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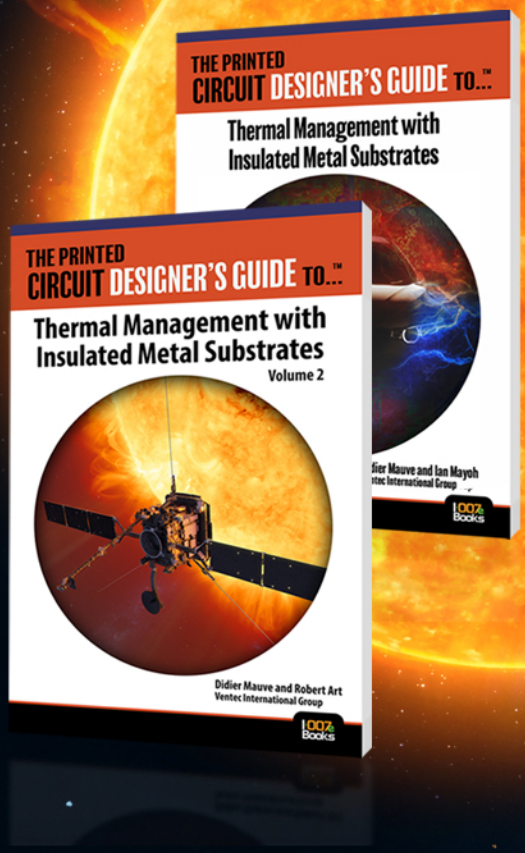

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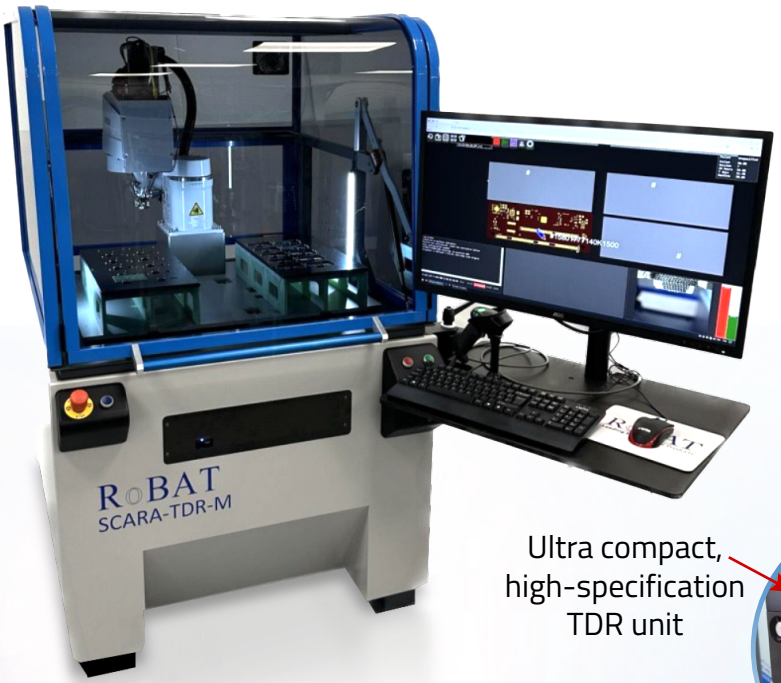

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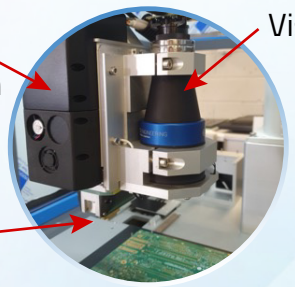

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The Many Facets of Sustainability

Marcy's Musings

by Marcy LaRont, I-CONNECT007

"We don't need to have a handful of people doing zero waste perfectly. We need a million people doing it imperfectly."

—Anne Marie Bonneau (Zero Waste Chef)

I borrowed this quote from the world of cooking and online influencers because it speaks to the reality of how to make a real and continuous impact when large-scale change is ultimately needed. We're all doing things to further economic and environmental sustainability within our organizations, and we're likely operating on a spectrum that ranges from doing nothing to doing it all perfectly. I find it heartening to learn and understand the continuous efforts in sustainability practices as we work toward systems like zero liquid discharge across the board (pun intended).

Sustainability is one of the most widely used terms in business today, especially for electronics and manufacturing. Oxford defines it as "the ability to be maintained at a certain rate or level." When we talk about sustainabil-

ity, we most often think of environmental sustainability, or the ability to operate our businesses in a way that does not hurt or deplete our natural resources and our global environment. For most business owners, though, sustainability primarily means their ability to continue doing business.

In this month's issue we look at sustainability in some of its flavors and forms and the impact this buzzword is having on our industry. As IPC's lead sustainability strategist, Dr. Kelly Scanlon, has said, the concept of sustainability applies to many other areas, including the economy, training, and education.

To kick off this issue, we interviewed technologist and entrepreneur Alex Stepinski. I am fortunate to have conversations with many intelligent, genuine contributors to the industry, but Alex is in a class by himself. Alex addresses zero liquid discharge and the technology changes making it more affordable for even smaller-sized manufacturers.

As I continued exploring the wide-ranging concept of sustainability, I was intrigued by the idea of recyclable PCBs and circularity. Is it a myth or possibility? In a fascinating interview, Jan Pedersen of NCAB Group explained the concepts as well as the groundwork being laid to make it an eventuality.

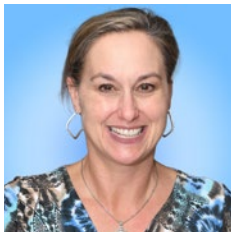
For further clarity, Nolan Johnson spoke with Erik Pedersen of ICAPE Group, a global PCB supplier, about designing for sustainability, and the cost to achieve the ultimate value proposition for customers. We invited Charles Nehrig of TTM, the U.S.'s largest PCB manufacturer, to detail the investment and technology that make up TTM's wastewater treatment system. And Marina Hornasek-Metzl of AT&S provides an accounting of the paradox of digitalization and reaching environmental sustainability goals, acknowledging the enormous amount of waste created by electronics while there is a corollary need for more electronics to be made to create solutions that could help solve climate change. She also discusses how digitalization ultimately can provide the semiconductor industry with the means to achieving its ESG goals—something that affects all of us in the value chain.

Among our talented columnists in this issue, I'm highlighting those who took on the topic of sustainability from their unique perspective. IPC President and CEO Dr. John W. Mitchell gives us a broad overview, while Don Ball of Chemcut talks about reducing etch water system usage, and Paige Fiet writes about attracting "generation green." If you have potential job openings (i.e., that means all of you), pay close attention to her advice, as the young generation of workers and their values come in a package, and the environment is one of them. But be sure to also read the important topics from columnists Happy Holden, Travis Kelly, Steve Williams, and Preeya Kuray, who writes about the importance of standards in the chip packaging industry.

Finally, the ever-talented Pete Starkey reviews a new webinar from SUSS that discusses the use of inkjet solder mask, showing development in this area of additive manufacturing. Also, look for my interview with two newer members of IPC's government relations team in Washington, D.C.

So, whether your sustainable practices range from fewer Styrofoam coffee cups in the break room to switching out large systems in your factory, there's always something more to do and think about. I hope this issue brings to light some new ideas and/or helps to reinforce the path you are on.

Grab a cup of coffee (in your reusable mug!), turn on your DND, and let's read and learn together. I'd love to hear your feedback on the topics addressed in this issue. **PCB007**



Marcy LaRont is the editor of *PCB007 Magazine*. Marcy started her career in PCBs in 1993 and brings a wide array of business experience and perspective to I-Connect007. To contact Marcy, click here.

The Delicate Balance of Sustainable Business and Going Green

Feature Interview by the I-Connect007 Editorial Team

Alex Stepinski is known throughout the industry as an innovator and disruptor committed to environmental sustainability, primarily through his current work around zero liquid discharge (ZLD) for PCB fabrication. But Alex says financial sustainability must come first. Standing firm in his belief that green is the most financially sustainable option for manufacturing and financial success, he explains his position and vision for a greener, more lucrative future for bare board fabricators. "Before I retire in about 10 years," he says, "I want to make sure that all new fabs, and at least 25% of the old ones are zero liquid discharge in this industry."

Nolan Johnson: Alex, what are the biggest technological and cost challenges for zero liquid discharge?

Alex Stepinski: Globally, the single biggest challenge of ZLD is the economics, but overall, there are three distinct technical challenges. The first is how to reduce the amount of liquid chemicals you have to boil, which is the biggest cost. Next, it's about how to treat the portfolio of organic compounds cost-efficiently. Third, you must have a way to deal with mistakes, such as when the wrong chemistry is dumped into the wrong place—something that happens in every shop.

Zero liquid discharge in Europe is primarily done by concentrating the waste and then shipping it out to central facilities where the liquid is boiled off at scale. They have a different ecosystem. Because we don't have this ecosystem in place in the U.S. yet, I originally took this concept when I worked in New Hampshire, purchased boiling units normally used in

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European centralized treatment facilities, and put them into some of the new fab shops. Boiling chemistry is the biggest cost driver in this system. Through my travels and due diligence, I often extract ideas from other industries, and my most recent significant process discovery provides a nearly 95% reduction in the chemical boiling cost for ZLD.

Barry Matties: That is tremendous for ROI. How are you accomplishing that?

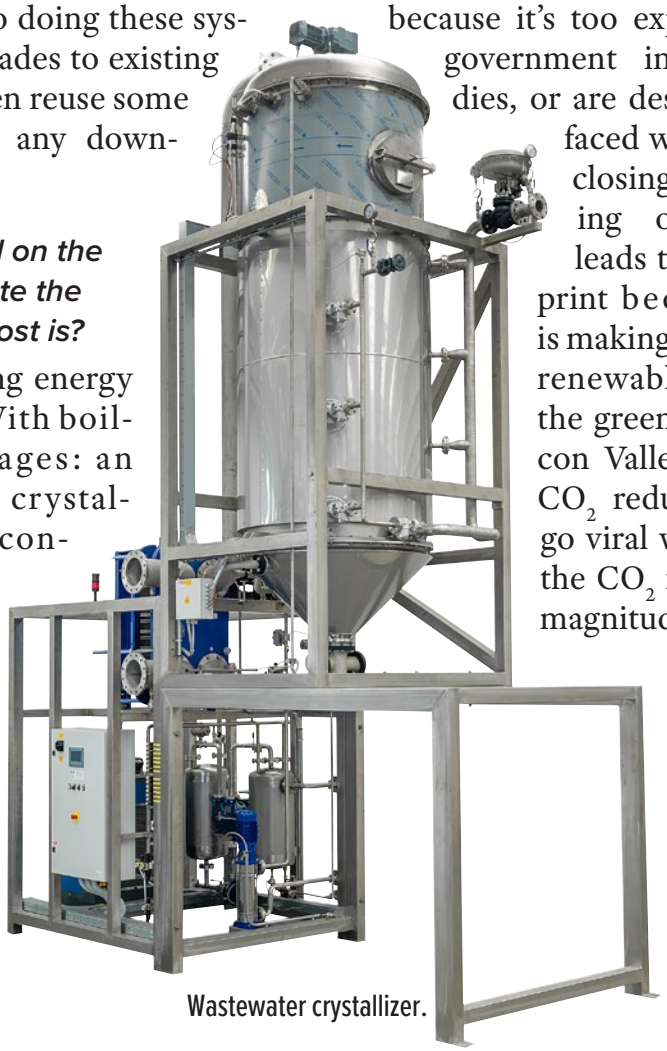
Specifically for larger systems, the big savings come from an electrochemical technology that originated in the uranium mining industry, but I have about half a dozen methods for smaller and mid-size systems that are also very efficient, depending on which chemistries I am dealing with in each situation. It depends on how much you have to invest, and whether it is some type of retrofit, as to what you end up with for kit. I am also doing these system installations as upgrades to existing plants, where we can even reuse some components and avoid any downtime.

Matties: You are focused on the source of energy to create the heat. Is that where the cost is?

Yes, the focus is reducing energy use and reducing CO_2. With boiling, there are two stages: an evaporator and a final crystallizer. The evaporator concentrates the chemicals, and the crystallizer performs the solid conversion. I have been able to eliminate the evaporator—the biggest cost of the system—and go directly to the crystallizer with a concentrated brine. Since the energy generation required for the evaporator generally leads to a massive CO_2 footprint in addition to the high OpEx, this is a needed improvement. The energy requirements become small enough with this approach that we not only save money but we can also use a renewable source of energy. This eliminates the mega-CO_2 footprint of the first-generation system architecture, which I invented and patented at GreenSource, and which independently co-evolved slightly differently in the Indian market around the same time.

Matties: Did this reduce cycle time?

Absolutely. It is a much faster process as well, with large-scale economies. My previous systems work was at OEMs in the U.S. market where they are building expensive parts, but the technology will never take off in the global regions where most circuit boards are made because it's too expensive, unless you get government intervention and subsidies, or are desperate because you are faced with either going ZLD or closing the doors. Also, relying on evaporation/boiling leads to a very large CO_2 footprint because almost nobody is making the energy for this from renewables. When so much of the green push comes from Silicon Valley companies pushing CO_2 reduction, it won't exactly go viral when you are increasing the CO_2 footprint by an order of magnitude just to go ZLD. Our new design solves this, and it's about half the capital price of the original systems sold in the U.S. market. It is now even an attractive capital purchase for fabs in India, many of which have already been ZLD for 10 years.



Wastewater crystallizer.

Matties: The risk with ZLD is that if there is a problem with your system, there is a greater chance that it can shut down production than if you just use fresh water due to increased error risk from the higher complexity.

Yes, and that is a bad situation. This challenge certainly has slowed global implementation. It's been particularly hurtful in India, where a strict ZLD regulation kicked in on Dec. 31, 2023. Everyone must now be compliant. It increases their cost and makes it much more difficult to invest in India, creating the situation where there are 37 facilities being built in Southeast Asia and only a few in India (though there are other hurdles there vs. ASEAN, particularly regarding PRC).

Relevant to this situation, this new system design addresses the three big issues with zero liquid discharge to reduce the risk to a very low level. We were able to reduce the boiling by 95%. I also came up with a new physical method to destroy the organics that is cheaper, more efficient, and delivers non-detectable TOC levels.

The third big issue is human error, like when things get dumped in the wrong place or a solenoid gets programmed incorrectly, etc. To solve this, whenever we design a system, we take all the different chemistries in a PCB shop, parametrize them through Aspen+, and simulate the situation of having everything go to the wrong place. Then, we develop methods to address those things when they happen based on the client's local chemical management infrastructure. If something incorrect occurs, the system automatically isolates the non-conformance for separate treatment and/or goes multi-pass based on the prescription interpolated from the analytics. Workers aren't even involved, except to know that there was an error in manufacturing that needs correction and a fault alarm explaining the likely source of the error. But we can't use the traditional methods of reverse osmosis and ion exchange resins to accomplish this alone. It requires different methods of concentration, and many more sensors, which I'm bringing to the market now. The advanced sensor array also gives you feedback on manufacturing process efficiency to tell you whether you are wasting chemistry or not (think SPC of waste as an extra process control monitor) even if there is not a major non-conformance occurring. Companies can set their own alarm thresholds.

Alex Stepinski

The sludge generation is another key piece. We use electrochemistry and physical treatment methods instead of chemicals. I regenerate membranes with electrolysis. I'm not using sulfuric acid and caustic to regenerate membranes, which creates even more sludge that you can't put down the drain in zero-waste mode. This is a massive chemical reduction, using 98% less chemistry than a typical system, and no proprietary chemicals at all. The existing waste treatment industry is somewhat of a chemical mafia, and we are disrupting this. They insist that you need these chemicals and consumables because it is their cash cow.

Matties: You're not using a sludge press.

We centrifuge it continuously into a roll-off at equivalent dryness, so nobody touches anything. That is another key element.

Johnson: What about scalability?

This new combination of technology scales very well. At the low end, in a small shop doing 30,000 to 100,000 gallons of water a day, our new design vs. a traditional-method system carries a three- to five-year ROI. But the big systems that you see in Southeast Asia, which might be more common here with CHIPS Act investments, have the ROI down to six to 12 months. It's encouraged by money, not the government. It is a decision people want to make even if they already have a system. The investment return is very high because you're able to make DI water inexpensively from your waste, and you don't need a permit. The capital cost has been reduced significantly with the new equipment components, and those savings add up.

Marcy LaRont: You focus on ZLD, which deals with the issues of water and chemical consumption and waste output. This is huge for environmental sustainability in how we operate our businesses but how is sustainability defined in the larger sense for the bare board fabricator?

First and foremost, sustainability has to do with the ability to be profitable and remain in business. In business, you have two focus points: your red/black P&L line (which you want to keep in the black), and the blue or valuation line. What is the blue line in your business? Is your value growing or shrinking? What's the risk in your business? Risk comes from high labor costs and low-cost foreign competitors in the market. How do you address this? No one wants to pay $10,000 for an iPhone just to re-shore it.

I've historically focused on North America and Europe. The big challenge in both regions is that everything has become uncompetitive on a global basis, with very high labor costs. PCBs made in the U.S. are five to 10 times more than overseas prices. European PCBs are lower cost on average, but still high. The decision to buy in these regions generally has to do with a company's tolerance for strategic risk. Today, that cost is very high, and aside from a very few exceptions, China + 1 means ASEAN with a pinch of India, and not reshoring to the West.

Right now, you see investments in the U.S. market. Are those sustainable? Currently, there are not enough people to do the work, and

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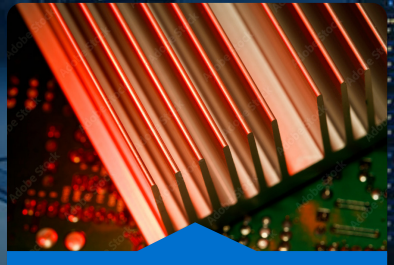

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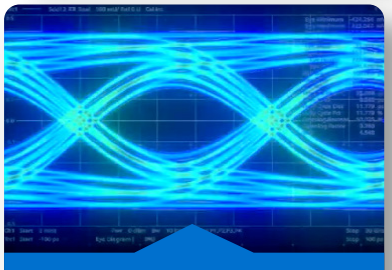

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everybody charges a lot because of the supply-demand disparity. Will that change? Let's keep in mind that we originally outsourced all this business because it was dirty and smelled bad, and the manufacturing jobs were seen as repetitive and low paying. If we move to a war footing, it's a different story regarding incentives, but we are not there today.

Going forward, a sustainable business model for bare board fabrication companies must be very green and interesting enough for people to want to get involved.

Today, many people are more than happy to work from home in software jobs, or on the IT side. That has been a huge shift. But not everything can be solved through IT. It won't fix a broken pipe, and no programming exists without hardware. What's missing is getting things done in the physical domain. The U.S. is lacking the trades to do it, and we don't have the engineers who want to go into that space. A partial solution toward getting enough people into that space is to make operations more efficient so that you need a smaller staff. That needs to happen, but right now we are not looking enough in that direction, and just focusing on education/apprenticeship is not enough when the teachers only know the old methods.

A U.S. factory must be a totally different business model than in Asia. Taiwan Semiconductor (TSMC) pushed back the completion of its 3 nm semiconductor fab in Arizona by a couple of years because they couldn't find people in the U.S. who could operate the same way as their low-cost labor model in Taiwan. They are now asking for subsidies just to meet that target. Sound familiar? We need a more sustainable business model here. We won't be sustainable without smart investments that push us in the right direction for productivity.

Matties: When people hear "sustainable," they immediately think green, but you're saying it's a balance with business sustainability.

Exactly. You generally don't just do things in business because they are environmentally green unless they are legally mandated, or perhaps you see it as a competitive advantage that you can market to improve your recruitment chances and make more traditional competitors look less desirable. The greenest PCB shop is a closed one, but now, with the latest tech, there is a way to have economical PCB fabs while also dropping the environmental impact to a negligible level.

Matties: In an interview with a rather large fabricator here in the U.S., I asked whether they would bring in a zero liquid discharge system. They said their production demand was so high that they didn't have the time or desire to shut down for installation. Isn't there a misperception about what it means to bring in a ZLD system?

We can get the ROI down to six months for larger Asian fabricators now and to a few years in the States without shutting down. That's worth a look.

Matties: How do you raise this side of the argument, so it has a higher priority for fabricators?

I am doing a lot of communication over the next two quarters, particularly through trade shows and webinars, showing that ZLD is now a good investment. We have devised several ways to do the changeover and installation without a complete shutdown. For about half the total investment, you can achieve 100% rinse water recycling and just batch treat your concentrates. If you double the investment, you go to zero liquid discharge. It's a two-step approach.

Matties: So, there just needs to be more conversation around this?

Yes, there needs to be a lot of education. The current market is very crystallized around the old solutions; everyone is doing something that someone else is doing and has been doing for years. The latest information on ZLD or other green technology is not widely adver-

tised. It only comes up when someone is putting up a new factory or their old system has just melted down. That's where the market is right now. My recent focus has been on how to encourage somebody whose system is running fine to invest in this system by lowering the hurdle rate and making a stronger ROI. Having achieved this and gotten some orders for the tech to confirm the market readiness, we are now segueing into marketing and scaling.

The first step was the invention, followed by getting it IP-protected. IP theft is always a risk, especially in such a competitive market. And you don't want someone blocking or acquiring you to stop the technology from being used. My goal is not to get acquired (unless it is by someone who funds more rapid achievement of our goals), but rather, to just get rid of the waste. I'm kind of an activist.

Also, many people actually think that they are doing green things already by partially recycling water or using less water. Interestingly, using less water does not benefit the environment like people think. The less water a fab uses generally means that the contamination of what they discharge is higher because that contamination has to go somewhere. A factory that recycles 80%, or that reduced its water use by 80% sounds pretty good to most folks, but the reality is that the discharge from such a factory is a five times higher concentration of carcinogenic petrochemical derivatives, microplastics, and toxic salts than if they did nothing. Chemical suppliers who constantly change formulations to use new chemicals that are not on the list of lists (until they are) have become experts at greenwashing. You are basically trading less water for stronger poison no matter how you spin it. This marketing reminds me of the "Institute for Tobacco Studies" in the movie "Thank You for Not Smoking." There is a reason that the Dead Sea earned its name. The only solution is ZLD.

LaRont: Alex, are there other green technologies that fabricators should be paying attention to?

