus

We offer:

- Competitive salary and commission plan with a comprehensive benefits package
- A fun, high-energy company with an entrepreneurial spirit
- A great group of people to work with!

apply now

CML

Analyst Programmer, Hong Kong

We believe in caring about our people because they are our greatest asset. CML works with multicultural stakeholders daily to achieve more and bring them the best solutions. That's why we continuously invest in optimizing our culture and focus on providing our team with opportunities to develop their skills (e.g., through professional coaching to achieve their highest potential).

The analyst programmer will assist the IT and ERP manager in Hong Kong to support the company's BI systems, ERP systems, and other related IT-landscape applications.

In addition, this post will participate in system development projects and provide support including, but not limited to, user requirement collection and analysis, user training, system documentation, system support and maintenance, enhancement, and programming.

- Develop and enhance related IT systems and applications
- Prepare functional specifications
- Transfer the relevant business and interface processes into IT systems and other applications to get a maximum automation degree and prepare all required business reports
- Conduct function testing and prepare documentation
- Manage help desk/hotline service

CML is a leading provider of printed circuit boards. We develop tailor-made sourcing and manufacturing solutions for our customers worldwide with strong partnerships and reliable connections.

apply now

Career Opportunities

APCT, Printed Circuit Board Solutions: Opportunities Await

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

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

We invite you to read about APCT at APCT.com 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.

apply now

Development Chemist
Carson City, NV

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

Essential Duties:

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

Required Education/Experience:

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

Working Conditions:

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

apply now

Career Opportunities

INDIUM CORPORATION®

Multiple Positions Available

The Indium Corporation believes that materials science changes the world. As leaders in the electronics assembly industry we are seeking thought leaders that are well-qualified to join our dynamic global team.

Indium Corporation offers a diverse range of career opportunities, including:

- Maintenance and skilled trades
- Engineering
- Marketing and sales
- Finance and accounting
- Machine operators and production
- Research and development
- Operations

For full job description and other immediate openings in a number of departments:

www.indium.com/jobs

apply now

Manncorp™

SMT Field Technician
Huntingdon Valley, PA

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

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

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

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

apply now

Career Opportunities

U.S. CIRCUIT

Sales Representatives (Specific Territories)

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

- Florida
- Denver
- Washington
- Los Angeles

Experience:

- Candidates must have previous PCB sales experience.

Compensation:

- 7% commission

Contact Mike Fariba for more information.

mfariba@uscircuit.com

apply now

ELECTROLUBE
THE SOLUTIONS PEOPLE

We Are Recruiting!

A fantastic opportunity has arisen within Electrolube, a progressive global electro-chemicals manufacturer. This prestigious new role is for a sales development manager with a strong technical sales background (electro-chemicals industry desirable) and great commercial awareness. The key focus of this role is to increase profitable sales of the Electrolube brand within the Midwest area of the United States; this is to be achieved via a strategic program of major account development and progression of new accounts/projects. Monitoring of competitor activity and recognition of new opportunities are also integral to this challenging role. Full product training to be provided.

The successful candidate will benefit from a generous package and report directly to the U.S. general manager.

Applicants should apply with their CV to melanie.latham@hkw.co.uk (agencies welcome)

apply now

Career Opportunities

ZENTECH

Zentech Manufacturing: Hiring Multiple Positions

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

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

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

Please email resume below.

