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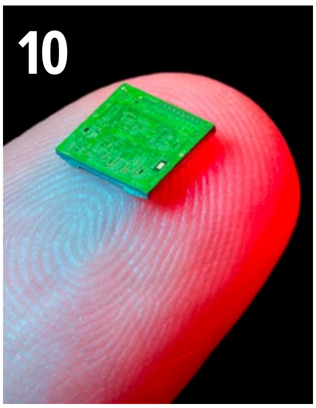
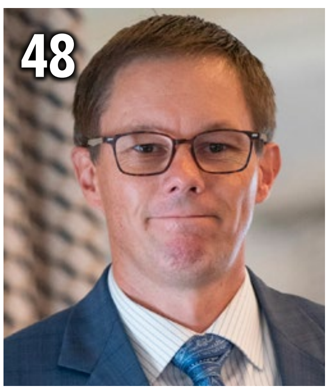
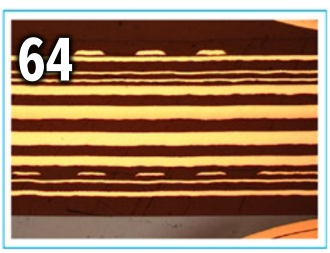
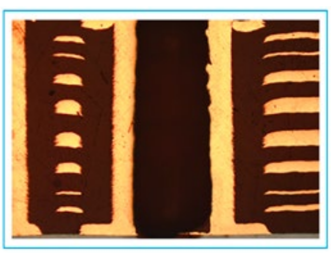
An Eye on UHDI

Even as HDI finally moves into the mainsteam, UHDI is following right behind. In this issue, we launch the conversation into the strategic value of UHDI technology on the future of the PCB industry. What is UHDI? Why does it matter? What is involved in adding UHDI to your manufacturing portfolio? Are there customers looking for this technology today?









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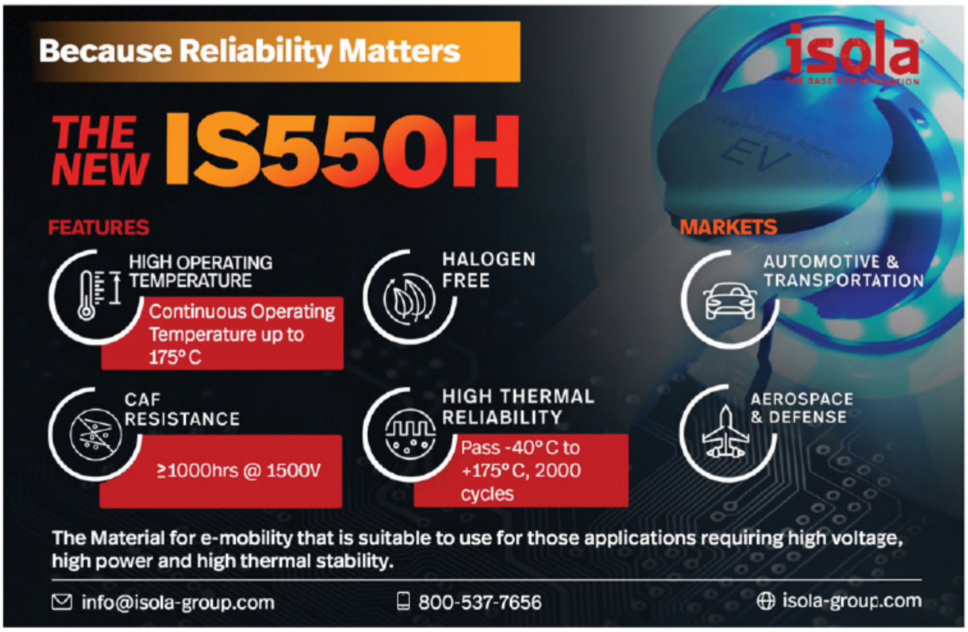

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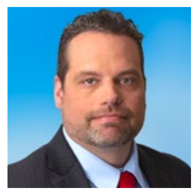

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UHDI: Raising Awareness and Interesting Questions

Nolan's Notes

by Nolan Johnson, I-CONNECT007

It was over lunch on the second day of the recent IPC Symposium on Advanced Packaging when I asked a question that triggered an interesting discussion about advanced packaging and ultra high density interconnect (UHDI). While these two technologies are distinct, they are also symbiotic; it takes both to make either one successful. As the symposium delivered on its agenda, the interrelationship between these two technologies became crystal clear.

UHDI is the fabrication technology necessary if you want to manufacture the interposer subcomponents so critical to connecting the semiconductor chips to the enveloping package. For the history of semiconductors, each component package contained one and only one chip. Advanced packaging uses sophisticated techniques to include and connect multiple chips inside one package. This allows for a more modular approach to building up the finished product.

But how do the chips get connected inside? Interposers—super small fanout or interconnect features. Interposers provide the interim fanout steps from nanometer-scale IC pads to the ultimate goal of BGA solder balls leading to the outside world. Interposers work a

lot like a PCB, but their feature sizes are in the micron range—much smaller than most PCB shops can fabricate, and much larger than current semiconductor facilities can build. Ironically, the advanced packaging component that fills the gap needs to be built with a technology that is right in the middle of the fabrication gap. It is within this fabrication gap that UHDI resides: To make the interposers necessary to deploy advanced packaging, UHDI fabrication is necessary; advanced packaging is the "killer application" that makes UHDI a financially feasible investment for a fabricator. There, in a nutshell, is the symbiosis.

Our technical editor, Happy Holden, "father of HDI," is well-quoted saying that HDI took a long time to be adopted, in part because it took a long time for the cost vs. capability evaluation to flip. Until cellphones, there just hadn't been a "killer application" for HDI that pushed it out of its niche status. It seems safe to say that UHDI will grow out of its niche status and into a major technology supporting the semiconductor industry's appetite for advanced packaging.

Ah, but there's a piece missing from this puzzle, upon which my lunchtime question centered. I asked, "Which mid-career engineer is more likely to pivot their career into UHDI for substrates—PCB fabricators or IC manufacturers?" Our conversation kicked this conundrum around for much longer than I expected. So, what was the outcome?

On the one hand, PCB fabs seem the most likely to understand the interposer game, but they will need a facility that resembles the semiconductor fabs of 25 or 30 years ago. That's a big step up for most of them. Will they be able to pick up the necessary expertise?

That's precisely the challenge for the semiconductor engineer. Moving to UHDI feature sizes is a big step backward from current semiconductor feature sizes. While the semiconductor engineers would have the experience, would they also find it lacking in challenge? The upshot: Even when we build out packaging capabilities, where will the skilled staffing come from? Suddenly, and once again, the industry's gaze turns to the academic community to educate talent, and to employers to remain competitive with hiring packages. But that's an entirely different conversation.

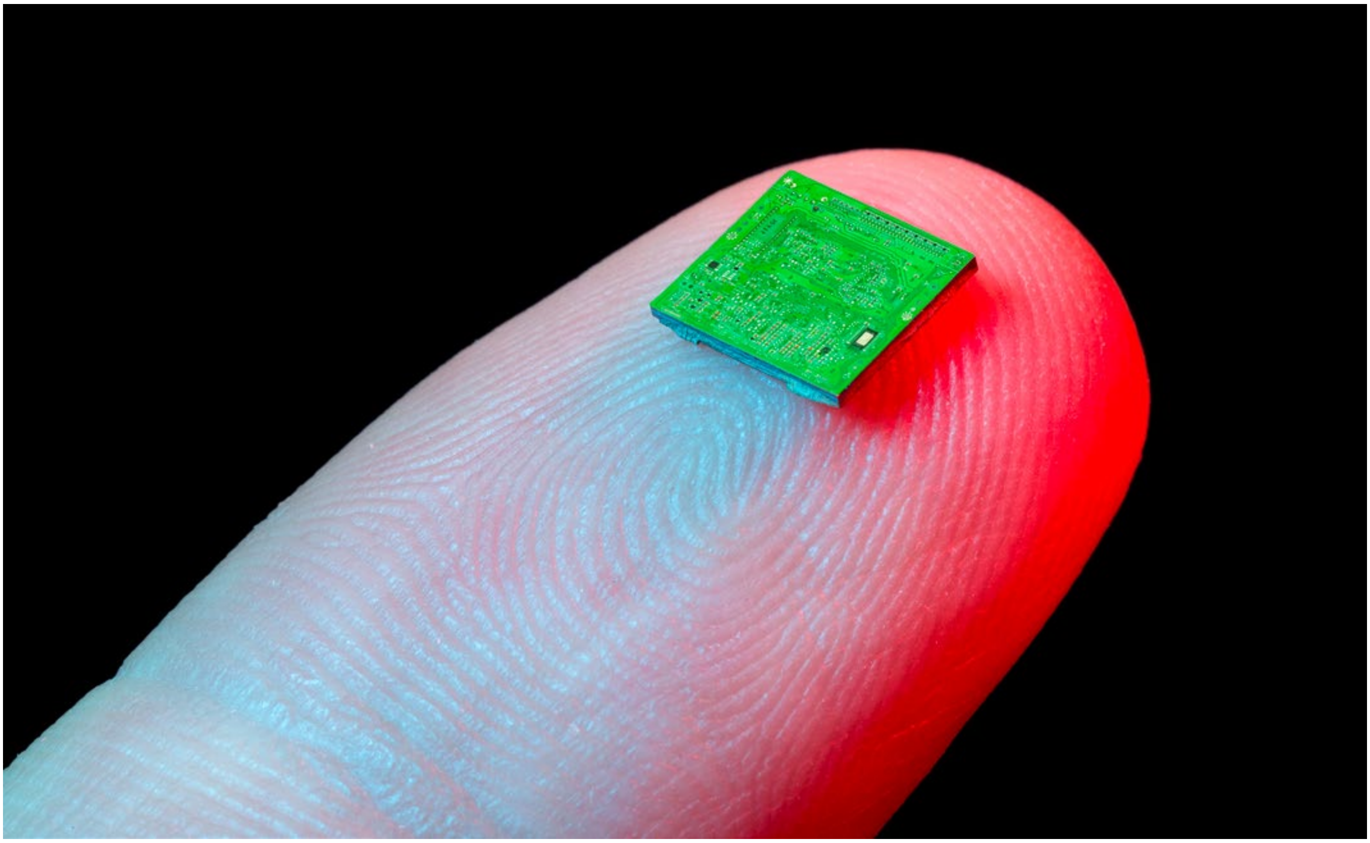
In this issue of *PCB007 Magazine,* we pull out the microscope and peer down into the UHDI niche in the marketplace. Calumet's Todd Brassard and Meredith LaBeau discuss UHDI and the give-and-take that comes with helping define a new market niche in their interview, while Sunny Patel at Candor Industries sheds light on the operational side of ramping up UHDI skill sets and facilities. Jan Pederson shares his industry-wide perspective on supply and demand for UHDI as well. As features get smaller, drilling and cutting capabilities must also become more precise; in a group discussion with the MKS/ESI team, they share their work to deliver laser systems for UHDI applications. Of course, we bring you columns from IPC's Dr. John Mitchell, Gardien's Todd Kolmodin, Chemcut's Christopher Bonsell, Paige Fiet in her IPC role, Travis Kelly representing PCBAA, and our very own Happy Holden.

There is still a lot to work through in UDHI; there are many more questions than answers at this moment. But what is clear is that we will be embracing this technology, adding these capabilities, whether we want to or not. Semiconductor advancements will require it.

As always, our mission is to help move the conversation forward in the industry. To that end, we appreciate your feedback and suggestions identifying the most important topics. To be honest, yours are among our favorite emails to receive. Please keep in touch. **PCB007**

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

Understanding the UHDI Market



Feature Interview by the I-Connect007 Editorial Team

"We know what we know from firsthand experience. We don't have a surefire way to measure our progress against our peers, so we don't put much time into worrying about it. Rather we focus on doing our part, working with our customers and suppliers to see and push what's possible."—Todd Brassard

The more we investigate UHDI in the current market, the more advanced packaging becomes a part of the conversation. The two emerging technologies lean on each other for their overall success. UHDI is the method by which state-of-the-art advanced packaging will be fabricated; substrates are creating a market for UHDI capabilities.

Yet there are so many questions to be answered. At the recent IPC Advanced Packaging Symposium, an organizer said he had expected the event to help refine the conversation. Instead, the size and scope of the need and the challenges to deliver on the need only got larger as the conference went on. The I-Connect007 Editorial Team met with Calumet's Todd Brassard and Meredith LaBeau just prior to the symposium; the same sense of ambiguity is present in their conversation.

Nolan Johnson: UHDI is coming over the horizon for our industry. There are certainly IC design trends and manufacturing trends which are pushing us to even smaller features than we can do now, so this will be something that the industry needs to respond to. In a global sense, Calumet is a small shop, yet you've been working on UHDI. Tell us about that.

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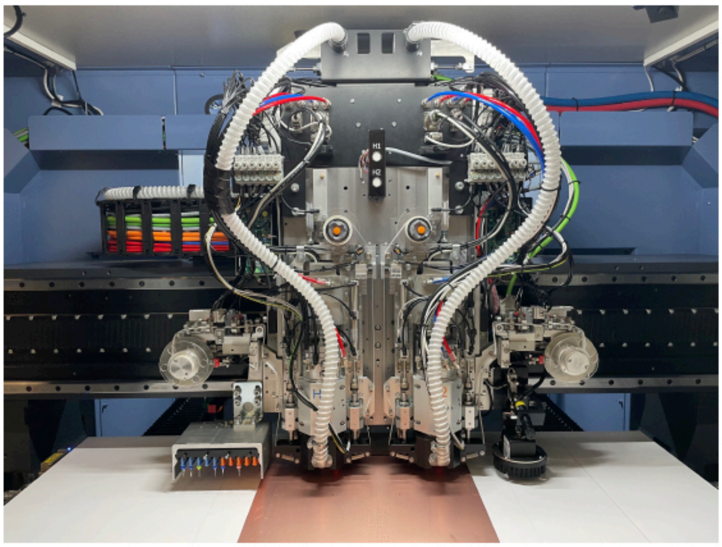

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Todd Brassard: You might call it innovation for the United States, but the truth is that UHDI is a 20-year-old technology, and the U.S. is playing catch-up to offshore manufacturers. When I first tried to understand what a substrate was, much of my initial insight and perspective came from a 1990 doctoral thesis titled something like, "Quality concerns in manufacturing flip chip assemblies with organic substrates." This was a well-formed document from over 30 years ago. I thought, "How could the U.S. PCB industry have its head in the sand for 30 years?" I suppose we all know the answer to that question at this point.


Todd Brassard

Happy Holden: During that period, I heard Nan Ya spent $400 million on a new plant to make these substrates. Whoever heard of a PCB shop that cost $400 million? All class 100, 11 stories tall, with AOI machines costing $1.5 million each.

Brassard: Some amount of capital investment is unavoidable to get into substrates, but for certain types of substrates, PCB manufacturers have 90% of the capital equipment needed, although one discovers quickly that UHDI capability is a prerequisite for most, if not all, substrates.

Johnson: Can you convert a PCB shop into a substrate shop, or do you need to build it to be a substrate shop in the first place?

Brassard: Before you can answer that question, you must understand that there are a wide range of advanced package constructions and associated types of substrate with many levels of complexity; some are definitely doable by U.S. PCB manufacturers with minimal capital investment, but more complex designs need significant CapEX investment. What level of technology does the U.S. require with respect to building substrates today, tomorrow, in the coming decades?

The right PCB manufacturers with the right equipment set, engineers, and workforce will be able to stand up solutions to meet some percentage of the industry's immediate needs in a relatively short term. But I am confident that a subset of U.S. PCB manufacturers, in time, can and will catch and surpass the capabilities of offshore manufacturers—not the capacities or the large-scale economics, but the low-volume incredibly advanced technologies. The road is already forming before us, the U.S. will close the gap, push past the narrow definitions of SOTP and SOTA, and get back to innovating.

Let's keep in mind that as microelectronics continue to shrink, more of the design of a system will be built on a substrate as opposed to a PCB.

Meredith LaBeau: As technology pushes to miniaturization and heterogenous integration it seems natural that the printed circuit boards of today will be the substrates of the future. The need to fan out technology will drive the build-up concept as seen in substrates. We can already witness the technology drive from HDI PCBs to UHDI build-up PCBs and substrates. This could potentially be manufacturing technology that resets the technology curve allowing for new manufacturing innovations.

Johnson: It's on the bleeding edge, but that's where it always starts.

Meredith LaBeau

Brassard: The bleeding edge for the United States, but 20-year-old technology for Asia. What's needed for U.S. PCB manufacturers to invest in substrates is demand signals. What types of advanced packages do we want to build in the U.S.? Substrates that support a single chip, or dozens of chiplets, or more advanced 2.5D and 3D integrations, and in what quantities? It's interesting that U.S. OEMs are looking for U.S. manufacturers to not "rinse and repeat" what's possible offshore, but instead to push past SOTA and trailblaze new technologies enabling new capabilities with no limits on innovation and willingness to get outside the box.

I can only hope that the CHIPS Act funding targets the entire microelectronics ecosystem, which includes substrates and circuit boards. I keep hearing that CHIPS Act funding is a once in a century investment, yet Asia seems to be making these investments annually. With China investing billions into building up its manufacturing infrastructure, the U.S. should do the same, treating the need to have a pipeline of ever advancing technology as infrastructure, like building highways.

The need for ever advancing technology is a form of infrastructure where capability to advance and innovate must be always maintained within the U.S. industrial base—like roads are needed to cross the country. But how do we rebuild a more resilient industrial base and prevent it from going offshore again?

Johnson: The first time that happened was shareholder value. The second time will be lack of capacity. How do we get capacity in place?

Brassard: The term "capacity" can't be used in the general sense. The EA once told me, "If you call a circuit board a green thing, there's capacity in the U.S., but the moment that green thing becomes a challenging technology to build, we have a capacity problem."

Johnson: Why shouldn't we move our capabilities forward into more sophisticated processes?

Brassard: We should, but there's a need for capital investment. There must also be demand signals to trigger that investment.

Johnson: There's cash. Isn't this the time to invest?

Brassard: Most of the CHIPS Act funding is for chips. But chips don't float or function outside of packaging and integration into a system, just like a Formula 1 engine sitting on a block isn't speeding around a track without the rest of the race car. To win the race, you need the entire package, including substrates and circuit boards, which must keep up with the high-powered engine, the chips.

Johnson: Right now, in our business, there is plenty of work to be had.

Brassard: Yes. In addition to demand for high technology, our market is currently rich with demand for conventional circuit boards, which don't require PCB shops to invest in new technologies to participate and be profitable. Despite the current opportunities to do well with conventional work, we believe advancing capabilities is sound, if not necessary, business strategy. We want to attract the best engineers and the strongest workforce, and a company full of people working for the "good of the country" is important work, easy to sell, and exciting to be part of.

> We want to attract the best engineers and the strongest workforce, and a company full of people working for the "good of the country" is important work, easy to sell, and exciting to be part of.

LaBeau: Our prevailing theory is that you can't maintain a rich and engaged workforce if you're just a build-to-print shop, with no room to innovate, design, or develop new technological solutions. The engineers are not going to stay. We made the choice to help bring manufacturing innovation back to the U.S. with young, smart, and creative engineers, and a workforce that works hard every day for a good cause, protecting our nation and helping the U.S. be globally competitive with the products we produce in the United States.

Johnson: You're saying that the PCB shops that decided to focus on punching them out have lost that technological edge? They don't have the skill set in their staff to move forward?

LaBeau: That is not necessarily true; we have discovered that it is vitally important to engage and develop their skill sets. There are shops doing great stuff, especially in the advanced HDI arena. When you start to get sub-25 micron, you don't see much domestic technology because the supply chain is not completely informed yet: "We may have a chemistry for that, but it is likely what is in Asia." From those comments you can begin to paint a picture about the domestic marketplace.

Johnson: You don't necessarily know where this is going until you get on the path.

LaBeau: Yes, and we don't know where it will go. We're reflecting on the same things you are reflecting on as a business case right now. If we capitalize, then on what? What capacity do we need? Do we capitalize an amount and then hope there will be additional support to increase the investment? We learn from our customers that they're waking up to the idea of wanting to have American made application-specific substrates. That's where that market niche might be for America.

Brassard: And an on ramp for U.S. PCB manufacturers who are paying attention.

An Intel plant producing millions of processors will likely want a large-scale narrowly focused interposer plant nearby, but that's not where the U.S. PCB industry will begin its journey to relevance, and dare I say, greatness. Rather, U.S. defense, aerospace, telecommunications, and medical OEMs are looking for novel application-specific substrates to go with their highly proprietary and guarded ASIC designs.

If you buy a substrate in Asia, you must fit their formula for what they build, like getting your carry-on to fit in the little box before you can take it on to the airplane. Their narrow design parameters allow them to achieve 99.96% yields. Therefore, domestic manufacturers have an opportunity to do for OEMs what Asia will not or cannot, that is to produce novel substrate designs that don't fit the Asian mold. Suddenly, U.S. manufacturers are back

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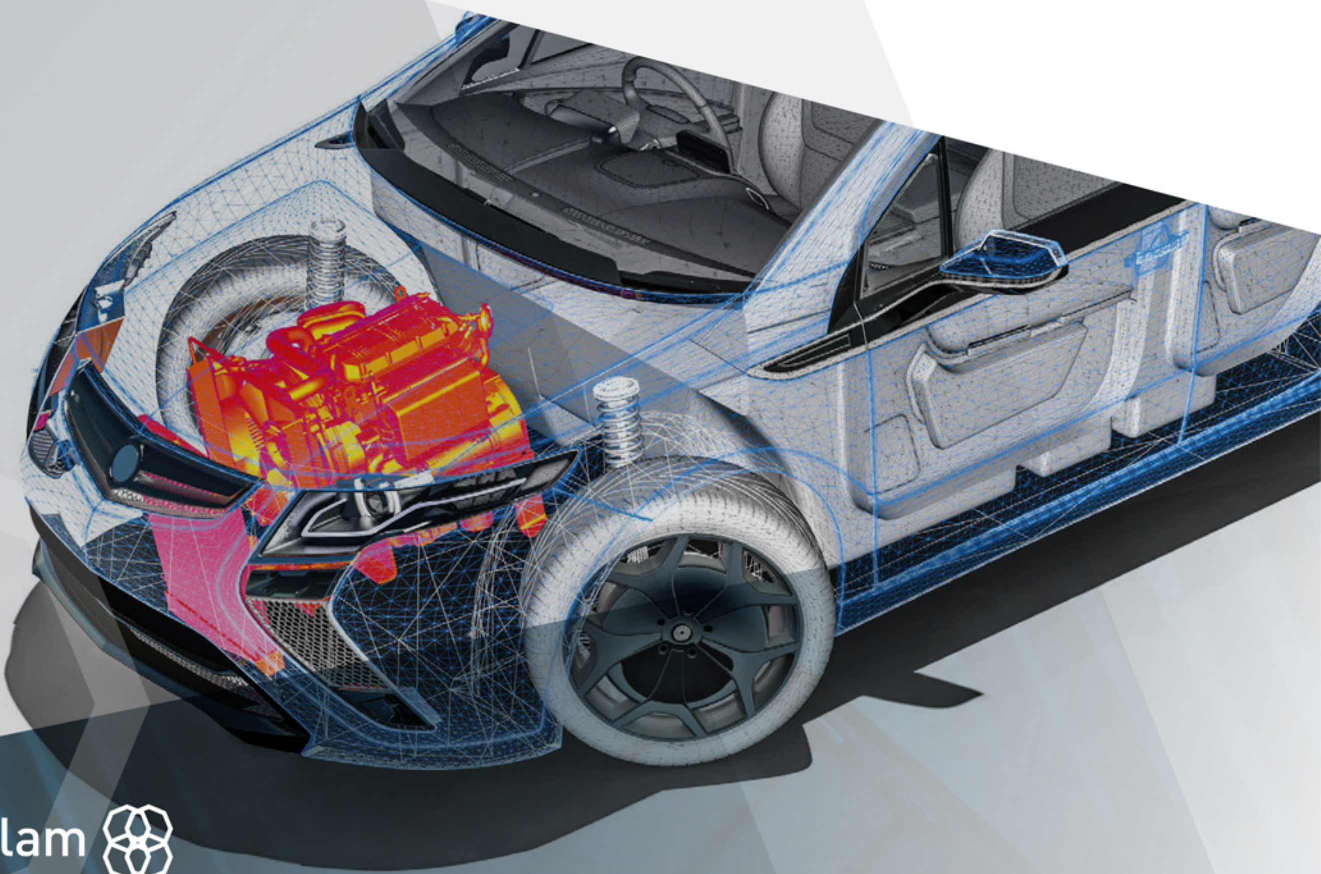

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to doing interesting things right here in America with manufacturing. But how quickly can PCB manufacturers create stand up capability?

Our approach is closer to SpaceX than NASA. I feel like NASA does a decade of research in advance then gets it right on the first launch, whereas SpaceX keeps blowing up rockets on the launch pad until they find the critical path to success, in less time with lower cost. We call this "innovation through iteration." Because we are a fabricator with our capabilities in-house, we can iterate quickly to find critical paths to successful manufacturing techniques and novel approaches. Note that this makes fabs the hubs in domestic innovation, in the middle of engaging customers, suppliers, vendors, universities, etc.

What we believe companies need to be successful, first and foremost, is the right attitude.

Johnson: Todd, do you feel like that development process is faster, cheaper, or both?

Brassard: Both, but results will vary. We have had very challenging designs requiring less than a dozen iterations to solve, but also designs that have taken three times as many iterations. What we believe companies need to be successful, first and foremost, is the right attitude. This is followed by talented engineers, the right equipment set, and a progressive workforce who understand how important their jobs are to the success of the company, their country, community, and families.

Johnson: Will there be enough capacity in the United States to meet demand?

Brassard: We believe there will be tremendous demand for domestically produced substrates. Enough that all manufacturers that want in will have their piece depending on their capabilities.

LaBeau: There must be enough domestic capacity, or it will be the next reason to ship the manufacturing technology back to Asia, thereby not meeting the "lab-to-fab" infrastructure needed to bolster the U.S. microelectronics ecosystem.

Johnson: What do the fabs need to do to stand up the infrastructure to do this?

Brassard: It starts with a demand signal, followed by a little research, an informed capital investment, and you need to dedicate engineering time to develop new processes. These days, because of geopolitical instabilities, it seems the U.S. government should have a role to play in speeding up the U.S. fabricator's ability to invest with CapEx and process development, and offer demand signals to rebuild the U.S. electronics industrial base more quickly.

Like I said earlier, technology development needs to be treated like infrastructure, like building roads. The government must assure that the U.S. has a constant stream of advancing technology to keep up with the rest of the world that's making the holistic investments and winning the industrial capability and capacity races. The government must invest or incentivize until economics can take over. Build the roads and prosperity will follow.

Johnson: Like our ability to have products—food products, in particular—in every corner store, the way we do now that we take for granted, that we will have bananas year-round is because of our investment in the road network.

Brassard: That's a great analogy. Does the government do any investment in making sure people get bananas?

Johnson: No, they build roads, which allows us to get bananas.

Brassard: You are exploring the right topics. With respect to UHDI, U.S. fabricators generally have more questions than answers. We have done the work. We understand what the OEMs' early needs are from the domestic industry, and the types of people and equipment sets necessary for the various levels of complexity and capacity, as well as the associated costs, acceptable yields, profit margins, and scalability.

For now, our customers need us to solve specific problems and gain specific manufacturing capabilities within the United States, but U.S. OEMs want to work with fabricators that can innovate with them, getting outside of the box, and standing up novel technologies that are second to none in the world. This brings tremendous opportunities to U.S. fabricators and PCB manufacturers who understand the foundational principles of fabricating boards and make the jump to substrates.

LaBeau: Now that word is out that we are exploring capability and capacity, the inquiries grow exponentially, and we don't currently have the bandwidth to take everyone on all at once. There is a substantial DoD demand, but there's also a commercial demand. We are working to get the most out of our capital investment at each step in our advancement.

Brassard: We believe PCB shops can enter the substrate market. But should they?

Johnson: I see the overlap in those two statements.

LaBeau: There is overlap between boards and substrates, but substrates will require much higher levels of cleanliness, metrology, and testing outside of the traditional PCB equipment supply chain.

Brassard: PCB shops can push into substrates to a point, but then something more will be required to produce the most novel substrate or substrate-like PCB designs.

Johnson: It starts to look like IC now.

We are working to get the most out of our capital investment at each step in our advancement.

LaBeau: Yes, in a few different ways. For example, when certain processes require similar but different than PCB chemistries to run at substrate scales.

Also, does the United States have the wherewithal to develop new materials? That would stimulate more of a U.S. substrate market as well and ensure we are not continuing to ship the products within the ecosystem back and forth from the Pacific Rim to the U.S. and back, often referred to as the "FedEx supply chain." We can develop strong domestic manufacturing, equipment sets, and materials technologies.

Johnson: We'll know in the next few years. Thank you both for your time.

Brassard: Thank you, Nolan. PCB007

Todd Brassard is VP/COO of Calumet Electronics.

Meredith LaBeau is chief technology officer at Calumet Electronics.