In our industry, there are technology solutions addressing the three types of waste: solid waste, liquid waste, and airborne emissions. ZLD deals with the liquid waste, but the system is also reducing the solid waste because we've taken the chemicals out of the waste treatment process. So, the sludge volume is less than that of a normal system. Also, we are not demineralizing the incoming city water, and saving the sludge volume there.

Matties: How much lower is the solid waste with the chemical reduction?

Typically, it's about 30% lower. On the solid side, it can be reduced even further by adding circular regeneration at each individual process step. This is unpopular with chemical and consumables suppliers, but it is great for business owners because you only fill the swimming pool once. I want to develop a model where the chemical suppliers provide the circular economy systems. Then they can get rid of the waste, and they can keep their margins if their IP is under control, but that is a more difficult business model than just selling stuff. From a sustainability perspective, you're reducing all the hazardous chemicals into a one-time use. It is a much better model for the world. It will take time and happen in steps, but it means less profit for chemical companies.

LaRont: That leaves air emissions. Are you considering working on any technology to help reduce air emissions in the future?

Yes. Once the central ZLD system adoption rate is higher, tackling air emissions is my next project if someone doesn't go there first (I wish they would). In most of the world's shops, they put a fume scrubber up and then vent it out to deal with air emissions, but a significant amount still gets out. You can also add chemicals to the water to make the reaction more efficient, put filters on specific processes, or add a cooling column to reduce the emissions at the source. Then there is the completely closed-loop system for air—something nobody looks at. The process-specific filtration is generally as far as anyone has gone, only about 1% do that, and it's mostly in Europe. The circular systems are the best. I've done a couple of facilities in my career. Nobody has tried to "fix" this issue, but if you do it the right way, it can be done with a decent ROI by saving chemicals and eliminating permits.

Matties: Who's making the decisions to consider new systems?

Right now, the best candidates are those who have a high cost to their waste treatment, are considering new factories, or are replacing their old systems. The idea is to target those candidates for the next 12 to 18 months and get the systems in the field as reference accounts in each region, as most of the install base is currently state-side. Once we have more regional reference accounts, we target the existing factories to show them that there is a better way. At the same time, in having those reference accounts, you market heavily with the OEMs so that they will create demand for these systems. Hopefully, other companies respond to my disruption with some positive initiatives of their own to compete.

Matties: Where should a board fabricator's attention be right now?

Everybody is looking for taxpayer funding, but another interesting idea is to try and fish somewhere else. AI is an interesting space for investment, and it has its hardware requirements. Embedded component CapEx investments have a low hurdle rate as well and are becoming increasingly desirable. Finally, ZLD is always a good idea to market yourself as green and hygienic vs. others.

LaRont: Alex, you mentioned that this movement toward environmental sustainability should not be driven legislatively because of the long timeframe. Are global standards a regional factor? What is the timeline in regard to legislative and regulatory pressure, regardless of where technology and ROI are at?

I don't think there will be that much regulatory pressure any time soon in the U.S. or Europe. The only place we really see that pressure is in China, and some in India. The U.S. and Europe have lost enough economically over the years that there is not much desire to put more regulations out there. I know of new facilities going up in Europe and the U.S. that do not have ZLD constraints. In the U.S., only some of the new factories are ZLD. We can still do this the right way through innovation that changes our market by making it the logical economic choice.

Matties: What else should we be looking at when it comes to sustainability?

We need to pay attention to the sustainability of the equipment supply chain. With investments in the U.S. market right now, every factory has a completely different equipment investment strategy, and it is not a domestic one. There is no globally competitive equipment supplier in the U.S., just holding companies. Also, in Europe, there are, effectively, just a couple of companies operating competitively at the leading edge globally.

LaRont: Alex, thank you very much for your time. It is always a pleasure to speak with you. PCB007

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Attracting 'Generation Green'

The New Chapter

Feature Column by Paige Fiet, TTM-LOGAN

In the electronics industry, we talk a lot about sustainability in terms of recruitment and retention of the next generation of engineers. But what if the key to sustaining the industry long into the future is through the more common definition of the word? What if, for just a moment, we think about sustainability in terms of the environment and what we as an industry are doing to care for it? Because, if you weren't aware, Gen Z cares tremendously about the environment and the actions companies are taking to preserve it. Without Gen Z joining the electronics industry's workforce, we won't be able to sustain the industry for much longer.

Why should companies care about Gen Z's love for the environment? For starters, it is believed Gen Z values environmental sustainability much more than their elder counterparts. According to a recent study[1], 62% of Gen Z shoppers prefer to buy from sustainable brands, with 73% willing to pay more for sustainable products. Shopping habits are just the beginning. Gen Zers (like all of us) want to live and work in communities that value sustainable practices. According to another survey[2], 64% of Gen Z noted the importance of an employer to act on environmental issues. In fact, 54% would take a pay cut to work for a business that reflects their ethics.

This passion for the world around us has long held importance to the newest generation, but it seems only to be growing with the rise of social media. In October 2021, TikTok recorded a view count of over two billion on hashtags #NatureLover and #EarthDay in a mere year's time. Today's digital climate allows for influencers to push agendas they deem important to

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millions of Gen Z (and Generation Alpha) followers. Videos with creators using eco-friendly products, recycled materials, and vegan clothes are trending daily. "Going Green" is the new cool for this generation.

So, where do employers start to attract these eco-friendly leaders? In short, by becoming eco-friendly leaders themselves. More and more young professionals are looking for businesses to take on the responsibility for their environmental impact. Gen Z is looking for future employers to make sustainability part of their brand by creating open and honest lines of communication on efforts they are making to prioritize environmental initiatives. However, business beware, Gen Zers are known to quickly "cancel" a brand or company they believe is "greenwashing"—pretending to be environmentally conscious.

Beyond taking action to reduce their carbon footprint and recycling, here are some ideas to promote sustainability inside and outside of the office.

- **Host community clean-up days.** By organizing and encouraging volunteer groups to aid in a community clean-up day, companies are showing their care for the community that supports them. In addition, employees are given a sense of pride by keeping the community they live in happy, healthy, and clean.
- **Encourage alternate modes of transportation.** Are employees able to bike between buildings instead of driving? Can they work from home one to two days a week? Are there walking options for them on their way to/from work? Reducing the amount of driving time reduces your employees' carbon footprints; the more people involved, the greater the impact.
- **Consider adding recycling bins around the office.** Are your employees using a lot of paper, cardboard, or even batteries? Maybe consider adding a handful of recycling bins around the office to reduce waste.
- **Switch to eco-friendly water and coffee cups.** Most offices and breakrooms have water filtration systems or coffee makers stocked with single-use plastic or Styrofoam cups. Consider swapping them for cups made of recyclable materials. Also, encourage reusable water bottles and thermoses.

Adding in just a couple of these actions will increase employee satisfaction and may help the mental well-being of your employees. In fact, in the Bupa study[2], 68% of Gen Zers are anxious about environmental issues compared to 63% of millenials, 62% of Gen X, and 65% of baby boomers. This study found that mental health costs for UK businesses are €45 billion a year. Imagine what we could do for our employees by participating in the environmental revolution.

To recruit and retain an environmentally conscious generation, companies must take environmental sustainability seriously. Showing employees you care enough about them that you're willing to instill practices that benefit the communities around you is an act of showing them how much you care. Who wants to live and work in a place where the water is not drinkable and environmental resources are limited? It's time for businesses to take ownership of their consumption and make changes to maintain the resources we currently use for future generations. The sustainability of our businesses and industry is dependent on the sustainability actions we take for the planet. **PCB007**

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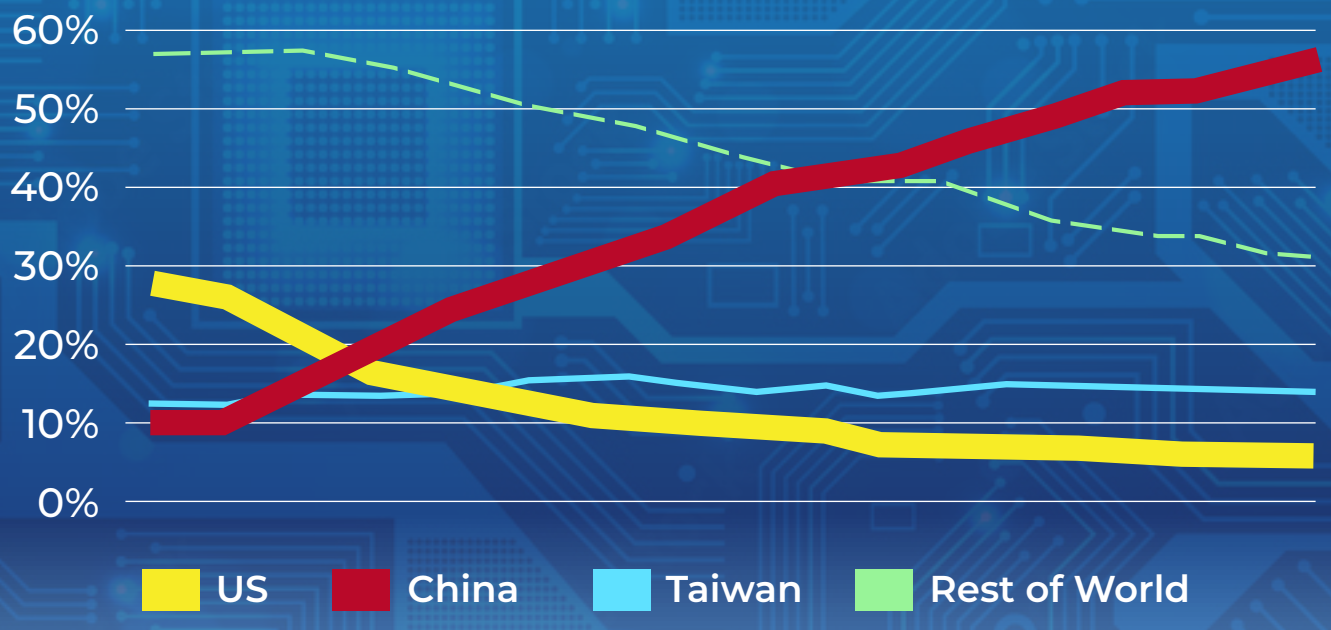
Paige Fiet is a process engineer at TTM-Logan, and in the IPC Emerging Engineer Program. To read past columns, click here.

CONGRESS MUST ACT TO RESTORE AMERICAN LEADERSHIP

Global Production of PCBs



Over the past three decades American-made PCBs shrunk from 30 percent to 4 percent of the world's supply

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- Accelerating efforts to secure critical supply chains

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Digitalisation and ESG

Feature Article by Marina Hornasek-Metzl,
AT&S

Digitalisation and ESG are prominent, high-priority topics in the global business community. The first focuses on applying technology throughout the value chain to produce faster, smarter, and more desirable business outcomes. The latter emphasises the broader value a business is expected to create for its stakeholders from an environmental, social, and governance perspective[1].

Digitalisation has the potential to reduce global emissions by up to 20% in sectors such as energy, materials, and mobility. By 2030, these industries can reduce emissions by 4-10% by accelerating the adoption of digital technologies[2]. However, the energy consumption of digital technologies is also a significant contributor to carbon emissions. During the first months of COVID-19 stay-at-home orders from January to March 2020, internet use grew by 40%, ultimately demanding 42.6 million megawatt-hours of additional electricity globally[3].

The Paradox of the Semiconductor Industry in Meeting Global Climate Goals

The industry presents a paradox. Meeting global climate goals will, in part, rely on semiconductors. They're integral to electric vehi-

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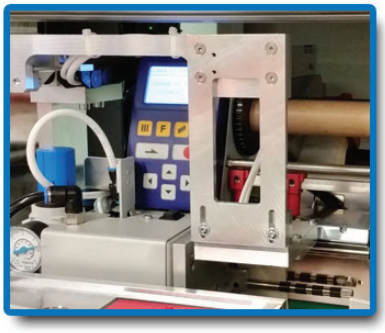

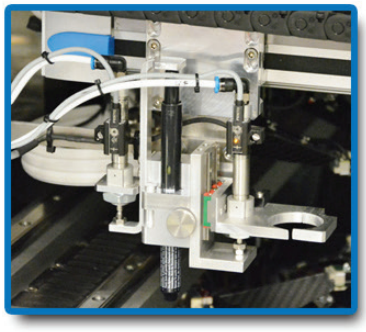

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cles, solar arrays, and wind turbines. But chip manufacturing also contributes to the climate crisis (Figure 1). It requires huge amounts of energy and water—a chip fabrication plant, or fab, can use millions of litres of water a day—and creates hazardous waste. While the industry contends with its emissions, manufacturing expansion, and advancement, these are required to, among other things, support the global economy and limit the impacts of climate change for all industries, adding an intriguing level of nuance to the semiconductor emissions story.

Semiconductors are required for climate change solutions such as electrification, low-carbon energy, electric vehicles, and digitalisation, which have led to a reduction in global emissions of 1 to 2 gigatons in 2020 with the potential to enable annual emissions avoidance of 2 to 5 gigatons by 2025[4]. In addition to more chips, the world demands greater computational power for applications, such as artificial intelligence, which could aid in climate change solutions. Advanced semiconductors require more steps to manufacture, and these steps utilize more electricity and chemicals. Growing emissions intensity per unit of production compounds the emissions impact of increasing manufacturing output.

Several semiconductor players, such as AT&S, have committed to science-based emissions targets[5]. Over the next few months or years, more semiconductor companies are expected to commit to ambitious and actionable emissions targets.

How Digitalisation Helps the Semiconductor Industry Achieve ESG Goals

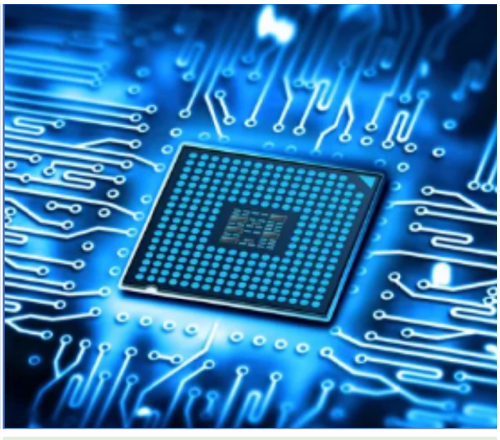
Digitalisation is transforming the semiconductor industry in many ways. The industry can improve its ESG data management and reporting by automating data collection and analysis. This can help identify areas where it can reduce its carbon footprint and develop more effective ESG strategies. The semiconductor industry is responsible for a signifi-

Around 37 billion tonnes (gt) worldwide from all sources

Source: ipcc.ch (Excluding land use, land use change and forestry.)

Around 1.2 billion tons ICT industry

Source: Freitag, C. et al 2021



Around 1.75 million tons semiconductor manufacturing (Includes Scope 1, 2, and 3 consumables and services)

Source: SEMI SCC Whitepaper on Transparency, Ambition, and Collaboration, 2023

Figure 1: CO_2 -equivalent emissions from semiconductor industry in perspective.

cant amount of greenhouse gas emissions, but here are some ways to reduce the carbon footprint:[6,7]

1. **Optimising energy consumption:** Semiconductor companies can reduce their carbon footprint by optimising energy consumption. For example, they can use renewable energy sources, such as solar and wind power to power their operations.
2. **Reducing waste:** Semiconductor manufacturing generates hazardous and non-hazardous waste streams. Here, collaboration with the supply chain to identify opportunities for waste reduction or alternative use, and identify ways to reduce manufacturing waste by improving yield, optimising processes and minimising the waste of scrap material, is crucial.
3. **Improving supply chain transparency:** Semiconductor companies can improve their supply chain transparency and traceability, essential for ESG reporting. This can be achieved by using digital technologies such as blockchain to track the movement of goods and materials throughout the supply chain. More companies are building supply chain data management platforms and adopting full material disclosure and life cycle assessments to evaluate the environmental and social impact of their supply chains, from manufacturing to transportation, and product use to product recycling. In manufacturing, big data and machine learning have enabled solutions to optimise production scheduling decisions and navigate a wide array of complex factors, including customer orders, batch sizes, line capacity, and workers' skill levels. As a result, plant productivity increases, the carbon footprint is reduced, and the well-being of shop floor employees improves.
4. **Improving stakeholder engagement:** Semiconductor companies can improve their stakeholder engagement by providing more channels for communication and feedback. This can help them to better understand the needs and expectations of their stakeholders and develop more effective ESG strategies.
5. **Developing innovative solutions:** Semiconductor companies can improve their ESG performance by developing innovative solutions that address ESG challenges. For example, they can develop new materials and processes that reduce the environmental impact of semiconductor manufacturing.

The Impact of Green Electronics

Along with 48 other companies and research institutions covering the entire value chain, AT&S is working on the development of new technologies to make electronics production in Europe more sustainable as part of the EECONE (European ECOsystem for greeN Electronics) project. The 35 million euro project is scheduled to run for three years and is funded with 20 million euros from the European Union and participating member states.

If our substrates and PCBs are as environmentally friendly as possible in their use of resources, and electronic waste can be further reduced, we will be able to make a considerable contribution to a more sustainable future.

EECONE, a large-scale research project under the leadership of the German chip manufacturer Infineon, is intended to find new ways to make the electronics industry in Europe more sustainable along the entire value chain. The objective is to minimise the use of valuable resources in the production processes by exploring better ways to recycle, repair and treat electronic components and, among other things, find alternatively usable materials. Reducing non-reusable waste and improving recycling systems is a subject of research within the project.

At the same time, other project partners will work on more resource-efficient ways of microchip production and on more sustain-

able design as part of EECONE. The development of economical, connected sensors which make do without an external power supply is also part of the research plan, as is the use of data analysis tools to optimise the lifetime of electronic products.

New Opportunities to Improve Sustainability Through Digitalisation

Digitalisation has indeed opened new opportunities for the semiconductor industry. The industry is leveraging digital technologies to improve product development, manufacturing, and lifecycle processes. The future of digital transformation in the semiconductor industry is to pursue Industry 4.0 to go beyond chips. Digitalisation offers great opportunities to improve sustainability, and maybe even to help save the planet. **PCB007**

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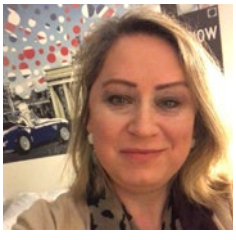

Marina Hornasek-Metzl is the senior director of corporate ESG at AT&S.

Nano Dimension Announces Another Deep Learning AI Patent Granted to its DeepCube Technology

Nano Dimension Ltd. was granted a patent for technology developed by its industrial artificial intelligence (AI) group, DeepCube, that enables better training and optimization of decentralized deep learning-based AI models.

The U.S. patent addresses one of the core challenges of deploying AI models in the real-world, specifically continuously training models on new data when that data belongs to a customer. In the industry at-large, dealing with new customer data has often been a limitation due to sensitivity and confidentiality concerns that limit data shareability. The new patent addresses this challenge by ultimately training and improving the AI models on customers' premises, without Nano Dimension having direct access to the new data or model.

DeepCube is currently developing an end-to-end AI platform for industrial usage that is not only limited to additive manufacturing. The software platform is intended to run autonomously on customers' premises, and continuously improve itself, such that the more it is used, the higher the accuracy will become.

Nano Dimension's DeepCube alone has 50 patent applications filed, of which 27 have already been granted. These patent applications are filed in eight different jurisdictions, providing a truly global IP protection.

(Source: Nano Dimension)

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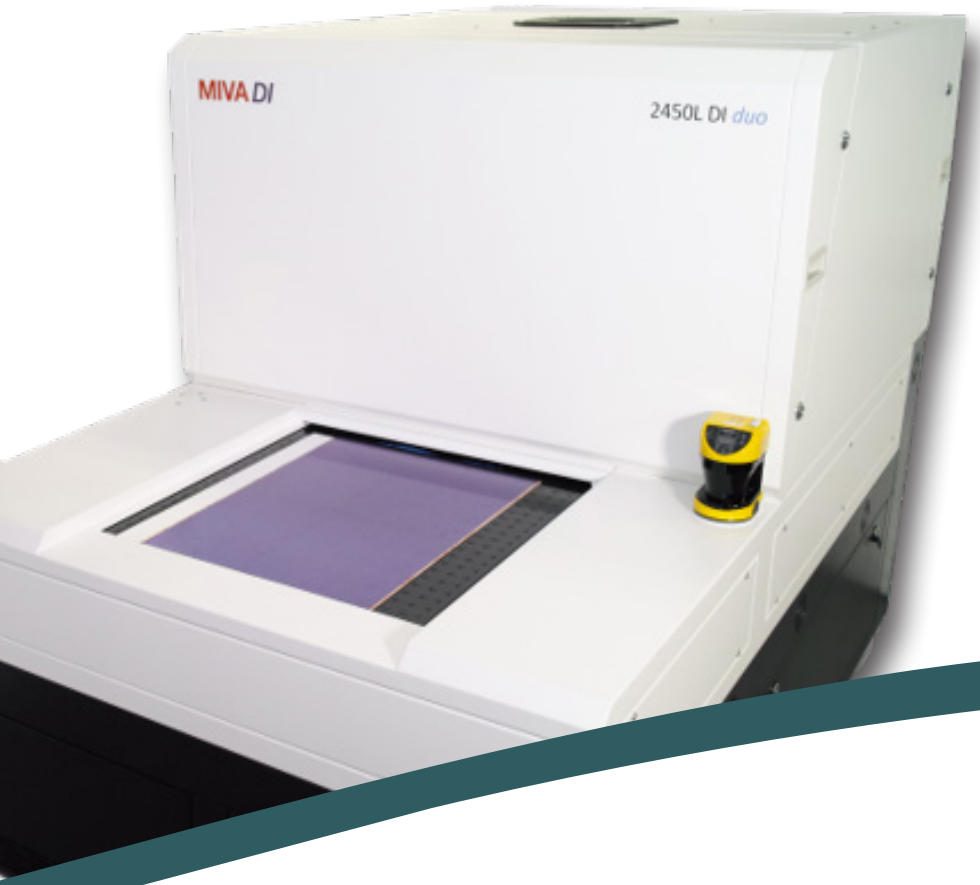

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Sustainability Challenges: A Collaborative Approach

One World, One Industry

Feature Column by Dr. John W. Mitchell, IPC PRESIDENT AND CEO

My personal belief is that changes to the electronics industry due to sustainability will be the most far-reaching in the industry's history. This is not about if sustainability will impact us, but about when and if my organization will be left behind. We need to accelerate work that promotes sustainability and aims to achieve the ambitious sustainability goals set before us. The "we" includes all of us as individuals, but also as valued members of the global electronics manufacturing community. This diverse community can together address our greatest sustainability challenges.