apply now

BLACKFOX
Premier Training & Certification

IPC Master Instructor

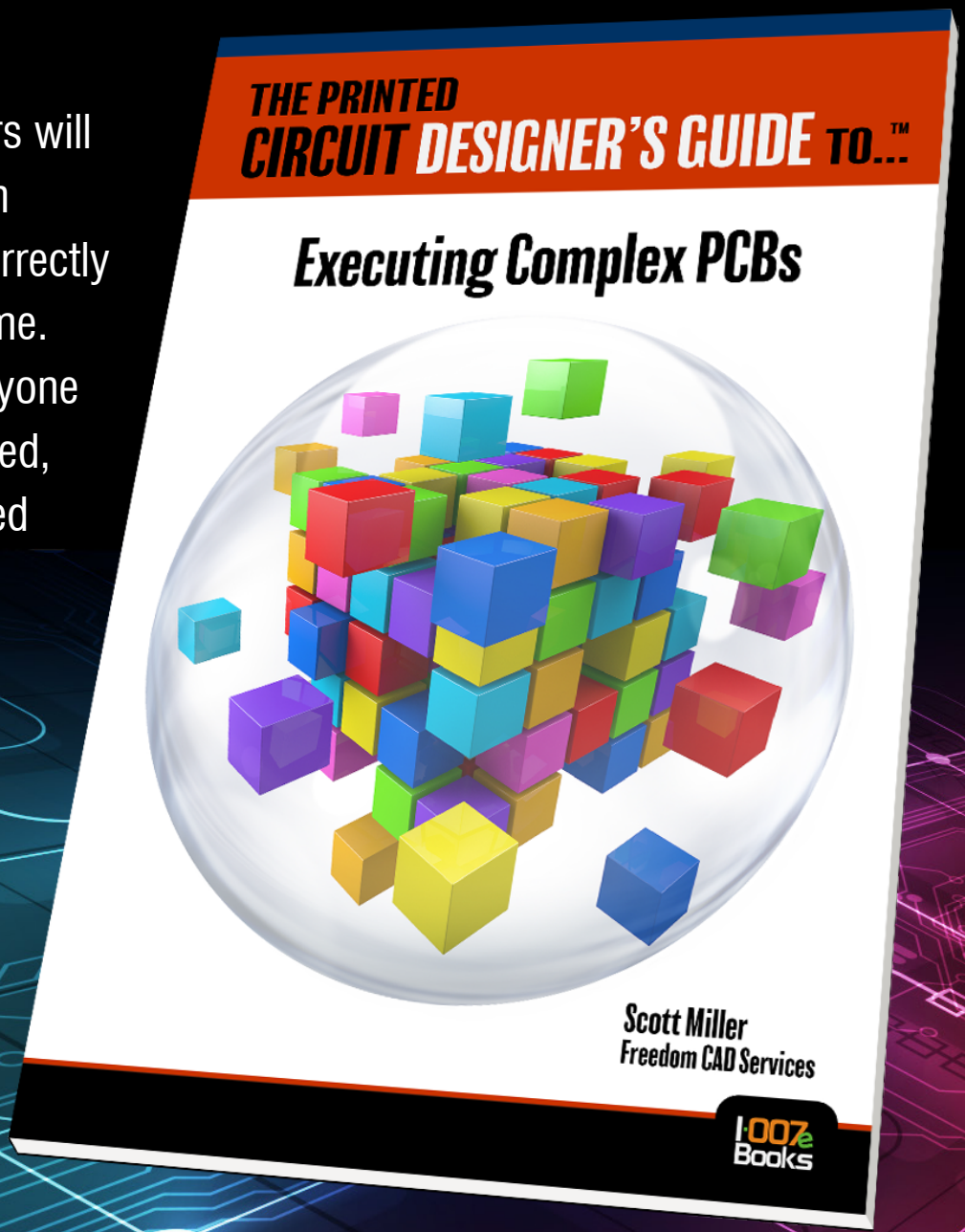
This position is responsible for IPC and skill-based instruction and certification at the training center as well as training events as assigned by company's sales/operations VP. This position may be part-time, full-time, and/or an independent contractor, depending upon the demand and the individual's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

For more information, click below.

apply now

Your how-to guide for making Rev 1 work.

In this book, readers will learn how to design complex boards correctly the first time, on time. A must-read for anyone designing high-speed, sophisticated printed circuit boards.



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I-007ebooks.com/ecd

Events Calendar

Printed Electronics USA ▶
November 20–21, 2019
Santa Clara, CA, USA

IPC APEX EXPO 2020 ▶
February 4–6, 2020
San Diego, CA, USA

Medical Design & Manufacturing ▶
February 11–13, 2020
Anaheim, California, USA

Embedded World ▶
February 25–27, 2020
Nuremberg, Germany

CPCA Show 2020 ▶
March 16–18, 2020
Shanghai, China

Electronica & Productronica China ▶
March 18–20, 2020
Shanghai, China

LOPEC Exhibition and Conference (Driving the Future of Printed Electronics) ▶
March 24–26, 2020
Munich, Germany

KPCA and KIEP Show ▶
April 22–24, 2020
Kintex, Korea

IMAPS High Temperature Electronics HiTEC ▶
April 22–24, 2020
Albuquerque, New Mexico, USA

Additional Event Calendars

Coming Soon to *PCB007 Magazine:*

DECEMBER 2019: What You Need to Know
No matter your age or experience level, to move technology forward, we all need to be continuous learners. In this issue, we highlight the highest impact topics to further your expertise.

JANUARY 2020: IPC APEX EXPO Preview
Join us in the January issue as we share what to expect and what to look for in San Diego at IPC APEX EXPO 2020.

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

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

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

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

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

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

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

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

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

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

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

MAGAZINE LAYOUT: **RON MEOGROSSI**

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

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myiconnect007.com

mediakit.iconnect007.com

EDITORIAL CONTACT

Nolan Johnson

nolan@iconnect007.com

+1 503 597-8037 GMT-7

SALES CONTACT

Barb Hockaday

barb@iconnect007.com

+1 916 365-1727 GMT-7

www.iconnect007.com