Rallying Around a Robust Ecosystem

One World, One Industry

by Dr. John Mitchell, IPC PRESIDENT AND CEO

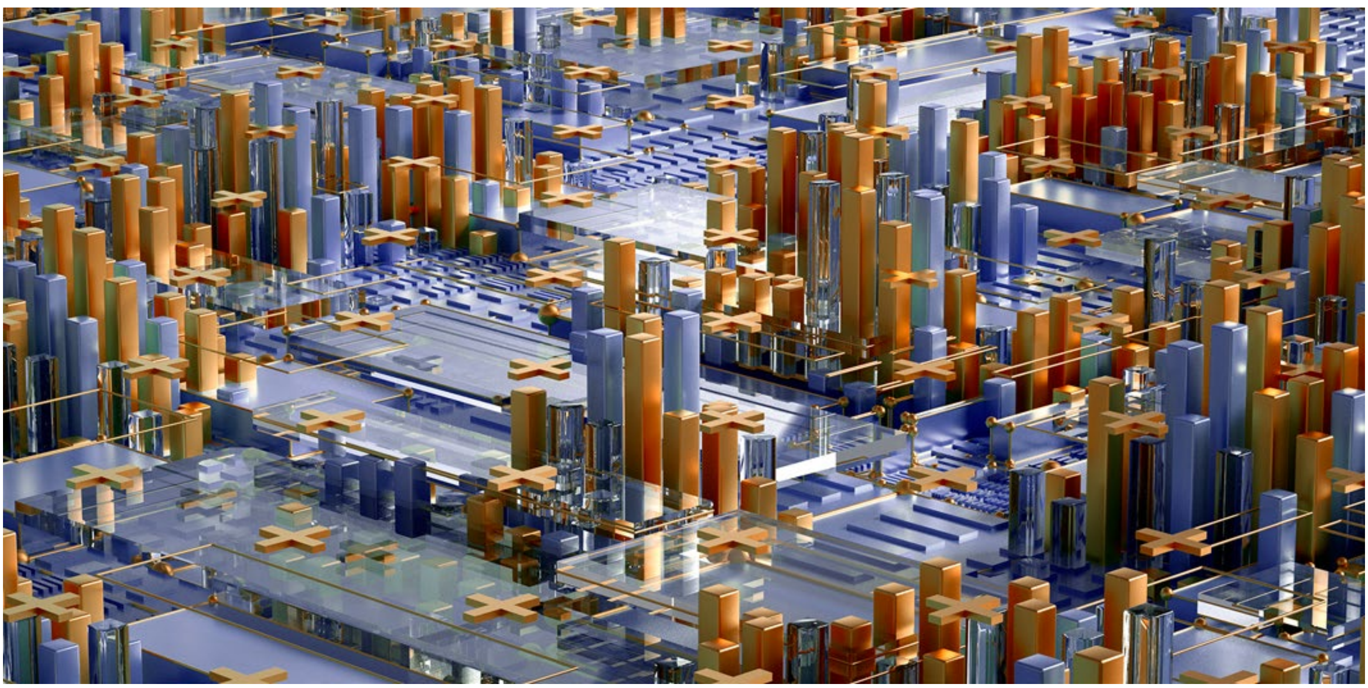
After a multi-year advocacy effort, the U.S. CHIPS and Science Act has been enacted and the funding is now in place for its implementation. At a time in which it is easy to be cynical about Washington, the CHIPS and Science Act is further proof that U.S. political leaders can come together on a bipartisan basis and do big things.

Notably, the U.S. is not alone in seeking to strengthen its domestic semiconductor industry. Governments globally are marshaling resources and policy mechanisms to make their own semiconductor industries more competitive in the global marketplace.

IPC is heavily engaged in Brussels where the European Union is making progress in the enactment of its own Chips Act. Our message to European policymakers is not unlike the message that IPC has communicated to U.S. officials: Advanced packaging must be central to any initiative to bolster a domestic semiconductor industry because advanced packaging is driving semiconductor advancements.

Unfortunately, not everybody has gotten the memo. I still meet far too many people working on technology policy who ask me: What is advanced packaging? Why do we even need these capabilities? Isn't this what the chip fabricators do?

Thankfully, these questions are becoming the exception rather than the rule, and that is a testament to the industry's collective efforts to

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educate policymakers and, just as importantly, to those technical experts in government who have taken pains to educate their colleagues and counterparts.

It is by virtue of this collective educational and advocacy effort that, today, the U.S. government is on the cusp of allocating $5 billion or more to advanced packaging R&D and capacity-building over the next five years.

But building a domestic advanced packaging ecosystem will require difficult strategic decisions, more coherent manufacturing policies, risky long-term bets, and greater collaboration between industry and the government.

There is certainly data to back up the industry's focus to propel advanced packaging forward. IPC recently surveyed nearly 100 industry leaders in semiconductors and related fields, and we learned that there is strong support for increased public and private investment in advanced packaging efforts.

For example, 94% of electronics industry leaders report that improving the performance of semiconductors is increasingly reliant on advanced packaging. In addition, 84% believe that government initiatives to bolster the semiconductor supply chain require significant investment in advanced packaging capabilities. The survey is part of a new report titled "Towards a Robust Advanced Packaging Ecosystem."

IPC is an industry leader in standards development, workforce training, industry intelligence, and advocacy. Much of IPC's work in these areas centers around electronic interconnection and, of course, electronic interconnection is core to advancements in packaging. IPC's representation of the advanced packaging industry, then, carries on work IPC has been doing in collaboration with leading electronics manufacturers for decades here in the U.S. and around the globe.

Please visit ipc.org to learn more. **PCB007**

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

Discovery of New Nanowire Assembly Process Could Enable More Powerful Computer Chips

Researchers from Oxford University's Department of Materials have developed a technique to precisely manipulate and place nanowires with sub-micron accuracy. This discovery could accelerate the development of even smaller and more powerful computer chips.

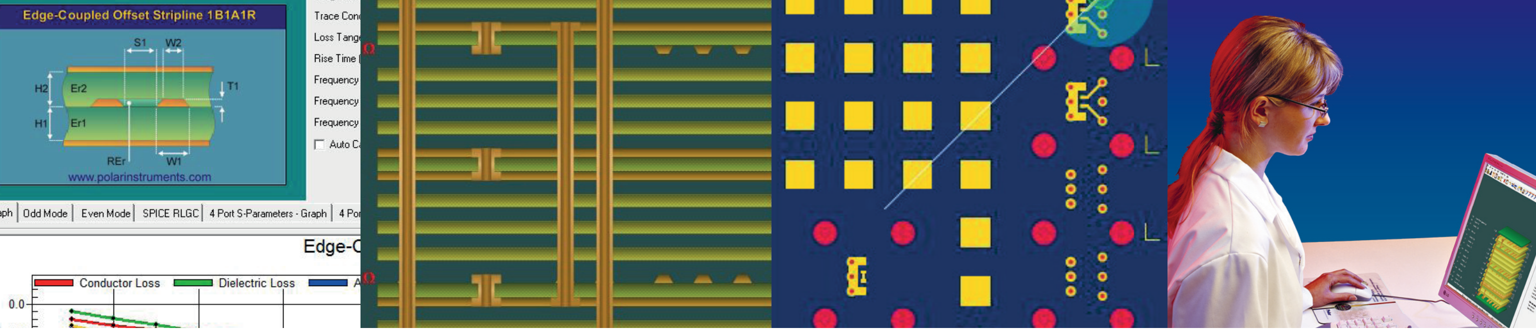
The innovative method uses novel tools, including ultra-thin filaments of polyethylene terephthalate (PET) with tapered nanoscale tips that are used to pick up individual nanowires. The nanowires are then transferred to a transparent dome-shaped elastic stamp mounted on a glass slide. This stamp is then turned upside down and aligned with the device chip, with the nanowire then printed gently onto the surface.

Deposited nanowires showed strong adhesive qualities, remaining in place even when the device was immersed in liquid. The research team were also able to place nanowires on fragile substrates, such as ultra-thin 50 nanometre membranes, demonstrating the delicacy and versatility of the stamping technique.

Nanowires, materials with diameters 1000 times smaller than a human hair. Their minuscule size could allow the development of smaller transistors and miniaturised computer chips. A major obstacle, however, to realising the full potential of nanowires has been the inability to precisely position them within devices.

DPhil student Utku Emre Ali, who developed the technique, said: 'This new pick-and-place assembly process has enabled us to create first-of-its-kind devices in the nanowire realm...Furthermore, this technique could be fully automated, making full-scale fabrication of high quality nanowire-integrated chips a real possibility.'

(University of Oxford News & Events)



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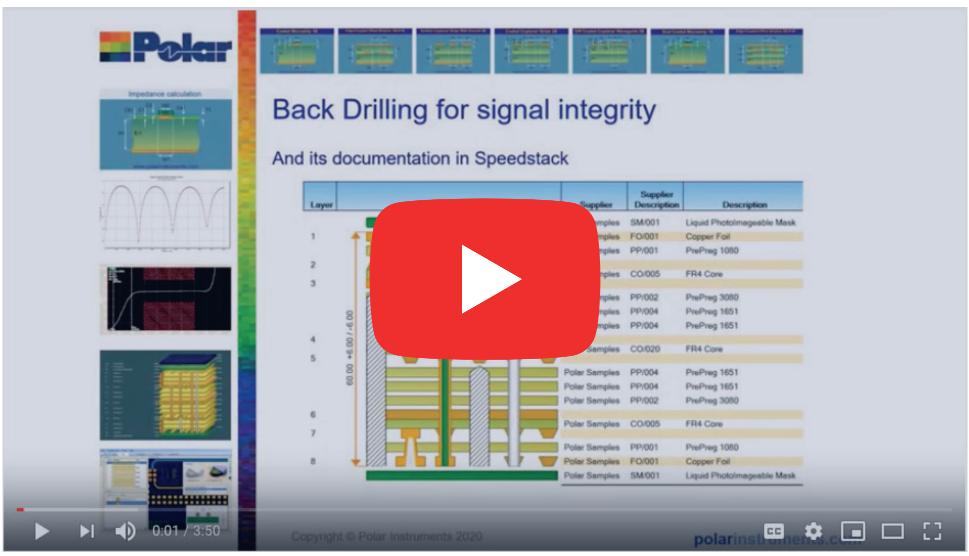

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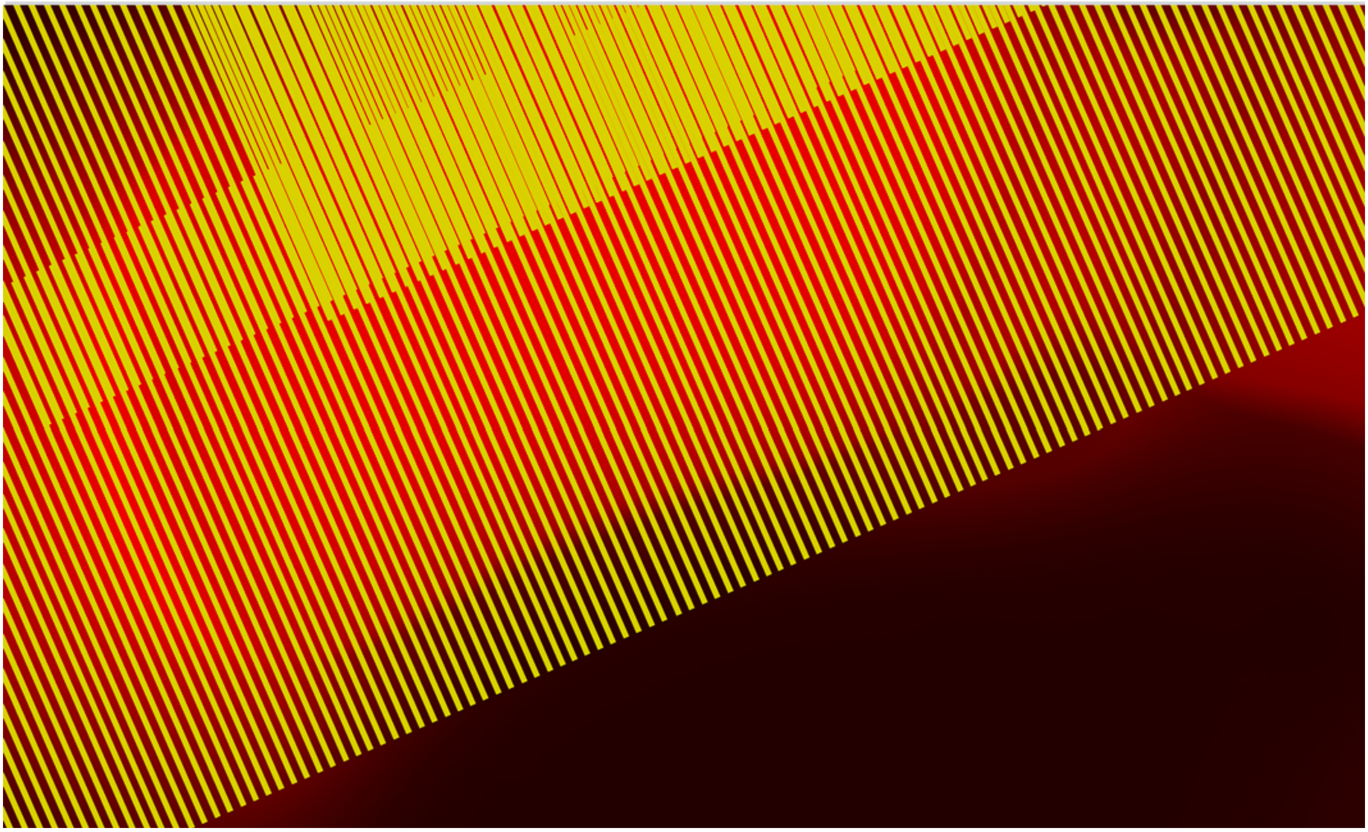


The Growing Need for UHDI

Feature Interview by the I-Connect007 Editorial Team

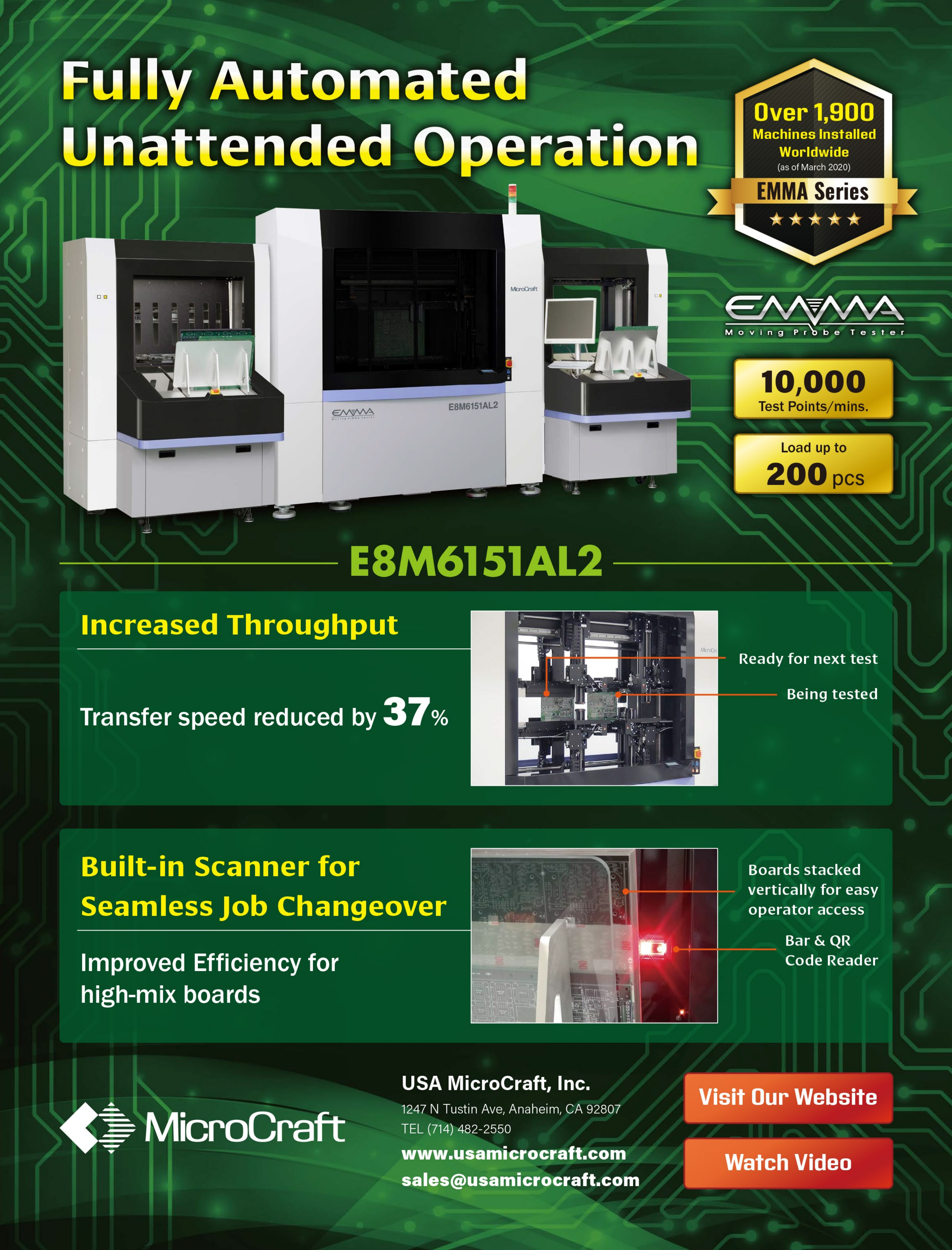
Jan Pedersen of NCAB Group is deeply involved in IPC standards development surrounding ultra HDI and keeps his finger on the pulse of the industry surrounding this type of fabrication. With Asia still dominating this area, Jan sees the need for U.S. and European PCB fabricators to make the investment if they want to stay competitive.

Nolan Johnson: Jan, you're very involved in UHDI design and manufacturing. What's your perspective on these topics within the industry now, and where UHDI is going?

Jan Pedersen: There are seven to 10 factories globally that can produce what we call ultra HDI. The definition for UHDI is 50-micron and below track and gap. You can use subtractive methods down to, let's say, 35 or 40 microns, and then when you creep down below that level you need mSAP or xSAP technologies.

That has been around for many years. It's not really a new technology. It was introduced into the packaging or the component industry in the 1970s and '80s, but it was brought up again when Apple and others started to do smartphones. There are those factories that are involved in this, but they are factored for one customer, so it's very hard for a smaller customer to get into UHDI, and most companies are smaller than Apple.

If you are a bit smaller, you don't get access. It's simple as that. I've tried it myself, tried to place an order with a big European PCB group that claims they have the capability. But when you have your Gerbers and your data and you



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Jan Pedersen

want to produce boards there, they say, "Oh, sorry. This is basically for one customer," and they don't accept us putting their competitors, which could be anybody, into the same factory.

Johnson: Given that, what is driving the development of UHDI?

Pedersen: For us, it's coming from telecom and 5G, and you assume we'll see 6G. But quite a few of our customers come from these industries. We see that need growing in the automotive and medical industries, and I'm discussing it almost globally. I'm looking to see if there is any availability of production capabilities in the U.S. today. We don't find it. There's one factory in Europe that has limited capacity, and then the rest are in Asia and producing for the big names.

Johnson: Where does HDI stop and UHDI begin?

Pedersen: Let's use the ultra HDI definition of 50 microns down. It's subtractive down to approximately 40 microns.

Where we are today approximately on BGA pitch below 350 microns, we talk about pads of 140, and then you are basically into mSAP or substrate-like PCB technologies, whatever that is. There are quite a few technologies out there now that can be used. But we see that we are going from a subtractive into an mSAP level; this depends on where you are coming from and how far you are coming with the investments in your factory, because some of the factories that are producing mSAP have invested in imaging, AOI—everything needed for that resolution now.

When you have a subtractive in that factor, they can go quite far down here. But if you don't have all the other investments and just go for mSAP, that doesn't help you.

I'm saying this as background because you have this producibility level C in IPC-2226, where you have 50-micron track and gap. Everything below that is ultra HDI—substrate-like PCBs can be produced by either subtractive or SAP-related technologies. If you go below that again, down to 15 to 20 microns, you need an embedded trace substrate or similar technologies. Then of course you come to high-end IC substrates which are in single microns.

In the U.S. today for substrate-like PCB, it's below 50 microns, not touching 20 microns, but maybe 35 or 40. When I had my Gerbers and asked for quotations, they said they couldn't do it. They do have mSAP equipment, if you can call it that, or a process in-house, but have not yet invested in the imaging and AOI that is able to detect down to 20 microns. I think they stop somewhere around 35 today.

Johnson: That coincides with some of the numbers that I've heard from the U.S. manufacturers. They're saying it's under 50.

Pedersen: That's also what you see in Asia when people haven't gone to mSAP yet, but invested in imaging, etching, plating, and inspection equipment that brings them down to somewhere around 30 microns.

Johnson: This is interesting, in that it seems that we're making moves here—IPC 2226, and the advanced packaging work that's about to happen—this is strategically important for IPC.

Pedersen: Yes. Customers are saying, "Tell us when you have the capability, and we will design accordingly." There are not that many factories that can do, as an example, the high-mix, low-volume (HMLV) needed when you are in the early design stage, which means they don't have access to the existing manufacturing facilities. In China, there are a lot of investments in this HMLV segment. But we also see a growing need in the automotive industry, which will end up in high volume.

Barry Matties: How fast is this market moving? What's the demand increase year over year for ultra HDI?

Pedersen: It's very hard to say, but my personal impression is whenever we have a capability, that capability will be filled to capacity some months after availability. It takes time for design, but it's what I think will happen because we have too many customers now asking, "When can you have capability, and when can we use these components? Because we can't use them today."

Johnson: This is the situation that a CTO dreams about.

Matties: Are the circuit board designers ready for ultra HDI?

Pedersen: Yes, but they need the parameters. As an example, in the IPC European standards Steering Committee, Alison James from IPC Europe gave a presentation of how the European Chips Act works toward related industry, not necessarily chips. If Europe will be investing in chips, they need carriers and boards with a resolution that can carry these things. What I've heard is that the European Chips Act will include related industries needed for chip production. As an example, you have a chip, you need to have the capability to assemble it, and you need a PCB to carry it, right? You can't just have a chip and not be able to use it.

Matties: Right. The investment will spill into the bare board fabrication and assembly?

Pedersen: Yes. I don't have proof this will happen, but how can they do without it? I think the same with the U.S. CHIPS Act. You have a plan for five years. In Europe, we are slower. It's actually said that it shall be within 10 years, and that gives a little perspective of how many years we are behind.

Matties: So, if a fabricator decides to make that investment today, then the work would come in and there would be an ROI in play in pretty short order?

Pedersen: If I had the capability today, I would be able to fill a high-mix, low-volume factory quite fast. It's not necessarily just because there are a lot of customers coming, but there are those who have quite a big need.

If I had the capability today, I would be able to fill a high-mix, low-volume factory quite fast.

For example, we have requests from Germany, Denmark, and Sweden to give them DFM guidelines to design to this level. We tell them it will be soon, but we don't have it yet. If we use the parameters from the big companies, then we won't necessarily be able to use that for the smaller companies that are growing. We have companies in China that are investing in UHDI. I placed samples with them, and they

produced 25-micron track and gap beautifully. They will be able to produce within the end of the year. This was based on the subcontracted processes they're currently installing.

Matties: With this type of work, in terms of profitability, there's obviously a premium pricing, correct?

Pedersen: My thinking is that the need is so big that you will be able to have some better profit than you have on multilayer boards. When we look at the market reports from Prismark and others that talk about the compound average growth rate (CAGR) for multilayer PCBs, it's something like 6%. Flex circuits are a little bit less, but if you look at the substrate-like PCBs, it's much higher.

In IPC, we bought a report just before the last trade show that is based on substrate-like PCBs where they split between below-25 or 25-micron track and gap and 30-micron track and gap, which is a substantial difference because it's a different technology that can reach it. But the CAGR is something like 15%, while a normal model layer would have 4 to 6%.

I have a technology strategy within NCAB to deliver samples of ultra HDI within the year. We have already made them, we just don't have the circuits on hand yet, but I'm pretty sure we will have it within the year.

We plan to grow through the next year and have a capacity that will satisfy most of our customers. It depends on which level we can reach. Below 50 microns is still not a common capability, but among those who are professional in HDI, they are down to 40-micron track capability. Some are even more aggressive and can do down to 35.

Matties: What is most important to share with today's fabricators from this conversation?

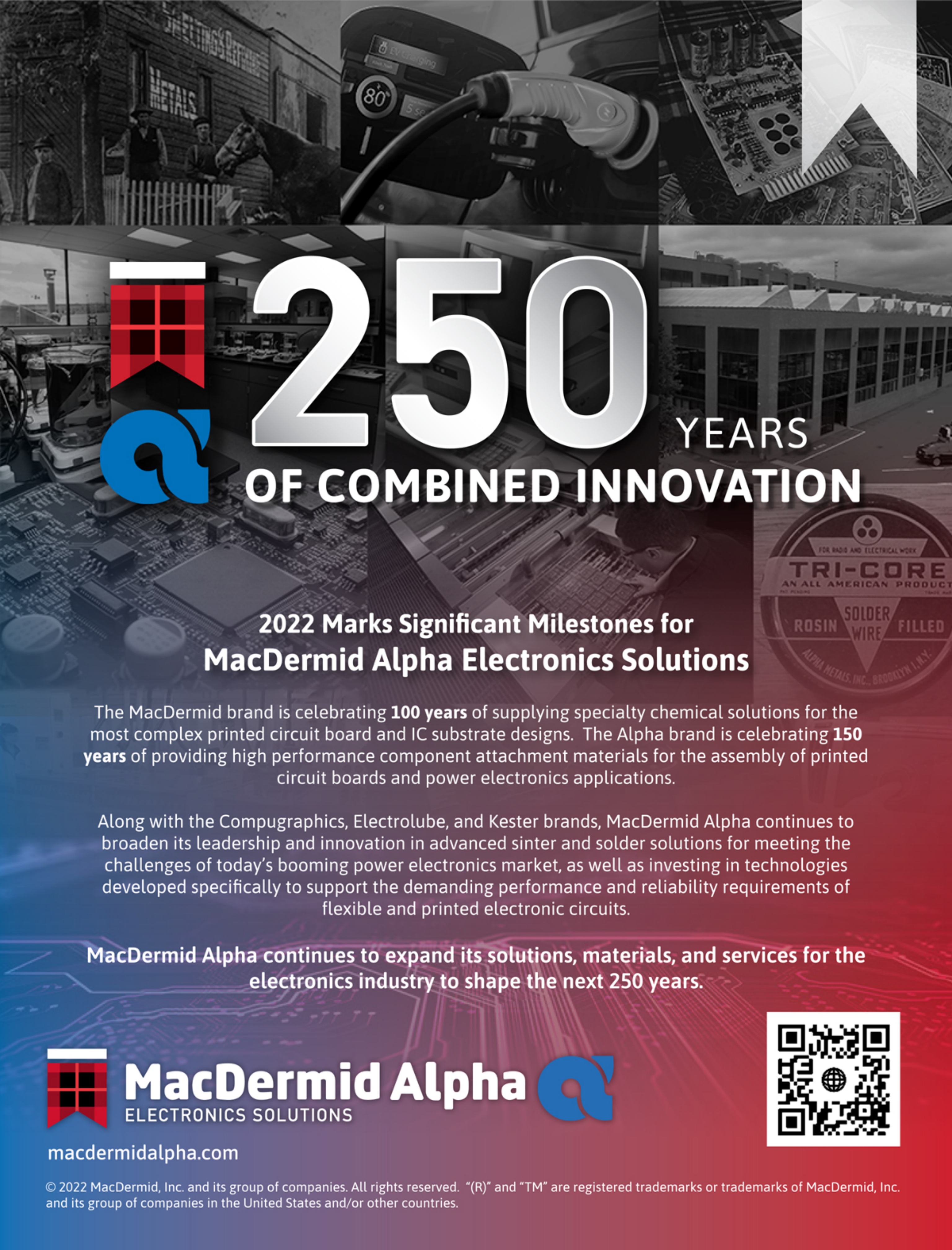
Pedersen: There is a big need and it's growing. We will never go back again. That has never happened. Also, when you see the global recession that is basically happening now, it won't affect the electronics industry and the new developments much because there will always be a big need for these emerging technologies.

Matties: Right.

Pedersen: We have seen this in electronics through other recessions. Yes, maybe there is a slowdown, but with new technologies, you will always see a need. There are a lot of things happening that are affecting us. The war in Ukraine, for example, is affecting energy and electricity prices. We will probably see some companies bankrupt because of it. You also see the movement of China around Taiwan, which is not helping. But it's important to be encouraging about the future of technology.

Matties: Do you think the electronics industry will survive all this?

Pedersen: I think so. Not all of it, but those who invest in UHDI at these levels will sur-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vive because there are not too many of them, and you will not see the whole industry turn into this overnight. There will always be enough orders for those who invest today. It's almost independent of the recession that we might see in the rest of the electronics industry.

Matties: Looking at equipment, the two big pieces a fabricator really needs to invest in are imaging and AOI?

Pedersen: Imaging, AOI, and copper plating is needed. You must have a plating system that is able to do this resolution.

> There will always be enough orders for those who invest today.

Matties: Is that the equipment, or is that chemical?

Pedersen: Both. Vertical plating is needed, when they go to mSAP.

Andy Shaughnessy: Some fabricators tell us that the main hurdle to starting UHDI was getting an LDI machine, which can run $800,000 or $900,000.

Pedersen: You're absolutely right. It's LDI and AOI. You need a better AOI. But it depends on what level you are starting from. If you are an HDI factory where you have vertical plating and up-to-date etching lines, you will be able to cope with using that and adding LDI and AOI. You need both. When you have an LDI that is bringing you down to 20-micron track and gap and your AOI stops at 35, what do you do now?

Shaughnessy: One thing we've heard is that North America has no real clue about how big a problem cleanliness is at that level. Little particulates that are not a problem at 5-mil lines and spaces can kill a board at 15 microns, right?

Pedersen: Yes, now you're talking about the facilities. You have equipment that you need for the processing, but the facilities around almost need a cleanroom area, at least where you are doing imaging and solder mask. If you are producing an HDI board today, you will need this certain cleanness level, but you need to extend that further when going into UHDI.

Johnson: I'll give an example. Back when IC was doing manufacturing in these sorts of dimensions, 15 microns and so forth, the cleanroom would have a restriction on employees. They couldn't be smokers, for example, because if they percolated even one nicotine molecule out of the pores of their skin and it landed on an IC, it could short it out.

Now we're starting to deal with these sorts of dimensions in a printed circuit board. Cleanliness is important. We're now talking about molecular shorts.

Pedersen: Yes, these things are important, and they are basic when you come down to these levels. You need to take care. We have been moving from a 100-micron track and gap on the standard PCB, going into HDI where you suddenly have a cleanroom for the solder mask, and all the things you need to just go to the next level when you are going down this ladder.