Why Is IPC Involved?

IPC is committed to helping this community respond to and thrive in our world of continual change. IPC has global reach, is dedicated to electronics manufacturers, and has a long history of collaborating with the industry. IPC knows the industry and that it has the capacity to build electronics better. That means building sustainably if given the right solutions and tools. IPC is positioned to help with industry standards, workforce training, certification and validation programs, industry intelligence, and advocacy.

What Does It Mean to Build Electronics Sustainably?

Honestly, there are several aspects to what this means, and I can only touch on a few. It means we make conscientious lifecycle management decisions for all electronics manu-

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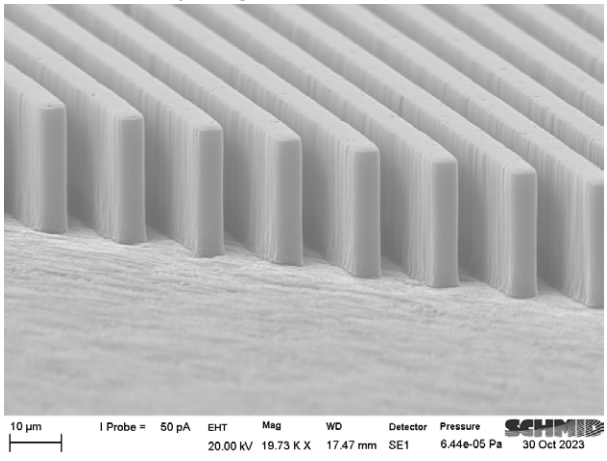

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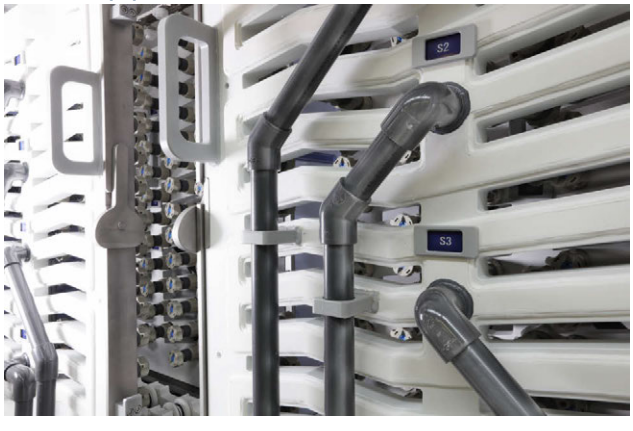

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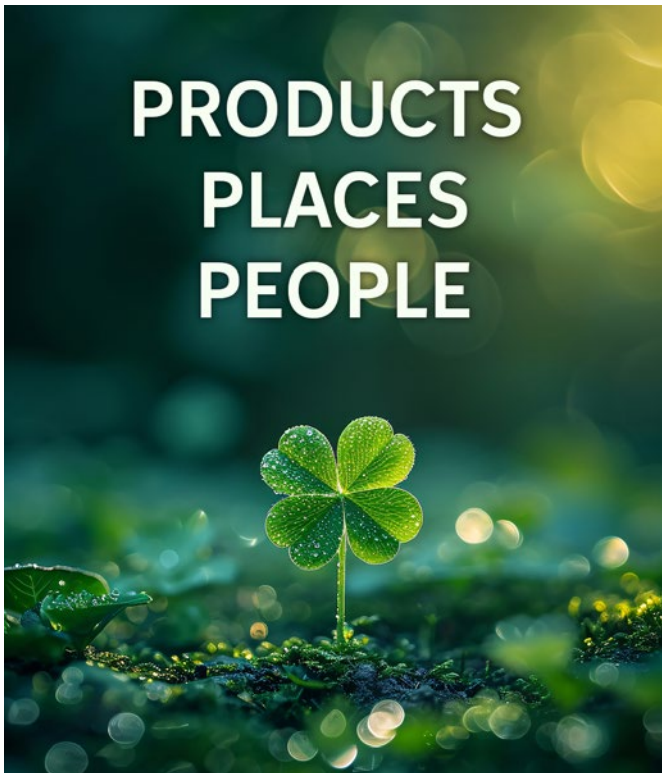

facturing processes and products. More practically, this means we are paying attention to information that can increase resource efficiency and decrease unwanted impacts. I tend to think of sustainability as impacting three broad "Ps" of our environment: products, places, and people. Much of the effort at this point, likely because more of the regulatory information has been clarified here, has been focused on places: where and how we manufacture our products. But for real progress to happen, all three Ps need to go through modification at some point.

What Are the Key Issues?

Information

In this issue, Charles Nehrig, TTM Technologies Inc., calls attention to the critical uses of water in printed circuit board manufacturing processes. He highlights how his company has embedded water use reduction and water footprint goals into its operational and business goals. They know how they're performing against these goals because they use network-based tracking of water consumption in all manufacturing locations.

Technological innovation

Also within this issue, Dr. Marina Hornasek-Metzl, AT&S, explains how digitalization helps the industry achieve its sustainability goals. Automating data collection and analysis helps to identify where impact reduction is possible. She also highlights that this industry presents a paradox: Electronics present sustainability solutions and challenges. Indeed, there are synergies between the circular economy agenda and digital technologies and digitalization. Electronics manufacturing processes require natural resources, chemicals and materials, and human workers; these processes present circularity challenges. At the same time, electronics products assure progress toward reducing impacts.

AT&S and dozens of other companies and research institutions are working in Europe to develop new technologies to make electronics production more sustainable. Digitalization and leveraging digital technologies will continue to improve what we make and how we make it. Technology solutions like ion exchange systems are less fancy but still elegant solutions, in particular for wastewater treatment. We value processes paired with flexibility and innovation to solve sustainability challenges.

This issue of *PCB007 Magazine* gives the industry examples of real solutions useful to them now and into the future. Addressing sustainability for electronics challenges takes a collaborative approach with free-flowing communication. **PCB007**

To learn more about IPC's own Sustainability for Electronics initiative, click here, or contact Kelly Scanlon, IPC's lead sustainability strategist, at KellyScanlon@ipc.org.

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

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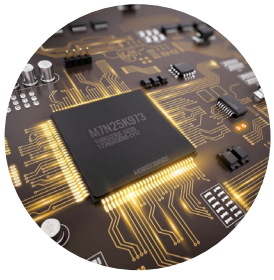

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Reducing Etch System Water Usage, Part 1

The Chemical Connection

Feature Column by Don Ball, CHEMCUT

Water conservation has become an important component of the overall system design for most manufacturing operations today. Changing climate conditions and increasing populations are beginning to strain the freshwater supplies in many areas of the country. As a result, as equipment suppliers, we see an increasing number of requests for options that reduce water usage in proposed wet processing systems. Etching systems tend to use more water because of the need for close temperature control to maintain steady etch rates and the rinsing requirements for complete removal of corrosive etchants from the surface of the product before the next process step. This column contains some simple suggestions for reducing water usage in etch systems that won't strain the budget too much.

Cooling Water

One large source of water usage in the etch system is cooling water to maintain the etchant temperature. Most cooling coils are made of titanium because of the corrosive nature of the etchant. Titanium is not the most efficient metal for heat transfer, so it is common practice to hook up a water feed to the cooling coil and run it wide open.

Checking the cooling water temperatures at the entrance and exit of the cooling coil under these conditions will usually show no temperature change. This is good if the etchant tem-

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perature is steady since it means the full length of the coil is being used efficiently. However, it may not be necessary to run the water at full flow. You should put a valve on the cooling coil input and slowly reduce the water flow until the difference in the temperature (ΔT) of the cooling water at the output is a degree or two higher than the input temperature while running the etcher at peak loading. This will reduce the amount of water used to the minimum needed to maintain the etchant temperature and cooling coil efficiency. (Believe it or not, higher ΔTs will decrease the efficiency of the cooling coil.) Depending on cooling coil design and plant water pressure, this simple step can cut cooling coil water usage by as much as 25%.

The ultimate reduction in cooling water use would be the addition of a chiller to the cooling water line. This is a well-established technology that chills the water to well below ambient, thus increasing cooling coil efficiency. It then removes the heat from the water from the output of the cooling coil and returns it to the system. In this way, the water usage for cooling is reduced to nearly zero. Note that there is no such thing as a completely closed water cycling loop.

Since the typical flow rate of cooling water in an etcher is four to five gallons per minute or more, you can see that this is a significant savings. The number of hours your etcher runs per day, along with the cost of water in your area, will quickly tell you if this investment is cost-effective for you. Also, keep in mind that the chillers can be used on other cooling water lines besides the etcher.

In 2000, for example, our injection molding equipment used 3 million gallons of cooling water for the year. In 2001, we added two chillers to the injection mold cooling water lines. In 2023, our water usage for injection molding shop cooling water was 96,000 gallons even though we have added a couple of injection molding lines over the years to keep up with increasing production.

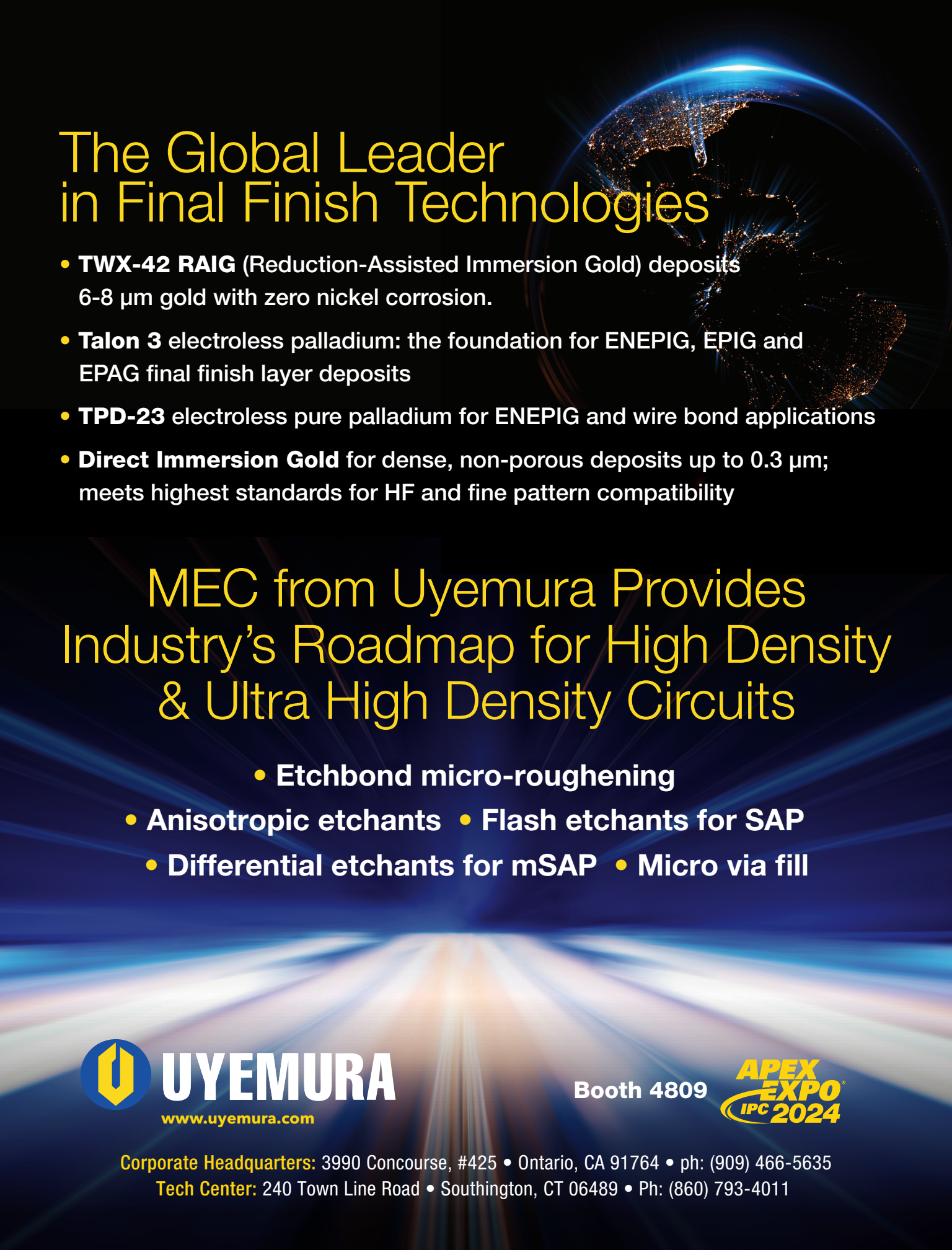
Rinses

The other main consumer of water in the etching line are the rinses. When I first started in this business in the early 1970s, it was common to feed the spray rinses with fresh water and discharge it directly to the drain. Of course, this is not an acceptable practice today. The first effort at reducing water usage was to use lower flow rate nozzles when it was realized huge amounts of water weren't needed to rinse the boards if the water was sprayed under pressure. If you can believe it, double-sided boards with 0.010" (250 µm) spaces were considered state-of-the-art. That solution didn't last very long before more water savings were demanded. Retrofitting existing equipment is harder since reducing water flow usually means adding modules to the etch line, which isn't always straightforward and easy. New lines, however, could be designed with built-in water-saving features.

A relatively easy retrofit was to add a sump under the flow-through rinse and feed fresh water into only the last spray tube while recirculating the water through the rest of the spray tubes and overflowing to the drain or in-house waste treatment system. This has the advantage of more efficient use of the water, reduced flow to waste treatment, and the last thing the panel sees as it exits the rinse is fresh rinse water. Depending on the number of spray tubes in the rinse water, usage can be reduced by as much as 50–75%.

In my next column, I will cover cascade rinses, flood rinses, and ways to reduce etcher water consumption to almost zero. See you then. **PCB007**

Don Ball is a process engineer at Chemcut. To read past columns or contact Ball, click here.



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Water Management in a Large Printed Circuit Board Manufacturer

Feature Article by Charles Nehrig
TTM TECHNOLOGIES

TTM's environmental management is grounded in its Environmental Statement and Environmental Policy, which promotes measures that make for a more responsible environmental management process. Our management system helps TTM work toward minimizing its environmental footprint and increasing the sustainability of its operations. TTM monitors its environmental performance just as it monitors its operational performance, and provides the resources required to adhere to the Company's environmental responsibilities. This enables TTM to reduce the use of natural resources required to manufacture printed circuit boards, electrical assemblies, and electrical parts and components produced at the TTM facilities.

Key to those natural resources is water. Water is a critical operational component for TTM and a critical natural resource for those who live in the communities where we operate. As a result, TTM has taken a very measured approach in the management and treatment of water and wastewater associated with our manufacturing operations. Toward this effort, TTM's operational goals, key performance indicators (KPIs), capital plans, and sustainability goals have a component that is explicitly directed at water use reduction and water footprint reduction. TTM has undertaken improvement efforts and initiatives to reduce (or eliminate) the impact of each TTM location.

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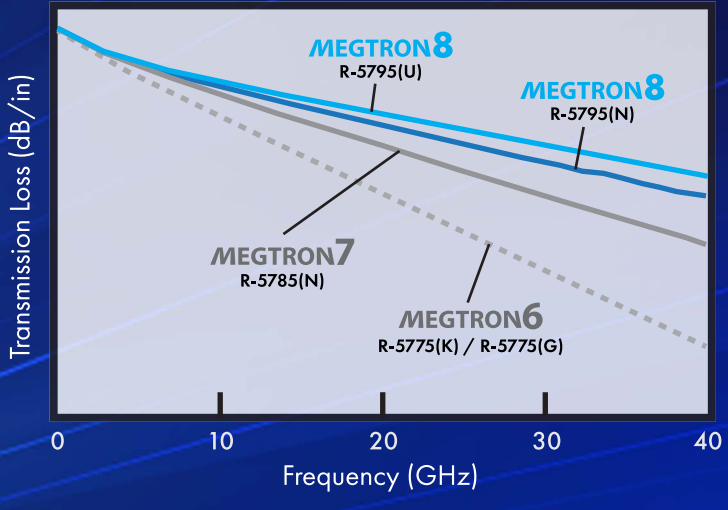
Ultra-low Df glass cloth type	Laminate	**R-5795(U)**
	Prepreg	**R-5690(U)**
Low Dk glass cloth type	Laminate	**R-5795(N)**
	Prepreg	**R-5690(N)**

	Dk	Df
R-5795(U)	3.1 @ 14GHz	0.0012 @ 14GHz
R-5795(N)	3.1 @ 14GHz	0.0016 @ 14GHz

Frequency Dependence by Transmission Loss

About 30% improvement in transmission loss compared to MEGTRON 7 (N) at 28GHz



PCB construction	3L PCB Strip line
Copper thickness	18 μm (IL)
Core	0.13 mm
Prepreg	0.15 mm
Zo Impedance	50Ω
Inner treatment	No-surface treatment
Measurement method	2 port S-parameter
Frequency range	0.2 - 40GHz
De-embedded	Multiline TRL method

Evaluation Sample (cross section)

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Charles Nehrig

The company's most critical environmental initiatives with respect to water management fall into the following categories:

Wastewater Treatment and System Upgrades

TTM has gradually replaced existing wastewater treatment (WWT) systems with a treatment technology that relies less on chemical precipitation and more on ion exchange. Although chemical precipitation WWT systems are robust and produce effective and compliant wastewater, and they rely heavily on chemical treatment agents to promote contaminant removal (metals); the precipitate that is produced is typically a sludge with a high moisture content and a low metal content. In the end, the standard precipitant-based WWT systems are an inefficient use of chemical treatment aids and produce a reclaimable material that requires excess energy and/or handling to reclaim the metal, oftentimes resulting in a poor return on the metal recovered, as well as the capital invested.

TTM has undertaken the elimination of chemical precipitation WWT systems (clarifiers, batch precipitation and micro-filtration) in favor of selective ion exchange. The ion exchange systems are very similar to the deionized water systems that most manufacturing processes employ to provide product water of the correct technical specification. Most of these ion exchange WWT systems are built in-house by TTM utilizing off-of-the shelf industrial equipment and water treatment technologies. This approach provides a smaller and more sustainable footprint for the same treatment needs.

Over time, TTM has found that this means of treatment is scalable and can be altered to reflect or respond to increased manufacturing capacity utilizing the same basic WWT infrastructure. Selection of the correct ion exchange resin media is key to developing a robust and repeatable treatment process.

Wastewater Segregation

Key to the change from chemical precipitation to ion exchange is accurate wastewater segregation and use. As identified above, chemical precipitation is a robust and worthy treatment technology that is particularly forgiving to unsegregated or minimally segregated wastewater streams (WWT influent). In most cases, generating compliant treated wastewater is a function of treatment chemical use.

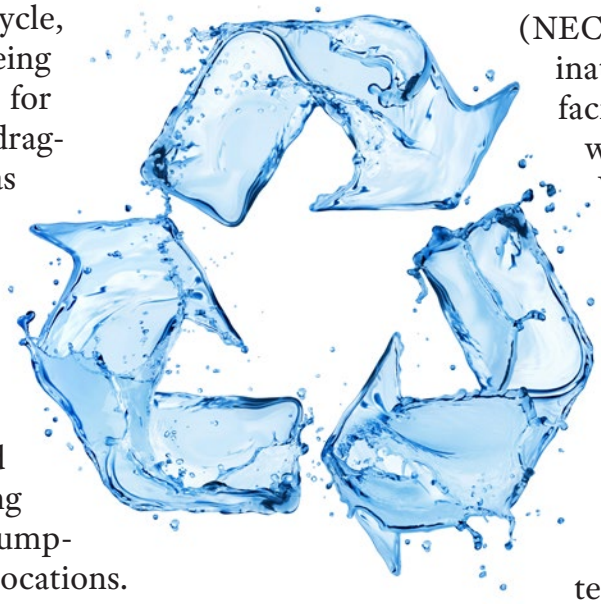
Segregation reduces or eliminates this effect. While the complete elimination of all chemical precipitation reactions during treatment is not reasonable, a dramatic reduction is very achievable and often increases recovered resource value. Grouping and segregating wastewater by various contaminant components (i.e. metals, pH, organic content, chelation, buffering) is critical to both reduce consumption, reduce treatment chemical use, and to set the groundwork for alternative treatment technologies.

Water Use Reduction

TTM has initiated many key programs to reduce the use of water. This has been done for several reasons:

1. Water consumption and the ability to discharge compliant wastewater can be an operational gate to some operations.
2. Equipment suppliers often provide worst-case guidance when in the technical start-up phase of equipment installation, and the amount of water needed is typically in excess of actual.
3. Process chemical suppliers often take the same approach, requiring the end-user (the part manufacturer) to use far in excess of what is needed for that process or for the individual process step. Historically, this has been proven out with only minor exceptions.

Simple individual testing with off-the-shelf measurement equipment can be utilized to "tune" each rinse of a specific process line, dialing in the water needed to allow for the turnover of an uncontaminated rinse bath prior to the next rinse cycle, and to ensure the part being processed will be ready for the next step (eliminate drag-out). Each process step has a script and a setting for the rinse and feed flows, as determined during worst-case (full occupancy) processing and testing.



TTM has also adopted a network-based tracking system for all water consumption in all manufacturing locations. In this system, all water consumers at each location are measured by a standard flowmeter (with pulseable or output capabilities), recorded, tracked, and reviewed on a continuous basis. Each system will alarm and notify personnel of high use, demand, or any parameter that is appropriate for the specific application. The application has been pioneered by the Advanced Manufacturing Group and EHS Team at TTM. The result is a standard approach used in all manufacturing sites to reduce water consumption and normalize operations, with the goal of reducing water consumption and defining appropriate use.

TTM has undertaken a goal of transitioning certain facilities to zero liquid discharge (ZLD). This effort will result in zero wastewater discharged as a result of circuit board manufacturing. Much of the operational aspects are, and were, key to approaching this goal. ZLD is the end state of all water management efforts. ZLD is currently in place at three TTM locations.

Stormwater: No Exposure Certified Facilities

Though stormwater is not a consumable resource, it is a water resource that requires management. With the majority of the North American (NA) manufacturing facilities being identified as no-exposure certified (NEC) facilities, TTM has eliminated the footprint of those facilities with respect to stormwater potential impacts. While all sites that operate under a state stormwater discharge facility permit discharge in a compliant manner, TTM will continue to improve and add those remaining facilities to the roster of facilities that have achieved the goal of eliminating all stormwater impact at their manufacturing sites.

TTM will continue to work every day to improve the sustainability of site operations and to ensure that every site's environmental footprint is made smaller. **PCB007**

Charles Nehrig is the senior director of EHS and sustainability at TTM Technologies.

Going Beyond the CHIPS Act to Power American Manufacturing

American Made Advocacy

by Travis Kelly, PCBAA

Where have all the factories gone? A tour of America's former bustling manufacturing communities is a stark reminder that, for the past three decades, we let the microelectronics manufacturing ecosystem disappear overseas, primarily to Asia. For decades, foreign competitors seeking to control critical markets played a long game. Government investment and subsidies were effective in undercutting U.S. and European companies. As other countries created this unfair competitive advantage in manufacturing, the know-how also migrated in their direction. This resulted in the serious workforce challenges the semiconductor and printed circuit board industries face today.

It's no surprise that 30 years of different strategies led to starkly different results. We depend on the rest of the world for the technology stack that enables semiconductors to function. The U.S. contributes just 4% of the world's supply of PCBs, less than 1% of the substrates, and 3% of the advanced packaging capability.

The implications are profound. First, the long supply chain between the U.S. and Asia is vulnerable to natural disasters, political decisions, and disruptions tied to global chokepoints. As we have seen in the Red Sea, small bands of bad actors can cripple the global supply chain for months.

More and more American companies are examining their global supply chain and seeking to rebalance risk with a more balanced portfolio. Diversifying their footprint across Asia is a first step, but it doesn't get those microelectron-

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ics any closer to the United States. Asia has shipping chokepoints that, if disrupted by natural or manmade disasters, could become factors for microelectronics headed to and from the U.S.

We will continue to play catch up and remain overdependent on a long and vulnerable supply chain for 90% of the printed circuit boards and the rest of the microelectronics ecosystem powering our critical infrastructure and national defense systems if Congress doesn't address the entire microelectronics ecosystem.

The CHIPS Act claims to have addressed critical disruptions in the semiconductor supply chain. The funding thus far has been for semiconductors but not for the rest of the technology stack. The new fabs being built in the U.S. will begin producing chips in a year or two, but this doesn't solve the supply chain challenge. We will still ship components back and forth across the globe when we should be investing in the U.S. microelectronics ecosystem.

The one thing the CHIPS Act did well was attract private investors. The same could be done for printed circuit boards and substrates. The Protecting Circuit Board and Substrates Act would do just that. HR 3249 calls for a $3 billion investment in R&D, workforce development, and manufacturing, along with a 25% tax incentive for companies buying PCBs made in America.

Without government investment, we will be perpetually dependent on countries abroad for the technology stack that chips need to function.

We know we will never have 100% of the manufacturing and assembly in the U.S. However, the current situation leaves us vulnerable to forces outside our control, and Congress needs to pass legislation to restore this vital industry. We can't afford another decade of decline.

The PCBAA believes in, and fights for, market fairness and a level playing field on which U.S. PCB and substrate manufacturers can compete and win. This is the year to join our effort by visiting us at pcbaa.org or contacting me directly. **PCB007**

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

Lighting the Path: Exploring Exciton Binding Energies in Organic Semiconductors

Organic semiconductors are materials that find applications in various electronic devices. Exciton binding energy is an important attribute that influences the behavior of these materials. Now, researchers have employed advanced spectroscopic techniques to accurately determine these energies for various organic semiconductor materials, with a high precision of 0.1 electron volts. Their study reveals unexpected correlations that are poised to shape the future of organic optoelectronics, influence design principles, and find potential applications in bio-related materials.

Advancing research in this domain, a team of researchers led by Professor Hiroyuki Yoshida from the Graduate School of Engineering at Chiba University, Japan, have now shed light on the exciton binding energies of organic semiconductors. Their study was recently published online in The Journal of Physical Chemistry Letters on December 11, 2023.

The team first experimentally measured the exciton binding energies for 42 organic semiconductors including 32 solar cell materials, seven organic light-emitting diode materials, and three crystalline compounds of pentacene. To compute the exciton binding energies, the researchers calculated the energy difference between the bound exciton and its "free carrier" state.

The outcomes of this study are set to shape the fundamental principles pertaining to organic optoelectronics and also have potential real-life applications. (Source: Chiba University)

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IPS Technology Showcase

Interview by Barry Matties
I-CONNECT007

In part two of our interview with IPS team members Travis Houchin, Larry Boehm, and Kaal Glazier, we shift the conversation to the upcoming IPC APEX EXPO in April.

Barry Matties: I would like to discuss the technology you will showcase at IPC APEX EXPO and what you expect from this year's show.

Travis Houchin: We will showcase our vertical rotary processing machines (VRP), which can produce extremely tight lines and spaces. We'll also have a conveyorized piece of equipment. No doubt we will have many conversations about contact-free processing as many are moving into producing UHDI. Visitors will also see our very low-volume, small-footprint equipment.

Is there a growing demand for vertical, contact-free processing?

Houchin: Yes. Interest in contact-free vertical processing is growing compared with traditional conveyorized machines. The ability to etch fine lines and spaces is increasing for all our customers. We have designed affordable small pieces of equipment with low sump volume and small footprints. People are using these a lot to experiment with vertical and contact-free processing to see what can be achieved and how it benefits them.

Overall, is vertical on a comeback?

Houchin: It is. We are finding so many more people wanting to do vertical processing for several reasons, including eliminating puddling on the top surface and track marks from wheels on the conveyor. So, we are seeing vertical as the way of the future.

Vertical is not a new concept for IPS. Of course, IPS is well-known for its automated plating lines and horizontal lines, but you also have a long history in vertical equipment.

Houchin: Correct. Our VCM and VRP product line has been around for 30-plus

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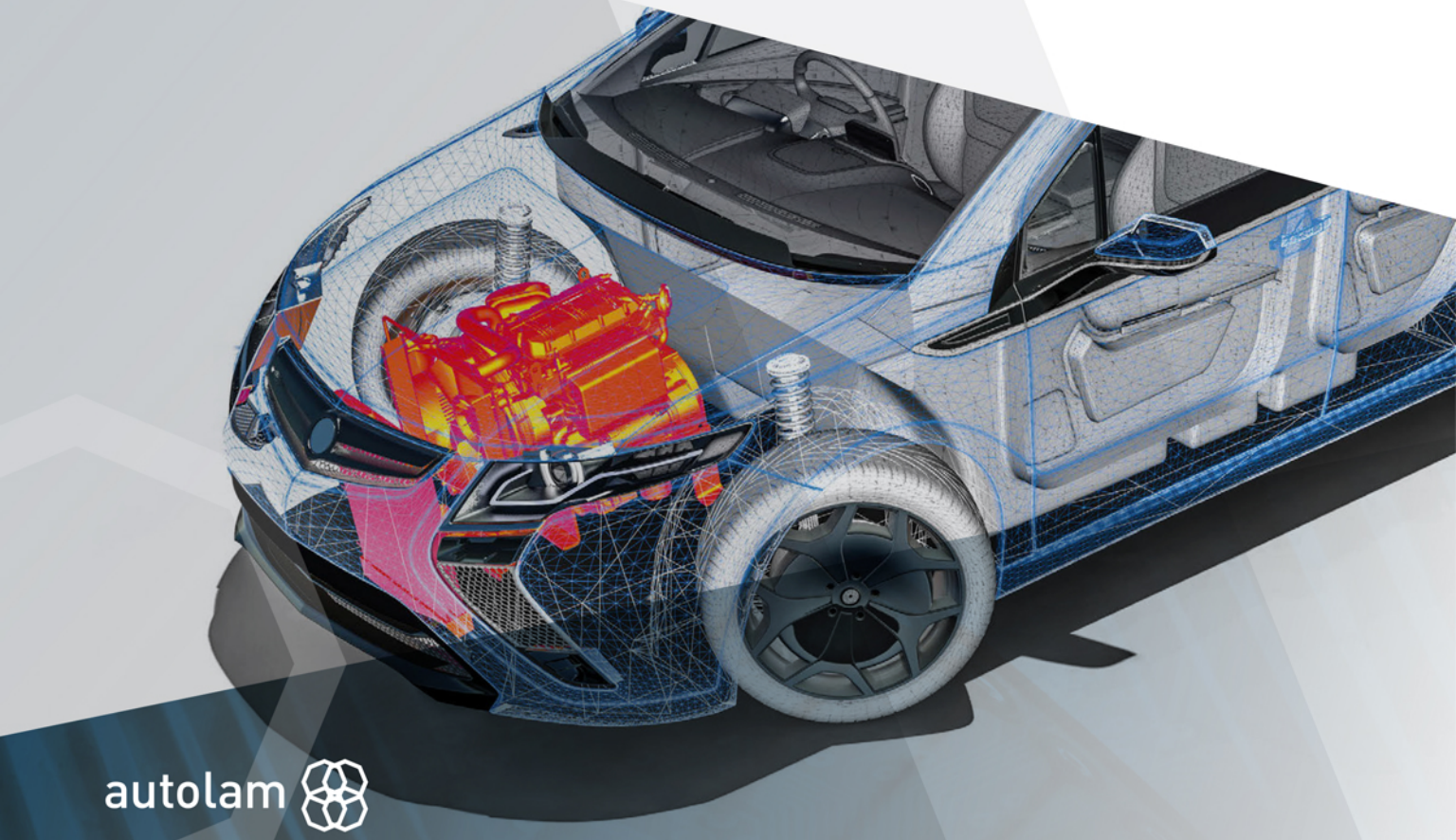

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years. We have had all the patents on that. We have been able to continue R&D and improve it over the years. This ensures we are well prepared to meet our customers' future needs for manufacturing and advancing their offerings. More people are inquiring frequently; it's definitely trending.

Kaal, I understand that R&D is something that excites you.

Kaal Glazier: Yes, I was interested in R&D as a college student. Now, in my job, I always look at the next trends and ask how we can experiment and create new products to meet those trends. IPS is committed to ongoing R&D, and in many cases, we work closely with our customers in that process. For example, I can only talk about this generally (for confidentiality reasons), but a particular customer asked us about doing a small test piece. We worked with them on their specific needs, and we produced a small machine that easily fit their footprint requirements. It also met their technical requirements to run a few high-end test panels at a time. Additionally, it provided them with a competitive advantage.

Larry Boehm: Our smaller machines enable people to run that small test panel with a minimized floor footprint. For example, once a new chip comes out, how will it interface with these new PCBs? Does it need a new PCB? That's where some of our smaller machines can help them. They can produce just three to four panels to see whether their technology works. Now they have a small machine they can afford, and they can install it immediately and do those proof tests.

Overall, the total cost to the customer that Kaal mentioned was much lower to produce test panels with the small line than if the customer went with a full-scale line.

Cost is always a concern, but maybe even more so today. Are you seeing increases? Are things stabilizing?

Houchin: Everything has been stabilizing. Some of our supply chains have eliminated the extremely long lead times and the price uncertainty of not knowing whether an item will cost more in a week or two. Occasionally, we may bump into long lead times on some items, but we can forecast and know the forecast is solid.

Larry, overall, what do you expect from IPC APEX EXPO?

Boehm: Right now, we're at a technological high point where everybody will want to go to the show to see what's out there and the new technologies that are developing. I think it will be a good show with a pretty high attendance rate. Also, many people are curious about the change in venue to Anaheim. Overall, it should be a busy show, and we expect our booth will have a good crowd to look at the latest technology.

Great. Thanks to all of you, and we look forward to seeing you there.

Houchin: Thank you. **PCB007**

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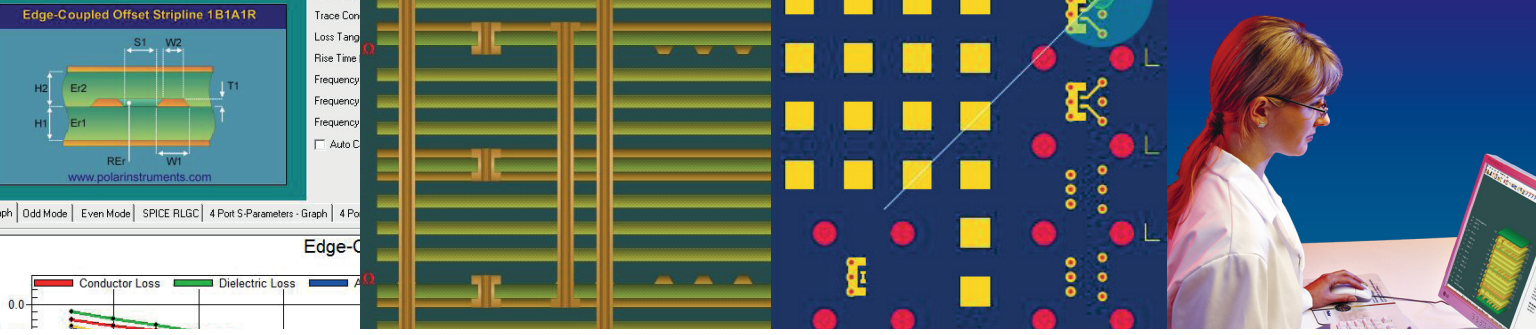

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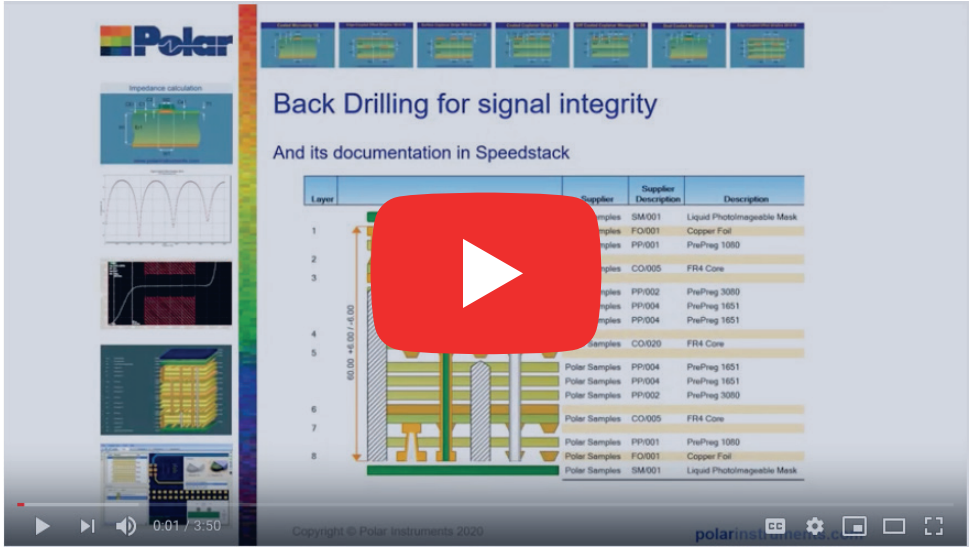

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An Ultimate Goal in Sustainability: Recyclable PCBs

Feature Interview by Marcy LaRont
I-CONNECT007

Who doesn't believe in recycling? "Re-use, repurpose, recycle" has been a drumbeat for more than two decades. Our children learn about it in primary school. Full university departments devoted to environmental science and sustainability forward their discipline for the world's benefit. In theory, we all get behind the concept of recycling, even if the nuances of execution may fall short.

When I first heard of recyclable PCBs, I was skeptical. There are so many distinct elements of a printed circuit board: fiberglass, solder, metal finishes, and all manner of components. I have been far more apt to picture them being repurposed (unfortunate art deco PCB earrings come to mind) than recycled. But Jan Pedersen begs to differ with my lack of vision. As director of technology at NCAB, Jan is a true champion and visionary of the concept and is working to prove out the practice.

Marcy LaRont: Jan, can you explain the concept of circularity as it relates to recyclability? Honestly, I had not heard the term before your IPC Community article.

Jan Pedersen: Circularity, in the purest sense, is to reuse the scrapped PCB to produce a new PCB or another product. We use circularity to explain the lifecycle of materials, from nature and back to nature, or cradle to cradle, if you like. That can mean reusing the material in a new product or simply returning it back to nature.

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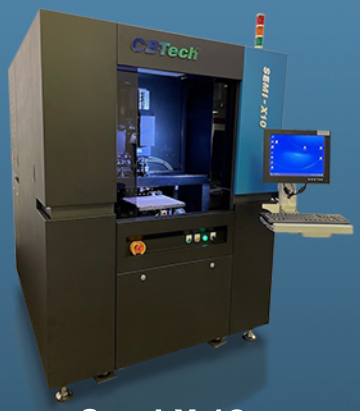

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Now, we all know that a PCB and its constituents are not good for nature, so we have to look at how we can circle the material back into a new product.

That's fascinating to me. I know that PCB particulates, like the fiberglass laminate, can sometimes be ground up and used in things like concrete. But it feels like true circularity with a printed circuit board would be impossible.

It is not easy to find a true solution. Having said that, promising projects are going on in China and the Western world.

In Europe today, we separate the metals, grind down the PCB, and burn the residue to produce electricity. The waste gasses are collected and used in agriculture. That is the best we can do today, supported by a reasonably good infrastructure. But this is not the case in all countries, so there's a ways to go. It's not the ultimate solution. The best solution would be to find a PCB material that can go seamlessly back into nature, like Jiva's Soluboard product, or to reuse the waste from a PCB to create a different product.

At NCAB, we test materials designed for circularity. Even with a long way to go, it should not stop us from going in that direction.

Absolutely. If that stopped us, we wouldn't do a lot of things. What does that infrastructure look like?

In Europe, waste from electronic materials is collected and sent out for separation. Today, there is one place in Sweden where the materials are sent to separate out the metals. You are left with the residue—some blend of epoxy and fiberglass—which is burnt to create electricity. Of course, you actually use some energy to create that electricity.

Everyone is looking for alternate ways to create electricity. I love the idea that a printed circuit board, that is, in essence, "dirty," could be used to provide an essential resource.

Jan Pedersen

What we need to avoid is PCBs, with or without components, going to a landfill.

What about recycling of components?

I am focusing just on PCBs. But in the IPC European standards steering committee (V-ESSC), we talk about those things, such as the reballing of BGAs, and the idea of reusing components, which will require some components to be built somewhat differently to withstand the repair and another soldering process. I believe this is a developing industry.

Some alternate materials may make recycling PCBs more feasible, including a plant-based material substrate, but what about thermal reliability and the many stresses that most circuit boards are built to withstand? What are these materials?

There are two material tracks, the FR-4-like and the plant-based, where we will need to accept different properties.

FR-4-like: There are at least two laminate factories in Asia working on material that can be recycled to be used as raw materials in the production of basically the same laminate. With these materials, we are already at a stage where

we can produce quite complex PCBs. Still, the product will be under development for years.

Plant-based: These are developed by the English company, Jiva Materials, with the goal of recycling back to nature instead of being reused to build a new product. For lower-end PCB technologies, this material is very promising. For more complex builds, time and extensive R&D will be required.

How long will this take to germinate? Maybe 20 years, or can it happen faster? Is government support critical, or will industry drive itself?

Infrastructure and building a system of support around the technology will be one of our biggest challenges, maybe more than the development of the materials themselves. How will we collect the waste? How will we reuse it?

With any new technology or ecosystem, sometimes we work on it and it seems like nothing happens for a long time, but when the right people are on board at the right time, things begin to change. Government support or pressure could move this much faster. It really depends on the attention we get.

> Infrastructure and building a system of support around the technology will be one of our biggest challenges...

One example is the momentum in the U.S. and Europe around advocacy and our respective legislation around chips.

Yes. Chips are an interesting example because the carriers of those chips are made of semi-additive manufactured PCBs, which means the processes to manufacture that product inherently require less energy, water, and material, and a lot less copper. So, if we could move the PCB industry from traditional, subtractive processes—etching away all the copper—to additive manufacturing, it will help reduce our carbon footprint as well.

There is a nexus where industry creating less waste, and using less water and fewer raw materials meets with an industry also moving toward the end game of total circularity or recyclability. Jan, what is your testing process for these new materials?

We are testing FR-4-like material as we test all materials: to see that they meet IPC requirements. These FR-4-like materials have a quality level very similar to a normal FR-4 or halogen-free material. So, we are subjecting these new materials to all the same stresses that traditional materials must withstand.

It's another story when we look into the plant-based materials that today cannot meet the same requirements and will more naturally be assimilated into the environment. There are still huge developments that must happen to reach a stage where these materials can be used in high-reliability electronics applications.

I imagine, even after significant development and testing, there will still be a technology divide as to which applications must use FR-4-like materials and which can use plant-based materials. Does that remain to be seen?

Yes, I believe that is true. For both material types we will see great development in the next years.

If we get attention, and ultimately, if people are willing to buy the materials at lower technology levels, the development of these alternate laminate technologies will increase faster.

Where are you currently with your testing of these materials?

We have just received our next delivery of the Asian version of the FR-4 style, now being tested by NCAB and some good partners. A new development of the same material has been announced, and we see another laminate factory going in the same direction; they're all Asian manufacturers.

NCAB seems very committed to sustainability. Please share some of the history and context of that commitment.

I came to NCAB in 2022 and found a company with a significant focus on sustainability, more so than any other company I had worked with. Initially driven by our ISO 14001 certification, we started 15 years ago by making sustainability part of our factory audits. In the beginning, it was a Corporate Social Responsibility (CSR) type of audit. As the focus on sustainability increased, by 2010, we were conducting full sustainability audits. In 2018, Anna Lothsson, the strategic purchasing director, became the global sustainability director, a newly created position. Today, we have separate sustainability audits at all factories. NCAB has published a sustainability report as part of the corporate yearly report since 2014. In 2022, we created a focus group within our Technical Council. This prompted a more direct focus on PCB circularity.

Is sustainability one of NCAB's core values?

Yes and having sustainability as our backbone means it is considered in everything we do. When I'm presenting something on technology, I consider how to include sustainability in the discussion. How can sustainability be part of our technology roadmap? That is how we're talking to people.

Part of designing for excellence is designing for sustainability. Do you believe the sustainable road provides better overall cost for the customer?