This will bring us to another level, down to 20-micron track and gap, and further down to 15. I have customers asking for 17-micron track and gap now, and I can't deliver to them. There are factories that can do it, but I don't have access to them. It's similar to when I was in Taiwan 20 years ago going into the factory, you were asked to wear protective clothes to enter the facility.

Matties: So, when you have somebody like your customer that you just mentioned with the 17-micron requirement, and you don't have access, what do they do? How do they get their job done?

Pedersen: They don't. They have to redesign the board.

Matties: They haven't designed the board by the time they come to you?

Kathy Nargi-Toth with Jan Pedersen at the Advanced Packaging Symposium.

Pedersen: They're waiting on designing to this level because they need to know that they can produce the boards.

Matties: The big challenge with ultra HDI is in the bare board fabrication, right?

Pedersen: Yes.

Matties: So, where do material suppliers fit into the ultra HDI conversation? Are they driving it? Are they reacting to it? What's going on there?

Pedersen: That's a good question. I would say that they are working together with the big names, the big players, to develop these materials.

Matties: Are there any final thoughts that you want to share regarding ultra HDI?

Pedersen: We need to understand UHDI. We need to test, and we need to have test methods. How about the peel strength of the copper when you have such thin copper and new technologies? Those are the things we are working on within the IPC ultra HDI subcommittee.

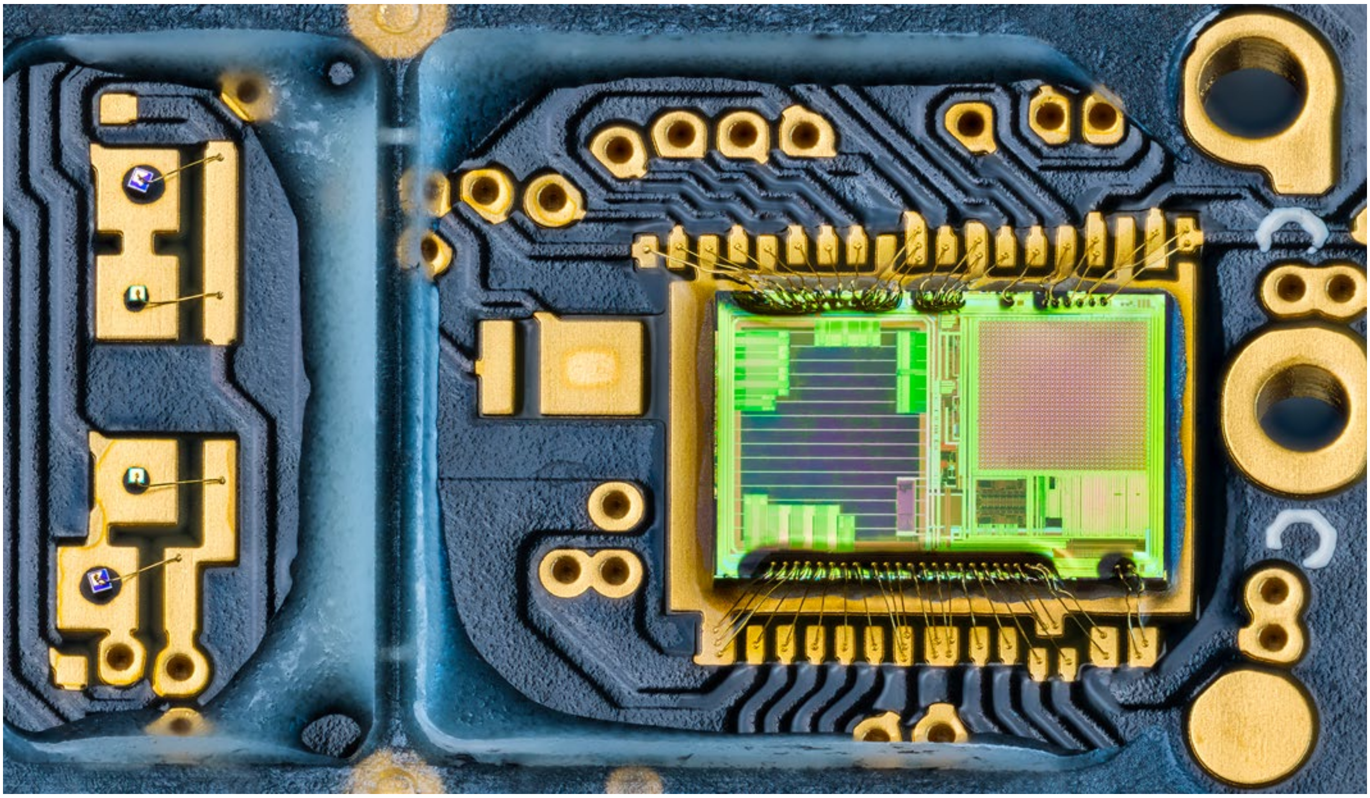
I have a focus group in my NCAB Technical Council working with ultra HDI as well. We have quite a few of our U.S. colleagues there, and that's important for us that we are upfront and trying to understand as part of the development within IPC, the standards, and being part of the recent advanced packaging symposium to understand how the regulations are like the EU Chips Act, the U.S. CHIPS Act, and so on. It was extremely important for us to take part in that and to be part of the development of these emerging technologies.

Matties: Nice. This is really interesting and educational for me, for sure. Thank you, Jan.

Johnson: Yes, you've done a great job of putting into context all the different pieces. I appreciate that.

Pedersen: Okay, thank you. PCB007

Candor: UHDI Under Development



Feature Interview by Nolan Johnson
I-CONNECT007

Candor Industries is a PCB fabricator investing in UHDI fabrication capabilities in Canada. To support advanced packaging, as well as the current pace of IC process shrinks, PCB fabrication capabilities must shrink to keep up. Sunny Patel, Candor's technical sales manager, brings us up to speed on what Candor has learned in their journey to add UHDI. What we gain from this interview is that, while certainly not insignificant, the stretch to add UHDI may be not as far as one might think.

Nolan Johnson: Sunny, is Candor officially stepping into the realm of UHDI?

Sunny Patel: We're starting to get there. The first dabbling in UHDI has been these direct on-chip boards that some of our customers are trying to do. Every layer seems sequentially drilled with 2-mil line and space, or 2-mil line with 1.5-mil spacing. We haven't done a lot of it, but we have seen some demand for it.

Johnson: Where do you draw the line between UHDI and HDI? When does it become UHDI to you?

Patel: For us, UHDI is when it becomes more than sub-drilling and sequential blind vias; it's a mixture of that, plus sub-3-mil lines/spaces, from my perspective. It becomes case-by-case specific on how to process these boards. I suppose that is the limitation of our equipment, but also our understanding of how things etch

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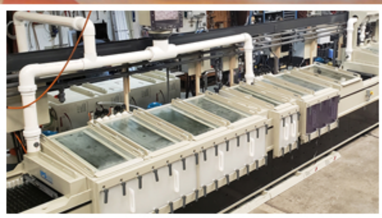


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Sunny Patel

differently in that space. The basic tools that you have, the direct imaging, and the really tight registration of your layers are all important. But then you start getting into etch factor adjustments in different areas, like the horns or making sharper square pads, and extreme reduction of copper on the surface becomes very important.

Johnson: Do you need clean room facilities?

Patel: Most board shops use a clean room already or at least the ones I've seen; we all have a clean room. On the imaging side, that's very important, but it's more than that. It's a whole new ball game. We've done the sequential blind vias, but how do we plate those areas but also limit the copper surface and make sure the etching is still perfect every time for every layer set? The processes are very involved now. You need someone who can look at the data. Based on experience, you know how things are going to etch in that sub-2-mil space and adjust here and there.

Johnson: Is there more custom tuning to get that ready to go?

Patel: Yes, and everyone in that space is experienced with semiconductor-level tolerances. There seems to be a big learning curve for those designers because they're usually designing with that in mind. There seems to be a bit of a knowledge gap on learning how a circuit board factory works and the limitations of it all.

Johnson: Yes, the dimensions on the silicon 20 years ago weren't much smaller than the dimensions we're putting on the boards now. At that point for ICs, we were doing silicon in clean room environments and a great deal of standardization and process work and precision in that which doesn't seem to have migrated over into the printed circuit board manufacturing industry until now. How close are we to needing to have a clean room environment throughout the facility?

Patel: I'm not entirely sure if we need a clean room for every system. But we need more control. Obviously, the imaging has always been a clean room setup, but the control of the plating and the control of the drilling becomes so much more critical. There doesn't necessarily need to be a clean room throughout the whole department. For example, with a laser drill you need that vacuum system and the enclosed ventilation system in that kind of equipment whenever you're doing the actual process.

With plating, it becomes more about chemistry control. The fluid dynamics must be fine-tuned to make sure that you're even across the panel. That's what people are transitioning toward, like the knife edge movement vs. the traditional rack movement of plating, enclosed vertical plating lines. So, the systems are becoming more controlled. I don't know if the whole line must be in a clean room, but it has to be less open to the environment.

Johnson: The dimensions you're trying to manufacture are now inside the tolerances you used to allow. It changes what you can do with your equipment.

Patel: Exactly. Some fabs have 20-year-old equipment; plating tanks never get improved and it's very traditional. You can't just use the same equipment you used in the 1980s or '90s to produce the same boards that you're doing now. You must innovate that type of fluid dynamics or purchase the right pieces of equipment to keep up.

Johnson: Based on your experience, is there room to optimize existing equipment and dial it in so that you can do HDMI? Are you looking at a new line to get those UHDI dimensions?

Patel: I think that becomes a production issue. Yes, you can finesse your equipment to do prototype work, low volume, four or five panels, with someone taking care of the system while it's running. But can you do 100 panels of this in that same format? No, I don't think so.

Johnson: How are you transitioning the manufacturing floor? I'm sure it's a step-by-step process.

Patel: Right. Yogen Patel has always looked to simplify, to eliminate extra steps with technology that improves it. One example is liquid photoresist instead of dry film. That's a big thing because our coated resist is very thin. When you go to UHDI with dry film, you can get away with a 0.5-mil dry film or even a 0.3-mil for imaging. Of course, it gets very hard to handle, but people are using this already.

That was our original roadmap. Direct imaging becomes very important, and the type of direct imagery you use, too, because some of these LEDs have a limitation on the pixel size. It becomes very important which machine you pick for that type of work. For us last year, we picked up a lot of pieces that will help us in this type of work with the direct imager, the Indubond machine, or very consistent pressing, and then the DIS bonder.

You don't have to pick that exact equipment. But the idea is that you're trying to improve the layer registration, trying to reduce the use of thick film plots so that you have direct photolithography for sharper imaging. You need even pressing so that you don't have variation between the manufacturing panel thickness. All those things are very important.

The next tool you need is a very solid laser drill that reduces the amount of carbonation that you get because that's a very big quality headache. Doing UHDI without a laser drill is just very difficult when you're dealing with sequential drilling and blind vias. It's possible, but it's not easy.

Doing UHDI without a laser drill is just very difficult when you're dealing with sequential drilling and blind vias. It's possible, but it's not easy.

I really like the idea of the green pico laser because we're seeing evaporation vs. carbonation of material. I know TTM has a vertical plating line, but we've been working on a vertical plating line for five, six years now. It's almost ready, but that's the step that we're going toward where it's knife edge inner anode system for extremely even plating. We're doing things to avoid extra plating on the surface. We're looking at more automation so that there are fewer chances of any material mechanical issues. Much of it is software as well. We invested in pre-CAM software for etch factor automatic adjustments. There are a lot of things to get.

Johnson: Let's dive into each one of those processes. You have laser drilling onsite at Candor?

Patel: Not yet, but we should have it between December and March.

Johnson: Who are you looking at?

Patel: I've had three test vehicles with three suppliers we're evaluating.

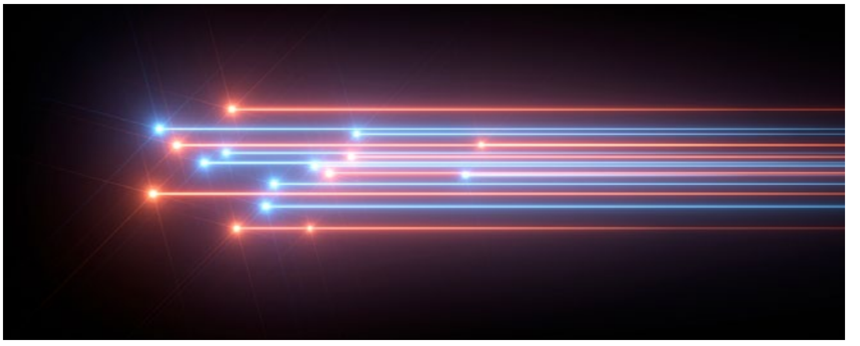
Johnson: You've done demo tests with them?

Patel: Yes. We're at different stages with each of the three vendors. Some lasers have some limitations, and we're hoping to find one laser that can handle all our requirements. We didn't need to use plasma for the blind vias thanks to a percarbonate clean. Overall, the regular accuracy of the laser is great. Eliminating that quality risk is very important, especially when you start building up layers. Then every via counts.

Johnson: You mentioned using some different software. What specifically?

Patel: We work with Ucamco, which was bought by CIMS network, and they have something called Integr8or as a pre-CAM software which paints things like, "This is a pad, this is a ground area, this is a trace via," into the DPS data. They have a system built in called the YELO, and they adjust the copper based on a set of rules that you use. If it was like UHDI rules, it goes through and does the best copper adjustments for that particular design density. The idea for us is trying to keep the manufacturing side of things as consistent as possible. The more variables that you start introducing, the more chance of failures. YELO allows the operators to get in the window of their standard work. That's our goal.

Johnson: Moving that design as much as possible into the center of your process window.



Patel: Yes.

Johnson: Do you do any sort of failure analysis or predictive failure analysis?

Patel: We don't drill down to a specific via that will cause a failure or a predictive failure, but we can tell you about aspect ratios and the possibility of adjusting the process.

Johnson: Going back to the earlier part of our conversation, Sunny, you were talking about using existing equipment to do handcrafted small batch prototypes, but not production. Would you characterize your facility as being in production for UHDI?

Patel: No, but we're on the cusp. We have maybe 80% of the tools and the process is in place. But we need one more piece of equipment; we need to develop our software a little more and we will be there. We can do preproduction volumes right now for certain specific designs, but it's not a blanket statement. We still must do some development work with it, make sure that we've got it, manufacture a couple of releases, and then go into production.

Johnson: I'm sure that there's some additional training knowledge and expertise that needs to be on hand. Can you quantify that?

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Patel: We try to cross-train everyone as much as we can. But it's a lot of experience-based knowledge, a lot of being hands-on to it and explaining before they run that type of design, if it ever comes up. We have a good relationship with everyone because we're okay with them learning. There's really very little red tape from our management side of things, in that sense.

We always have a good back and forth with operators to figure out where the problems lie and keep them involved in fixing or improving processes. It's definitely a challenge. It could take a year or two for someone to get fully up to speed with all the type of work that runs through here.

Johnson: It sounds as if the adoption challenges for UHDI are similar to what HDI faced when it first came out. Are there still issues in getting standard HDI done?

> I think it's a lot easier now and the window of difficulty has decreased.

Patel: I think it's a lot easier now and the window of difficulty has decreased. There are still some curve balls that can happen, but standard HDI has improved in production. It's the gray area between HDI and UHDI that makes it difficult. By now, I think the people in every vertical of the industry understand HDI. The material guys, chemistry, the equipment manufacturers, the designers—everyone's got enough experience with that level so now it's easier.

Johnson: Sunny, when design teams submit jobs requiring UHDI work, how different is the methodology?

Patel: It's more holistic now, where you need to get everyone in a design meeting—the assembly, the designers, the fabs—and make sure everyone is on the same page in terms of the design and everyone gives their feedback on these types of jobs to optimize it as best as possible.

We work with a lot of assembly houses. From our perspective, we want to be on good terms with everyone. Politics must be removed from that situation. Whatever is best for the design is what should be focused on. That's how it should be, from my perspective.

Johnson: Right. Having come from a board fab background, I know that sometimes you can work with the design team and say, "Based on the specifics of your design, this is an assembly house really well suited to what you want to do."

Patel: Yes, but they should know that already. If they don't have that understanding, then of course you'd want to guide them to the right people without stepping on anyone's toes. Everyone has their niche. Even on the board shop side, not everyone wants to do everything.

Johnson: This has been insightful. Any final words or thoughts for fellow fabricators looking at moving into UHDI?

Patel: Do your homework.

Johnson: I agree.

Patel: Be patient. Anyone who wants to do UHDI would have to be okay with failing sometimes and have a real interest in digging down into problem-solving.

Johnson: Thank you, Sunny. I really appreciate this.

Patel: Thanks. I enjoyed it. **PCB007**

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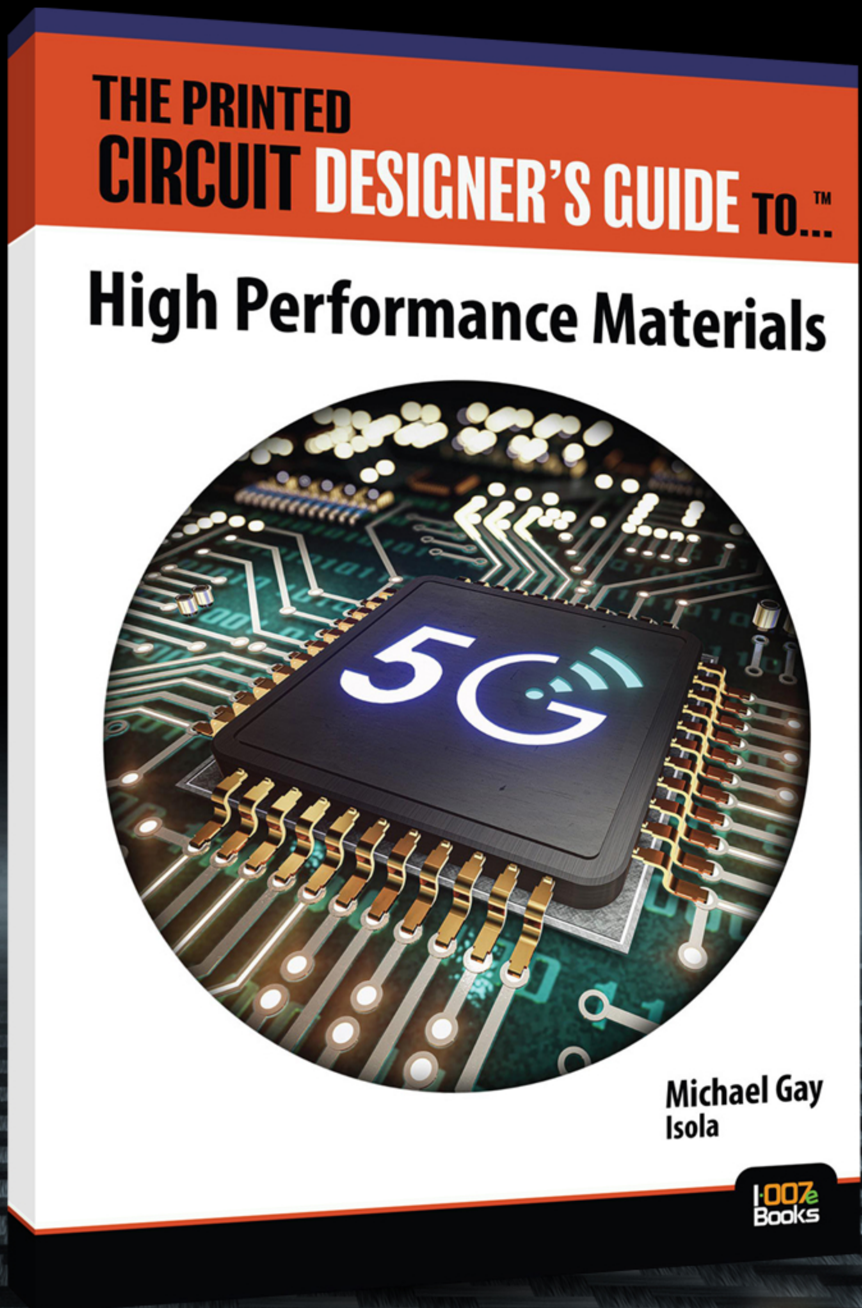

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Decision Time: Invest or Delegate?

Testing Todd

by **Todd Kolmodin,** GARDIEN SERVICES USA

The cost of quality has us rethinking our processes in our everyday life, particularly as state-of-the-art technology presents challenges in our manufacturing theatres. In the 1980s and '90s, it wasn't as much of a challenge, as PCBs were stable, and the technology curve was rather flat. Surface mount technology had made its appearance and multilayer technology was basically 18 layers or less.

During this time, equipment manufacturers were in the driver's seat. Netlist testing came online, and these new fixture testers took confidence to a new level above the routine "self-learn." However, these machines were expensive. It was not uncommon during this era to spend $750,000 to over $1 million on a fixture tester that could perform netlist testing. Flying probes were just starting to hit the market but confidence in this new technology was not high and many OEMs were not ready to trust these new testers. So, fixture testers flooded the market and were successful during this age.

Technology evolved and advanced very rapidly. Designs and component packages became smaller. New build technology emerged such as microvias, blind and buried designs, sequential lamination, and other processes that allowed for the amazing products we consider routine today. This has challenged PCB manufacturers that had invested in equipment to satisfy their ET needs but now are struggling to test these new designs with the expensive equipment purchased years ago.

As they struggle to keep delivery times competitive, manufacturers are faced with a decision: Do I invest, or should I delegate? To stay competitive, a large percentage of capital must be slated for PCB manufacturing equipment. This is understandable as that is where the revenue is generated.

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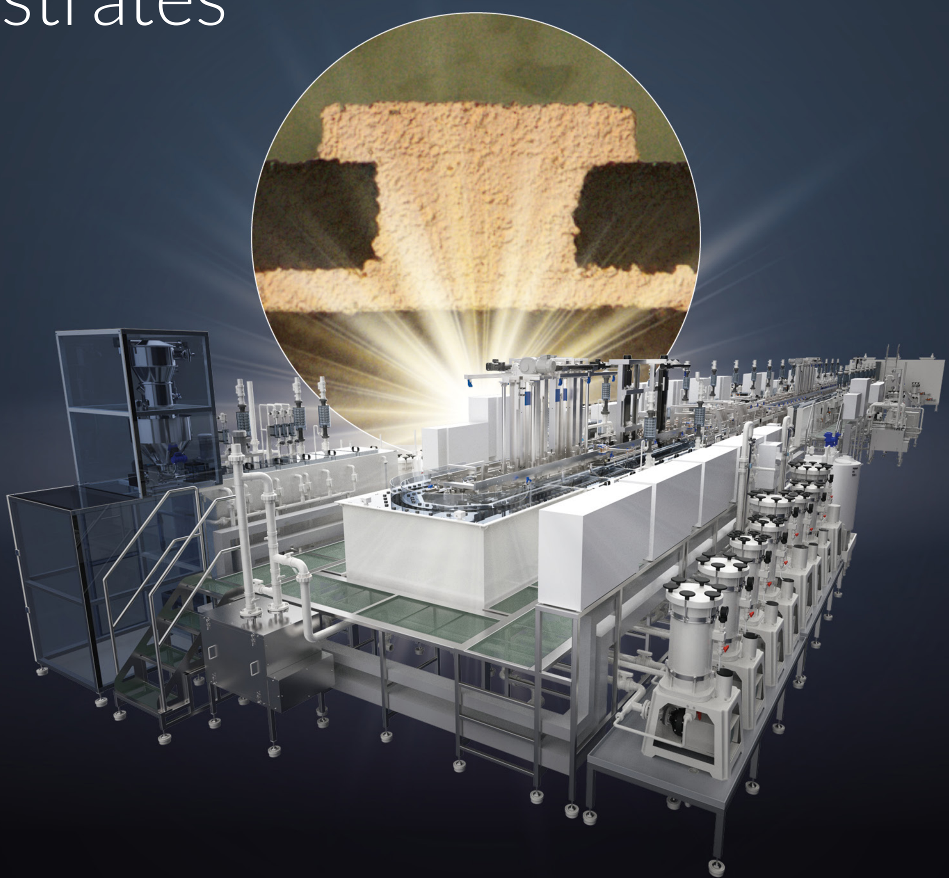

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Newer equipment begets higher technology builds and thus, more revenue. The drawback is knowing how to get this product out the back door. There are delays in electrical testing due to long test times using equipment that is not best suited for today's demand.

Newer equipment begets higher technology builds and thus, more revenue. The drawback is knowing how to get this product out the back door.

Decision time: Do we update our equipment, or do we delegate it? This is a deep question with many variables. Usually, ET is just another department in a large operation. Payroll, utilities, supplies, and such are amortized and integral to the entire operation. In the decision-making process, one must evaluate the real cost of electrical test. Years ago, I had a conversation with a higher management individual at a large PCB manufacturer who candidly stated, "Todd, I can't even spell electrical test." So, there you go.

To really understand the cost of ET, you need to dig into the trenches of the operation. What are your standard cycle times, cost of equipment maintenance, supporting equipment cost and maintenance, down times, and the availability of spare parts for what are, many times, older equipment with no further OEM support? Once you have your arms around the cost of quality regarding ET, you can have a better idea where you stand.

Now it's time to investigate whether my dollars spent on ET make sense. If I invest and update my ET theatre, what are my expected deliverables? Will one machine decrease my cycle time? Can I perform more tests such as 4-Wire Kelvin, buried passives, IR, and Hi-Pot? What capital budget do I have to work with? Interesting enough, although ET QA is a significant part of the overall process, many ET managers find that capital expenditures have been directed to the manufacturing process. "Make do" is the common response.

Thus, the outsource option make sense. We now have the cost of ET in our hands and the cost/availability of upgrading. Is the overall cost to upgrade feasible against the gains expected? Many times, the answer is "no." Although the upgrade provides advantages over current methods, it does not significantly reduce cycle time as the equipment is quickly saturated with the higher technology product and many times, cycle time increases.

Now, there are two camps on the outsourcing topic. There are those who always believe that "we can do it ourselves." There are benefits to that if you have the knowledge, equipment, and experience to take ET head-on and provide all the deliverables your customers expect. It is imperative that you know your cost of quality, or you are living in a dream and wasting dollars on your bottom line with inefficiency and lost time. Reinventing the wheel is not always the best option.

The other camp embraces new ideas and has learned that the cost of quality does not calculate favorably to invest large amounts of capital to just get to the technology level required by increasing demand. They already have calculated that reinventing the wheel will only result in a flat tire. Here, outsourcing is the favorable option. Again, this can be just sending product to a service center to be tested using an on-demand scenario (which many do). Maybe you just want to lose the ET headache altogether. There are options where outsourcing the entire ET operation may be feasible. Scenarios may include just equipment, equipment and labor, or even full black box integration. No more equipment/technology

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challenges, known cost of quality, and confidence that all industry/customer requirements are met. Gained expertise to represent in quality audits for ISO, DLA, and 9100 are just another benefit.

When drawing conclusions, whether it's time to invest or delegate, depends on your individual circumstances. Do you know your cost of quality? You need that in hand to make justifiable decisions regarding capacity and cost. I know it's hard to get past some trains of thought or perceptions but sometimes reinventing the wheel or throwing capital at a squeaky wheel is only a temporary solution. Remember to consider where you are today vs. where you want to be in the future. Where does the capital need to go?

Just remember, whether you decide to invest or delegate, you want to find a partner that provides solutions and not just selling equipment. **PCB007**

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

Advanced Packaging Symposium Special Coverage

by Nolan Johnson

IPC took a visionary step in October by hosting a two-day Advanced Packaging Symposium. Held at the Kimpton Monaco hotel in Washington, D.C., the event brought together industry experts, government representatives, advocacy groups, and manufacturers to discuss the strategic need for packaging capability, both advanced and traditional, outside the Asian region.

Opening day speakers included keynotes from TechSearch's Jan Vardaman, and Intel's Tom Rucker. Additional speakers throughout the day represented DoD, NIST, the European Union, Western Digital, IBM, AMD, Northrup Grumman, and BAE Systems. The second day's agenda included: SRC, SkyWater, Amkor, Integra, Samsung, AT&S, AGC Tactonic, OKUNO, and Lam Research. A lively mid-morning panel was comprised of representatives from Averatek, Calumet, GreenSource Fabrication, Sanmina, and TTM. A recurring theme was the urgent need for in-region capabilities.

Read the five interviews we conducted regarding this event along with photo coverage which we published in the November 2022 issue of *SMT007 Magazine*.

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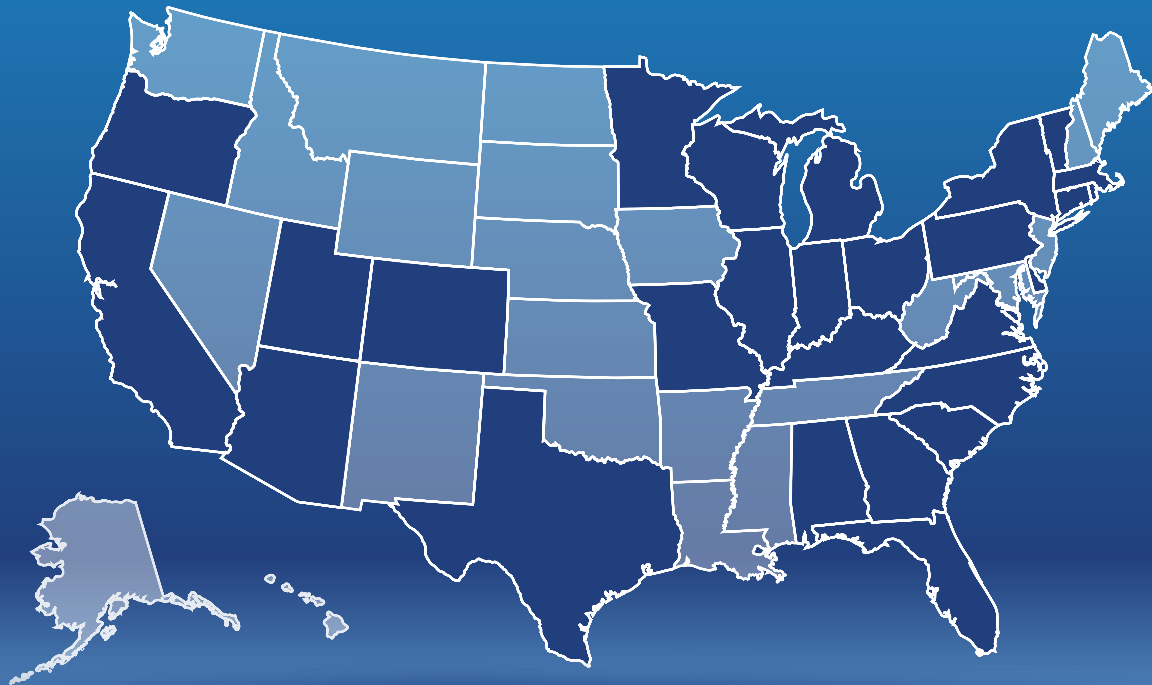

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Cupric Chloride Regeneration Options

The Chemical Connection

by **Christopher Bonsell**, CHEMCUT

Cupric chloride ($CuCl_2$), if you recall my June 2022 column "Etchants of the Industry: Cupric vs. Alkaline," is the second-most used etchant in PCB etching next to alkaline etchant. It holds many benefits such as simple maintenance, easy wastewater treatment, reduced cost of etching, and efficient regeneration. Many times, I have discussed how critical it is to implement regeneration because it allows you to maintain a consistent etch quality and reduces the cost of etching. What makes cupric's etch regeneration simple is that it is a matter of what you choose to use. Thankfully, utilizing any regeneration option for cupric chloride is as simple as feeding your regeneration chemicals into the etch bath and letting the chemistry take place. Although all are relatively simple to implement, some have certain benefits over others.

When it comes to regeneration for $CuCl_2$, you have three options: hydrogen peroxide (H_2O_2) and hydrochloric acid (HCl), sodium chlorate ($NaClO_3$) and HCl, or chlorine gas (Cl_2). The regeneration reactions for the listed reagents are shown in Table 1, and how these reactions all tie in together is shown in Figure 1.

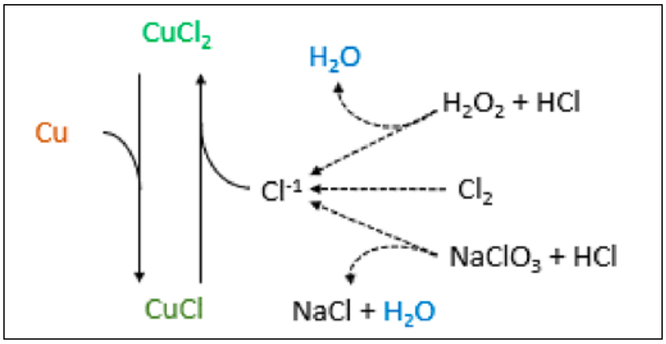

Figure 1: Diagram of how each regeneration reaction provides a chloride ion to convert CuCl (the spent form of the etchant) back to $CuCl_2$.

	Cupric Chloride Reactions
Etch	$Cu^0 + Cu^{+2}Cl_2 \rightarrow 2\ Cu^{+1}Cl$
Regeneration Option (Hydrogen Peroxide & HCl)	$H2O2 + 2\ HCl \rightarrow 2\ Cl^{-1} + 2\ H_2O$
Regeneration Option (Sodium Chlorate & HCl)	$Cu^{+1}Cl + NaClO_3 + 6\ HCl \rightarrow NaCl + 3\ Cu^{+2}Cl_2 + 3\ H_2O$
Regeneration Option (Chlorine Gas)	$Cl^{-1} + Cu^{+1}Cl \rightarrow Cu^{+2}Cl_2$

Table 1: Etch and regeneration reactions for cupric chloride[1]

Hydrogen Peroxide and HCl

The first regeneration option is H_2O_2 and HCl. One great benefit of this option is it only has one byproduct to the reaction: water. As a byproduct, this water is not problematic because it can be used for maintaining the specific gravity (SG) of your etching solution. As you etch more copper, the SG of your etching solution will increase because of the metal content rising. With water being the byprod-

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Figure 2: A metered pumping system for regeneration made by Chemcut.

uct of this reaction, your water consumption will be reduced. What is also useful about this option is that you can use a simple pump system to feed it into your etcher. This pump system would connect to the chemical drums and tie it in with a few controls (i.e., metering pumps, ORP monitors, and/or panel counters). These controls will be used to cue the pump system to provide your etcher with an adequate supply of regenerating reagents (Figure 2).

The drawback of this option is that H_2O_2 is a thermodynamically unstable molecule, and over time it will decompose and become water. This means the longer it is sitting idly in a drum after opening, the less effective your regeneration controls will be because you will no longer have an accurate understanding of your H_2O_2 concentration. There are typically some additives to ensure the H_2O_2 does not break down too quickly, but it is still a possibility. With H_2O_2 there may also be additional safety measures required since it is a highly reactive oxidizer.

Sodium Chlorate and HCl

Utilizing $NaClO_3$ and HCl for regeneration will look similar to how regeneration is done with H_2O_2 and HCl, since it can also be set up with a simple pump system. Utilizing these reagents provides the same benefit of reducing water consumption in maintaining SG. $NaClO_3$ will give the same benefits as H_2O_2 without the worry of your chemicals decomposing over time. Both $NaClO_3$ and H_2O_2 are strong oxidizers, but $NaClO_3$ is easier and safer to handle. Perhaps these are the reasons why regeneration through $NaClO_3$ is the most popular of the three options.

Although it has some great benefits, it has the drawback where water is no longer the only byproduct. For this reaction, NaCl is also a byproduct and over time, as you are etching and performing regeneration, you will accumulate salt inside your etcher. At a certain point, the salt content will be so high that the salt will take the form of a solid inside your etcher, which can be difficult to remove. This can be problematic from a few standpoints. From a production standpoint, it can interfere with how effective your etching process is by plugging up your nozzles and it can cause abrasions on your PCBs or damage the photoresist. From another standpoint, it can also impact the longevity of your equipment. If it goes untreated long enough, you may see more mechanical issues with your machine. Although salt build-up could be severely problematic, it can easily be prevented with routine maintenance and cleaning.

Chlorine Gas

Chlorine gas for regeneration may be the most efficient option available. This is because the Cl_2 regeneration reaction produces no byproducts that can accumulate or mess with the balance of the etchant. It is also highly economical because the cost of the gas is significantly lower than the other reagents. Although it is generally considered the best option, it is a method that is not highly used due to the number of regulations that are imposed on the use of Cl_2. Even with the reagent cost being significantly low, in some cases, the amount of regulations and safety precautions add up to making it more expensive than the counterpart options.

If you do get the opportunity to use Cl_2 for regeneration, you should note that feeding it into your etching system will be a different process than the previous options. To bring the Cl_2 into your etching solution you will need to pull it into your etcher by vacuum. This vacuum will pull the Cl_2 from the storage tank and introduce it to the spent etchant via sparging or feeding into a recirculating loop (see Figure 3). This feeding method is a safety measure to prevent major releases of Cl_2 in case there is a leak in one of the connections between the tank and the etcher.

Summary

Regenerating $CuCl_2$ can be relatively simple, and it is mostly a matter of picking which option you want. Which option you choose will likely depend on your location. The best option to go for is chlorine gas regeneration because it is cost-effective, but depending on your location, there may be too many regulations and barriers to entry for that to be a feasible option. If Cl_2 is not a valid choice for you, then the other two options can come down to many different factors that can be unique to your process. With the information I have provided, you should be able to make an informed decision about which one would suit your cupric etch process best. **PCB007**

Figure 3: A free-standing regeneration unit designed to pull chlorine gas in by vacuum and introduce the gas into the etchant.

References

1. "Process Guidelines for Cupric Chloride Etching," Chemcut.net

Christopher Bonsell is a chemical process engineer at Chemcut. To read past columns, click here.

The UHDI Spectrum

Feature Interview by the I-Connect007 Editorial Team

During an interview with IPC Chief Technologist Matt Kelly regarding advanced packaging, we took a side trip into a discussion of UHDI: What is it? How is it different from printed circuit boards? Why are they so critical to semiconductors? Matt details not only the challenges, but the payoffs of investing in UHDI technology. For advanced packaging, be sure to read our January 2023 issue, where we start off the new year with a deeper dive into this very relevant topic.

Nolan Johnson: I have been hearing some PCB fabs in North America talking about their initial experimentation with making substrates. They're saying that it is fundamentally different.

Matt Kelly: Oh, absolutely. If you'd like, you can reference our November 2021 report. One of the key findings is that there has never been IC substrate capability in North America. We've had R&D, and pilot line capabilities, but nothing in significant volume. This is not a "bring it back" story, but rather "create it essentially for the first time."

There are different levels of substrates. Low end substrates are wire-bonded substrates—a chip wire-bonded to the substrate. If we are talking about line and spacing dimensions (as one metric), this is the easiest and the lowest tech substrate type. These are in the range of 25-micron lines and spaces.

Twenty-five microns is 1 mil. This is the range where people talk about "lines blur-

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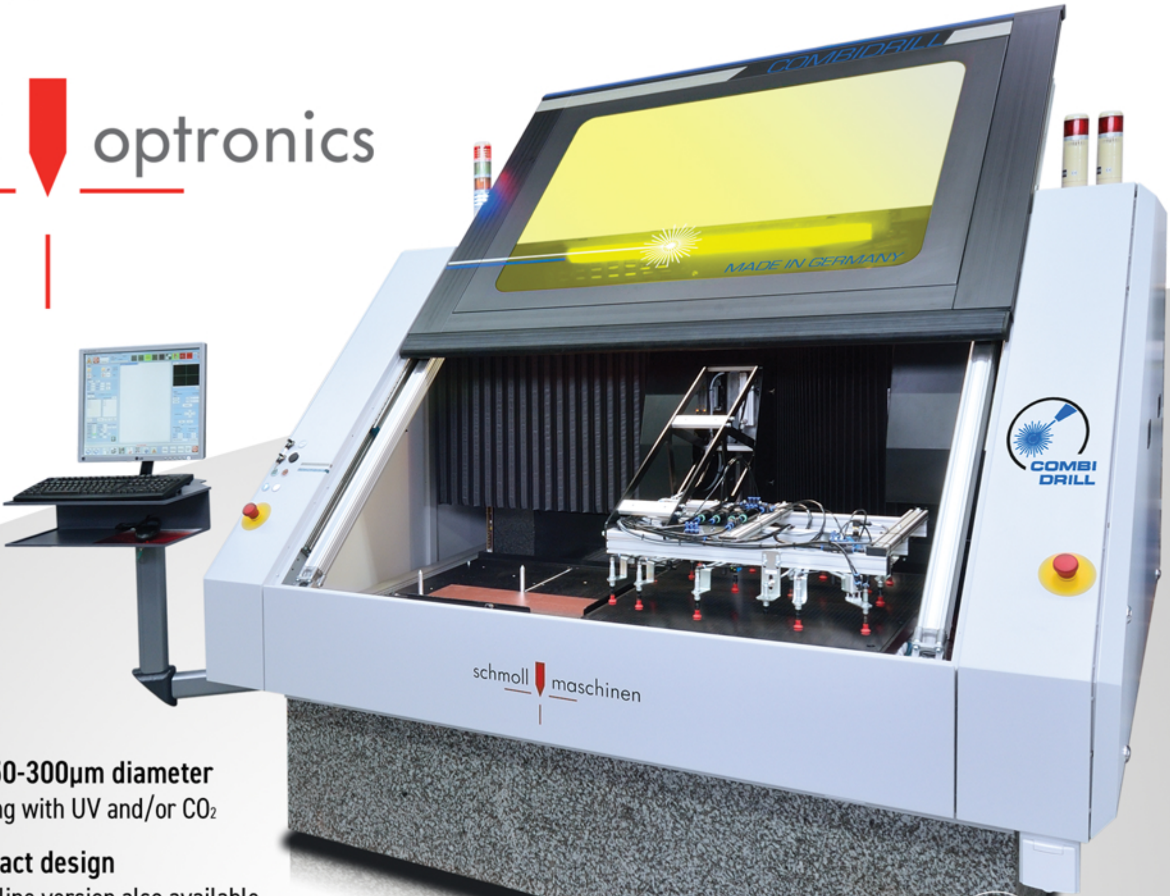

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Matt Kelly

ring" between the UHDI PCB and IC-substrates technologies and capabilities. On the PCB side, if we're down into 2-, 3-mil—that's 50–75-micron lines and spaces. This is where the HDI-, UHDI-PCB, and low-end IC substrates start to overlap.

If I go to the other end of the spectrum with substrates, the low-end is a 25-micron line and space wire-bonded substrate. Can North America build that? Some can, but these are considered commodity-level packaging substrates and it's hard to find a business case to support and justify production. It's legacy technology that is not economically feasible to build outside of low-cost geographies.

Now, if we talk about high performance compute, active, logic, and memory—your 'Intel Inside' processor chip—TSMC, Samsung, and Intel are the top three producers worldwide. When you characterize substrates with these high-end processor packages, you're into ranges of 9-12-micron lines and spaces.

Newly developed roadmaps from the ASIC coalition are forecasting 5-micron lines and spaces within the next two to five years, and 2-micron lines and spaces within the next five to 10 years. When a North American printed circuit board fabricator says, "I want to start building substrates," my very first comment is, "Be careful what you're getting into because there is a wide variety of technology areas within substrates."

Just because you might be able to build a wire-bonded 25-micron substrate does not mean you can build a CPU-based 10-micron substrate. To illustrate using a car example, a wire-bonded substrate is like a well-built Toyota Camry: You know what you're getting, it does a good job, and it works. These CPU-grade substrates are like Lamborghini or McLaren race cars. While you say they're both substrates, they are indeed very different things.

When someone says they can fabricate these small line and space features, my first question is, "What's your yield?" because I'll often get an answer of 20%, and that kind of yield production will put you out of business.

Johnson: At the same time, these "Lamborghini" substrates are critical to moving packaging forward. Somebody must step up to do them.

Kelly: Right. We are really thrilled that the CHIPS Act is putting a lot of money into semiconductor technologies, but for the past year we've been advocating for the idea that the silicon must interconnect with something. You can spend $20 billion on a fab and it's impressive. You took all that money and technology, and you have a pile of very advanced chips on your desk, but they're completely useless.

It's the same with substrates. You can produce high-performance ones with high quality, but they are completely useless until you interconnect the chip on the substrate in a qualified manner. Only at this point do you actually have a for-sale part number. It's the first time you

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have a finished good that can be sold. Everything else up to this point has been a sub-component input. For me, this is the first line in the sand.

If we produce these chips in new fabs being built in the U.S. Southwest, what happens next? They are sent to Asia for packaging, so you've essentially lengthened your supply chain, not shortened it.

If we produce these chips in new fabs being built in the U.S. Southwest, what happens next? They are sent to Asia for packaging, so you've essentially lengthened your supply chain, not shortened it.

That's why having the capability to build some IC substrate domestically must be a regional discussion, whether it's Europe or North America. Now, we're seeing a model change where it's a regional-plus global model. We should not have any disillusions that the global supply chain is not alive and well. This is not just overcoming the global supply chain; there are lots of things that will never move.

For example, let's talk about chip passives: capacitors and resistors. Plants in Malaysia and other Southeast Asia locations won't be moving. My point is that there will always be a global supply chain that you need to work with. However, we are seeing a stronger need and desire for a regional-plus global model.

A regional supplier might be able to deliver at cost-parity at best. It most likely may be even higher cost. But strategically, when you make that decision to say, "I need to have this type of component or these elements made regionally, come what may," you're doing it for very good reason. The thought process may be, "I might be parity at best, but I'm doing it because I'm protecting something that I care about." So, when you set up that regional-plus global model, it allows you to make those types of decisions. Otherwise, if you say global only, then this is where everyone says, "I can't build it at that price. It will cost me too much, so I won't make the switch."

Barry Matties: Matt, how will the funding be brought into our industry?

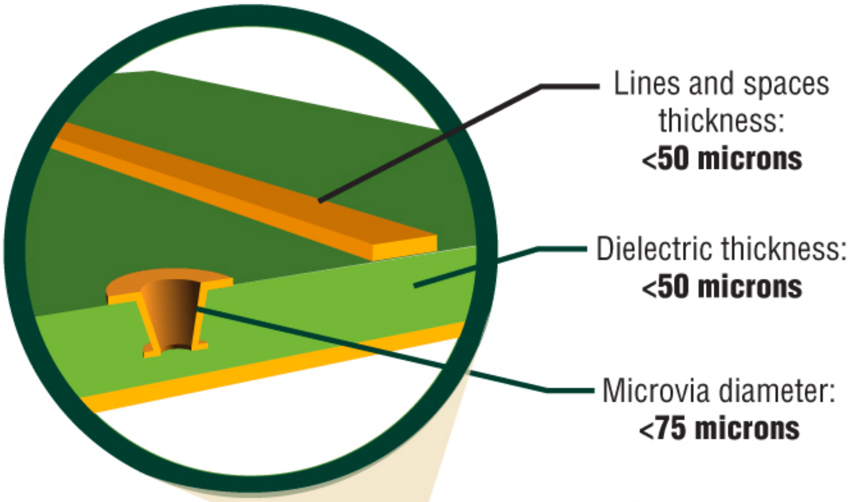
Kelly: If they can produce substrates to a certain level, with North American defense as the main market, then they can tap into it. IC substrates are included in the definitions of advanced packaging. That's one of the main drivers for printed circuit board companies looking into this area.

With this overlap between substrates and printed circuit boards, IPC is making the argument on behalf of the industry that we define it as "minimum viable capability" so that we can have some of that investment flow; maybe outside of the CHIPS Act through some of these other funding programs. Step one is seeing what kind of information or investment we can get for substrates, and then continuing that in terms of what we can attract for printed circuit board technologies as well.

Matties: Matt, thanks for talking this through with us.

Kelly: My pleasure. PCB007

Anatomy of Ultra HDI



...and getting even smaller

- Lines and spaces 20–40 µm can be achieved using modified Semi-additive Process (mSAP)
- Semi-additive Process (SAP) makes lines and spaces <20 µm possible
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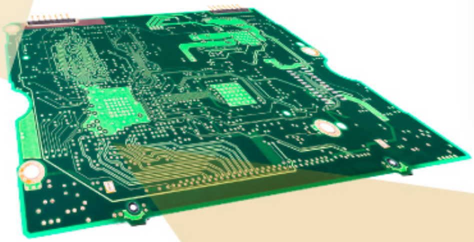

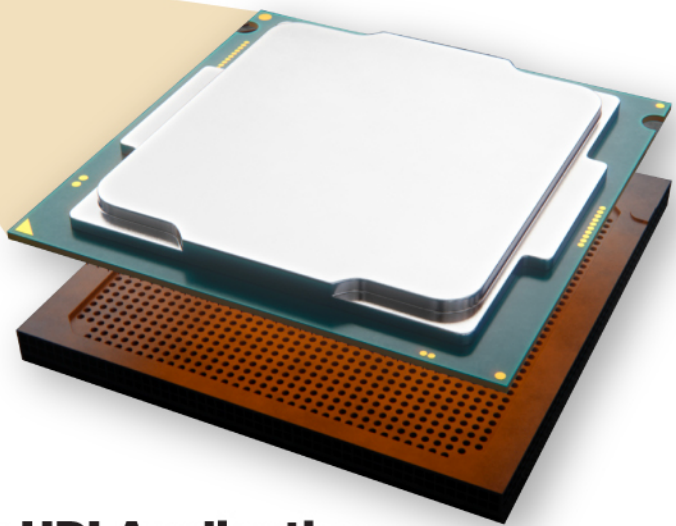

Chiplet Integration

2.5D and 3D IC packaging has gained momentum as an ideal chiplet integration platform due to their merits on achieving extremely high packaging density and high energy efficiency.

New thin, organic materials (ABF) replaces silicon as the substrate.

Source: ASE Technology Holding, Co., Ltd.

Examples of Ultra HDI Applications

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MilAero007 Highlights

Sunstone and I-007eBooks Launch Book on Designing for Reality ▶

I-007eBooks is excited to announce the release of the latest title in its series for designers, *The Printed Circuit Designer's Guide to... Designing for Reality.* This book covers both written and unwritten rules for how to create a realistic, manufacturable design.

PCB Legislative Update: HR 7677 ▶

Electronic industry association leaders like IPC, PCBAA, and USPAE have been trekking to Capitol Hill almost weekly this year to reinforce the dire state of the industry and seek additional co-sponsors for HR 7677, a bill supporting the American printed circuit board industry.

Collins Aerospace Receives Milestone Certification for Combined Vision Systems ▶

Collins Aerospace has achieved a technical standard order (TSO) for its combined vision system (CVS) for business aviation aircraft. The CVS provides clarity to pilots in all types of weather to navigate aircraft confidently and securely through low visibility situations.

Boeing-Built SES Satellites Send, Receive First Signals ▶

Two newly launched Boeing-built satellites are sending and receiving signals as they continue their journey to their orbital destinations. "Our unique dual-launch configuration was again successful on this mission," said Ryan Reid, president of Boeing Satellite Systems International.

Industry Well Represented on New U.S. Government Advisory Committee on Microelectronics Industry ▶

Two of the electronics industry's most far-sighted and innovative leaders have been named to the U.S. Department of Commerce's new Industrial Advisory Committee (IAC), which will provide guidance to the Secretary of Commerce on a range of issues related to CHIPS for America Act programs.

Collins Aerospace and U.S. Army to Develop Best Practices for Airworthiness Certification ▶

This joint effort will address the need to provide faster integration of new capabilities, greater mission flexibility and lower acquisition cost.

Lockheed Martin: U.S. Army's Q-53 Multi-Mission Radar Demonstrates Counter-UAS Mission ▶

The U.S. Army's AN/TPQ-53 (Q-53) Multi-Mission Radar (MMR) successfully integrated with an Army command and control system and provided tracking data to launch a counter unmanned aerial system (C-UAS) defeat system in Yuma, Arizona.

American Standard Circuits Successfully Completes AS9100:D and ISO 9001:2015 Audits ▶

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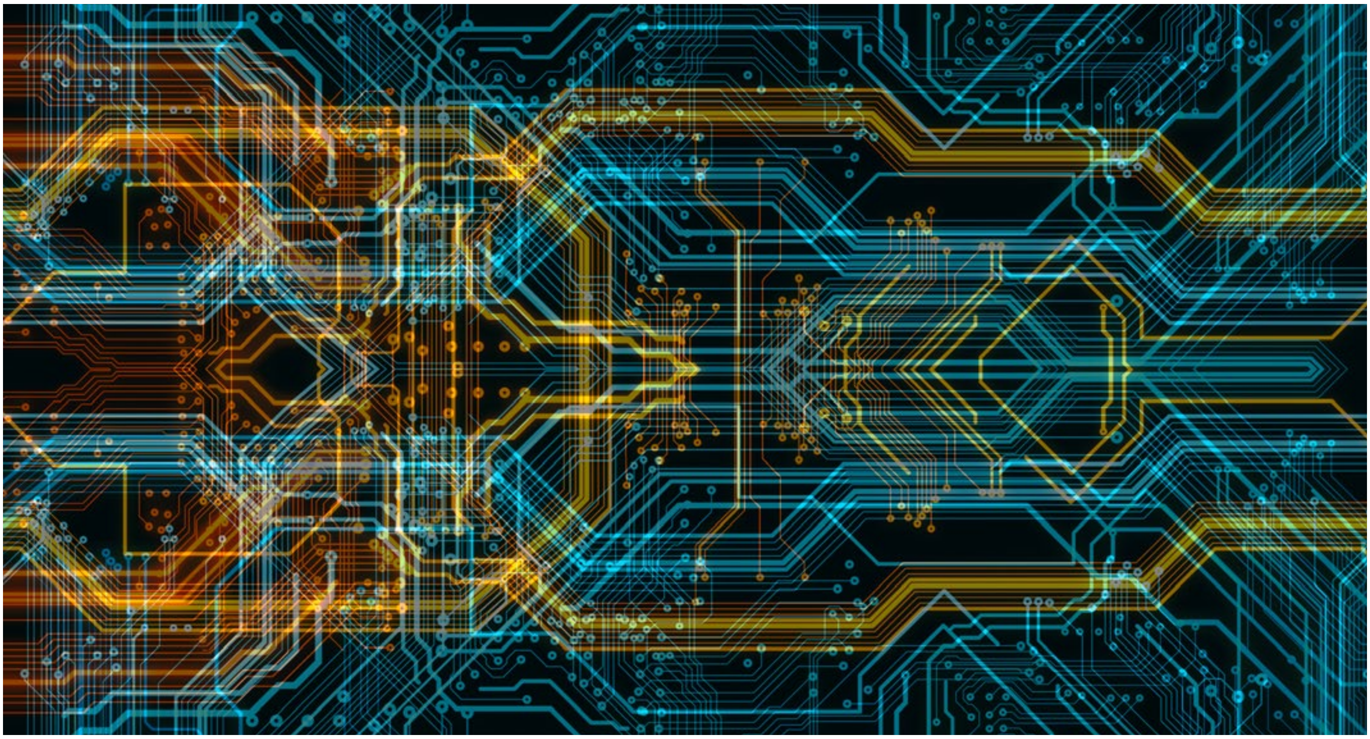

MKS Discusses the Cutting Edge of Technology

Interview by Nolan Johnson
I-CONNECT007

During a recent tour of the MKS facility in Beaverton, Oregon, I met with Todd Templeton, Chris Ryder, Kyle Baker, and Martin Orrick. As a reminder, MKS acquired ESI in 2019 and has retained the ESI brand. In this interview, they explain their approach to HDI and ultra HDI, the current state of base materials, and what the future looks like on the cutting edge of technology.

Nolan Johnson: Todd, what are you seeing in the market and what's happening with your customers? What are the dynamics and what are their pain points?

Todd Templeton: When it comes to HDI, we have seen a big shift in historical spending recently, with a lot more investment into the IC substrate space. In 2019, we introduced the Geode™ drilling system, primarily targeted at the HDI market. Since then, we've heard customers say, "That's great, but what can you do for me over here in IC substrate?" Therefore, we're looking at ABF (Ajinomoto Build-up Film) substrates and investing more heavily to meet customer demand.

Chris Ryder: We're expanding the Geode CO_2 via drilling system into that IC substrate space, and it has turned out to be an excellent modular platform for a broad range of applications. It has worked well in adopting and adapting into various rigid panel products. The Geode via drilling system already has quite a breadth of

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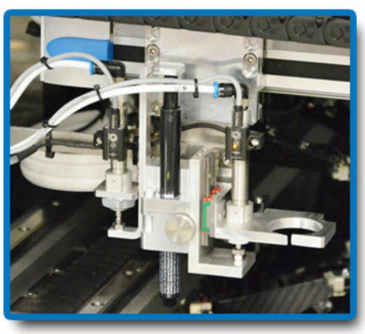

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range from standard commodity HDI products to mSAP and SLP substrates, but these are all copper-clad materials. Hence, we've been evolving and adapting the platform toward an additional ABF-specific configuration for the FCBGA market with a future plan to expand in that market.

To be clear, we already serve some portion of the ABF-based market with the higher end of the Geode via drilling system configurations, but there's effort to focus more specifically on that product range and market segment. As we move forward, we'll certainly be sharing more details.


Chris Ryder

Johnson: Are you finding more willingness to invest uniformly across the globe?

Templeton: Yes, we're seeing it all over. It's not regionally dependent. As Chris was saying, we have a solid platform with our products to address the HDI and mSAP markets, but our customers are saying, "Our investment has increasingly shifted to IC substrate; do you have a solution for me there?" With some minor adjustments to our system architecture, we can have a compelling product in that space. It has been driving some of our development and focus in the rigid panel space. When it comes to flex, we have multiple legs of the stool that support demand for our products.

Johnson: When the pandemic started, you had a good idea that those applications would lead the way. Has that shifted and changed?

Templeton: Has it changed? Primarily, that time was driven by 5G. We were looking to make sure everything had the right components, such as antennas, the bay stations, etc. I don't think that it's shifted much since then.

Ryder: The pandemic created more demand for high-power, high-performance computing, or "HPC." That's certainly been a driver behind the FCBGA and ABF upward trend. Development in this market was there before the pandemic, but the focus has grown and accelerated demand since.

Johnson: As well as the cloud-based data centers, and core streaming content?

Ryder: Yes. Servers, HPC, and data centers have definitely seen growth. There has been an uptick in demand over the last couple of years. On the other hand, our customers have become more thoughtful about which technologies to invest in, as well as the timing of these investments. This has somewhat changed the technology adoption pace of the past decade or so.

Johnson: It would seem to imply it's slowing down and getting conservative.

Ryder: Not necessarily. Manufacturers are looking to react more swiftly to present trends vs. second guessing long-term trends. Our customers, for example, are looking for shorter lead times on our equipment to facilitate more timely decisions on when to execute for product integration, product implementation, and time to market. There have been some areas in the industry where we've succeeded by having a quicker response to those demands. When customers decide to pull the trigger on a project, they can't deal with a one-year lead time for a manufacturing tool. Our agility has been beneficial for us.

Johnson: There are places in the market where it looks like we're on the verge of some aggressive investment from circuit board fabrication into assembly. We learned many lessons regarding over-optimizing the supply chain into China.

Ryder: I see the recent uptick in business and development in Southeast Asia and North America as an ovewhelmingly positive development for our company and my team.

Templeton: The trend has indeed reversed somewhat, where there's more investment in what can be done here in the United States and Europe. Previously that wasn't really a serious option.

Ryder: Our via drilling systems, for example, have found increased relevance for the North American PCB manufacturing market; to be honest, that was not my core focus when we developed the tool. While the technology envelope of the U.S. PCB market differs from the Asian market, there is a renewed focus and regional investment on technology development and we're proud to be a part of that.