Sustainability is being folded into cost now and can be a unique selling proposition. But cost is a big issue. You cannot typically convince a customer to buy at a little higher price just for a greener product, especially since it's still not that green. We are at the very earliest stage of development.

What's next?

Sustainability is not only material circularity. We also must look at production processes, and what we can do today. While we are waiting for recyclable materials, there are still things we can do to reduce the environmental footprint.

At NCAB, we are working on several ideas. We are developing a scorecard for PCB processes on sustainability, with a focus on water and energy consumption, waste created, and total CO_2 footprint. We already have a system to report CO_2 consumption on customer orders, even at the quotation stage. Like any CO_2 report, these are not exact numbers, but we are close to the truth.

Doesn't Europe require you to provide some documentation on your CO_2 footprint? I understand that OEMs are now asking for this.

That is correct. It is not a strict requirement yet, but it soon will be. We are also developing a new guideline, Design for Sustainability, where we lead the designer into an awareness of the nature of their design. I expect this guideline to be available in a few months. It also covers new technologies such as additive manufacturing.

There is another very practical thing we have been thinking about, and I discussed this at length with Dieter Weiss at IPC WinterCom in Barcelona in January. PCBs basically have a

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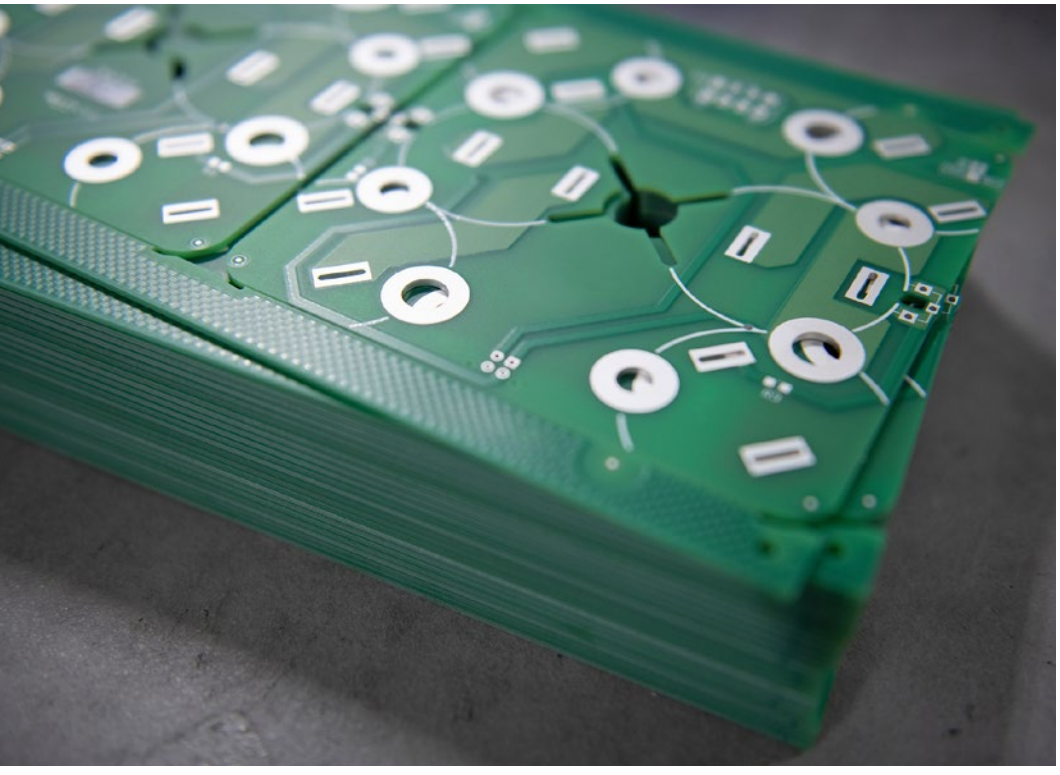

thickness of 1.6 mm. This has long been a standard, and much of the hardware to deal with PCBs is built for this 1.6 mm thickness. In our discussion, we suggested reducing that standard 1.6 mm thickness to 1.0 or even thinner when possible. Benefits include reducing the amount of raw material required, easing processing, reducing energy consumption, and it will be less expensive to ship due to lighter weights. This will reduce the CO_2 footprint quite significantly. Of course, there are arguments to stay with 1.6 mm or even greater thicknesses for some designs, but honestly, the biggest volume of PCBs are still simple designs and could easily be made thinner.

There are things we can do now. It is not perfect, but it's a start. But the biggest green shift in electronics is still ahead of us.

Is reliability affected by decreasing board thickness from 1.6 mm to 1.0 mm?

It should be better for the reliability of plated through-holes. We plan to measure the difference in the reliability of a 1.6 mm vs. a 1.0 mm board. We can't just say, "I think it is." We need the data.

How is NCAB working with IPC to advance the idea of circularity and recycling in PCB production? What are the next logical steps?

Honestly, this is a difficult question to answer. Although I have a fantastic and supportive environment in NCAB, it is another story when you work with an organization like IPC and other global players. I see good initiative for meeting regulatory requirements, such as how to report and ensure you meet local and international rules. I feel that NCAB is pushing this at an early stage. Those who work for the development of solutions instead of just reporting to meet government regulations are few.

At NCAB, we hold a yearly sustainability webinar and last year it attracted more than 400 people from the industry. We also speak at conferences and directly to our customers, and I sense more attention from IPC on our practical work. On the other side, standards must come because of industrialization, so maybe it is the nature of what we do here, being in front and creating a path, or at least exposing the horizon for those who want to create a better world.

You really are the pioneers. Jan, it has truly been a pleasure talking with you. This is exciting and fascinating work.

Thank you, Marcy, for giving me the opportunity to spread the word about what we are doing to a bigger audience. There is a future with PCB recycling and circularity, but it will take some time to get there. **PCB007**

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The Many Complexities of PFAS

Feature Interview by Marcy LaRont
I-CONNECT007

As our industry grapples with environmental sustainability in our products and processes, per- and polyfluorinated substances (PFAS) naturally come up in discussion, especially as they pertain to advocacy and government regulations. Kelly Scanlon, lead sustainability strategist at IPC, provides some basic education (or re-education) around PFAS, and the discussion and activity surrounding them. This is a complicated topic area that is prone to misunderstanding and misinterpretation.

In its simplest definition, PFAS is a group of chemicals used to make fluoropolymer coatings and products that resist heat, oil, stains, grease, and water. Fluoropolymer coatings can be in a variety of products. Though this definition is not inaccurate, it can be misleading. Depending on who you ask, there are upward of 10,000 PFAS chemistries that can meet various definitions. Given this lack of confluence in an agreed-upon working definition of PFAS, as well as agreement as to all the chemicals that fall under that moniker, answering questions regarding PFAS with clarity and undisputed accuracy is a challenge.

Regarding PFAS, there are many regulatory activities at the local through national levels in various jurisdictions around the world. Though some of these questions may seem prosaic, the answers are not easy because all questions regarding PFAS tend to be politically fraught.

IPC has engaged in policy actions related to PFAS in the U.S. and the EU. These have been multi-year engagements, and the regulations are only slowly emerging given the complexity of the chemicals and their uses.

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What products and/or processes are PFAS chemicals prevalent in as they relate to electronics manufacturing?

Kelly Scanlon: We do not have a definitive list of PFAS uses in electronics. This is because of several important factors, including the complexity of electronics, the complexity of PFAS, and the inability to have full supply chain transparency for all chemicals. There are several sources of information about the uses of PFAS in electronics manufacturing processes and products. Some are more reputable than others, but there is no definitive list.

Why are these chemicals so deleterious? What are their effects on the environment, human health, etc.?

This is a controversial question without fully supported answers. PFAS are categorized as persistent, bioaccumulative, and toxic (PBT) chemicals. Not all PFAS have been studied. The toxicological and epidemiological literature about the human health and environmental risks associated with PFAS is dense and growing denser each day as more scientists work to understand the lifecycles of these chemicals. Some treat all PFAS as PBTs and others find nuances that make interpretation of risk very challenging. Many government resources are available that help outline what is and is not known about PFAS.

Can you name any replacement products or processes/technologies that are aimed at solving this issue?

Given the number of PFAS and the variety of uses of these chemicals in a variety of products, a "drop-in replacement" does not exist. Some technologies are evolving that may provide alternative manufacturing processes, and there are some product alternatives, but in general, industry uses these specific chemicals because they provide the function and level of performance needed, and which cannot be achieved through other means. Many believe it will be a very long time (if ever) before we find safer alternative chemicals and can implement them into all processes and products that currently use PFAS.

Closed-loop wastewater treatment is a way of managing wastewater but not a replacement for PFAS in processes and products. Finding better ways to prevent PFAS releases and remediating that which has already been released is important. IPC is most concerned about policies limiting PFAS' use in current and future applications, which would significantly and negatively affect many electronics businesses' ability to operate and/or grow. The semiconductor industry has been vocal about the impact on semiconductor manufacturing should there be any restrictions on PFAS.

How is IPC involved in this space?

IPC's advocacy team has engaged in the U.S. and the EU for several years on emerging policies that would restrict all uses of PFAS and/or require industry to report on PFAS uses and share information about associated risks. In September 2023, IPC worked with several stakeholders, including IPC members, to provide a response to the European Chemicals Agency's (ECHA) proposed restriction of universal PFAS under the REACH Regulation. We have worked with industry to gather expert insights and provide responses to policymakers who are tasked with regulating these chemicals. It is a long list of contributions and engagements that IPC has undertaken over the course of several years. We have, and continue to provide, webinars and educational events to talk about emerging policies, gather more insights about supply chain challenges and the essential uses of PFAS, and talk about rules that have been passed and what they mean to the industry. **PCB007**

For questions, comments, or to learn more about getting involved in the IPC sustainability discussion, contact Kelly Scanlon at kellyscanlon@ipc.org.

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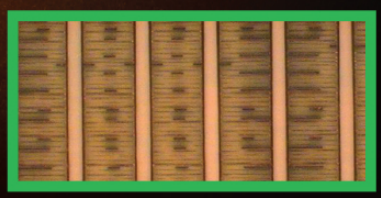

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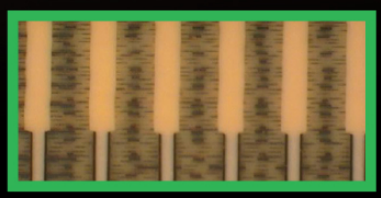

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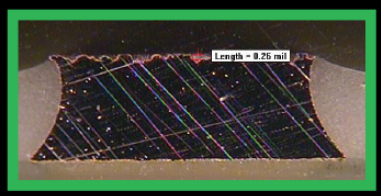

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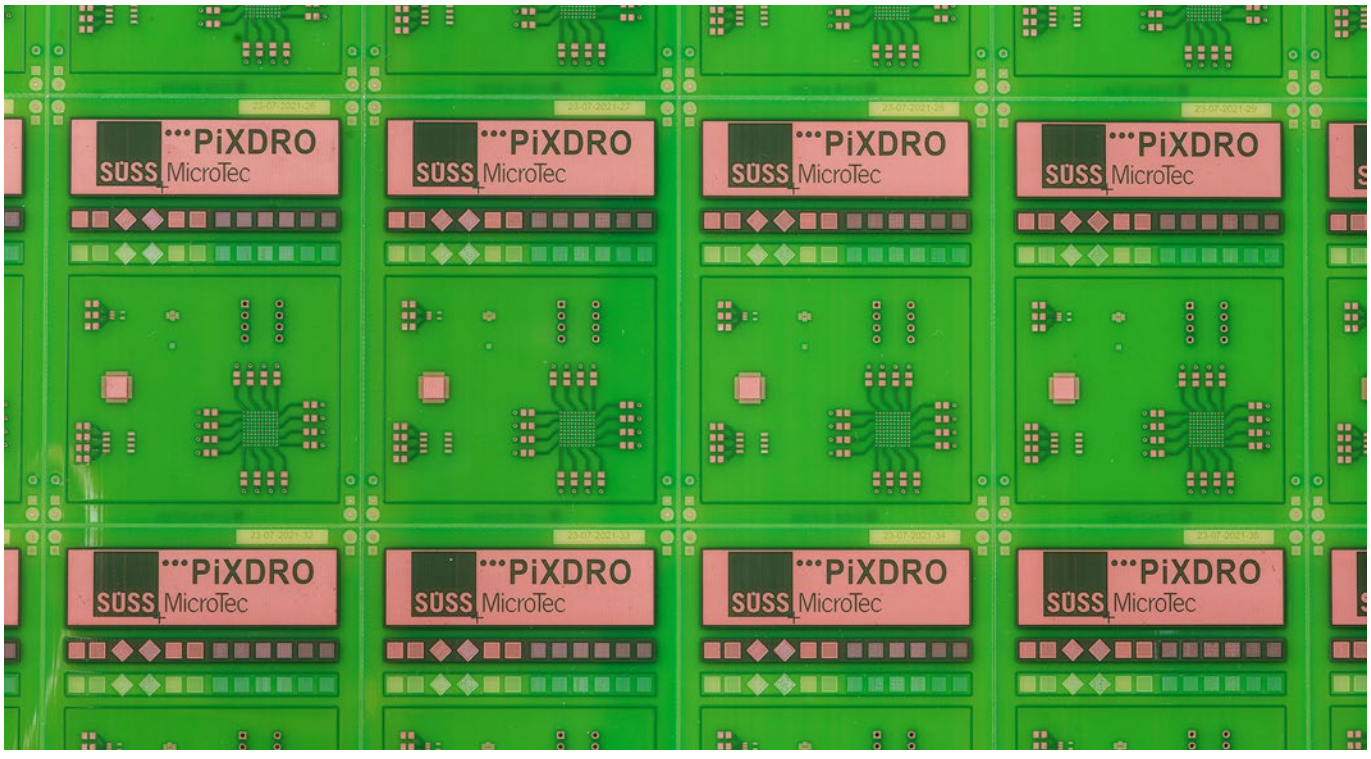

Inkjet Solder Mask Has 'Arrived'

Article by Pete Starkey
I-CONNECT007

I have followed the progress of inkjet imaging in PCB manufacture since the late 1990s, seen many contenders come and go, attended and reviewed more than a few conference and seminar presentations, and met some leading experts in this technology.

Although inkjet legend printing has become well established, and the feasibility of inkjet primary imaging convincingly demonstrated, inkjet solder mask has, until recently, remained a near-unattainable goal. I recall Dr. Steve Jones of Printed Electronics Ltd. commenting upon the apparently inverse relationship between the functionality of a solder mask formulation and its "jet-ability."

Yes, there have been lots of optimistic claims made. I've seen numerous demonstrations of inkjet printers producing solder mask images on PCBs in pretty green paint. In most instances, I received vague or evasive answers when I asked pointed questions. It takes a rather special kind of green paint to satisfy the qualification and performance specification requirements of international standards and end-user approvals, and a rather special kind of printing machine to apply it correctly.

But the leaders have persevered. Close cooperation between formulators and equipment manufacturers has resulted in products and processes that fulfill all those requirements. PCB fabricators, end users, and approvals authorities have realised the benefits, and inkjet solder mask has become an accepted reality.

I was delighted to be invited to attend an interactive webinar entitled "Solder Mask Coating Made Easy with Additive Manufacturing," hosted by SÜSS MicroTec Netherlands in Eindhoven. The webinar was introduced and moderated by André Bodegom, manag-

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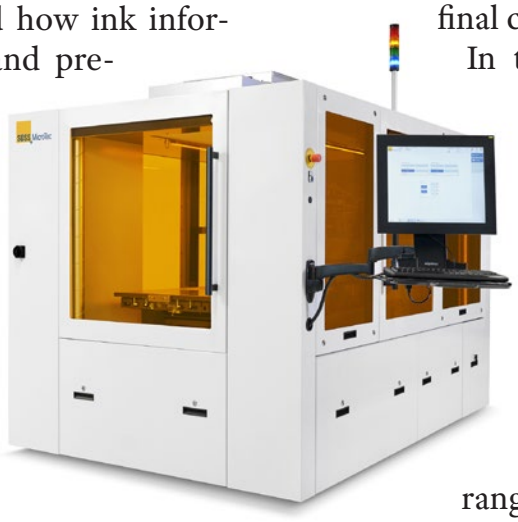
ing director at Adeon Technologies, and the speakers were Mariana Van Dam, senior product manager PCB imaging solutions at AGFA in Belgium; Ashley Steers, sales manager at Electra Polymers in the UK; and Dr. Luca Gautero, product manager at SUSS MicroTec Netherlands. These are all experts I know personally and whose technical knowledge and objectivity I have always held in the highest regard. This webinar promised to be a no-nonsense learning opportunity.

The session began with a video demonstration of the JETxSM18 printer by SÜSS MicroTec technical sales and support manager Peter deVrieze. He explained the process from data input to finished print, describing how fiducial positions are defined and how ink information, board information, and pretreatment information are fed into a "flow engine." The heavy data processing is done by algorithm, and the flow engine automatically determines the required droplet size and flow-out compensation parameters to then create the print layers, producing a work package that can be shared to a network drive or to different printers as required. The work package can be retrieved at the printer using a barcode scanner or the printer's HMI. It is simply a matter of loading the board and pressing the start button. The printer recognises the board and aligns to its fiducials, correcting the image information as necessary to achieve exact registration, then rasterises the data and prints the required solder mask pattern.



De Vrieze listed some of the features of the machine. It employs six print heads, each with 2,048 nozzles producing droplets of 2 picolitres, mounted in-line to give an effective print width of 9 inches. Flow-out of the ink is controlled by pin-curing with UV light, and separate UV bars are mounted before and after the print head array to enable printing in two directions.

He explained that the image is built up in a series of layers, depending on the recipe specified, beginning with printing dams and ramps followed by fill layers. In his particular example, ramps and fill layers were printed in two passes each, and a UV bump was included in the recipe. He remarked that the finish (shiny or matte) could be controlled by changing the parameters in the recipe. In his example, ink was placed only where required, and its local thickness was controlled according to the recipe. When the board was removed from the machine, the ink was cured enough to be handled, and an oven was used for final curing.

In the comfort of the webinar studio, André Bodegom first introduced Mariana Van Dam, who reviewed Agfa's 20 years of inkjet expertise, with dedicated R&D facilities and more than 200 patent families on inkjet inks. The company has the capacity to produce 2 million litres of inkjet ink per year. The range of inks for PCBs includes acid etch resists and legend inks as well as solder mask. The solder mask conforms to the requirements of IPC-SM-840E, UL94 V-0, and Automotive E2000, and is fully REACH, RoHS, and VOC-compliant.

She summarised the benefits of inkjet solder mask compared with liquid photoimageable solder mask: 50% reduction in process time, 50% reduction in operating staff, 70% savings in power consumption, and 50% savings in ink consumption, as well as a much-reduced floorspace footprint and less peripheral equipment. Additional benefits included no solder mask in vias and no missing dams, as well as all the advantages of a fully additive 3D technology. For optimal adhesion and best edge definition, it was recommended to prepare copper

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surfaces with a micro-etch and an anti-bleed treatment before inkjet printing.

She concluded that the breakthrough of inkjet solder mask is happening; there are already more than 35 installations worldwide, and OEMs are validating the product.

Ashley Steers titled his presentation, "Solder mask challenges and unique selling points of inkjet solder mask." He commented that Electra Polymers is celebrating 40 years of servicing the PCB market. The company has diversified into printed electronics and wafer-level packaging, but PCB ink materials remain more than 50% of its global revenue, and Electra established leadership in the technology of inkjet solder mask, having several years' experience with customers who switched to 100% inkjet. The company has invested heavily in inkjet solder mask manufacturing capacity and is expected to be the world's largest supplier by the end of 2024.

Steers addressed some of the internal challenges faced by present-day PCB manufacturers; one of the largest is finding and keeping skilled personnel. He listed generational and environmental benefits of inkjet, emphasising that it was a computer-driven digital technique with a clean, hands-off process and the opportunity to automate. Furthermore, it was a shorter process, requiring fewer people and overhead, and it is no longer the skilled art that screen printing has been.

The risk of defects is less—the result of an enclosed, filtered coating environment and no wet inks exposed to ovens or unfiltered environments. Inkjet is a fully additive process, and there is no developing stage that could undercut fine features.

Environmental and regulatory benefits include greatly reduced water and power consumption and no volatile organic compounds. Electra's ink complies with REACH and other related regulations. In addition to meeting industry specification requirements, the repeatability of an automated, front-end-driven process is a significant positive point when selling to OEMs and CEMs, together with its flexibility, sustainability, and scope for Industry 4.0 integration.

In his conclusion, Steers said, "Inkjet solder mask has arrived; it's no longer on the way."

Dr. Luca Gautero reviewed and summarised the information presented in the Peter de Vrieze demonstration, then invited questions from the webinar audience of more than 100 people. Bodegom very capably managed the Q&A session, as members of the panel generously shared the benefit of their experience in response to questions about future developments, factors determining edge definition, surface treatment recommendations, comparative material costs, typical thicknesses for different applications, managing panel warpage, accuracy of solder mask-defined pads, resistance to new metallic finish chemistries, compatibility with third-party automation systems, expected print-head life, and printing multiple colours. So much additional knowledge came out of this session that it was effectively a technology tutorial in its own right.

Bodegom brought proceedings to a close, with grateful thanks to members of the panel, to SÜSS MicroTec for hosting the event, and to all those who attended.

As I had expected, the webinar proved to be a no-nonsense learning opportunity and a confirmation that inkjet solder mask is no longer "on the way." It has arrived. **PCB007**

Click here to view this webinar.

Pete Starkey is a technical editor for I-Connect007.

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MilAero007 Highlights

Department of Defense to Expand Manufacturing of PCBA for Hypersonic Weapons ▸

The Department of Defense announced an award of $11.7 million via the Defense Production Act Investment (DPAI) Program to Ensign-Bickford Aerospace & Defense (EBAD) that will provide additional printed circuit board assembly (PCBA) production capacity at their Simsbury, CT location. EBAD will increase existing capacity and manufacturing processes to reduce cost and accelerate PCBA production.