> "In the end, it's a question of economics, and the investments required for the high-end space may not yet be completely amenable to the current domestic market for PCB and substrate."
> — Chris Ryder

Johnson: Getting more modular and adaptable is a strength in North America and Europe. Not so much in Asia, where they've optimized on full-blown production. That sets up the ability to do expansion in North America. Are you seeing that?

Ryder: We see indications of it. There has been some indicative investment. We recently announced being named a strategic partner and supplier for TTM, for example. Currently we don't see an expansion boom, but clearly a renewed focus on manufacturing excellence. We'll see where it heads. The CHIPS Act is a step in the right direction, but it's also three or four steps up the supply chain. It starts to address the semiconductor sourcing problem, but it doesn't directly address sourcing of PCBs, substrates, and packaging technology. But perhaps we'll see some domestic investments in these market segments spin off the semiconductor boom.

Johnson: Based on the activity you're seeing, what types of facilities are North American companies investing in? Are there more greenfield opportunities?

Ryder: I don't see many greenfield facilities going up now, but that's not to say there aren't any.

Johnson: So, the companies are modifying and updating existing facilities?

Kyle Baker: Primarily, yes, albeit on a smaller scale than what we typically see from customers in Asia.

Johnson: When you think about the feature sizes and tolerances in HDI, but especially UHDI, there's work that happens in heterogenous integration, making those components and making things fit together. We start to push down into dimension sizes similar to what caused the semiconductor industry to make clean rooms. That's how it would seem to me.

Templeton: We are seeing that the cleanliness and the control within the factory environment is getting more critical, especially for our system. Certainly, as vias and density on the panels go up, that drives tighter tolerances on the system, the environment, temperature control, and humidity control. It all comes into play.

Johnson: As well as the substrate itself.

Ryder: A need for system cleanliness has always been there in the via drilling space, but there are two sides to the coin. There are factors from the shop floor cleanliness, and then those of the system within itself. These are two different requirements. In U.S. PCB manufacturing we're not seeing any current mismatch of cleanliness tolerances. But as features get smaller, there will need to be increased focus on the customer facility side. External factors, such as air quality and temperature integrity, play a big role in the capability of our systems to operate effectively. For our part, we'll need to work closely with current and future customers to ensure that, within and without, we have the optimum conditions to facilitate the miniaturization required.

Todd Templeton

Johnson: It seems like just over the horizon are new facilities with a cleaner environment to specialize in UHDI and HDI.

Ryder: I'm certainly not arguing that there shouldn't be tighter tolerances for higher-end products. In the end, it's a question of economics, and the investments required for the high-end space may not yet be completely amenable to the current domestic market for PCB and substrate.

Johnson: I don't know how different economically it is from semi, but with semi, higher performance is driving most of the factory requirements for PCB, and it's a lower cost product. How do you cut costs? How do you do it at the minimum level and still maintain profitability?

Ryder: To be sure, I think a shift in approach is here, and the answer is partially based in more inter-segment engagement. We're starting to see that the interaction at the system design level, or product design level, is increasing. It's not as easy any more to just say we need a system that can drill X amount of vias—whether it's from a software automation perspective, an actual panel loading perspective, or a product cleanliness product, micro/macro environment—requirements of capacity and quality are starting to intertwine.

There is some sense of co-development required to manufacture more efficiently, sustainably, and cost-effectively.

We're also hearing more about automation requirements.

Templeton: With semi, everything before was moved around manually and they went to FOUPs (front opening universal pods), and FOSBs (front opening shipping box), overhead lifts. That trend is what's coming into PCB, trying to automate panel handler, automate movement between processes.

Johnson: How do you respond to that with your equipment? What are the design concerns that might be shifting to that? Coming into COVID, there was a certain level. We knew we had an issue with staffing, but we have a much more acute issue with staffing on the backside. It does seem to be pushing the manufacturers that I'm talking to toward more automation so that they can take their existing staff and focus them on what they do well. Figuring that out, especially on the PCB fab side, has been particularly tricky. There's one U.S. fab—GreenSource in New Hampshire—that has a full-blown, lights out, straight through process, all the way into lamination. They put together a system that is a fully automated lot size of one. They'll even pump out the chemicals, rinse the tanks, and put in the new set of chemicals for the next board.


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They run in a conveyorized way; they've proven you can do it. It wasn't that huge of an investment, certainly not compared to a semiconductor factory, but nobody's really doing that yet. How does it work with automation and connecting the products to align?

Martin Orrick: The automation challenges we're seeing now are not that much different from pre-COVID. If you look at our equipment and break it into a rigid environment and an FPC environment, it's safe to say that 99.9% of all rigid applications require some level of automation in terms of just lifting panels from an input mechanism, be that a stack, a cassette, stacking panel, or processing with the tool and putting them in the similar output and capacity magazines. There are maybe one or two minor applications in the HDI space where you could potentially do hand load. But they are few and far between.

Martin Orrick

In the FPC side of the business, our tools get sold into various areas. Any of those doing high volume manufacturing, such as FPC for handsets, all tend to run automated, roll-to-roll solutions. They're either on 250- to 260-millimeter-wide webs, or 500- to 520-millimeter-wide webs. Some of the parts they put into production are in such high volumes that with some tools this is the only part that they do; they're just running that entirely. There are also tools in the FPC space that are used in non-roll-to-roll environments. Typically, that's in smaller lots, fast turnaround type applications where automation may not be necessary.

Most of the tools we sell into North America and Europe have been, until recently, automation-less, just manually loaded because they're running small lot sizes. But in general, on the overall FPC side of the business, it's probably 65% to 35% in terms of automated vs. non-automated tools. As we've seen the FPC technology advance, we will probably see more automation in the FPC space.

Johnson: I'm sure there's pressure to find some way to help automate even a high-mix environment. What does that look like?

Ryder: On the rigid panel side, our system is designed to be adapted to just about any automation sequence available. We have good third-party partners that design and build our automation. We have our standard product loaders, and we have different configurations of that. If we have a customer that needs something special, it's a straightforward process to accommodate their specifications.

Some of the trends we're seeing surround automated guided vehicles (AGVs). There are companies that build the AGVs to drive panels between manufacturing processes. It's very easy for us to design a port for the panels to drive into our systems for processing. You just need to have a system that has a flexible design concept, load/unload ports on the side, and then you need the software protocols that can manage the handshake between various loading schemes.

Orrick: Our systems have always been designed with automation capability. Standards for electrical interfaces, mechanical interfaces, and software interfaces have always been part of the protocols that we willingly shared with third-party providers. Because the major trends are being driven by the big fabricators, we work with these companies on automation solutions and everything else will work itself out.

Johnson: How do you move toward a turnkey solution?

Templeton: We're at a critical point in a larger process of asking, "Who are the right people to enable this? How do we connect? How do we make this happen?" But I see MKS being able to come in with a more comprehensive solution, asking, "What does your end-product need to look like?"

Johnson: Where do you see your product heading? What are you aiming toward?

Ryder: There are some really interesting base material developments going on. I know Martin works very closely with various technical alliances and consortia that span the whole spectrum from glass to highly engineered resin systems or non-clad materials and ceramics. You never quite know what concept will latch onto a product and demand a specific material, but clearly we have our eyes on all the trending materials and products. In addition, we recently closed the acquisition of Atotech, a global leader in process chemicals, equipment, software, and services for printed circuit boards, semiconductor IC packaging, and surface finishing. The combination of MKS and Atotech is expected to broaden capabilities to drive faster, better solutions for customers. We believe the combined expertise of MKS and Atotech should uniquely position MKS to Optimize the Interconnect℠, a significant enabling point of next-generation advanced electronics that represents the next frontier for miniaturization and complexity.

Moreover, we're seeing the lines between PCB and IC substrate manufacturing processes blur. Materials, chemistries, and design rules become intertwined, and your ability to adapt to these changes dictates your chance of success. So, we'll continue to develop our laser/material expertise along with our system's capabilities to manage general miniaturization trends.

Johnson: What drives new materials?

Orrick: Take 5G, for instance. Now you're moving frequency ranges that the base materials weren't working in before. Maybe you were working in something in the 3–4 GHz range and that's moved up to sub-6 GHz now. Again, millimeter wave moves up into the 20 to 40 GHz band. Previously, automotive radar was in the 30 GHz range, then moved up to 77 GHz. Now it's looking to the north of 100 GHz for improved performance. If you look at high-performance computing and increasing bandwidths, you need high-speed, low-loss materials. We've really seen that play across a big space of the industry.

> "Take 5G, for instance. Now you're moving frequency ranges that the base materials weren't working in before."
> — Martin Orrick

In the FC-BGA substrates for the HPC environment, we see the traditional ABF range of materials going into thinner materials, modifying the base materials to get the Dk and Df properties where they need to be. LCP has been a material used for 20 to 30 years. It's a well understood material, but it was just never cost-effective to put into large volume applications. It was implemented into mobile, and it hasn't necessarily become significantly more cost-effective, but putting it into a higher range of applications certainly helps increase the volume, and therefore bring down the price. We'll see more fluoropolymers in the next few years in high-frequency applications. There are a lot of the technologies already being developed, it's just been restricted to low volume avionics or military.

Johnson: Great. I appreciate the tour, gentlemen. Thanks for your time.

Orrick: Thanks. Good to meet you. PCB007

3D Electronic Devices With Additive Manufacturing

Feature Article by Shavi Spinzi
NANO DIMENSION

Imagine fabricating PCBs without the hassle of drilled vias and metal plating. Imagine PCBs with near-perfect registration. If we take it to the next stage, imagine drawing electronics in 3D space.

There is a way to do all this with additively manufactured electronics (AME). We just need to start to think in 3D. This will allow us to abandon the 2D limitations that we have become so used to and expand our horizons so that we can climb to higher levels of performance.

In this article, I will explore the two fundamental capabilities that are the cornerstones for drawing electronics in 3D space, which is where AME technology and 3D design capabilities converge.

The First Cornerstone of AME: Isolation and Conductive Materials

More than a decade ago, we saw the rise of printed electronics (PE), which is printing of conductive traces on a predefined substrate. The substrate is fixed, can be planar or a 3D shape and the printing process—either inkjet, aerosol jetting, or any other method—places the conductor on top of it.

AME differs from PE because it uses more than one material. The simplest configuration for AME consists of two materials: one conductive and one isolation/dielectric. It has the potential to grow to more than two materials by adding combinations of different conductive and isolation materials as well as sacrificial materials to build channels and different complex structures.

Why Do We Need 3D PCB Structures?

The first stage of AME was to imitate traditional PCB 2D structures by building multilayer boards (MLB), plated through-holes (PTH), and microvias to prove that AME can replace "traditional" PCB processes. It cer-

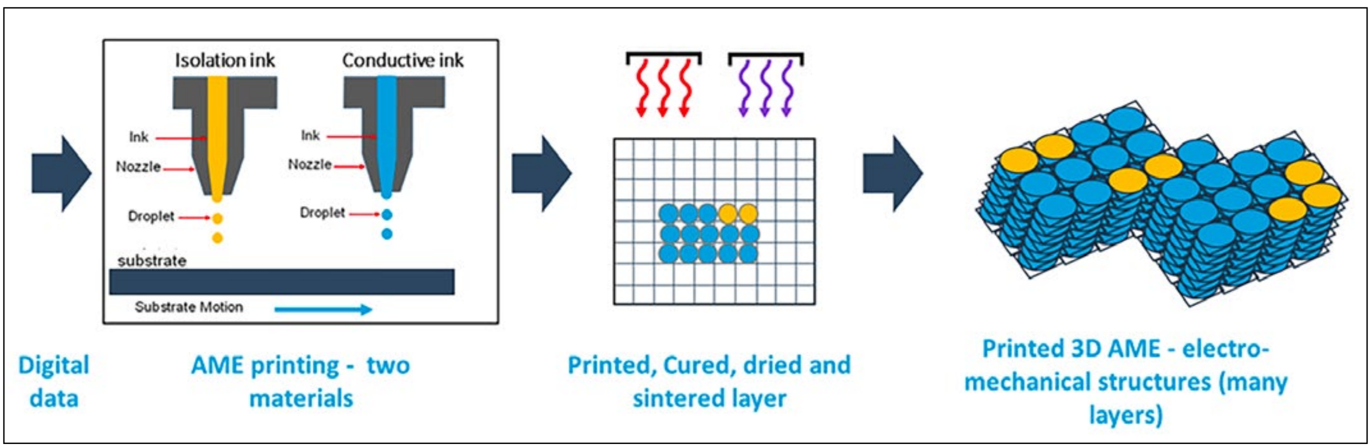

Figure 1: One of the advantages of the AME printing process is the ability to build complex 3D parts combined as conductive electronics and isolation structures, all performed in one print session.

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tainly is doable, but it does not achieve the full potential and capabilities of 3D AME. Let's review the following three examples:

1. In PCB traditional processes, the more layers required, the more complex and expensive the PCB, and the longer the lead time. In AME, there is no additional cost to add layers; in fact, there is no limitation on the number of layers. The real question is, "Do we need to continue to work in finite layer structures?"

2. PTH is a lengthy and high-cost process that requires drilling, plating, etching, and waste treatment. It is sensitive to registration between layers, and as we increase the layer count, layer registration becomes more difficult. In AME, there are almost no registration issues. The entire process is done by one tool with one printing process. The results are near-perfect registration with negligible registration error, and with mechanical repeatability of the same tool. If we do not require the insertions of pins in the PTH, AME can re-create electronic parts at the same cost and time with stacked filled VIPPO (via-in-pad plated over), and/or staggered.

3. Microvia manufacturing is the most expensive process. It is composed of laser drilling combined with via plating, cleaning, and in many cases even via conductive-resin filling. In AME, there is no extra cost of building conductive filled vias. Actually, the AME process builds pillars between layers that represent the via connection. This is all achieved during the same printing process, with no need to change tools to do drilling. Registration is close to perfect.

Traditional Drilling and Plating: The Most Expensive Processes

The combination of layer registration, drilling, and plating processes can lead to dramatic yield reduction during PCB manufacturing. These processes are complicated and represent the highest CapEx investment in annual PCB CapEx spend. The industry average CapEx of drilling and plating represents over 32% of total PCB CapEx. As technology becomes more complex and denser, this ratio is even higher. AME does not require drilling, board lamination, plating, and many other wet processes.

Current PCB Traditional VIA Technology vs. AME 3DT Alternative

As the amount of drilling increases (mechanical or laser), the higher the cost and the longer the lead time is required to complete the PCB orders.

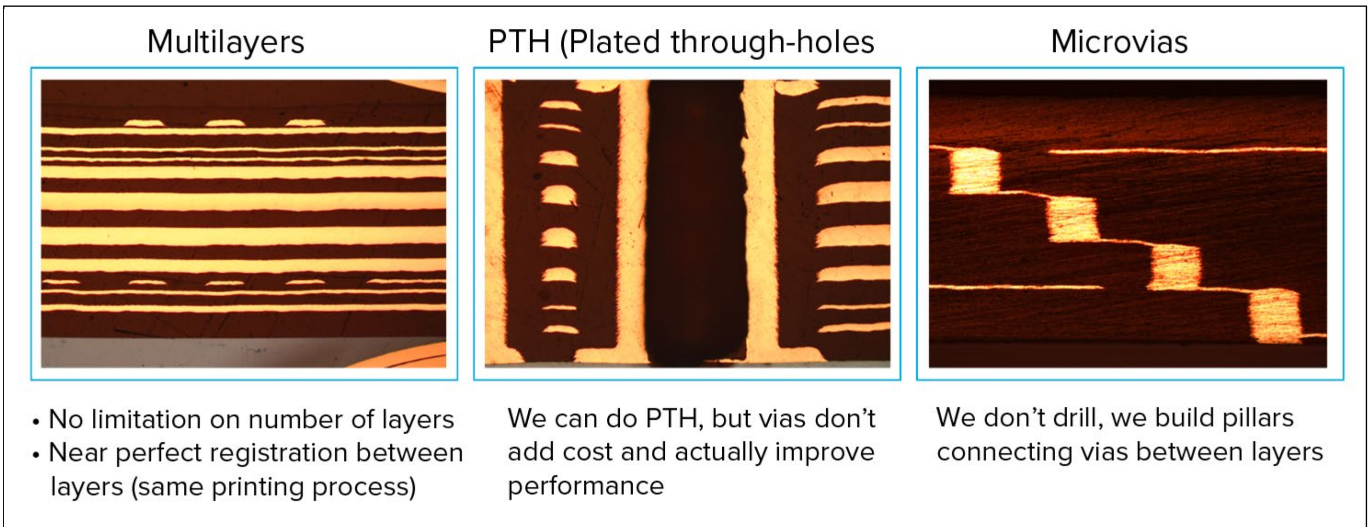


Figure 2: Microsections illustrating how AME can create simple and complex 3D PCB designs.

Category ($M)	Equipment	Key Suppliers	2019		2020		Growth
Imaging	DI, exposure system	ORC (JP), Orbotech (IL), ADTEC (JP), SCREEN (JP)	$510	10.4%	$700	11.0%	37.3%
Inspection	AOI, AVI	Orbotech (IL), Machvision (TW), Shirai (JP), GigaVis (KR)	$140	2.8%	$190	3.0%	35.7%
Drilling	Mechanical, laser drilling machine	Schmoll (DE), Mitsubishi (JP), Via Mechanics (JP), Han's (CN)	$970	19.7%	$1,260	19.7%	29.9%
Plating	Electroless, electrolytic copper plating line	ALMEX (JP), Atotech (DE), PAL (HK), AEL (TW)	$610	12.4%	$790	12.4%	29.5%
Lamination	Laminating press, roll laminator	Kitagawa (JP), Burkle (DE), TMP (US), LCM (TW)	$290	5.9%	$370	5.8%	27.6%
Wet Process	Developer, etcher, stripper (DES)	SCHMID (DE), AMPOC (TW), Songtex (TW)	$240	4.9%	$310	4.9%	29.2%
Automation	Loader, unloader, robotic, material handling and transport, AGV	SAA (TW), Kuttler (DE), Yokogawa (JP), Protek (CN)	$410	8.3%	$540	8.5%	31.7%
Testing	Electrical tester (bed-of-nail, universal, flying probe)	Nidec Read (JP), atg (DE), Hioki (JP) Surpass (CN)	$240	4.9%	$310	4.9%	29.2%
Others	Photoresist laminator, surface finishing, router, screen printer, desmear, black oxide		$1,500	30.5%	$1,910	29.9%	27.3%
		Total	*$4,920*	*100%*	*$6,380*	*100%*	*29.7%*

32%

Source: Prismark 2021

Figure 3: PCB equipment spending. (Courtesy of Primark 2021)

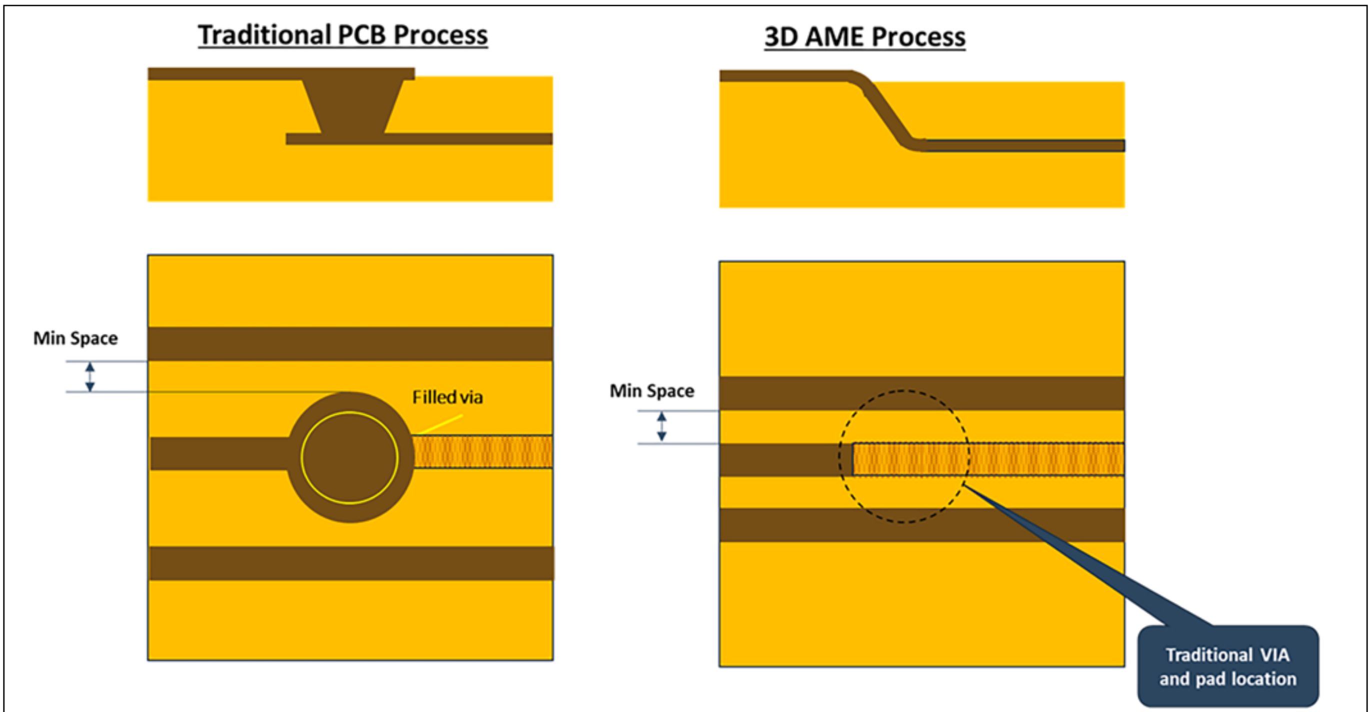


Figure 4: 3D AME: New capabilities—higher density by replacing vias with ZDT interconnect.

Drilling processes involve many technological considerations in the level of board design. For example, landing pads/capture pads are required. Those pads are placed to overcome the misalignment and tolerances of the PCB process, but the consequences of adding those pads is that they occupy a significant amount of PCB "real estate."

In addition, the via structure is a source of parasitic impedance mismatching. They differ in their final geometries, and it is difficult to consistently predict their high-frequency performance.

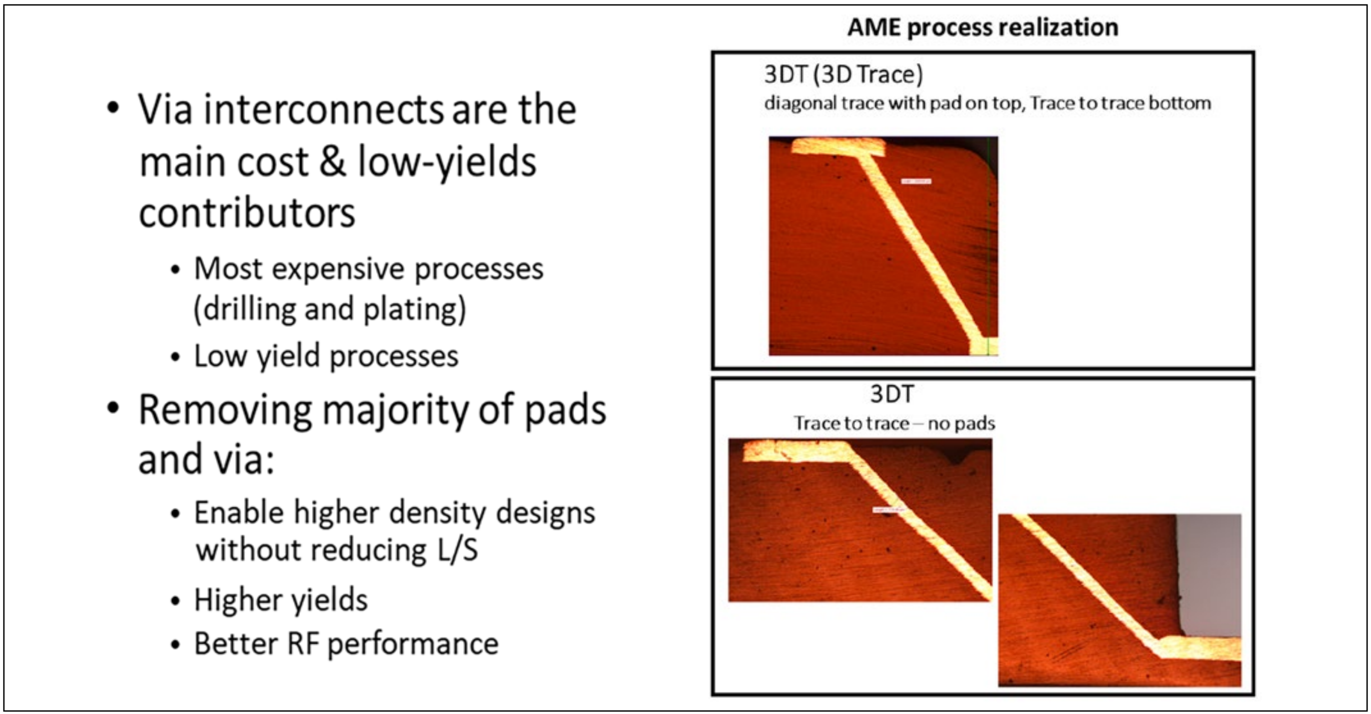
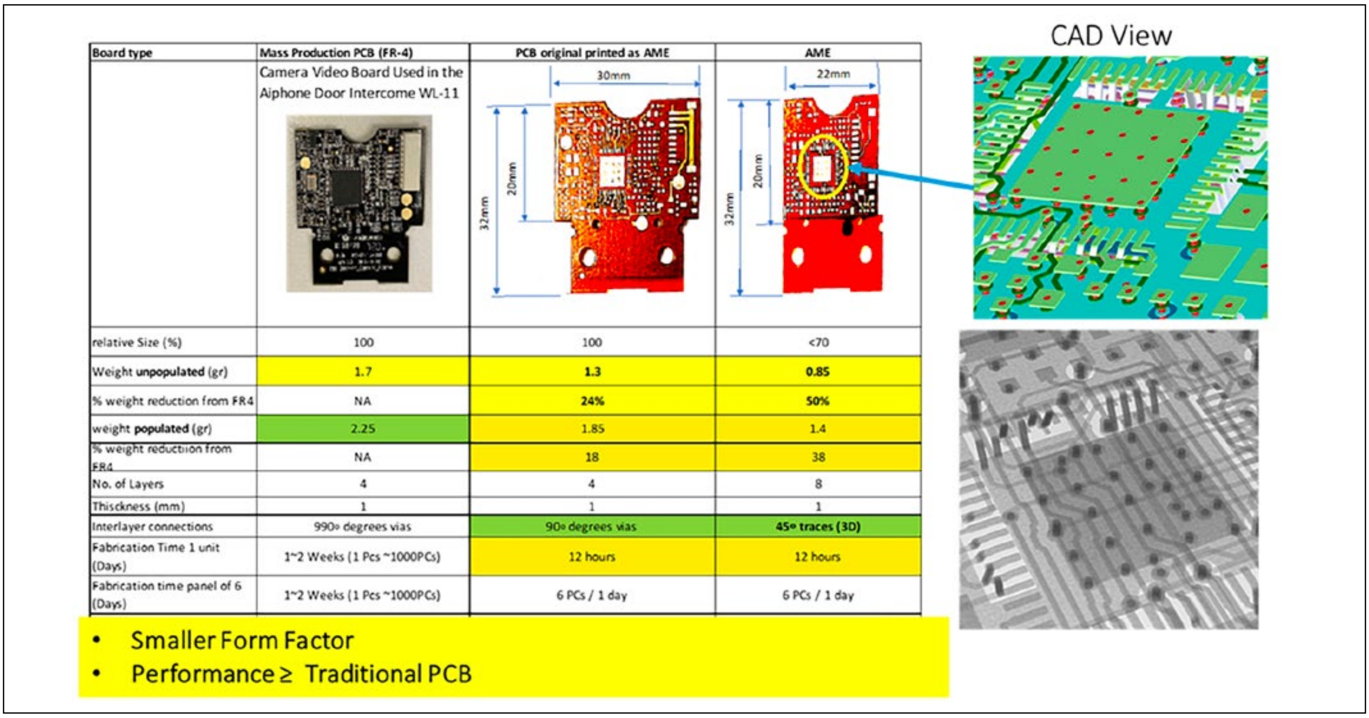


Figure 5: Different 3D AME diagonal interconnect (3DT) instead of PCB traditional via.

AME allows us to remove the via and to make a continuous connection between layers. We call it 3DT (3D trace). It does not require the extra real estate of landing/capture pads, and its high-frequency performance is noticeably superior.

Replacing Vias With 3DTs

We took an existing video board design; at the first stage we built it as-is but using AME design. At the second stage we converted the vias with 3DTs and we achieved a 30% reduction in size and better electrical performance.



Board type	Mass Production PCB (FR-4)	PCB original printed as AME	AME
	Camera Video Board Used in the Aiphone Door Intercome WL-11		
relative Size (%)	100	100	<70
Weight **unpopulated** (gr)	1.7	**1.3**	**0.85**
% weight reduction from FR4	NA	**24%**	**50%**
weight **populated** (gr)	2.25	1.85	1.4
% weight reduction from FR4	NA	18	38
No. of Layers	4	4	8
Thisckness (mm)	1	1	1
Interlayer connections	990º degrees vias	90º degrees vias	**45º traces (3D)**
Fabrication Time 1 unit (Days)	1~2 Weeks (1 Pcs ~1000PCs)	12 hours	12 hours
Fabrication time panel of 6 (Days)	1~2 Weeks (1 Pcs ~1000PCs)	6 PCs / 1 day	6 PCs / 1 day

Figure 6: Example showing how converting traditional via to 3D AME 3DT reduces PCB size by 30%.