Northrop Grumman Completes First BOLE Solid Rocket Motor Segment for NASA's Space Launch System ▸

Northrop Grumman Corporation completed the first Booster Obsolescence and Life Extension (BOLE) motor segment for the next-generation Space Launch System (SLS) solid rocket booster. BOLE adds nearly five metric tons of payload capacity for SLS Block 2 Moon and Mars missions above the enhancements already in work for the SLS Block 1B configuration slated to fly on Artemis IV. The new solid rocket boosters will be used on Block 2 beginning with Artemis IX when all the recovered and refurbished shuttle-era steel cases have been expended.

RTX's Collins Aerospace Completes Demonstration with Parasanti on Launched Effects Technology ▸

RTX announced its Collins Aerospace business completed a successful digital demonstration with Parasanti on Collins' RapidEdge™ Mission System for Collaborative Uncrewed Launched Effects (LE). Parasanti, a small business that provides edge computing solutions, was selected for the work through the Powered by Collins Initiative™ to foster technology innovation with Deep Tech small- to medium-sized enterprises. Collins' RapidEdge Mission System enhances mission effectiveness by addressing the system-of-systems aspects of a team of LE air vehicles.

U.S. Space Force Awards Boeing WGS-12 Communications Satellite Production Contract ▸

Boeing received a $439.6 million contract to build the 12th Wideband Global SATCOM (WGS) communications satellite for U.S. Space Force's Space Systems Command. The WGS constellation delivers vital high-capacity, secure, and resilient communications capabilities to the U.S. military and its allies.

Lockheed Martin Awarded $219M To Produce Additional PrSM Units For US Army ▸

The U.S. Army has awarded Lockheed Martin a $219 million contract to produce more Early Operational Capability (EOC) Precision Strike Missiles (PrSM). The award is the fourth production contract to date for the long-range surface-to-surface missile, which will allow for a significant increase in production capacity to meet Army demand. Lockheed Martin delivered the first missiles in December 2023 following a successful November production qualification test. Initial deliveries achieved a major modernization milestone for the U.S. Army, securing needed long-range precision fires capability.

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Design tips:

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- **Start with 3/8 or 1/4 oz. foil**, reducing etch comp and less likely to cause a spacing issue.
- **Boards that call for full body electrolytic gold are not comped** to avoid gold slivers occurring during the etching process.

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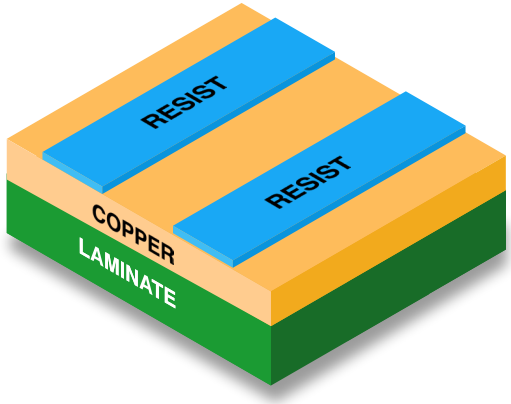
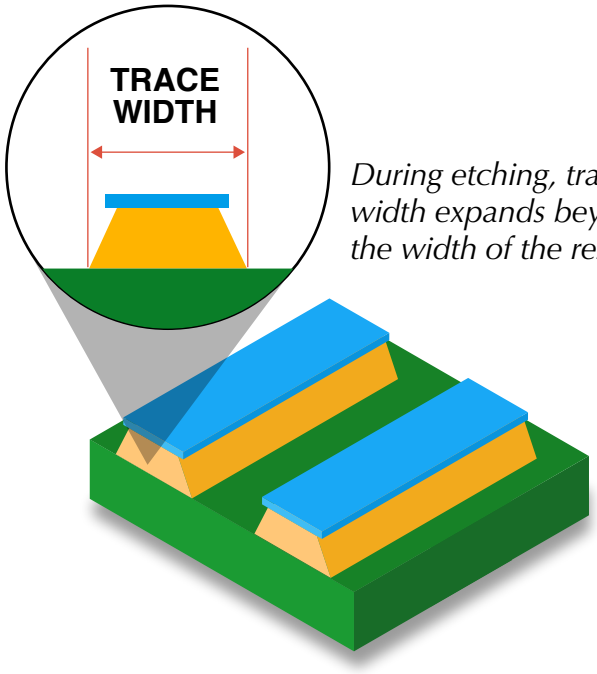


After etching



During etching, trace width expands beyond the width of the resist.

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I Hear the Train A Comin'

The Right Approach

by **Steve Williams,** THE RIGHT APPROACH CONSULTING

Training is often an afterthought in many organizations, and the longer a company has been in business, the more this seems to apply. Over the past couple of decades, it has been amazing to observe that the biggest offenders of this are the companies that overuse the sound bite, "Our most important assets are our people." When you dig into the process and peel back the onion, their commitment to training is not commensurate with that statement.

Don't Substitute Time-of-Service

One of the keystones of a world-class organization is the depth and breadth of its training program. Training can be defined as learning provided to improve performance on the present job. A well-managed program can be the differentiator between merely average and outstanding performance. The beauty of training is that it applies equally to any industry, business, and technology. Of course, the higher the degree of difficulty in the product or service, the more important training becomes.

A very common mistake that an organization typically makes when assessing the state of its training program is to substitute time-of-service for formal training. It has been my observation that the longer the average employee's tenure at a company, the less formal the training program. When you think about the reasons that drive this correlation, it certainly makes sense. Owners should be extremely

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proud of a long-term employee culture. However, not taking full advantage of this expertise can be a fatal mistake, especially for small businesses.

A typical scenario is walking through a manufacturing facility and stopping at a work center staffed by a highly skilled operator. The management escort quickly says, "Stanley, here is our department lead and one of our most experienced lathe operators."

When asked to see Stanley's training records, the manager states, "Stanley is our trainer, and all new employees apprentice with him before becoming certified to run a lathe."

When asked again to see Stanley's training records, the manager says, "Well, uh, Stanley was grandfathered in since he has been running this lathe for 30 years. He certainly doesn't need to be trained."

While Stanley may not need to be trained on the operation of the lathe, there are other "company-specific" aspects of training. Whether having a certificate from an outside training service or another company, technical education, or performance testing, there should be something on file to verify the operator's competency. Experienced people like Stanley are the greatest asset to any company's training program and should be the foundation the program is built around.

Tribal Knowledge

In this scenario, both the company and its employees tend to view training negatively, even insulting, like some form of remedial action. This perception couldn't be further from the truth. One of the greatest advantages of training in this situation is to capture the tribal knowledge of the highly skilled workforce. What I mean by tribal knowledge is the entirety of people like Stanley with expertise, experience, tricks of the trade, and the idiosyncrasies of the job that have been learned over the past number of years that are proba-

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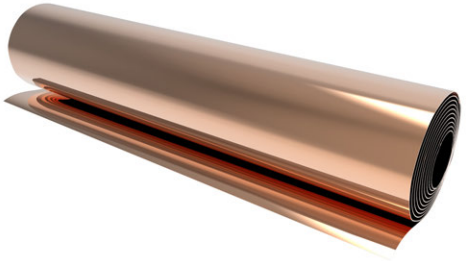

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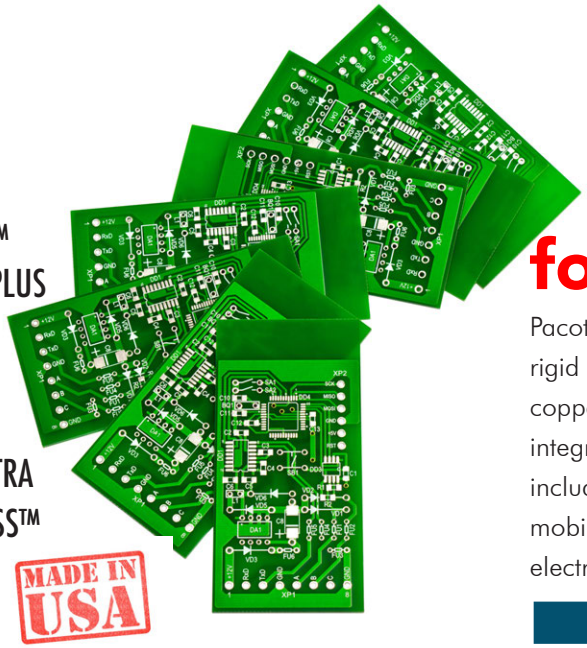

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bly not documented anywhere. Preserving this tribal knowledge and turning it into a training competitive advantage is critical to a company's long-term survival.

This particular problem is compounded by high employee turnover during times of uncertain economic environments. This logic becomes fatal when long-term employees begin retiring, and that tribal knowledge is lost forever. It has become all too common to witness companies cut costs by offering early retirement (or worse) to long-term experienced employees so that they can replace them with younger, inexpensive new employees.

What these companies fail to realize until it is too late is that this strategy severely backfires as decades of experience and tribal knowledge walk out the door with the employees. Many of the businesses that have not survived recent economic cycles were companies that had been successful for 30-plus years until several "Stanleys" began to retire. Others who have survived have never fully captured all the tribal knowledge that left with their best employees.

Once you begin to peel back the layers, it is amazing to note just how many outcomes (both positive and negative) in any business can ultimately be traced, in some fashion, back to training.

Training Records

Ironically, the companies that have the best-trained workforce many times have the weakest system. Most companies do a tremendous amount of training but do not take credit for it. A common mantra you will hear me say is, "If you can't prove it, it didn't happen." If you take the time to flowchart all your processes, you will be surprised by the amount of informal training that takes place daily that is not recorded in any way. It is critical to develop a simple method of documenting all training that takes place; in other words, you need a training record. Whether part of a training software solution or a simple paper document, complete a training record at every opportunity. Every sit-down with an employee is a potential training moment (new procedure revision, internal defects, customer returns, process changes, etc.).

Don't worry about creating huge employee training files; customers like to see lots of training evidence for the people who are making their products. A cautionary note: As with pretty much anything, the more complicated you make your training program and the documentation process, the higher the potential for failure.

Some companies fall into the habit of overtraining, for example, performing annual training on every work instruction. This is a significant expense in terms of time and money and is not very effective. How much effort do you think employees put into reviewing several work instructions they have read many times as part of the company's "read and understand" annual training? The better solution is to do a good job of the initial training and then only retrain when the work instruction changes, or if there is a performance issue or a finding in an internal audit. Then, don't just rely on the employee to read it independently. Sit down and review the changes or specifics that triggered the retraining. This is a much more efficient use of time and is ultimately more effective.

"It all has to do with the training; you can do a lot if you're properly trained." Are these the words of a modern corporate training officer attempting to motivate her workforce? Hardly. Elizabeth II, Queen of Great Britain and Northern Ireland made this salient proclamation over 50 years ago. What has held over the ages is not a secret; people perform better when properly trained. **PCB007**

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

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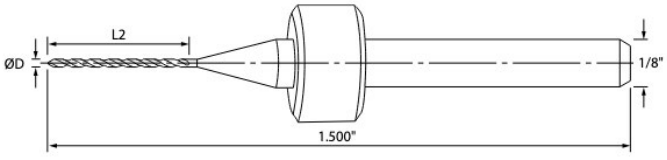

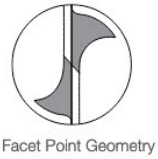

4 Facet Point Geometry

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

Checking In With ICAPE Group

Feature Interview by Nolan Johnson
I-CONNECT007

ICAPE Group's field application engineer Erik Pedersen drills down on sustainability, supply chain resiliency, and what value engineering really looks like in this exclusive interview. Founded in 1999, European-based ICAPE Group provides 21 million printed circuit boards and over six million technical parts to manufacturers every month. With 30 PCB manufacturing partners globally and 50 partners providing a wide array of technical parts, ICAPE Group has operations in China, Taiwan, Thailand, South Korea, Vietnam, South Africa, Europe, Mexico, and the United States. The company also focuses on the value proposition for its customers.

Sustainability

Nolan Johnson: How does ICAPE Group incorporate sustainable practices into manufacturing printed circuit boards?

Erik Pedersen: There are many things that we do in the process of manufacturing a PCB that focuses on sustainability. PCB fabricators reclaim precious metals from waste and have done so for many years, sending it out to salvage companies that reclaim the metals. Regarding epoxy fiberglass laminate, we can grind it down to small particles that can be used as filler material in things like construction and concrete. As far as the processes

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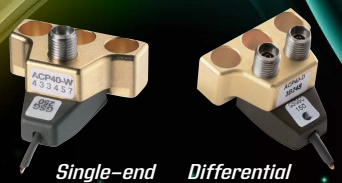

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themselves, we minimize waste and reclaim materials in as many steps as possible. On the electrolytic copper plating line, when the small copper balls (anodes) are sufficiently depleted, we collect them and send them to salvage for recovery. It is also common to collect router dust from drilling and routing to reclaim especially the gold particles. We reclaim the HASL and precious metals from rinsing during the wet processes. In the etch process, the spent etchant is treated to remove the copper, which is also recovered. This has all been going on for many years, but for someone unfamiliar with the fabrication process, it is important to educate them on all we do to reduce waste.

Today, sustainability is not something we only think about during the manufacturing process. PCB fabricators have been focused on environmental sustainability, reducing waste, and maximizing ROI in many ways for decades. Working toward better sustainability really should start long before the board arrives at the PCB shop, correct?

That is correct, Nolan. Probably the most important thing we do is to work on sustainability with our customers at the design stage. What are the most (ENIG) and least impactful (OSP) surface treatments to the environment? What is the cost? We also promote the use of halogen-free material. It is my personal belief that customers should pay more attention here. The halogens used to make the fire-retardant materials remain even when you grind down the waste materials. They are harmful to the environment. Today, there are halogen-free materials that have as good a performance as halogen materials, but they cost 20–30% more. But if most PCB makers (and OEMs) would use halogen-free material, the market would drive the price down and they would become more common, addressing a significant environmental issue. One example is NOKIA and Samsung requiring halogen-free material for their PCBs.

> "To move forward in making something a standard, legislation often is required."

Can you, as the PCB manufacturer, really influence this conversation with the customer, and how?

We can only appeal to our customers and provide the knowledge and the datasheets for comparison. We strive to educate our customers on the many potential benefits that speak to the impact not only on waste and the environment but also on product cost and reliability. It is the customer's decision in the end.

Do you see environmental sustainability being driven legislatively with any of your customers, or in any specific region?

For some, yes, but our customers' main concern is market competitiveness, and price is the primary factor. To move forward in making something a standard, legislation often is required. For instance, we have the lead-free prohibition by the EU which requires that the majority use lead-free surface treatments and solder alloys. Once it is in law form, things happen; but if it is not required by law, and there is no cost advantage, companies will continue to use what they have always used because they must remain competitive to survive. We don't view ourselves simply as a traditional PCB provider or manufacturer; rather, we see ourselves as proactive experts continually striving to discover improved and more sustainable solutions for our clients. Being a leading force for our customers is of utmost importance to us.

In terms of technology and competitive advantages, do halogen-free materials actually perform better than their halogen-filled counterparts?

No, they don't perform better, but they are equivalent in product performance without the

negative environmental impact. Halogen-free materials took off in the late 1990s and early 2000s, driven by cellphone manufacturers. Nokia was a main driver, and that was purely to prevent halogen material absorption by Nokia mobile phone users. Halogens were also in plastics in other parts of the mobile phone, so Nokia was concerned about this issue for their customers. Requiring halogen-free material was still a market-driven decision.

But even with regular materials, it is well known that 1.6 mm is a standard PCB thickness, but do you need 1.6 millimeters? Could it be 1.2 or one or even 0.8 mm?

There are those who say that we use 1.6 mm for historical purposes and it is no longer necessary.

Exactly. By making it 0.8 mm instead of 1.6, you get a product that is half the weight. What's not to like about that? It costs half the money to transport it halfway around the globe. Transportation is significantly more expensive today compared with just a few years ago, so there's money to be saved for our clients at many steps along the way. It will also have a positive impact on the environment.

It would be positive for the supply chain as well, because when you can make boards with half the substrate, that means, at least theoretically, that there will be more material capacity to do more boards.

Another small example is when you look at the balance between design values and PCB functionality and performance: A standard 1.6 mm PCB with a 0.20 mm through-via will reduce the number of panels you can stack at drilling. You can have only one or two panels per stack, or you will have out-bending at the exit hole. If we could increase the via size to 0.25, 0.30, or 0.35 mm, you can increase the number of panels in your stack. You will save time and energy and the material used to create these holes. Often, we see boards designed with 0.20 mm holes that could just as well have been made with 0.25 or 0.30 mm vias.

Erik Pedersen

This brings up another important point: As your BGA pitch starts to go below 0.8 mm, and you begin to apply laser-drilled microvias and buried vias to your design around the BGAs, but the rest of the board doesn't have the same kind of complexity, the default is to design the non-BGA board areas with through-holes. But there's absolutely no reason to use so much through-hole drilling when you have introduced laser-drilled microvias and buried vias. You can make the connections through them. What will you achieve by that? You will get less signal disturbance because every through-hole you have in a PCB acts as a kind of antenna, sending a signal out. If you can avoid going all the way through the board, but rather only go down to layer two or layer three, the signal disturbance stops there. The number of laser drilling steps and lamination cycles required depends upon the BGA size and pitch. When needed for, say, pitch 0.4 mm and below, stacked laser drilling steps can interconnect through all layers, which is what we call every-layer interconnect PCBs (ELICs).

Are you suggesting that once laser drilling is necessary, you should just use it as your default?

You would have fewer mechanically-drilled holes, but once a designer has introduced microvias due to the complexity of the design, then they should use them to the fullest extent because they'll save a lot of electricity and time used in the drilling process. Mechanical drill is the most time-consuming process in PCB fabrication. When you have a large production panel and 20,000 holes, that takes hours on a mechanical drill whereas 20,000 laser-drilled holes will take two to five minutes. You have to consider lamination steps and the pressing of the material for every two layers that you are adding, but since you have already introduced microvias and multiple lamination into the process, you are unlikely to be increasing the lamination cycles by adding more microvia connections.

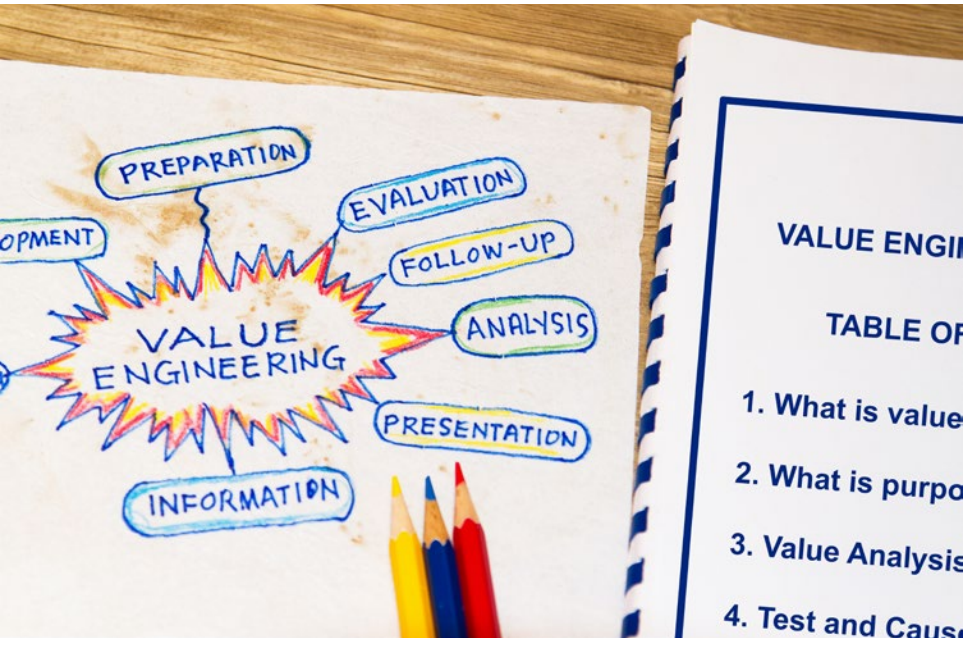
That is a perspective on utilizing laser drill that I don't think I've heard anybody express, but it makes a lot of sense.

Value Engineering

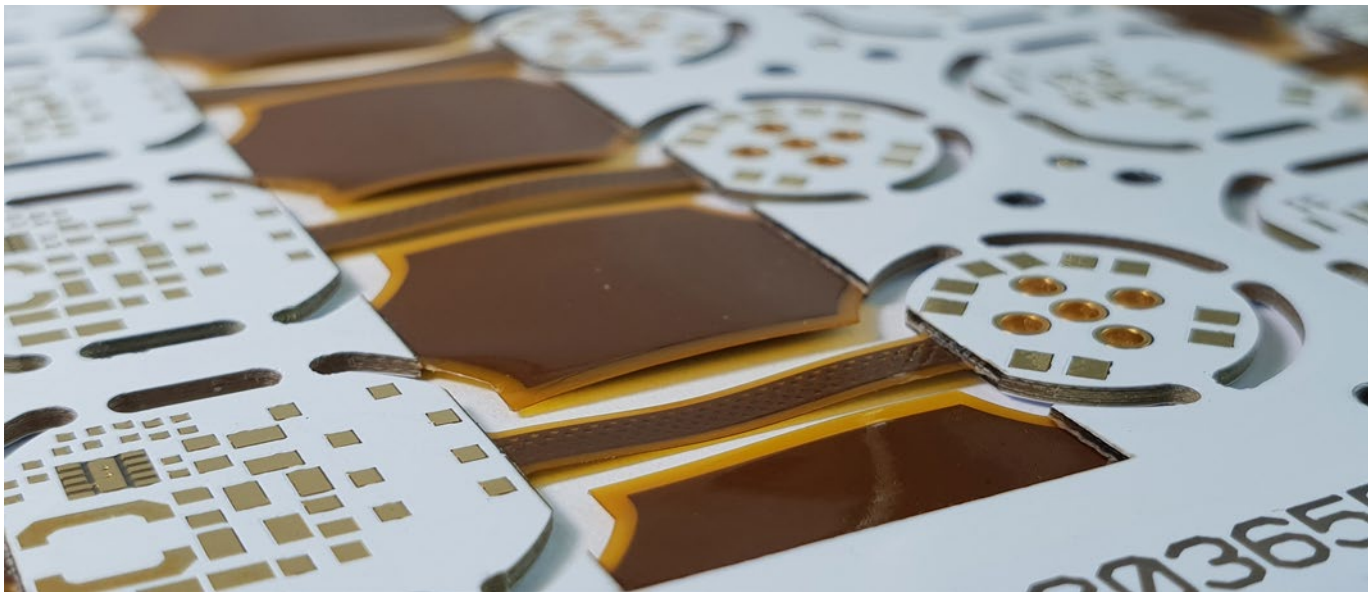
That's a great segue into a discussion on value engineering. How are some of the ways that ICAPE Group adds value for customers from the design phase all the way through the manufacturing process?

There is a lot that ICAPE does with and for customers, but the greatest value comes when we are able to engage with the customer early on with their PCB design. There are a lot of choices to be made by a designer. What core thicknesses do you need? What prepreg styles? What copper thickness? We help with these decisions. An area where we often support our customers is PCB specifications. We know from experience that this is a weak spot for many customers: specifying correctly so they get what they want in the end product. Most of the time, they know what they want, but often don't know how to describe it. So, we clear up any misunderstandings, address their doubts, and solve their problems.

It is certainly the case that designers are focused on what their performance specifications are, but they also must make sure that they are implementing in the board exactly what's on their schematic. There is a lot of focus on their layout to make sure that it is electrically correct with the schematic, but there is so much more to consider regarding manufacturability, and increasingly the materials themselves—different metals, and even copper smoothness—which all plays into speed and signal integrity and manufacturability. Oftentimes, these things are at odds. Managing those physical attributes is key to achieving the same or better performance.



This is where ICAPE adds great value. Of course, quality is one of the best gateways to cost savings. As an example, a few years ago, I was asked to do a review of a flex PCB design for an exoskeleton muscle-stimulating suit to be used for the physically



disabled—for someone who is partially paralyzed or suffers from spastic muscular disorder. This full-body suit stimulates the muscles to help the wearer have better control over their muscles. It's done with electromagnetic pulses getting in touch with the muscles.

The flex PCB was used to interconnect these impulse magnets, placed on the legs and arms, to the central controller which is placed on the chest of the suit. You can imagine the problems that could arise with such a flexible suit being bent in extreme and unpredictable ways. When I reviewed the long flex cable, I could immediately identify several weak spots in the wire routing of the traces and the placement of the via-holes. There also needed to be an improvement to the stainless-steel reinforcement behind the flex circuit. So, I did the review and wrote an email to our client including pictures and my suggestions for product improvement.

After just a few design review meetings over Microsoft Teams, the client was empowered to improve the design and construction of the suit, which also resulted in an improvement in their assembly yield. The flex PCB with the stainless-steel reinforcement was being assembled into some silicone, which was experiencing high failure rates. With these design changes, we managed to decrease their failure rate in the field, almost eliminating the end-user quality claims they had been receiving. That was all due to the placement of the via-holes and the trace wiring design. And by correcting the wire design and securing via-holes under the part that was reinforced by the 0.2 mm stainless steel, the connection didn't get damaged when it was bent in unpredictable ways.

There are other minor things when you have a flex piece, like you need to have curved edges instead of sharp angles, or you must add teardropping on the via pads to ensure better connection to the traces. Small recommendations can lead to big quality improvements. In the case of the exoskeletal muscle stimulating suit, the only thing this process cost was some engineering review time on our side and some reengineering by the designer working in close cooperation with us. We saved them a lot of money, and possibly even their reputation in having fewer end-user quality claims.

That all starts to roll down through the lifecycle of your product. Of course, the investment there is to make sure that you have a design iteration or two built into the design review process, not iterations in prototype builds.

Yes, and it is important to understand the functionality of the product and to be involved as

soon as possible. We have this relationship with many of our customers. They contact us before they draw a single line on the PCB design. There are differential lines here with a 100-ohm impedance. The customer comes to us beforehand and asks, "Can you please provide a stackup and some design values for us to run with?" Because if they start the design being insecure about these things, they risk doing a lot of work in vain that they will need to change as soon as we get our hands on the design.

Let's talk about that early collaboration between manufacturing and design to balance those constraints. For example, does ICAPE follow any specific methodologies or protocols with design teams? Are there tools or technologies that help you get to a more streamlined development process?

It's a matter of educating our sales force because they are the first face for our clients. Of course, they are speaking mainly with those who purchase the PCBs, but the clever salespeople involve the field application engineer to field the technical questions the salesperson knows they will be unable to answer. It is a team approach that works best. In today's world, the salesperson can simply arrange a Teams meeting. The world has really changed since COVID. We now have many design review meetings that way, which is good. I have one tomorrow afternoon with a German customer on a rigid-flex HDI project. Therefore, the sales guy has set up a meeting with one of our German FAEs, me, and the client's designer and developer. We will discuss what they want. He has a BGA pitch of 0.5 mm, so he will need a minimum of two levels of laser-drilled microvias or one laser-drilled and one buried mechanical-drilled via for routing. These are the things we will discuss, and I will provide him with the exact design rules needed to design or redesign this piece the right way for manufacturability at high volume.

If we are not able to be involved early on, we typically get involved when salespeople get feedback from the factory saying, "Can we change this?" or "This is not manufacturable." Then we review, identify the problem area, and find a solution. We speak with the client and resolve it. That's how we like to work at ICAPE Group. That is why our clients like working with us.

Ultimately, does that result in reducing the iterations that the design team goes through?

Yes. I have seen it happen that a design goes to the prototype PCB supplier. The prototype supplier does not have this interaction with the customer. They make modifications to build the board in small quantities, but the tolerances exceed what is producible in serial manufacturing (high volume). The customer does not know this until they get it quoted in volume and are told, "Sorry, we can't quote this. It is not manufacturable." It happens quite often. What could the customer have done? Our aim is never to be in this situation because it's really terrible to explain to the client that we could do a prototype build, but we cannot do serial manufacturing.

Is this a situation where prototyping with ICAPE Group is appropriate?

Yes, we are typically managing the prototype process for our customers, so we manage the design review and revision process closely. ICAPE Group has two prototype options

available. We have our company-owned quick turn prototyping factories in Europe, as well as our online shop, and we also have prototyping through our approved vendor list for high-mix, low-volume manufacturers. We are using some of the same manufacturers, but not all.

Supply Chain Resiliency

Let's change our focus a bit. Of course, ICAPE Group is in the middle of the supply chain for materials and parts, and supply chain challenges were magnified during COVID, which uncovered where our supply chain was not very resilient. Now we're adjusting to that and finding some new approaches. How do you manage your supply chain to be reliable and resilient with your global presence?

Certainly, during COVID, we learned a thing or two, but still, we're not living in a perfect world. Back in the late 1990s and 2000s, we outsourced and made China the predominant supplier of PCBs to the world. At ICAPE Group today, we have almost 30 approved suppliers for PCBs and 60 suppliers for technical parts, not just in China, but also in Thailand, Vietnam, Taiwan, South Korea, South Africa, and even Europe and the United States. We have purchased two PCB manufacturing sites in Sweden and South Africa and one keypad factory in France. Our purchasing department has regular meetings and strong relationships, not only with our suppliers but with their suppliers as well. This allows us to have a real forecast for our business.

Regarding our logistic solutions, we have more warehouses today. We can offer different logistics solutions like call-off, safety stock, VMI, and CMI. We have local warehouses in many countries. Traditionally, we have shipped goods by sea or air transport, and now we are also using train and truck transport. Today, we have more supply chain transparency and resiliency than ever before. When our customers plan and have a good forecast, they can purchase the PCBs in time enough to ship the product by sea rather than air. The cost is lower, and the CO_2 footprint is much lower with sea freight compared to air freight. We approach supply chain with an eye on sustainability and eco-friendly shipping practices; our goals are to optimize onsite resources, planning, execution, and to eliminate unnecessary trips.

It's like just-in-time except a little bit further out, allowing for a much more strategic plan upstream in the supply chain.

Today, any public European company with more than 500 employees is required to abide by new environmental regulations. We need to know our CO_2 footprint, not only for the manufacture of our printed circuit boards but also for shipping to the warehouse and then to the customer's door, for the activity in our offices, transportation, travel, etc., as well as from our suppliers.

If you are being asked to go up your supply chain with these numbers, your customers will also be asking you for this information.

Yes, we have begun receiving these demands, especially with the European automotive industry. Those customers have started to ask for our CO_2 footprint, specifically down at the board level.

Back to that idea of value engineering, providing that kind of detail can also add value for your customers and their ability to plan.

Exactly, it could change behavior by providing such information in this way.

That sounds like a great place for us to end. This has been a very informative hour. Thank you, Erik.

You are so welcome. **PCB007**

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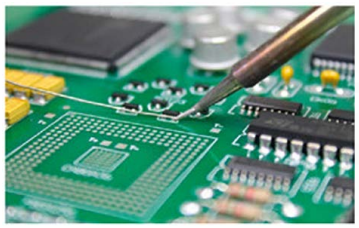

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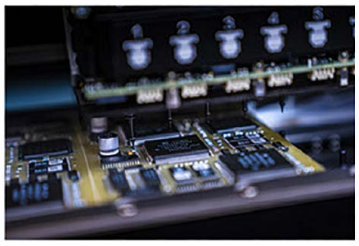

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The Top Five Things You Need to Know About

MANUFACTURING TRAINING

by Blackfox Training

Electronics manufacturing companies need skilled and certified workers to perform the intricate and important tasks required to build modern electronic equipment. Here, we explain five ways to gain these workers:

1 **Train and Certify Manufacturing Employees and Support Staff to the IPC Standards**

2 **Fill Training Gaps with Customized Courses that Focus on Basic Knowledge and Skills**

3 **Access Tools and Resources to Assess Your Workforce and Maintain Skill Levels**

4 **Stay Up to Date with Constant Changes in the Electronics Manufacturing Industry**

5 **Hire U.S. Military Veterans Who Have Already Completed Immense Training**

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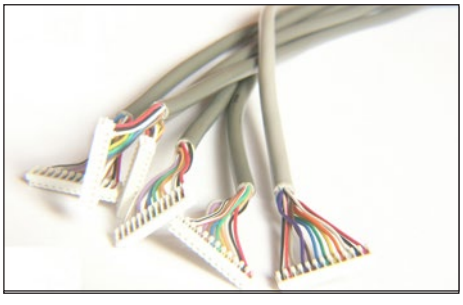

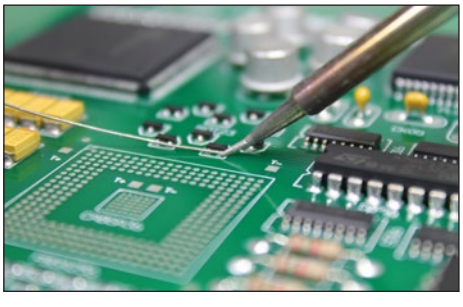

1 Train and Certify Manufacturing Employees and Support Staff to the IPC Standards

IPC certification is an internationally recognized credential that proves an employee's knowledge and skill level. IPC training and certification is industry developed and covers electronic manufacturing quality concerns, including PCB assembly and soldering, rework and repair, wire and cable harness production, and bare PCB fabrication. Having an IPC-certified workforce demonstrates an attention to detail and commitment to quality.

2 Fill Training Gaps with Customized Courses that Focus on Basic Knowledge and Skills

IPC training and other standardized courses don't cover every aspect of electronics manufacturing. Therefore, it is important to have customized courses that fill those missed gaps. Basic soldering, ESD, and electronic component identification are just a few examples of the many courses that complement IPC certification and ensure that your workforce is prepared for any challenges that may come their way.

3 Access Tools and Resources to Assess Your Workforce and Maintain Skill Levels

Assessing your workforce before and after training is an essential part of a proper manufacturing training program. The effectiveness of training and the retention of knowledge gained can be gauged through assessments that are computer-based, interview-based, or audit-based. In addition to assessments, both students and trainers need to have complete access to resource documents and training materials after training has been completed.

4 Stay Up to Date with Constant Changes in the Electronics Manufacturing Industry

Technological advances and new discoveries are occurring constantly that greatly impact how we manufacture electronic products and evaluate them for quality. This makes maintaining your IPC Certifications through renewal and recertification critically important. In addition, attending industry meetings and participating in IPC committees will ensure access to the latest information.

5 Hire U.S. Military Veterans Who Have Already Completed Immense Training

Now more than ever, highly skilled and efficient employees are needed in manufacturing. The U.S. military invests an enormous amount of training in our soldiers. They are equipped with a framework of skills and attributes such as loyalty, integrity, leadership, and excellent work ethic. They know how to learn new skills quickly and adapt to changing environments, which are highly desirable qualities for manufacturing.

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The Top Five Things You Need to Know About

DRILLING AUTOMATION SOLUTIONS

by Burkle North America and Schmoll Maschinen

Living in this era of rapid technological progress, PCB production is making a noticeable shift toward automation. What was once manufactured manually with human hands and low production numbers has transitioned to high-volume production using precise and efficient machines. Today, Industry 4.0 and artificial intelligence are further expanding the boundaries of automated production.

1 Automation in PCB Production

2 Registration, Alignment, Accuracy

3 Maximum Productivity with the Right Application

4 Automation Possibilities

5 Features for Automation to Increase Utilization

1 Automation in PCB Production

PCB manufacturers worldwide are investing in new equipment to improve technology and production, especially in the field of automation. In Europe, the automation of drilling machines is already standard to increase producivity and achieve a higher degree of utilization. The current talent shortage in the U.S. and Canada is accelerating the demand for automation as well. Drill and rout machines with shuttle system and loaders; direct imaging machines with robot arms; and X-ray capabilities with drill and inline automation already allow the automatic loading and unloading of PCBs and ensure contact-free panel handling in the factory, which results in both labor cost savings and quality assurance in the PCB.

2 Registration, Alignment, Accuracy

Highly technologized devices such as spindles, lighting heads, laser sources, cameras, code readers, and sensors are built-up on solid granite and then connected to the machine controller to deliver perfect results and ensure highly accurate PCB processing. For high-end panels, machines with CCD are an option, as any inaccuracies of the panel will be corrected. A two-pin system on panels is mandatory for automated drilling and a well-proven process to support the needed accuracy.

3 Maximum Productivity with the Right Application

Track and trace technology is also being adopted in the handling of PCBs. With a barcode or 2D code, panels can be uniquely identified and processed according to the specific CAD/CAM program. Integrated CCDs and scanner systems in the machines handle the reading of specific part programs.

Automated calibration procedures ensure machine accuracies at the highest level to ensure quality of drilled, routed, and imaged products. Automated spindle maintenance reduces machine down-time and increases productivity.

4 Automation Possibilities

The engineering industry has recently advanced with Industry 4.0 and the building up of several new standards. Drill, rout, and laser machines can be equipped with a loader to feed the panels automatically—one of the new simplified solutions. X-ray and direct imaging machines can now be put into a production line with belt conveyors and run at a constant speed, resulting in increased output. Panels are then handled with robot arms. More robotics have also been introduced to the market, including automated guided vehicles, automated line systems, and shuttle systems.

5 Features for Automation to Increase Utilization

Standard SW interfaces to the MES allow bi-directional communication between machines and high-level production controls, which allows for real-time status information. An operator can have remote access to all machines from the control room, allowing them to monitor automated PCB production, run statistics, and react quickly to any error message or breakdowns.

Visit Burkle North America online.

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The Top Five Things You Need to Know About

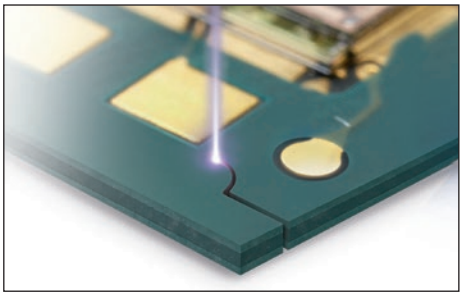
LASER DEPANELING

by LPKF

As high-tech manufacturing takes center stage across the globe, laser depaneling is more critical than ever. What was once an advanced technology focused on niche applications, is now fully scalable to the modern production environment. Laser depaneling is changing the SMT landscape with higher power, cleaner cuts, and more affordable equipment.

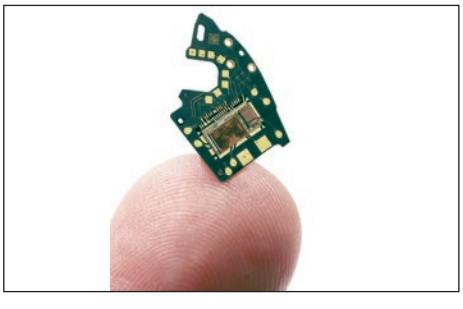
1 **Technical Cleanliness: Nothing Beats Laser...Period**

2 **Zero Consumables**



3 **High-volume Production**

4 **Unparalleled Accuracy and Zero Stress**



5 **Flexibility**

1 Technical Cleanliness: Nothing Beats Laser...Period

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2 Zero Consumables

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3 High-volume Production

With hundreds of lasers running full-time and three shifts/day worldwide, implementing laser depaneling can scale to your production needs. With full inline configurations and a modular approach, today's systems offer a number of in-house automation and board-handling solutions, and can also be integrated with almost any third-party automation.

4 Unparalleled Accuracy and Zero Stress

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5 Flexibility

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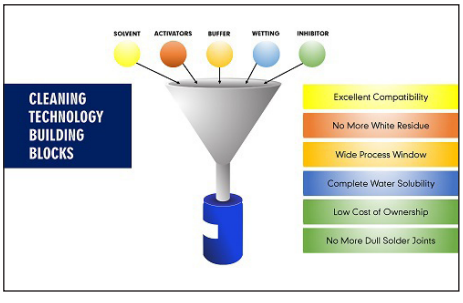
The Top Five Things You Need to Know About CLEANING

by KYZEN

An optimized cleaning process will provide reliable and dependable electronic assemblies. KYZEN's team of cleaning experts work with you to develop the most effective cleaning process for your needs. You can quickly increase productivity and yields by considering these Five Forces of Cleaning and implementing them in your process:

1 The Cleaning Agent: Choosing Wisely Will Save You Money in the Long Run



2 Concentration: More is Not Always Better

3 Time: Determine the Most Effective Wash Cycle Time

4 Temperature: Too High or Too Low Can Cost You More Than Money

5 Mechanical Energy: Adjusting Nozzles Can Make All the Difference

1 The Cleaning Agent: Choosing Wisely Will Save You Money in the Long Run

Consider the material of the substrate and the soil, and test to make sure your cleaning chemistry is effective on the soil sets you are using and compatible with all materials of construction in your assembly and your cleaning machine.

2 Concentration: More is Not Always Better

No two cleaning chemistries are created equal. The concentration at which they are effective will differ, and most often, the chemical supplier will supply a range for use. Start at the high side of the range and lower the concentration in small increments until you reach the optimal concentration for your unique process parameters.

3 Time: Determine the Most Effective Wash Cycle Time

A few factors will determine how long your assemblies will need to be exposed to the wash solution before they are completely residue-free. Is your soil easily removed? If not, can other process parameters be adjusted or optimized to shorten your wash cycle time?

4 Temperature: Too High or Too Low Can Cost You More Than Money

If your operating temperature is too high, you could harden the flux residue, making it harder to remove. High heat can also damage delicate substrates, not to mention the wear and tear to your machine. Running at a lower temperature may not take advantage of your chemistry's solvency, which will result in poor soil removal. Optimizing your process with thorough testing will help you find just the right temperature to bring success.

5 Mechanical Energy: Adjusting Nozzles Can Make All the Difference

Spray-in-air is the most common choice when it comes to PCB cleaning. Whether you choose a batch or inline washer is often determined by your throughput and floor space. There are a variety of adjustments you can make in each process to maximize the mechanical energy needed to completely clean and rinse your assemblies. Bonus tip: You are only as clean as your last rinse.

About KYZEN

KYZEN is the leading global cleaning chemistry supplier offering a wide range of products for electronics assembly cleaning processes. For expert cleaning advice, visit us at KYZEN.com.

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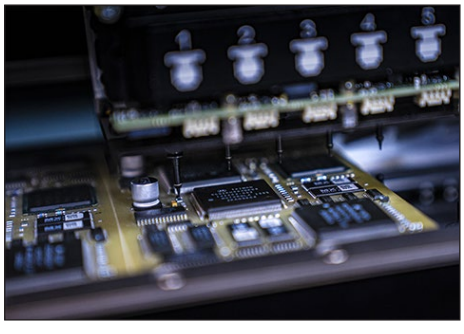
The Top Five Things You Need to Know About PLACEMENT

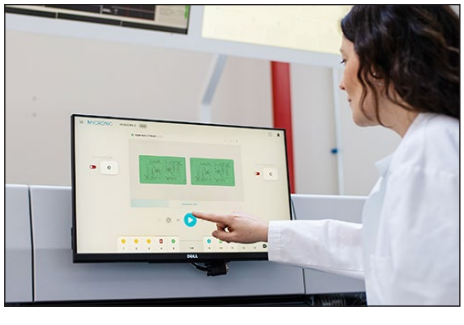
by Mycronic

Today's high-mix electronics manufacturers need to adapt to a rapidly changing environment. To meet customer expectations and maintain competitiveness and profitability, their component placement process must meet several conditions. Here are the top five things to consider:

1 **Combine High Placement Productivity With Consistent Reliability for Growing Batch Sizes**

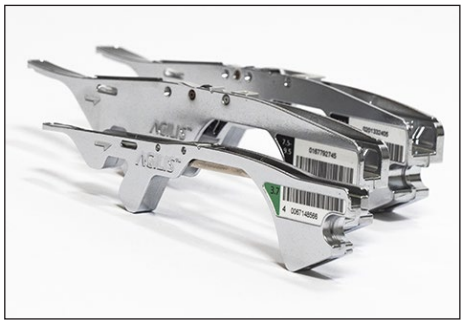


2 **Have the Versatility to Cope With an Expanding Diversity of Components**



3 **Create a User-friendly Graphical Interface for Efficient Operation and Faster Training**

4 **Have Extreme Flexibility With the Shortest Changeover Time**



5 **Utilize Live Process Control for Optimized Performance**

1 Combine High Placement Productivity with Consistent Reliability for Growing Production Volumes

To handle the demands of more complex products, diversified production, and shorter delivery times, high-mix producers need to significantly raise their placement productivity while maintaining the highest precision and quality. Boosted by the new MX7 mounthead, the MYPro A40 placement machine delivers an outstanding 59,000 CPH throughput, giving high-mix manufacturers the productivity and peak speed they need to meet aggressive production schedules.