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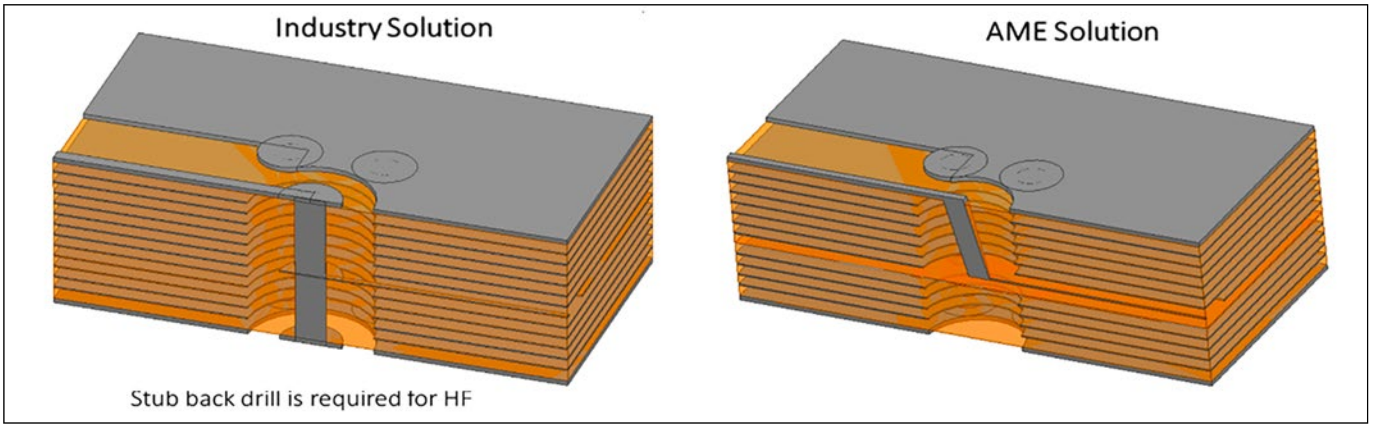


Figure 7: Comparison illustrating the conversion of a traditional via connection to 3DT.

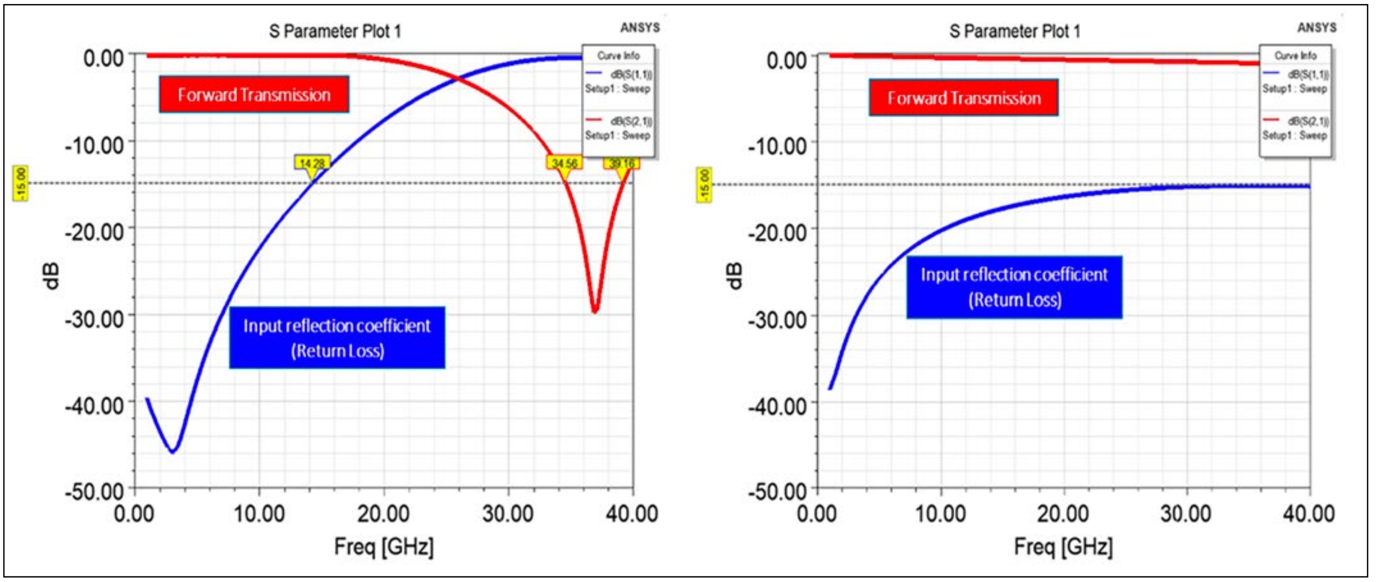


Figure 8: PCB with 4 GND via vs. AME 3DT diagonal trace implementation leads to better S11 and S21, input reflection and forward transmission.

3DT high-frequency properties show tremendous advantages over drilled/via-based routed PCB designs. We compared the RF performance of traditional via structure vs. a 3DT structure.

We received significantly better S11 and S21 performance with AME 3DT configuration (Figure 8).

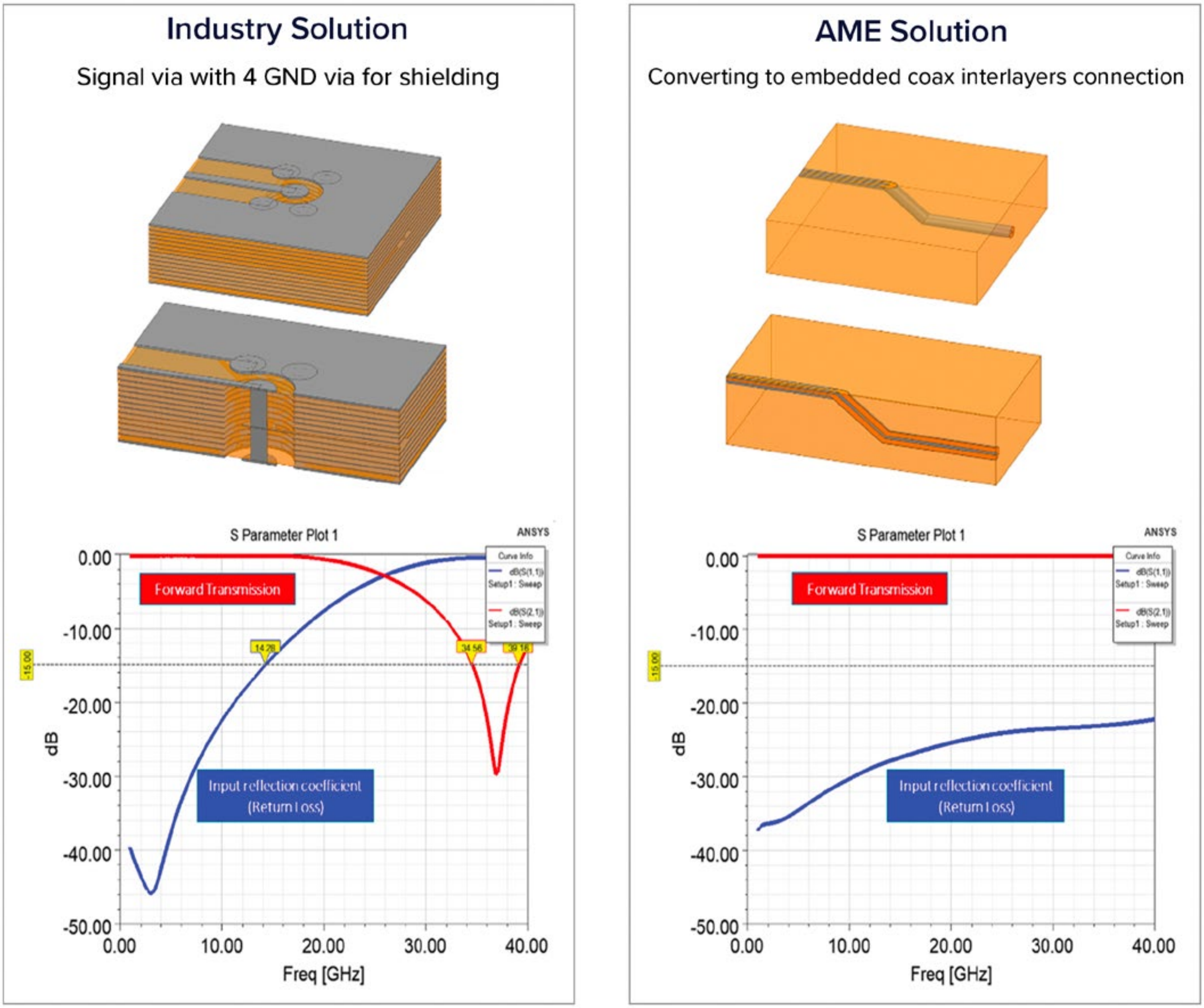
We took it to the next stage, and we converted the 3DT to an AME coax, which can be built as part of the structure printing process instead of the via in traditional PCB process. As a result, the high-frequency performance was much better than traditional via performance.

3D Electronic Devices Enabled by AME

3D AME enables designers to build different form factors for electronic devices and to fit them to the required mechanical device in a more appropriate way.

It also enables one print process of complex, 3D structures where conventional PCB production requires many stages and might even be impossible.

This example is taking 3D AME to new levels of complete 3D devices with better performance, embedded components and shielding. It created a new form factor with stronger mechanical properties.



Figures 9 and 10: Superior high-frequency performance of 3D AME with coax vs. traditional vias.

The Second Cornerstone for 3D AME: 3D Design Tools

How can you design 3D electronic devices? Today, ECAD and MCAD are two parallel processes, often with limited or no integration between them. Current ECAD design systems need to have critical new 3D capabilities to enable smooth 3D designs.

Future CAD systems need to have common/integrated ECAD and MCAD capabilities for 3D electro-mechanical CAD design (3D AME capabilities). They should be able to deliver accurate 3D AME simulation of 3D electronic structures. Components such as 3DT, printed coils, capacitors, and other 3D electronics need to be part of the 3D electronic simulation.

3D Industry Initiatives

There are several initiatives in the industry, including two developments by Cadence/Dassault Systems and by Siemens EDA. There are other CAD systems vendors that are working on bringing the 3D editing capabilities for AME, but it may take some time to for this to develop. Therefore, Nano Dimension has introduced its own software suite, FLIGHT, which enables 3D AME design capabilities through the integration of ECAD and MCAD systems.

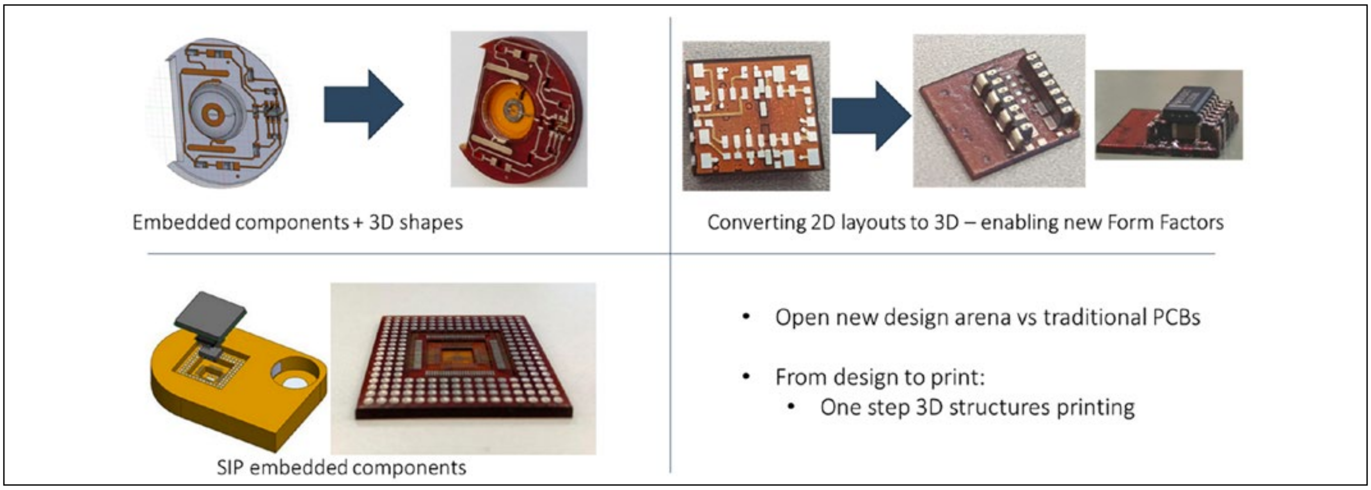


Figure 11: 3D structures with cavities and embedded components.

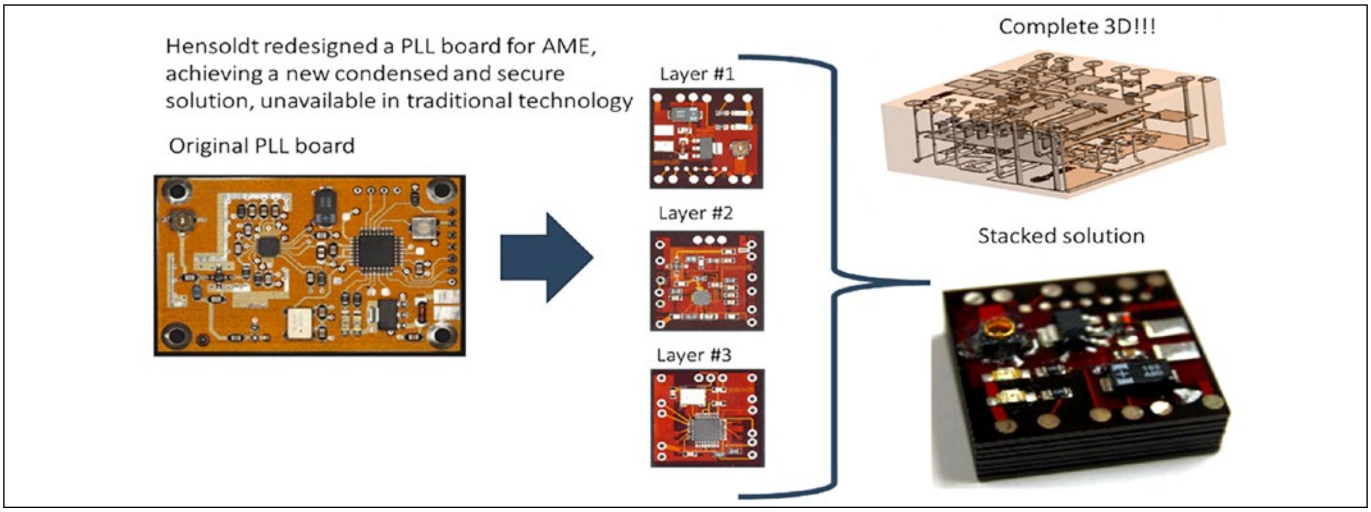


Figure 12: Complete 3D design with AME, with no layers or interconnect structures.

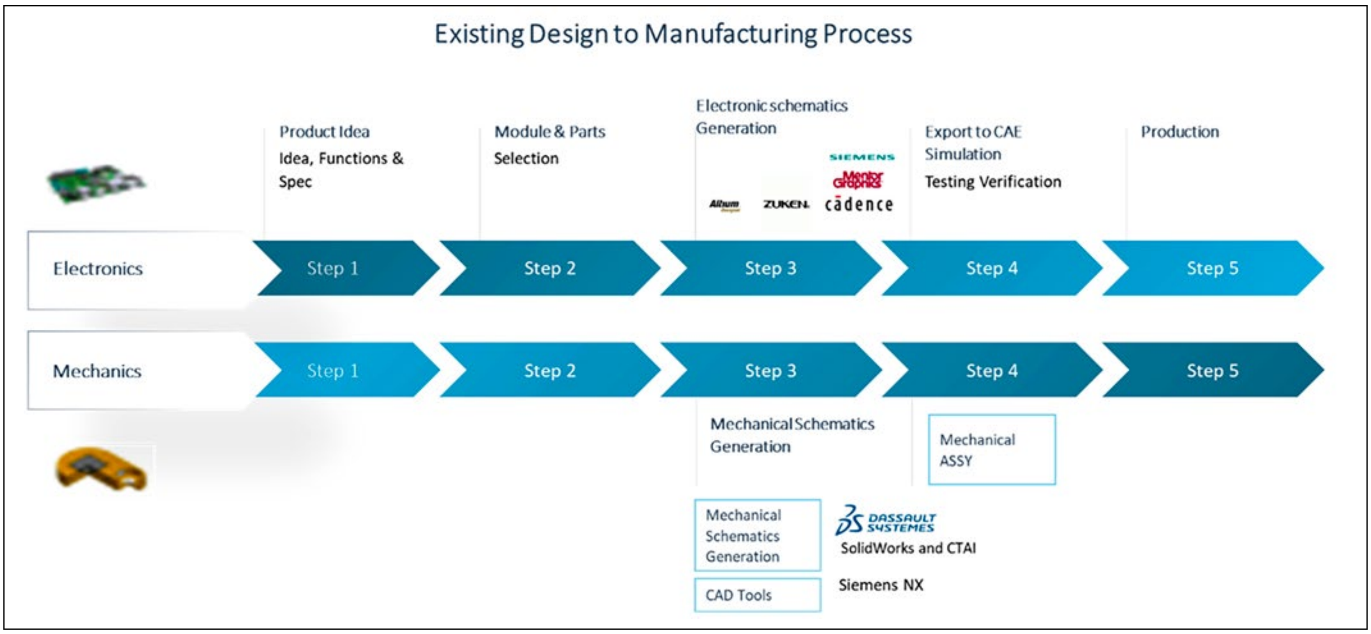


Figure 13: Existing ECAD and MCAD systems have no or limited connection between them.

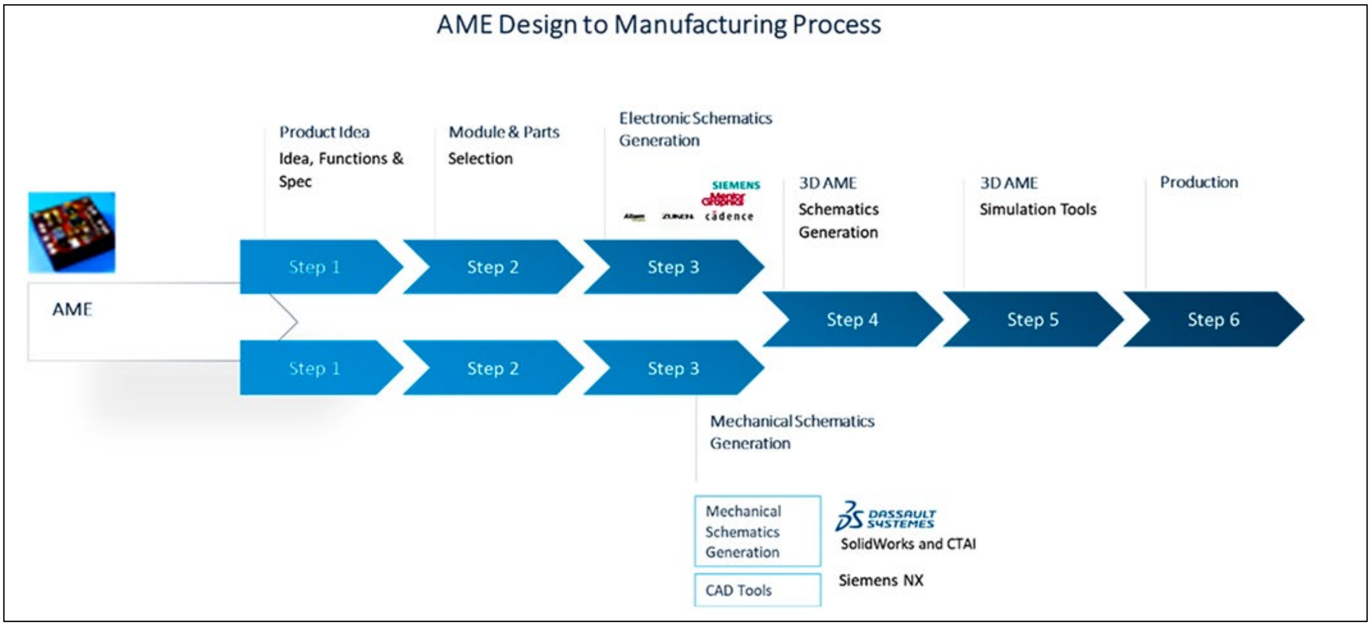


Figure 14: Integrated systems utilize the power of 3D design.

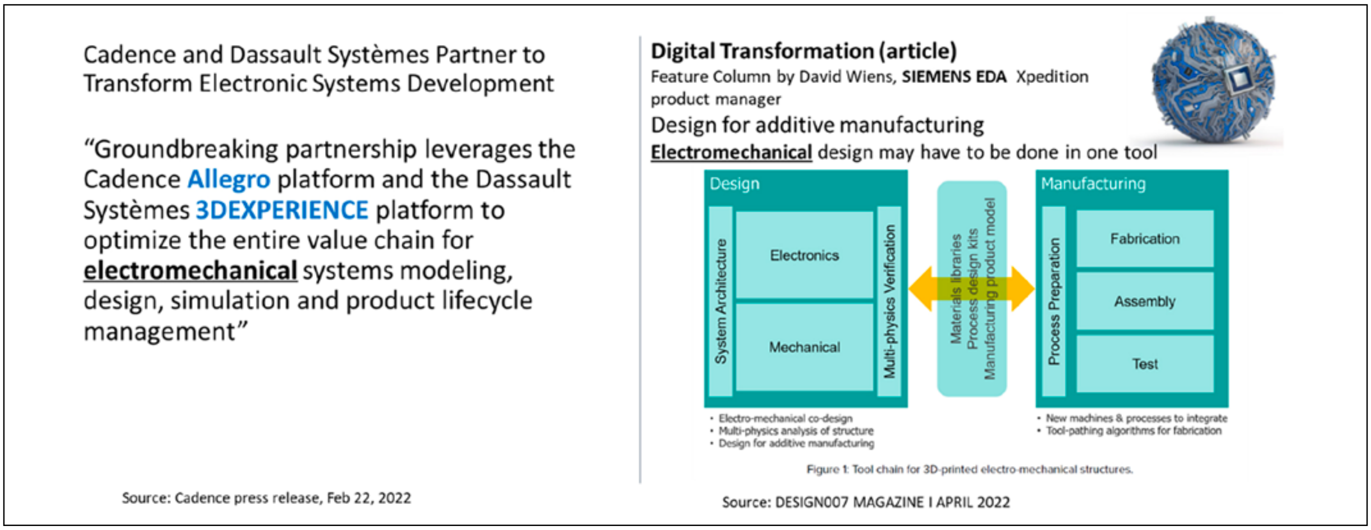


Figure 15: Industry initiatives toward 3D AME designs.

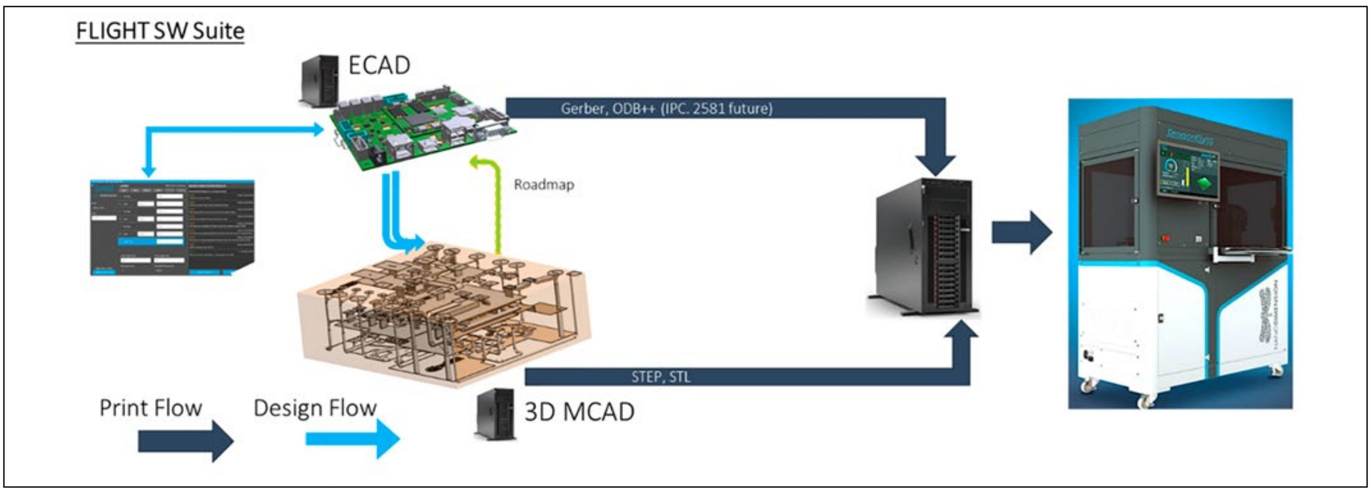


Figure 16: FLIGHT Software Suite will enable 3D AME designs today.

Summary

We reviewed two main cornerstones for 3D AME applications: The first is combined isolation and conductive materials which are the building blocks for 3D structures printing technology, and the second is 3D design CAD systems.

AME enables new capabilities in the integration of electro-mechanical designs. It allows designers to print embedded components such as coils, capacitors, coax interconnects and others. High-frequency performance is enhanced versus traditional processess, with better impedance control and accuracy.

On the mechanical structures, it reduces many complex stages into one print session, compared to traditional multi-stage PCB and other electronic devices.

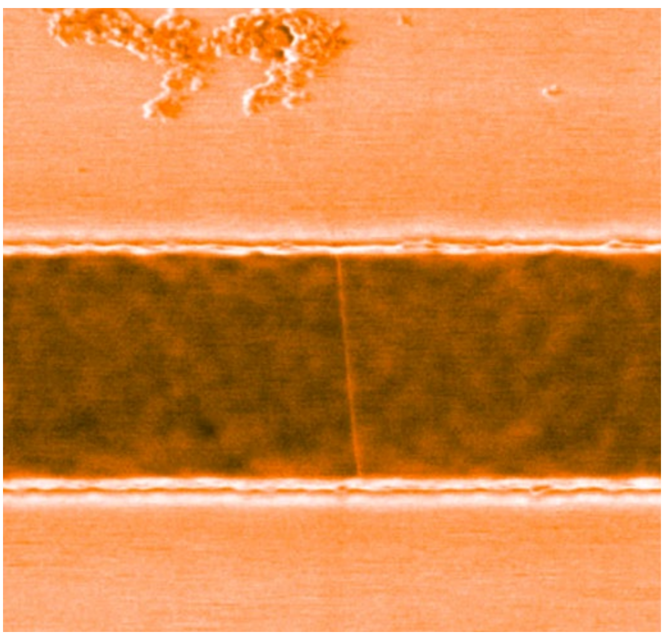
We explored the advantages of removing vias from electronic devices which enabled denser devices using the same trace width while enabling significantly better RF performance.

While we see the need for more complex electronics growing, as well as the need to get sophisticated designs implemented faster, 3D AME is undoubtedly the direction in which the electronics industry is headed. **PCB007**

Shavi Spinzi is VP of PCB technologies at Nano Dimension.

A Cleaner, Better Way to Produce Single-photon Emitters

Quantum technologies are on the verge of revolutionizing computing and communications, promising benefits such as secure communication, ultrasensitive sensing and parallel computing. Many of these applications require light sources that can generate single photons on demand. A promising source of single photons in the infrared wavelength range used in telecommunications is carbon nanotubes—cylinders of graphene sheets that are a mere nanometer or so in diameter—that have been imparted with new functions, or functionalized, by adding an organic molecule.



Now, Kato and Daichi Kozawa, also of Riken Center for Advanced Photonics (RAP), and their coworkers have developed a method for functionalizing carbon nanotubes that can be done in the vapor phase, and hence on nanotubes suspended across a trench in a silicon substrate.

The study was a collaboration born out of a prepandemic interaction at an international conference. Kato and Kozawa's team at RAP produced the suspended nanotubes and then sent them to chemists in the University of Maryland in the United States for functionalization, who then sent them back for analysis.

The team now intends to optimize the functionalization process so that just one organic molecule is introduced per nanotube.

(Source: Riken)

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A Day in the Life of a Process Engineer

The New Chapter

by **Paige Fiet**, TTM-LOGAN

College students often ask me what a day in the life of a process engineer entails. While each day is vastly different than the last, here is a "typical" day in the life of a process engineer in the PCB manufacturing industry.

7:45–8:30 a.m.

My day begins with a giant tumbler of black coffee. My morning ritual includes checking emails, following up on previous shifts' daily logs, and reviewing the previous day's quality and throughput reports. From there, I begin my action item list. I will write down any concerns from the shift logs, emails that need to be responded to, and any jobs that need to be reviewed for poor yields. On Monday mornings, this time will include creating a chart for my department of the previous week's defects and ways we can work to improve the top defects.

8:30–10:00 a.m.

My coffee has now been completed with the first wave of emails for the day. Time to check in with my department. With 10 processes and over 50 operators, my department is one of the largest at TTM-Logan. So, with my action list in hand, I will walk through each of the processes in chronological order. At each stop along the way, I ask the operators how things are going, verify the machine settings, answer any questions, and review any jobs that are on hold for engineering review. If a machine is down or a new tool is needed, it will be added to the action list for the day.

10:00–11:00 a.m.

Wow, the morning is flying by. At this point, I am getting a start on my to-do list. Typically, this involves answering questions about manufacturing for my front-end department, ordering new materials for the solder mask department, and/or checking in with the quality team on their audits of my department. Occasionally, this time is spent meeting with other process engineers at the Logan facility to discuss interdepartmental issues and brainstorm solutions to the problem(s). Other times, I am on a bi-weekly call with a fellow solder mask engi-

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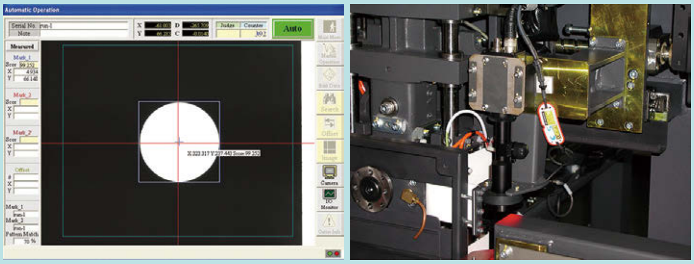

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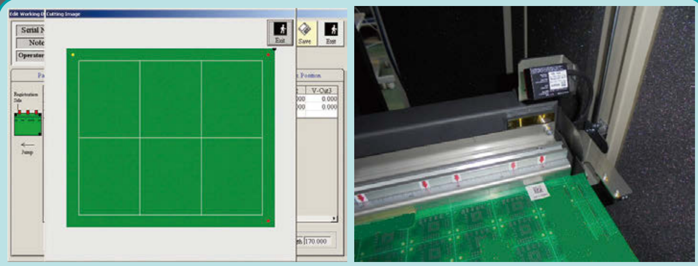

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neer at another facility discussing best practices and ways to help the other site improve.

11:00 a.m.–Noon

Now that things have quieted down (for now), I begin working on a long-term research project to test machine capabilities. I will typically meet with a senior front-end engineer to bring my test vehicle design to life. We discuss the purpose of the test along with what materials might be best to use. Once the panels are created, this time will be used to process them through my department. I will change the necessary settings and document as many variables as possible for later data analyzation.

Noon–1:00 p.m.

Lunch time! Sometimes I will head out for burgers with coworkers but most of the time you can find me at home enjoying lunch with my cat.

1:00–1:30 p.m.

Back in the office and I'm heading straight to my department. This time it's a quicker run-through to answer any new questions, make processing decisions, and confirm proper completion on any maintenance.

1:30–2:30 p.m.

Time to meet with the solder mask department leaders. Every other week, we meet to discuss quality trends, improvement plans, and production complaints.

2:30–3:00 p.m.

Day shift is now done, and swing shift is starting their workday. I head down to the department and join them for their start-of-shift stretching session. While they stretch, we review the previous day's quality and throughput. Again, if it's a Monday, we will review the prior week's quality concerns.

3:00–4:30 p.m.

Back to my research project. If need be, I will review my progress with the department's

technician and ask for help in furthering my testing. If the test vehicles are ready for analysis, I will review the designated points under various microscopes and will typically take my own cross-sections for further review. Next begins the analysis. All data and images will be recorded and analyzed based on my previous test plan. Once these are understood, they will drive changes to the manufacturing capability and processing of parts.

4:30–5:00 p.m.

After one last quick walk-through in the department, it is time to answer any unread emails and start a to-do list for the next day.

Of course, there is no typical day in PCB manufacturing. Although ideal, this timeline is not always accurate. Some days involve hours of hands-on work with machines and digging into root causes. Other days, I am at my desk updating processes and creating temporary process instructions to test a new process. One week may be spent visiting another facility to learn about their processing while the next may include working with suppliers to install new equipment. I've come to love the unpredictability of the job. Each day brings its own challenges and excitement. PCB007

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

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ICAPE: Staying on Top During 'Interesting' Times

Interview by Nolan Johnson
I-CONNECT007

We recently met with Nathan Martin, group purchasing director, and Jean-Christophe Miralles, supply chain director for Europe and U.S. at ICAPE Group. This wide-ranging conversation dug into market drivers, supply chain challenges, and how ICAPE Group creates consistency on its manufacturing floor.

Complementing the supply chain control is ICAPE Group's engineering expertise, which it uses to increase customer yields and quality. Corporate sustainability is a key strategic initiative for ICAPE Group, and it was enlightening to learn just how holistic their approach to sustainability is.

Nolan Johnson: It seems that you can't be in this market right now without encountering interesting dynamics. What is the point of view at ICAPE Group?

Nathan Martin: There is so much we can talk about. We follow general trends, read industry reports like Prismark, as well as all the daily reviews online and offline about the market. But we have our own truths at ICAPE Group because we are in the machine, and it's a little different than what you might read or see on the news.

Johnson: Let's start with inbound materials, meaning laminate, chemistries, etc. How is the supply chain in your fabrication facilities? What are you seeing on the market as far as availability or new products?

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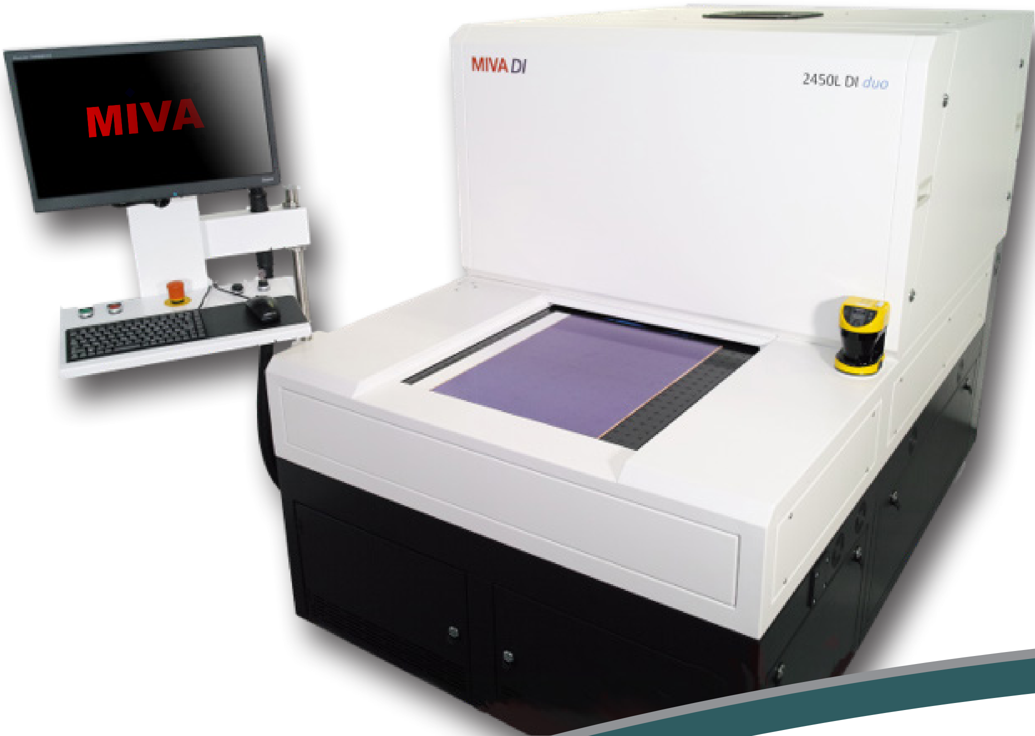

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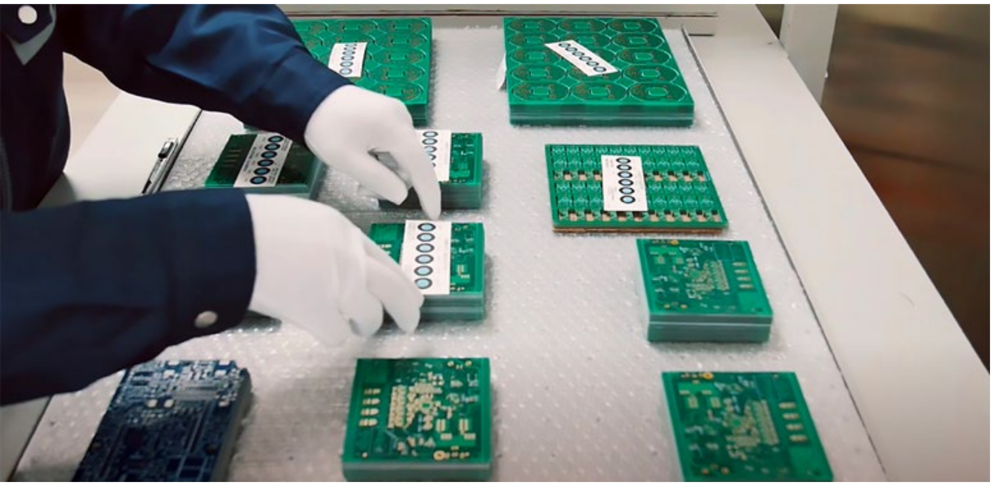


Our increases are due to specific investments and our IPO because we became a listed company in Paris in July. We did some M&As this year, but to be honest, the market in the second half is not as good as the first half.

Jean-Christophe Miralles: This is mainly because there was a pre-pandemic vs. a pandemic period where people were stocking up. Prices went up, but we have direct contact with the laminate producers, which are the suppliers of our partner factories. It's a very interesting insight for us. Today, demand is declining because companies still have inventory and therefore don't order as much, but demand will come back. In terms of revenue, it's still good, but in terms of quantities, not as much.

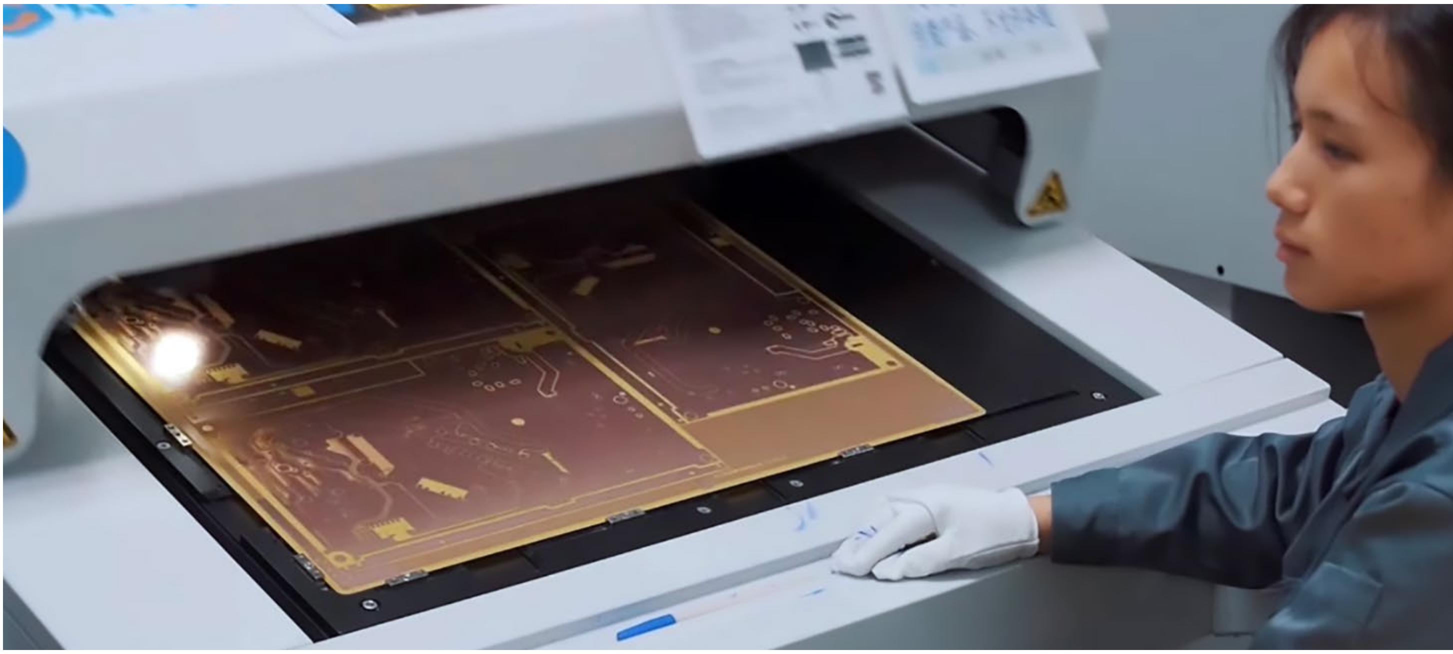
Martin: As a purchasing guy, no matter what the topic is, the key is to look at supply and demand. There is a cycle in every single industry. At some point, you have a crisis. Let's say we go back to the pre-pandemic status and look at what we do on a daily basis. I monitor our RFQs internally—what we get from the customer—as this demonstrates what a PCB or copper-clad laminate manufacturer would receive. That is the kind of monitoring we do. Right now, the situation is back to pre-pandemic status. There is no crazy shortage of copper-clad laminate. Everything is available, and the price is more or less back to what it was.

You can disregard other factors such as the increase in copper, because there is always demand and supply, and China creates such huge production facilities. If you look at Prismark, you see that H2 is not as good as H1. They need to sell everything now when the demand is a little less than what it was, then it's easier for us to access.

Johnson: That's good for the supply side now. But is customer demand for product down?

Martin: If you look at the overall data from industry reports, it's increasing, but ICAPE Group's percentage is higher than the forecast in those reports. If you look at the first half of 2022 compared to the first half of 2021, ICAPE's sales revenues as a group increased by 51%. That's not what is happening in the market.

Martin: Every company should be interested in the book-to-bill ratio. For us this ratio is excellent. Why? Because last year we had crazy shortages everywhere. People got scared and stocked up. Once they had stock, they placed fewer orders. Now, everyone says, "Ah, fewer orders." We reply, "Yes, because you just got these blanket orders for 12 months in the last year at the end of the year." That's what happened. But everything is a cycle, like when you are driving on a highway, someone slams on



the brakes, and the guy behind them slams on the brakes a little bit more, and so on, and you have this chain reaction. That's exactly what is happening here.

Johnson: It's not that it's a boom-or-bust situation in our industry. How are laminate prices trending?

Martin: Six years ago, I had just arrived in China, and we received this first notice of shortage from one supplier, and then the second, the third, and the fourth. I decided to contact the copper-clad laminate manufacturers directly; we contacted the top executives of the major laminate manufacturers in China and Taiwan.

We started talking to the suppliers of our partner factories to see what was happening. Since then, we have had clear monitoring of what's going on in terms of pricing. Today, it is back to pre-pandemic level. I wouldn't say it's stable, but it's back to pre-pandemic level.

Johnson: So, the drivers for unstable pricing are fluctuating demand, rather than their supply chain?

Martin: Yes, indeed. People will tell you that it's only related to copper. In fact, if you look at the standard 1.6-millimeter thickness, like any PCB copper-clad laminate, the real impact will be the resin, but they will move the price up and down based on demand. We monitor all the data we can on a listed company and even an unlisted company; we see the results, sales turnover, margin, etc. We have been doing these analyses for all the PCB and laminate manufacturers for a few years.

Two years ago, it started going up like crazy and the profits from those copper-clad laminate manufacturers exploded. Multiply it by 10. Now they have gone back to a more normal way of making money, so right now, it's really demand and supply. It goes up every year, but it's fixed.

Miralles: It's mainly demand because capacity is stable, but there are some industries where demand is decreasing. For example, for PCs or smartphones, the demand is weakening, so the supply is higher than the demand. That's why prices are also falling a little bit.

Johnson: How has this affected your approved vendor list (AVL)?

Martin: The AVL is the most important document. The president of ICAPE Group used to


Nathan Martin

call it a bible. It's the document that enables us to realize short, medium, and long-term strategies. So, with the structure of an AVL, you can basically understand the strategy of a company.

Johnson: You manage your strategies with the AVL; what's the long-term strategy? How do you build those relationships? What are your improvement plans?

Martin: We do not reveal the AVL, but you can find all the top partner factories of the group in the AVL. It's very simple: We do not find these partners out of the blue. All these partner factories have been in the AVL for more than a decade, and in some of the cases, two decades; we always have this target to build a relationship that lasts forever. That is the target. We do not want to create something that will stop in the next year. We always try to develop long-term relationships with our partners, and we do this simply by having a relationship with the founder.

From the top down, we meet everyone. You have to understand what the company is all about. When you talk to the boss, the boss says, "I had a dream," and he explains his dream for his company. When you talk to the VP or the sales director, then it's about sales. We need to feel that common energy, and it is more or less the same with our own strategy.

Johnson: So you have access to a wide variety of laminates that would perform at different levels depending on what the customer's needs are for that specification. After all, nowadays we have to include the laminate in the performance specification. That's become a factor.

Martin: Yes, exactly. Let's say that the AVL is a document that will simply match a partner factory with a customer. All customers are unique; they have specific needs. All the factories are unique, but the salespeople from the factory will tell you, "I do everything. I do this. I do that." But that's impossible. Our business, our core value, is to assess the factory to know what they do best, what their core business is.

We say, "You are excellent at this and we are going to offer this core business to our customer." Every customer is different and has a specific need. With our customers, they cannot go to 25 or 30 different factories with their projects. We're here in the middle, and we save them time they would have otherwise spent in Asia or elsewhere. Because we now have sources and partners all over the world.

Johnson: Part of your value-add is in bringing manufacturing perspective into technical conversations with your customers with regard to what material is a good match, what facility is a good production facility for what they're doing, getting them maximum yield?

Martin: Yes, that's right. Two years ago, we created a new department called Field Application Engineering (FAE), which helps OEMs

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meet with our designers. We ask "What do you need? What is driving this project or this need? What do you want?" Personally, I'm not a technical guy, and I let the true engineers handle this business.

Miralles: Nate, can you talk about the KPIs we have with the factories and how we support them? We have improvement plans, and it's like mutual cooperation between the factories and us.

Martin: Yes, sure. With the approved vendors and even with the new vendors, we have a mandatory annual audit. Every year we spend a few days checking every single thing from the machines to paper to people; we check everything. Now, we do it on a monthly basis based on KPIs because we have figures for everything. We know the quote requests and how many of them there are. We follow the time they take to make an offer. We track the accuracy of the technical question because they have an engineer as well. We monitor on-time delivery (OTDs). Jean-Christophe monitors the OTD. We monitor quality, of course, with defective pieces per million (DPPM), the lot reject rates (LRR) for the inspected batch, because we have people onsite at each factory who check the technical parts of the PCBs before they are shipped to the customer. We have strict targets to ensure an almost defect-free result.

Johnson: Using those KPIs, working with your suppliers obviously is an expected conversation. You have KPIs to ensure you're getting quality material to make a quality product. How does ICAPE Group identify or discuss a problem that the customer would need to solve by themselves, whether it's a design change that might improve yield, etc.? How do you get involved in that?

Martin: Let's just say that, sometimes, they treat a simple double-sided 4-layer or 6-layer and feel they have a need that is beyond their control. I've received these kinds of complex PCBs, or I see that they are using a certain American material. They will say, "When I see this that is non-standard, I might discuss it with the FAE people." FAE will join a specific meeting; we don't leave this to the sales team because they do not understand. They will go directly to the customer with that technical person to discuss specifically what the customer wants. This is step one. The customer will say, "I don't know, I just want to use this material because I heard it was good." But what's the reason? They don't know. We talk back and forth and they set some rules: "Let's say for this, I need this kind of material, and who as a manufacturer can do it?" The next step is on the manufacturing side and we'll start to discuss where the factory is.

Then it's written down and filed so we know what everybody can do. We also discuss with the technical person to be 100% sure before we make the recommendation, to be sure they can actually do it. We don't want to be in a situation where we said yes, but it could be a no. That is something we really don't like.

Johnson: How early do FAEs get involved with the customers for that kind of discussion?

Martin: It depends on the customer. Sometimes it can happen if, for instance, we talk about price stability.

Especially last year, the price went up which led to a lot of redesigns because of price or because of a component shortage: "I'm missing this component, I'll do a redesign." When this happens I don't have a specific rule, but I know it happens on a daily basis. Every week, I have a meeting where I discuss this specific topic with the FAE people. I know they are going to tell us that we have, for instance, this very nice project for the automotive industry that's going to ramp up in five years, with huge volumes for electric cars.

Johnson: Let's talk about corporate social responsibility.

Martin: CSR is extremely important because it's a common topic and the customers really care about it. Our partners have to sign an ethics contract, and they have to comply with environmental requirements.

We have an extremely strong commitment to CSR and our CSR manager reports directly to the CEO. Last year, we started doing CSR audits. We have a second audit model that gives us an idea of the company's impact on the world. We have two rankings: quality and CSR. All the AVL partners are ranked and have a score.

Johnson: Do you see improvement in your KPIs in your business operations from pursuing sustainability? Some are of the opinion we should do CSR even if it's just the cost of doing business.

Martin: Let's say that there is always room for improvement. It's a matter of development because in a country which is already developed like the U.S. or France, you have time to spend on these topics. But in other countries, they will get there; maybe not as fast but they will get there.

Jean-Christophe Miralles

Miralles: As you know, most of our things today are manufactured in Asia, and especially in China. Many of our customers are located in Europe or in the U.S., so transportation is a part of the answer. Sourcing is another challenge, especially in Asia, and Nathan is currently exploring new sourcing opportunities close to the customer.

Johnson: It is interesting how those come together, isn't it? By creating a more resilient supply chain and decentralizing manufacturing, you can shorten transportation, ease the logistics, and create a more sustainable system.

Miralles: As you can imagine, sourcing—transportation, packaging, and so on—can have a significant impact on sustainability. There are solutions to reduce that impact, but they come at a cost. We need to work with the customer to be sure they are willing to pay that cost to be more sustainable. Honestly speaking, that is not the game we play with our customers. We propose, but often they continue to choose more standard solutions. We're not surprised that our customers are not moving as fast as we had imagined. For example, we have some local solutions, and while that's progress, it's not so effective compared with today's expectations. But we see a way forward. We handle all our suppliers, including PCB, electronic parts, and transportation. We are not going to choose someone who doesn't have a policy of sustainability, CSR, and so on.

Martin: Partner factories follow a CSR standard like ISO 26000, and we do find a link between the quality of their products and the fact they follow rules that they don't necessarily have to respect. If a factory doesn't need to follow international rules, but they decide to do it because they think in the future that it will be required or because the working environment for their workers is very important to

them, there is a link to the quality of their products.

Johnson: Obviously a long-term solution is more local manufacturing, but with all the pricing and demand challenges in getting your materials either into the factories you're using or shipped to the customers, how do you manage that? How do you make sure that customers aren't worrying about that?

Miralles: Today, we have more capacity in terms of transportation, but mostly because of the decrease in demand. There are two factors. First, we had the capacity issue regarding the COVID situation and we are at the end of that situation. Capacity is increasing because the demand is decreased. There is a strong relationship between transportation and the world market: When the world market is decreasing, we have more transportation capacity but the price also goes down. Today our strategy is not so complicated, but we have to be flexible. This means we don't have long-term contracts with the forwarder because we want to be close to the price market on a frequent basis. We negotiate our costs every three months with our forwarder, to be closer to reality. Secondly, before I came on board, we started consolidation, meaning that we decrease the number of entries in Europe, for example, or shipment to the U.S. to have the maximum volume in order to have the benefits of consolidation and decrease the final price per customer. Finally, if we do that, we have internal discussions about our strategy in front of the customer, whereas, in the past, the logic was to have a warehouse or facilities close to the customers.

We don't want to change completely, of course. We only have a few facilities to serve—Europe. We need to be flexible, and maybe with the logic we are putting in place, we need the same logic for a period of time, meaning one or two years. But it's possible to update our offers often to be really close to the customers' expectations.

Johnson: What is in the near future for ICAPE Group?

Miralles: We have made some strategic acquisitions in the last year. There should be new opportunities to offer our customers and the possibility to manufacture PCBs ourselves.

Martin: We currently own two manufacturing facilities, one in the U.S. and one in South Africa.

Miralles: This is an important point because part of our strategy is to be close to the customer and to be able to manage a wide variety of products.

Johnson: Absolutely. With that we will close. Thank you. **PCB007**

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Palladium as a Final Finish

Happy's Tech Talk #14

by Happy Holden, I-CONNECT007

Introduction

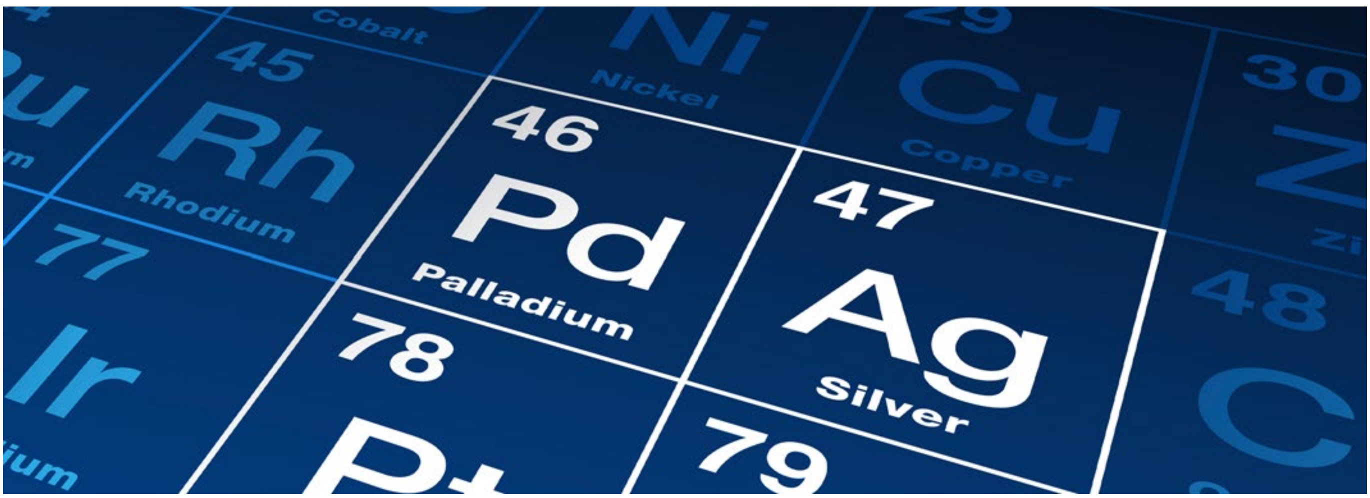
The late Karl Dietz never wrote on the topic of palladium as a final finish, but he did write about gold plating as a final finish and had an excellent discussion on copper plating[1–5]. But palladium now has a renaissance as a final finish. It was very popular in the 1970s, as the only other final finishes were tin-lead reflow, nickel-gold, OSP, or immersion tin. Palladium was very popular with the automotive industry then and a major supplier of boards was Photocircuits of Glenn Cove, New York.

Final Finishes

As semiconductors (IC transistors) become smaller and have faster rise times, the signal is more sensitive to any ferromagnetic metal in its path. So many alternatives have been developed to remove nickel as a barrier metal on copper for final finishes, especially in ENIG to improve insertion loss.

Everyone has their favorites. The simplest and cheapest is OSP, followed by lead-free HASL, but they have their pros and cons. Immersion silver is quite popular in North America and immersion tin is popular in Europe. ENIG has been a long-time standard, but the nickel now comes into play because it does not dissolve in the solder as the others do. Enter palladium to replace the nickel as a barrier metal. The new finishes are Pd/Ag, Ni/Pd, Ni/Pd/Au, Pd/Au, and Au/Pd/Au—all developed to replace the ENIG for solderability, shelf-life, and wire bonding.

During development of ENEPIG, it was recognized that the addition of a palladium (Pd) layer between the nickel and gold enabled both gold and aluminum wire bonding operations, in addition to the normal soldering application. In addition, the Pd layer was found to limit the corrosion of the nickel by an overly aggressive immersion gold process.



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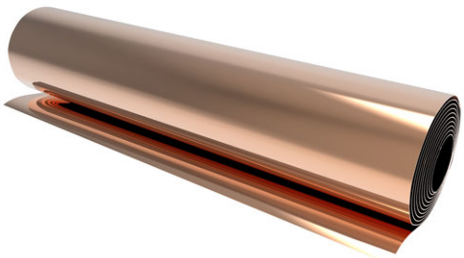

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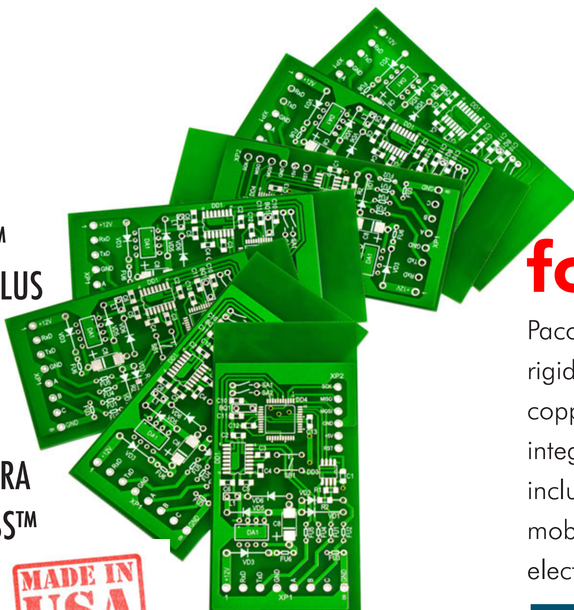

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An electrolytic nickel/gold finish was typically the process of record (POR) for such wire bonding needs. ENEP investigations into the ENEP process, which is essentially the ENEPIG process without the immersion gold step, actually followed the introduction of ENEPIG to the market. In comparison to ENEPIG, ENEP appears to offer a surface finish with benefits like stronger solder joint reliability under Pb-free conditions, lower cost (by elimination of gold) and, as recently investigated, Cu wire bonding capability.

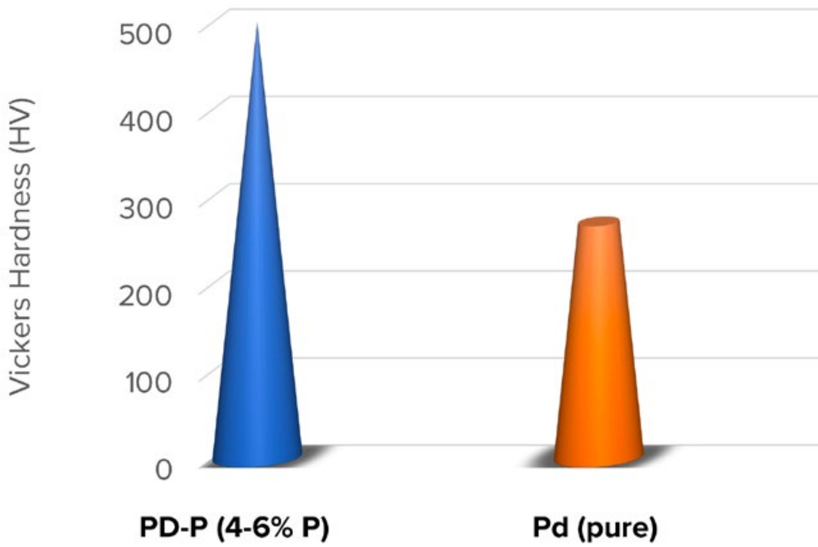


Figure 1: Comparison of hardness of palladium-phosphorus and pure palladium autocatalytic deposits[6].

Palladium Finish Used in Automotive

Early in the 2010s, palladium reemerged as a final finish. Electronic chemicals company OMG introduced its new palladium finish, PallaGuard. (OMG is now part of MacDermid.) Some of its features were:

- Eliminates black pad
- A single coating on copper
- Excellent silver replacement
- Short process time of 15 minutes
- Excellent shelf life
- Can be used to replace carbon switches
- Excellent replacement for harsh environments
- High gold bond shear test results

Properties

The properties of palladium, which was discovered in 1803 by the English chemist William Hyde Wollaston, are many:

- Pure palladium deposit, atomic number 46
- Melting point is 2,830.82°F (1,554.90°C)
- Palladium deposit with 2-3% phosphorus (Pd-P)
- Pure palladium 50% softer than Pd-P (Figure 1)
- Specific gravity is 11.9
- Resistivity, microohm-cm at 0°C: 10.7
- Electrical conductivity, percent IACS: 16
- Thermal conductivity, CGS units: 0.17
- Deposit thickness of 2–5 microinches for soldering and 5–15 microinches for wire bonding
- Pd has a hardness in the range 300 to 400 V.P.N. and is relatively free from internal stress, so that the plate does not suffer from curling and peeling troubles
- When solder joint strength is critical, or gold wire bonding is required
- Pure Pd has a better wetting angle and reflow spread than Pd-P (Figure 2)

New Applications of Palladium

For electronic assembly reliability especially for harsh environments, palladium has many advantages over nickel, except cost. For improved wire bonding reliability, a minimum of 5 microinches of electroless palladium over nickel or copper will eliminate any 0.7 mil gold wire surface failures and provide over 6 grams of pull strength.

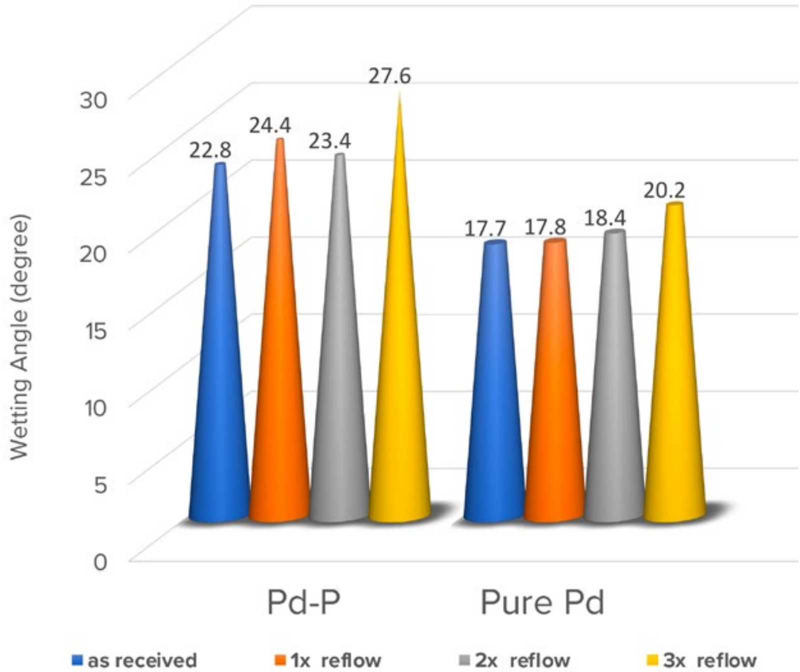


Figure 2: Comparison of wetting angle test results for Pd-P (left) and pure Pd (right) for various aging conditions.[6]

Black Pad—Nickel Corrosion

The use of an electroless palladium (EP) layer between the electroless nickel and the immersion gold will eliminate any nickel corrosion (black pad) and the thicker the Pd, the less immersion gold is deposited, thus reducing costs. The explanation is that the gold ions, at the lower EP thickness, had access to the underlying nickel and deposited at an accelerated rate, producing nickel corrosion. Lacking access to the underlying nickel, the immersion gold (IG) reaction with phos-palladium becomes self-limiting to 2 µin (0.05 µm).

Summary

The resurgence of palladium as a final finish or a barrier over copper or nickel has solved a number of problems. This is especially useful when the PCB may operate in a hazardous, corrosive, or extreme environment, such as with vehicles.

When compared to its predecessors—ENIG and electrolytic Ni/Au—ENEPIG has been shown to offer stronger solder interconnects and wire bonds. Pull and shear forces needed for failures on ENEPIG were a minimum of 5% higher than ENIG and Ni/Au when SAC3xx solders were used. Furthermore, the failure modes in the ENEPIG/SAC3xx solder interconnects were primarily ductile in the bulk, while failure modes in ENIG/SAC3xx and Ni/Au/SAC3xx were primarily brittle in the IMC, even after preconditioning steps were taken. Ductile failure in the bulk implies that ENEPIG has better solderability with SAC3xx solders than ENIG and Ni/Au[7]. **PCB007**

References

1. Tech Talk #54: Organic Additives in Copper Plating Baths (Part 1), by Karl Dietz, CircuiTree Magazine, February 2000.
2. Tech Talk #55, Organic Additives in Copper Plating Baths (Part 2), by Karl Dietz, CircuiTree Magazine, March 2000.
3. Tech Talk #145, Staying out of Trouble in Gold Electro-plating, by Karl Dietz, CircuiTree Magazine, Oct. 2007.
4. Tech Talk #154, Advances in Copper plating (Part A), by Karl Dietz, CircuiTree Magazine, July 2008.
5. Tech Talk #155, Advances in Copper plating (Part B), by Karl Dietz, CircuiTree Magazine, August 2008.
6. "Benefits of pure palladium for ENEP and ENEPIG surface finishes," by Mustafa Ozkok, ESTC Conference, October 2010.
7. "Review of Capabilities of the ENEPIG Surface Finish," by M. Ratzker, M. Pecht, G. Milad, Journal of Electronic Materials, Vol. 43, No. 11, 2014.

Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa Westwood, Merix, Foxconn, and Gentex. He is currently a contributing technical editor with I-Connect007, and the author of *Automation and Advanced Procedures in PCB Fabrication,* and *24 Essential Skills for Engineers.* To read past columns or contact Holden, click here.

Congress Must Redefine What's Critical

American Made Advocacy

by Travis Kelly, PCBAA

Now that the 2022 midterm elections are behind us, we can look forward to the 118th Congress beginning their work on Jan. 3, 2023. The ongoing effort to build secure and resilient supply chains will be front and center on their agenda.

On the heels of everything that has been done to invest in semiconductor reshoring, some might ask why further action is needed.

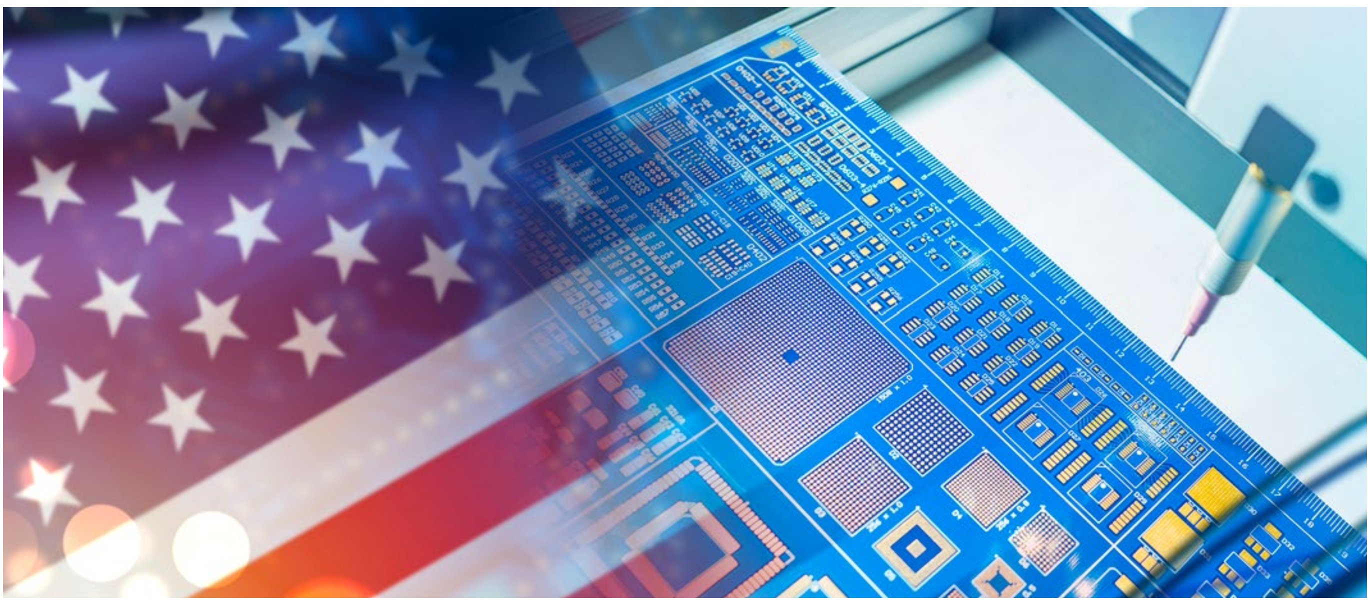
The CHIPs and Science Act that passed earlier this year was an important first step. But unless we invest in the entire microelectronics ecosystem, it won't be enough. A complex technology stack including semiconductors, substrates, and printed circuit boards makes almost all modern technologies possible. The entire ecosystem matters, and we can't simply invest in one layer and expect to achieve the result we're seeking.

In the case of printed circuit boards, there is a considerable challenge: Over the past two decades, domestic production of printed circuit boards decreased from 26% to 4% of global market share. In that same period, the industry shrunk from nearly 2,500 U.S.-based companies to fewer than 150.

This erosion has real implications for critical systems, but what do we mean by "critical" anyway?

Until now, the definition has been narrowly applied to aerospace and defense technologies. The Pentagon recognized decades ago that modern weapons systems—everything from submarines to night vision goggles—rely on microelectronics and directed U.S. industry to produce those technologies here at home.

Today that strict definition is outdated. Because of the way commercial and defense



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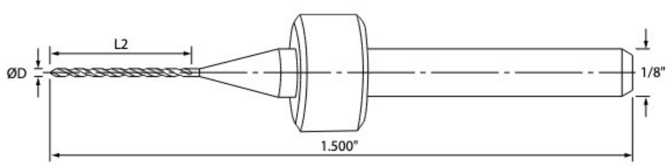
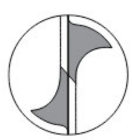
REPOINTING will be a new service offered by Insulectro through Kyocera. The company has recently invested in automated, state-of-the-art equipment and all repointing will be done in Southern California.





4 Facet Point Geometry

technologies are intertwined, there is no way to limit critical technologies to military applications. Nations, including the United States, are using economic and industrial policies across multiple industry verticals to influence geopolitical outcomes.

The time has come for policymakers to understand that banking, telecommunications, energy, transportation, and healthcare are also vital to our national security. All these sectors are powered by microelectronics and should be considered critical. This has implications for policies that take a holistic view of all the industry verticals that drive our economic and national security.

What are the common elements our nation needs to make this happen?

We need to invest in a broad and sustainable base of high-tech manufacturing and form public/private partnerships to both train the skilled workforce and invest in areas like microelectronics that are the foundation of every industry vertical in our modern world.

Bringing high-tech manufacturing back to the United States and having a world-class workforce does more than shore up the economy; it makes our nation more secure. Policymakers need to understand that industrial policy is national security policy and expand their thinking to include a broader definition of what constitutes a critical sector.

PCBs are just one example of a foundational microelectronic that makes modern life possible and that's why they need a secure and reliable domestic supply chain. The Printed Circuit Board Association of America was formed to educate, advocate, and legislate with this outcome in mind. **PCB007**

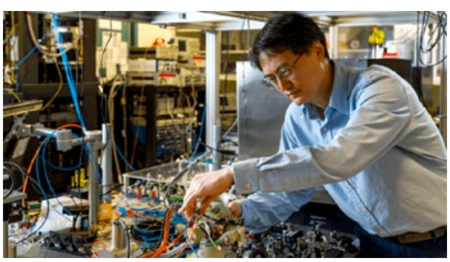
Travis Kelly is CEO of Isola-Group and current chairman of the Printed Circuit Board Association of America. To read past columns, click here.

A Vision for Navigating When GPS Goes Dark

A quantum inertial sensor can measure motion a thousand times more accurately than the devices that help navigate today's missiles, aircraft and drones. But its delicate, table-sized array of components that includes a complex laser and vacuum system has largely kept the technology confined to the lab. Jongmin Lee wants to change that.

Lee is part of a team at Sandia National Laboratories that envisions quantum inertial sensors as revolutionary, onboard navigational aids. If the team can reengineer the sensor into a compact, rugged device, the technology could safely guide vehicles where GPS signals are jammed or lost.

The team has successfully built a cold-atom interferometer, a core component of quantum sensors, designed to be much smaller and tougher than typical lab setups. The team describes their prototype in the academic journal Nature Communications, showing how to integrate several normally separated components into a single monolithic structure. In doing so, they reduced the key components of a system that existed on a large optical table down to a sturdy package roughly the size of a shoebox.



The prototype, funded by Sandia's Laboratory Directed Research and Development program, demonstrates significant strides toward moving advanced navigation tech out of the lab and into vehicles.

When a jet does a barrel roll through the sky, current onboard navigation tech can measure the aircraft's tilts and turns and accelerations to calculate its position without GPS, for a time. Small measurement errors gradually push a vehicle off course unless it periodically syncs with the satellites, Lee said.

Quantum sensing would operate in the same way, but the much better accuracy would mean onboard navigation wouldn't need to cross-check its calculations as often, reducing reliance on satellite systems.

(Source: Sandia Labs)

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TOP TEN

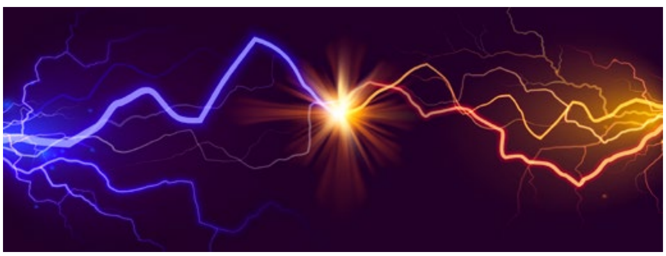
EDITOR'S PICKS

IPC Symposium: U.S. Must Address Critical Gaps in Advanced Packaging Needs

There is a significant capability gap in advanced substrate packaging in North America, forcing all semiconductors to be packaged in Asia and leaving North America at risk in its supply chain.

Trouble in Your Tank: Electrodeposition of Copper, Part 3—Plating Distribution and Throwing

Success in the plating room rests largely on the understanding of and the application of those critical principles that govern the process of electrodeposition. This month, I look at the fundamentals of plating distribution and throwing power, and what that means for the circuit board fabricator.

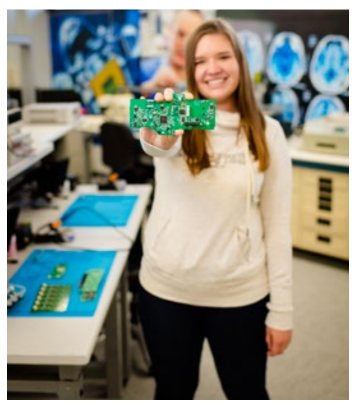


EIPC Technical Snapshot: 'Tremendous Uncertainty' in Global PCB Marketplace

Pete Starkey

For the past two years, EIPC's Technical Snapshot series has kept us extremely well-informed on developments in printed circuit materials and manufacturing technologies. But what is currently happening in the global PCB market, and how is Europe and the rest of the world affected by the current world situation?

The New Chapter: Let's Make Manufacturing 'Cool' Again



Computer science has become the new "cool." Today's students were groomed to want jobs in tech at big companies with happy hours, big paychecks, and high status. Let's face it, manufacturing just isn't sexy. It's dirty, manual, and for electronics, has a history of low margins. The pipeline into the field is broken. But it doesn't have to stay that way. Paige Fiet lays out the problem behind the board.

Copper Foil Market Worth U$17.32B by 2030 at 10.31% CAGR

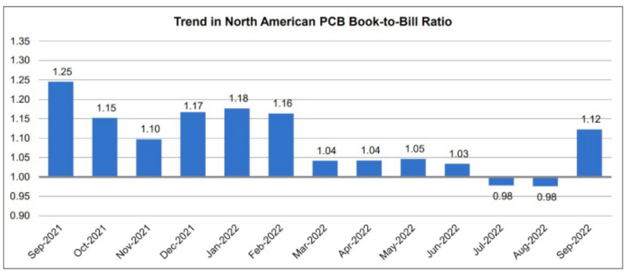
According to a Comprehensive Research Report by Market Research Future (MRFR), “Copper Foil Market Information by Product, Form, Category, Distribution Channel, and Region—Forecast till 2030,” the market is estimated to grow at a 10.31% CAGR to reach USD 17,321.8 Million by 2030.

Schweizer Electronic Inks Patent Transfer Agreement with China Subsidiary

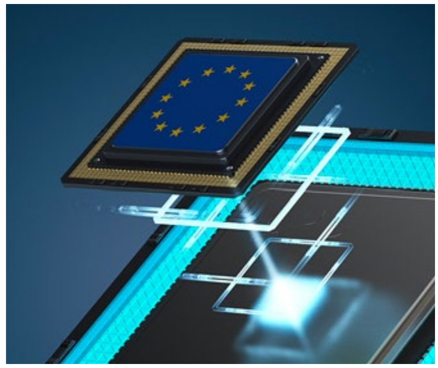
Schweizer Electronic AG and its subsidiary Schweizer Electronic (Jiangsu) Co. Ltd., based in Jiangsu, China (SEC), concluded a Contribution and Patent Transfer Agreement on 10 October 2022.

North American PCB Industry Sales Up 14.6% in September

IPC announced the September 2022 findings from its North American Printed Circuit Board (PCB) Statistical Program. The book-to-bill ratio stands at 1.12.



IPC, European Parliament Work to Bolster European Chips Act



The Member of the European Parliament (MEP) Eva Maydell expressed to participants of IPC’s European Executive Forum her commitment to see a European Chips Act that would bolster the entire semiconductor ecosystem, including those segments critical to advanced packaging.

Lessons Learned: Breaking Down the Four Types of Communication

Kelly Dack and Nolan Johnson explore the silver linings from the past two years, especially the importance of good communication. These skills are—as they have always been—key to the success of the project.

The New Chapter: Retaining Engineers in the Workplace

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- A technical background in chemistry or engineering is beneficial. Min. 2-year degree.
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Application Engineer

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

Qualifications

- Demonstrated experience: flex circuit/rigid-flex design including design rules, IPC; flex heater design +
- Ability to work in fast-paced environment, broad range of projects, maintain sense of urgency
- Ability to work as a team player
- Excellent written and verbal communication skills
- Willing to travel for sales support and customer support activities if needed

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Electrical Engineer

Located in State College, Pennsylvania, Chemcut, a world leader in wet processing equipment for the manufacture of printed circuit boards and chemical etching of various metals, is seeking an electrical engineer.

Objectives:

The electrical/controls engineer will not only work with other engineers, but interface with all departments (manufacturing, sales, service, process, and purchasing). The engineer will design customer systems, creating electrical and control packages, while focusing on customer requirements.

Responsibilities:

- Process customer orders (create schematics, BOMs, PLC programs, relay logic controls, etc.)
- Startup and debug customer equipment on production floor
- Interface with engineering colleagues and other departments, providing input & direction
- Provide electrical/control support to customer service
- May require occasional travel and overtime

Qualifications:

- Bachelor's degree in electrical engineering or an EMET degree
- Machine control design experience a plus
- Good communication skills working in a team environment
- Strong ability to work independently with minimal supervision
- PLC and HMI experience a plus (ex. Studio 5000 Logix Designer, Factory Talk)
- Experience with AutoCAD, Microsoft Word, and Excel

Chemcut benefits include: Medical, dental and vision Insurance, life and disability insurance, paid vacation and holidays, sick leave accrual, and 401K with company match.

To apply, please submit a cover letter and resume to hr@chemcut.net.

apply now

Career Opportunities

EMA Design Automation®

Technical Marketing Engineer

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

Requirements:

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

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

Send Resumes to: resumes@ema-eda.com

apply now

TAIYO AMERICA

Field Service Technician

Taiyo Circuit Automation designs and manufactures the world's finest dual sided soldermask coating and vertical drying equipment. Since 1981, we have served the printed circuit board industry with highly reliable innovative machinery, engineered to exceed.

PRIMARY FUNCTION:
The Field Service Technician is responsible for troubleshooting and providing technical services on Taiyo Circuit Automation's mechanical and electro-mechanical products and systems.

ESSENTIAL DUTIES:

1. Identify mechanical issues and implement process control solutions for process improvement and new projects
2. Consult with maintenance, operations, engineering, and management concerning process control and instrumentation
3. Specify, install, configure, calibrate, and maintain instrumentation, control system and electrical protection equipment

QUALIFICATIONS/SKILLS:

1. 3 years of experience with equipment, preferably in PCB or related electronics industry
2. 3 years of experience in similar process industries with hands-on experience in operations, maintenance and project implementation—OMRON, Koyo, Allen Bradley experience preferred
3. Experience in installation and calibration of process control elements and electrical measurement devices
4. The ability to read and understand electrical, pneumatic diagrams and control systems

REQUIRED EDUCATION/EXPERIENCE:

1. High school graduate
2. Associate degree in Industrial Engineering Technology, Mechanical or Electrical Engineering, preferred.
3. PLC experience

Email: BobW@Taiyo-america.com (Subject: "Application for Field Service Technician for TCA")

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Career Opportunities

Altium®

DevOps Engineer

Altium is a publicly traded global company responsible for the most widely used PCB design software in the industry. Altium 365® is our cloud-based design and collaboration platform; it gives more power to every contributor in the electronics product chain, from the PCB designers to manufacturing. Our R&D teams are the driving force behind Altium 365 and all our technological accomplishments.

- The primary role of the DevOps Engineer is to help continue our transition to a cloud-based SaaS model as part of the production engineering team
- The team's top priorities are product reliability, security, feature delivery, and automation
- DevOps is responsible for the CI/CD process, streamlining automation for provisioning and deployment, scalable infrastructure, uninterrupted service, other DevOps activities

Required Skills and Experience:

- Analysis, troubleshooting
- 4+ years' DevOps/SRE/ Linux/Windows
- AWS (EC2, RDS, S3, Storage, Route53, and network appliances
- Architecting and securing cloud networking

Altium offers a culture built and managed by engineers. We don't micromanage; we define the goals and give engineers the freedom and support to explore new ideas for delivering results. In doing so, we all have a hand in shaping the future of technology.

https://careers.altium.com/

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INDIUM CORPORATION®

Supplier Quality Manager

Headquarters, New Hartford, NY

JOB SUMMARY:
The Supplier Quality Manager is responsible for maintaining and improving the quality of Indium Corporation's supplier base as well as compliance with identified quality standards and risk mitigation. This position will work cross-functionally with Supply Chain, Operations, and our suppliers. The role will ensure that the quality levels of all Indium Corporation suppliers and products meet customer requirements while supporting the company's growth, vision, and values.

REQUIREMENTS:

- Bachelor's degree in business, supply chain or a science-based discipline
- Minimum 3 years in a supply chain role supporting or leading supplier quality
- Obtain and/or maintain International Automotive Task Force (IATF) auditor certification within first 3 months of employment
- Able to work independently or lead a team, as needed, to meet goals
- Excellent oral and written communication skills
- Knowledge of quality standards
- Proficiency in MS Office

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Career Opportunities

KOH YOUNG AMERICA

Technical Service & Applications Engineer

Full-Time — Midwest (WI, IL, MI)

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

Responsibilities

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

Skills and Qualifications

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

Benefits

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

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KYZEN

Where Science and Care Converge.

Regional Manager

Midwest Region

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

DETAILS OF FUNCTION:

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

QUALIFICATIONS:

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

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

fernando_rueda@kyzen.com

apply now

Career Opportunities

pluritec®
MACHINES FOR PRINTED CIRCUIT BOARDS

Field Service Engineer

Location: West Coast, Midwest

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

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

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

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

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

Must be able to travel extensively.

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Manncorp™

SMT Field Technician

Hatboro, PA

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

Duties and Responsibilities:

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

Requirements and Qualifications:

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

We Offer:

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

apply now

Career Opportunities

ventec INTERNATIONAL GROUP 騰輝電子

European Product Manager
Taiyo Inks, Germany

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

Duties include:

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

Skills and abilities required:

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

What's on offer:

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

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

apply now

MivaTek Global

Field Service Technician

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

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

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

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

More About Us

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

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Career Opportunities

The Test Connection, Inc.

Rewarding Careers

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

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

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

Associate Electronics Technician/ Engineer (ATE-MD)

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

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

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Test Engineer (TE-MD)

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

- Candidates must have at least three years of experience with in-circuit test equipment. A candidate would develop and debug our test systems and install in-circuit test sets remotely online or at customer's manufacturing locations nationwide.
- Candidates would also help support production testing and implement Engineering Change Orders and program enhancements, library model generation, perform testing and failure analysis of assembled boards, and other related tasks.
- Some travel required and these positions are available in the Hunt Valley, Md., office.

apply now

Sr. Test Engineer (STE-MD)

- Candidate would specialize in the development of in-circuit test (ICT) sets for Keysight 3070 (formerly Agilent & HP), Teradyne/ GenRad, and Flying Probe test systems.
- Strong candidates will have more than five years of experience with in-circuit test equipment. Some experience with flying probe test equipment is preferred. A candidate would develop, and debug on our test systems and install in-circuit test sets remotely online or at customer's manufacturing locations nationwide.
- Proficient working knowledge of Flash/ISP programming, MAC Address and Boundary Scan required. The candidate would also help support production testing implementing Engineering Change Orders and program enhancements, library model generation, perform testing and failure analysis of assembled boards, and other related tasks. An understanding of standalone boundary scan and flying probe desired.
- Some travel required. Positions are available in the Hunt Valley, Md., office.

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

We proudly serve customers nationwide and around the world.

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

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Career Opportunities

ARLON ELECTRONIC MATERIALS

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

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

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

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

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

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

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INSULECTRO

Are You Our Next Superstar?!

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

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

apply now

Career Opportunities

Prototron Circuits

Sales Representatives

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

Reasons you should work with Prototron:

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

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

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eptac

TRAIN. WORK SMARTER. SUCCEED.

Become a Certified IPC Master Instructor

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

Qualifications and skills

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

Benefits

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

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Career Opportunities

BLACKFOX Premier Training & Certification

IPC Instructor

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

Independent contractor, possible full-time employment

Job Description

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

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

Qualifications

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

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

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

Send resumes to Sharon Montana-Beard at sharonm@blackfox.com.

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

CAD/CAM Engineer

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

ESSENTIAL DUTIES AND RESPONSIBILITIES

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

ORGANIZATIONAL RELATIONSHIP

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

QUALIFICATIONS

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

PHYSICAL DEMANDS

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

apply now

Career Opportunities

U.S. CIRCUIT

Plating Supervisor

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

Competitive benefits package.
Pay will be commensurate
with experience.

Mail to:
mfariba@uscircuit.com

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APCT
Passion | Commitment | Trust

APCT, Printed Circuit Board Solutions: Opportunities Await

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

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

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

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

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CONFERENCE & EXHIBITION Jan. 24-26

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Advance your career in a new era of electronics manufacturing with networking at IPC APEX EXPO 2023. Meet leading innovators and designers, connect with peers, and create new business opportunities at North America's largest gathering of electronics manufacturing professionals on our world class show floor.

IPCAPEXEXPO.ORG

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MEET AND GREET AT OUR SOCIAL RECEPTIONS INCLUDING THE NEW CAREER CONNECTIONS NETWORKING EVENT WEDNESDAY, JANUARY 25!

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

NEW BOOK!

Designing for Reality by Matt Stevenson, Sunstone Circuits

Based on the wisdom of 50 years of PCB manufacturing at Sunstone Circuits, this book is a must-have reference for designers seeking to understand the PCB manufacturing process as it relates to their design. Designing for manufacturability requires understanding the production process fundamentals and factors within the process that often lead to variations in manufacturability, reliability, and cost of the board. Speaking of making better decisions, read it now!

Thermal Management with Insulated Metal Substrates, Vol. 2

by Didier Mauve and Robert Art, Ventec International Group

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

High Performance Materials

by Michael Gay, Isola

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

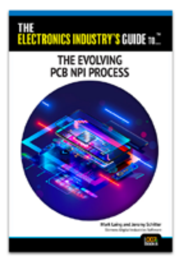
Stackups: The Design within the Design

by Bill Hargin, Z-zero

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

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

by Mark Laing and Jeremy Schitter, Siemens Digital Industries Software



The authors of this book take a look at how market changes in the past 15 years, coupled with the current slowdown of production and delivery of materials and components, has affected the process for new product introduction (NPI) in the global marketplace. As a result, companies may need to adapt and take a new direction to navigate and thrive in an uncertain and rapidly evolving future. Learn how to streamline the NPI process and better manage the supply chain. *Get it Now!*

Our library is open 24/7/365. Visit us at: I-007eBooks.com

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PCB007
MAGAZINE

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

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November 2022, Volume 12, Number 11
PCB007 MAGAZINE is published monthly
by IPC Publishing Group., Inc., dba I-Connect007

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Cybersecurity & Counterfeiti
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SEPTEMBER 2022
A NEW ERA IN MANUFACTURING
PCB007 MAGAZINE
OCTOBER 2022
FOCUS ON IMAGING
PCB007 MAGAZINE
NOVEMBER 2022
T R A C E S A R E G E T T I N G E V E N S M A L L E R A L O O K A T
DESIGN007 MAGAZINE
SEPTEMBER 2022
PAIN SCALE
DESIGN007 MAGAZINE
OCTOBER 2022
TO UHDI & BEYOND!
DESIGN007 MAGAZINE
NOVEMBER 2022
MAXWELL VS. MOORE
SEPTEMBER 2022
SMT007 MAGAZINE
OCTOBER 2022
MD&M
SMTAI 2022 PASSPORT
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