2 Have the Versatility to Cope With the ExpandingDiversity of Components

The wider the range of components your placement system can handle, the faster, more versatile, and more cost-effective your production process will be. This is why each nozzle of the MX7 individually picks, rotates, and places, allowing the high-speed mounthead to place the widest range of components in the industry. In fact, the MX7 mounthead mounts chip components as small as 01005 (0.4 × 0.2 mm), large BGAs, and components as large as 150 × 40 × 15 mm.

3 Create a User-friendly Graphical Interface for Efficient Operation and Faster Training

A high-mix platform is only as efficient as its operator. When human-machine interaction is clear and straightforward, with uncomplicated, step-by-step touchscreen guidance, the most relevant process data becomes more visible and actionable. The MYPro A40 is equipped with a new graphical user interface (GUI) for more natural, fluid interaction with the operator. This intuitive GUI makes both training operators and running the pick-and-place smoother—and more error-proof—than ever before.

4 Have Extreme Flexibility With the Shortest Changeover Time

The performance and responsiveness of a high-mix electronics manufacturer depends on its ability to switch from one production run to another as quickly and efficiently as possible. Today, changeovers should be completed in minutes, from feeder and program loading to production start-up. Mycronic's unique Agilis™ feeders with no moving parts are easier and quicker to load than any alternative and enable the shortest changeover time on the market.

5 Live Process Control for Optimized Performance

Pick-and-place production data is extremely valuable if used properly. Live KPIs enable production engineers to quickly spot any performance drift. An advanced dashboard gives them the actionable information they need to increase utilization, reduce reject rates, and improve line balancing in real-time. With live component misspick and reject analysis, MYCenter Analysis makes it possible to diagnose root causes before the problems multiply.

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The Top Five Things You Need to Know About

IMPLEMENTING SMART AUTOMATION SOLUTIONS

by Technica, U.S.A.

There are limited production hours available each year, so make them count. It starts by integrating reliable hardware and software automation solutions. But it doesn't end there; reassessment of your automation needs will be ongoing.

1 **Choose an experienced partner**

2 **Clearly define your short-term and long-term visions**

3 **Align Your Goals With Your Budget to Execute an Automation Solution**

4 **Evaluate the structure of your IT landscape**

5 **Position yourself for the journey of benefitting from big data**

1 Choose an experienced partner

To ensure the journey is rewarding, it's important to have an automation partner experienced in analyzing and examining your current processes to help you choose the best robotic and cell layout solutions. Working with a company that has actually implemented full-scale automation and smart factory status into similar companies is key in designing the solution that you desire.

2 Clearly define your short-term and long-term visions

Are you considering automation for certain purposes, such as lower operating costs, improved work safety, reduced factory lead times, increased production output, improved quality, or achieving a smart factory environment? Understanding your short- and long-term goals will determine the level of hardware and software tools that will be required to meet your goals and achieve a desired outcome.

3 Align Your Goals With Your Budget to Execute an Automation Solution

It takes a certain level of commitment as it relates to the investment of time and capital to implement a smart factory solution. How fast you begin to recognize your ROI will be based on a sound understanding of how to plan, create, and define the implementation.

4 Evaluate the structure of your IT landscape

Connectivity, tracking, controlling, and analyzing are major parts of implementing a smart factory concept. Having an IT structure that can support the data journey is also important in achieving smart factory data management, factory intelligence, and material process control. Implementation of tools on the shop floor, such as factory dashboards, advanced planning, and scheduling, are outcomes of your data journey.

5 Position yourself for the journey of benefitting from big data

Gathering data is a benefit of adding automation and connecting it to other equipment in the manufacturing process. Seamlessly sharing the collected data with enterprise software (ERP, MRP, PLM, MES, MOM) is where meaningful data will be gained to better control your processes and improve productivity. Having the personnel and software resources is important in recognizing the benefit of big data.

Integrated Mesh Power System (IMPS) for PCBs

Happy's Tech Talk #27

by Happy Holden, I-CONNECT007

A significant decrease in HDI substrate production cost can be achieved by reducing the number of substrate layers from conventional through-hole multilayers and microvia multilayers of eight, 10, 12, and more to only two layers. Besides reducing direct processing steps, the yield will increase as defect-producing operations are eliminated. The integrated mesh power system (IMPS) was invented in the latter years of MCM-D use for thin-film fabrication. Those geometries fit today into our use of ultra HDI.

A Look at the Benefits

In the late 1990s, thin film multichip modules (MCM-D) were supposed to save the interconnect industry. The fine-line lithography would allow miniaturization with ease. Unfortunately, the four or five metal layers to which integrated circuits were wire bonded proved to be too expensive when compared to printed circuit multilayers (Figure 1a) and the emerging silicon integration on ball grid arrays.

IMPS topology was created to reduce the cost of metal layers on thin-film and ceramic multichip modules. The IMPS topology can reduce the metal layers to only two or three. This results in substantial cost reduction and simplification while not affecting electrical performance.

IMPS Background

The scientists at the High Density Electronics Center (HiDEC) at the University of Arkansas invented IMPS in the mid-1990s[1]. IMPS allows for low inductance co-planar power and ground distribution, as well as dense, controlled-impedance, low crosstalk signal trans-

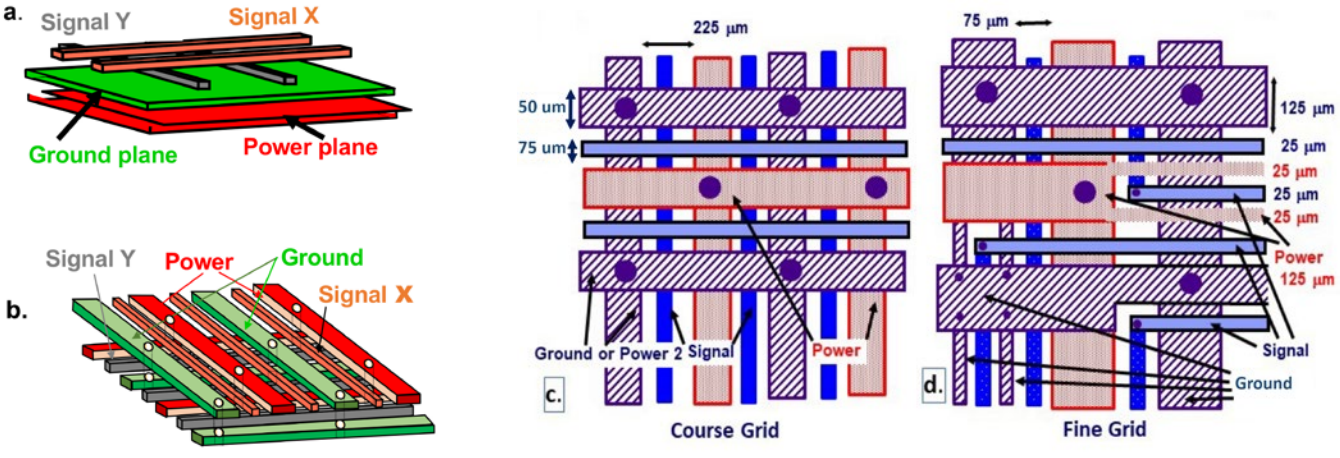

Figure 1: Interconnected mesh power system (IMPS) is a very cost-effective structur . a) Conventional multilayers of power-ground-signal X and signal Y on separate metal layers; b) The IMPS utilizes a "mesh" structure on just two-metal layers; c) IMPS course grid; d) A fine grid for the structur .

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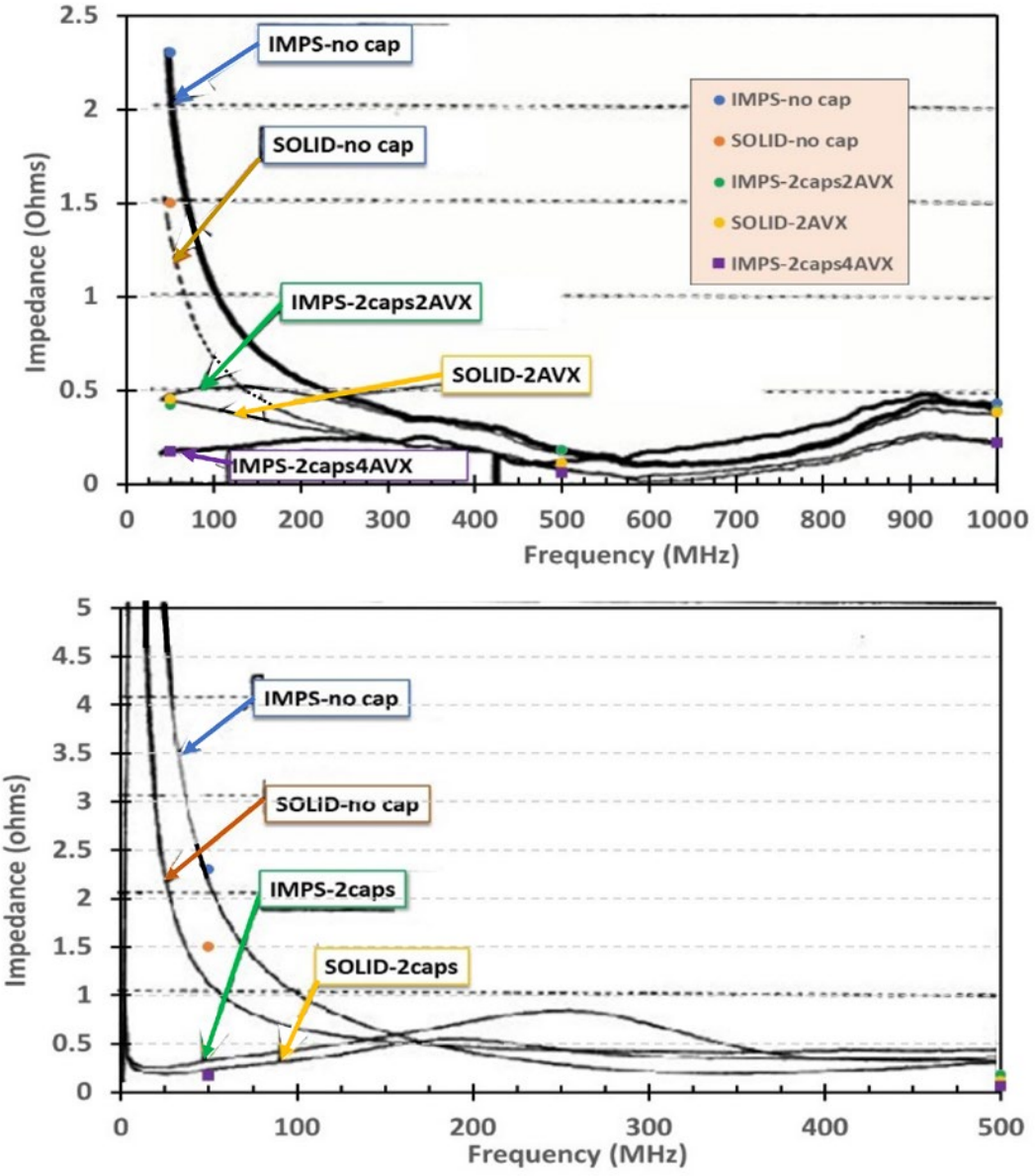

Figure 2: Electrical performance of IMPS is very close to solid planes. Top: Power distribution explanation with the metal conductor's impedance vs. frequency using an HP8510 network analyzer with different capacitors in the layer-pair; Bottom: Power distribution impedance using the HP4291A impedance meter.

mission in only two wiring layers. Figure 1b shows the basic IMPS topology.

The conventional metal wiring topology is to have signals on one metal layer and power and ground on separate metal layers. The resulting usage of these expensive metal layers is quite low. Signal layers may have only 50 to 60% utilization and power/ground layers only half that amount when either the coarse mesh or fine mesh is utilized (Figure 1c and 1d).

They may be made smaller (if signal losses can be tolerated), but the spacing cannot. High-speed, fast rise time signals are sensitive to crosstalk, so the signals still must be separated. IMPS uses that separation to route power and ground. To prevent current starvation at devices, an adjacent metal layer running orthogonally is connected by buried vias at each junction where the two layers cross. This layer-pair topology is an "interconnected mesh" that can thus provide all the power/ground connections without voltage loss and connect the signal for these devices.

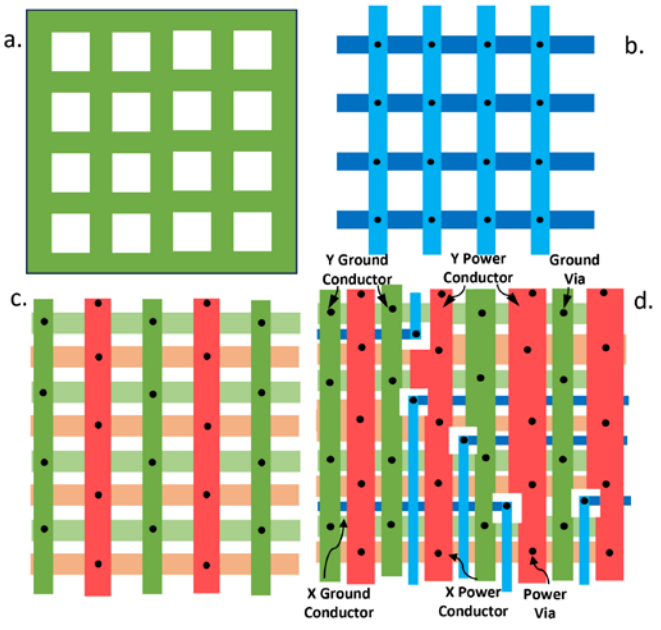

Figure 3: The IMPS design steps use only two metal layers: a) IC power mesh on one-metal layer as reference; b) The IMPS two-metal layer mesh of ground; c) The two-metal layers mesh for power distribution; d) Two-metal layer-pair conductors on the organic substrates, all integrated.

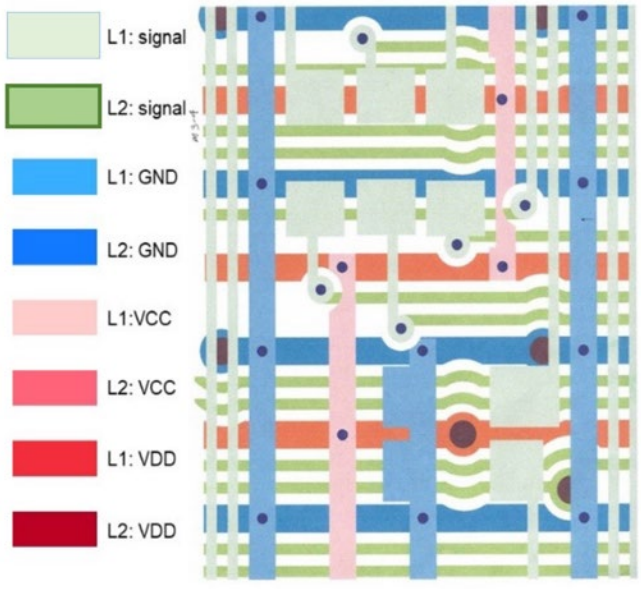

Figure 4: An IMPS BGA design can be executed with two-metal layer-pair on an organic substrates.

Electrical Performance

Power distribution impedance was measured with both an HP 8510 network analyzer and an HP 4291A impedance analyzer over a range of 45 MHz to 1 GHz[2]. Figure 2 shows the measured impedance for several substrates with combinations of decoupling capacitance. The results indicated there were minor differences between the IMPS power distribution structure and one using solid planes. Any planar effects were reported to be masked by attachment or wirebonding impedances and by the number and type of capacitors used. The transmission lines are planar waveguides.

IMPS Design

IMPS was developed in the late 1990s for MCM-D design using thin film metallization on liquid dielectrics. Fortunately, PCB technologies have improved in the last 30 years such that ultra HDI technologies can now achieve these thin-film geometries. The various SAP metallizations on polyimide film or ABF organic films can be employed, including the use of metal-backed thermal laminate. The design process is shown in Figure 3.

The architecture is based on the current use of a power mesh in integrated circuit design (Figure 3a). But instead of the single metal use, IMPS employs two metals and adjacent layers, connected by vias to form the mesh (Figure 3b). Figure 3b is the ground mesh, while Figure 3c shows the power mesh. The two are merged with the open area used of X-Y routings (Figure 3d).

Figure 4 illustrates a BGA example of IMPS for a BGA requiring two different voltage rails of VCC and VDD all on two-metal layers.

High-Density MCM-BGA Application

In 1996, HiDEC, using flexible film and Tape BGA (TBGA) technology along with microvias and the IMPS topology, was able to create an MCM-L with only two metal layers instead of the conventional four metal layers of an MCM-D[3,4]. This test vehicle puts two IMPS metal layers, which provide signal wiring and power distribution, on the two sides of a Kapton® film. One side contains mounting pads to which

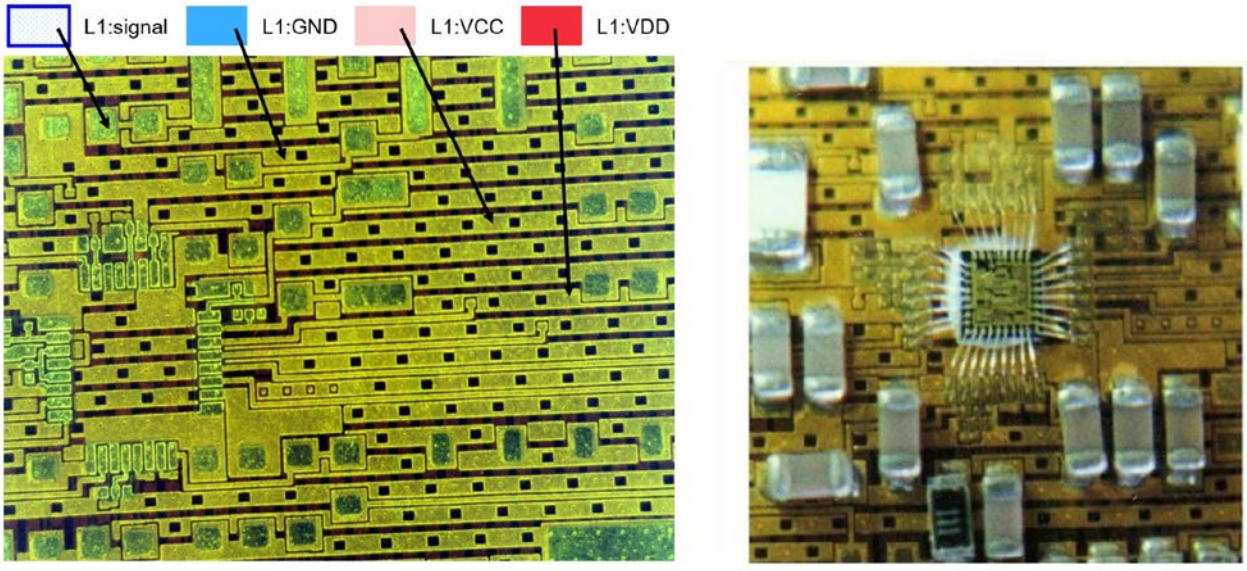

Figure 5: An IMPS topology before and after assembly.

the dies are wire bonded and discretes are soldered. This side is encapsulated. The other side has the lands in a ball grid array pattern. A part of the IMPS artwork is shown in Figure 4.

The test vehicle was built on 2-mil Sheldahl an adhesiveless polyimide film called ViaThin™[5]. The basic design rules are 50 µm lines and spaces, 150 µm via target lands over 25 µm laser-drilled vias. The IMPS mesh consisted of 200 µm lines and 50 µm spaces, with the lines offset from the via row or column centers. Wirebond pads consisted of 200 µm x 350 µm rectangles on both metal layers, tied together with two vias.

The test vehicle showed conclusively that the IMPS topology could be applied to MCM-Ls and BGA substrates without multi-layering. Figure 5 is another closeup of the IMPS topology in an MCM-L.

Summary

The new microvia topologies, IMPS, have demonstrated the application to simplifying complex multilayer, SLPC, and interposers. IMPS can reduce the structure to a two-metal interconnect. These results show that these topologies have the capacity to positively impact how electronic products are packaged and interconnected. **PCB007**

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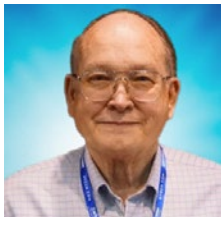


Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa Westwood, Merix, Foxconn, and Gentex. He is currently a contributing technical editor with I-Connect007, and the author of *Automation and Advanced Procedures in PCB Fabrication*, and *24 Essential Skills for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

Saying Goodbye to Industry Icon Tony Hilvers

It is with sadness that IPC announces the passing of Tony Hilvers, former IPC vice president of industry programs, on Tuesday, Feb. 6. Hilvers left IPC in 2012 after 29 years of service.

During his long tenure, Hilvers was responsible for the association's market research, government relations and environmental policy, meetings, and professional development departments.

In addition, he was responsible for industry segments including the PWB and EMS Management Councils, the PWB Suppliers Council, the Surface Mount Equipment Manufacturers (SMEMA) Council, the Solder Products Value Council, and associated events, including IPC APEX EXPO. While he was vice president of industry programs, IPC APEX EXPO was named one of the top 25 fastest-growing U.S. trade shows in attendance by Trade Show News Network.

While serving as director of educational services and marketing communications, he formed the EMS Management Council and published the first market research study on the EMS industry in 1984. Hilvers was also instrumental in launching IPC Printed Circuits Expo, IPC APEX Conference and Exhibition and the co-located IPC APEX EXPO and worked with the Hong Kong Printed Circuit Association to launch the HKPCA/IPC International Printed Circuits and Assembly Fair.

Said David Bergman, IPC's vice president of standards and technology and long-time colleague of Hilvers, "I had the privilege of working with Tony for nearly 30 years. I did sales visits, traveled internationally, collaborated, supported and was supported by Tony and his team. I always admired his ability to listen to a group of business leaders, figure out a program to solve a problem they were faced with, and then convince others that this program was worth their support. Tony's passion for the industry and his natural sales ability facilitated his creation of many new programs for IPC."

IPC extends its sincere condolences to Tony's family, friends, and former work colleagues.

(Source: IPC)

IPC Standards and Electronics Sustainability: More than Meets the Eye

Feature Article by Kelly Scanlon
IPC LEAD SUSTAINABILITY STRATEGIST

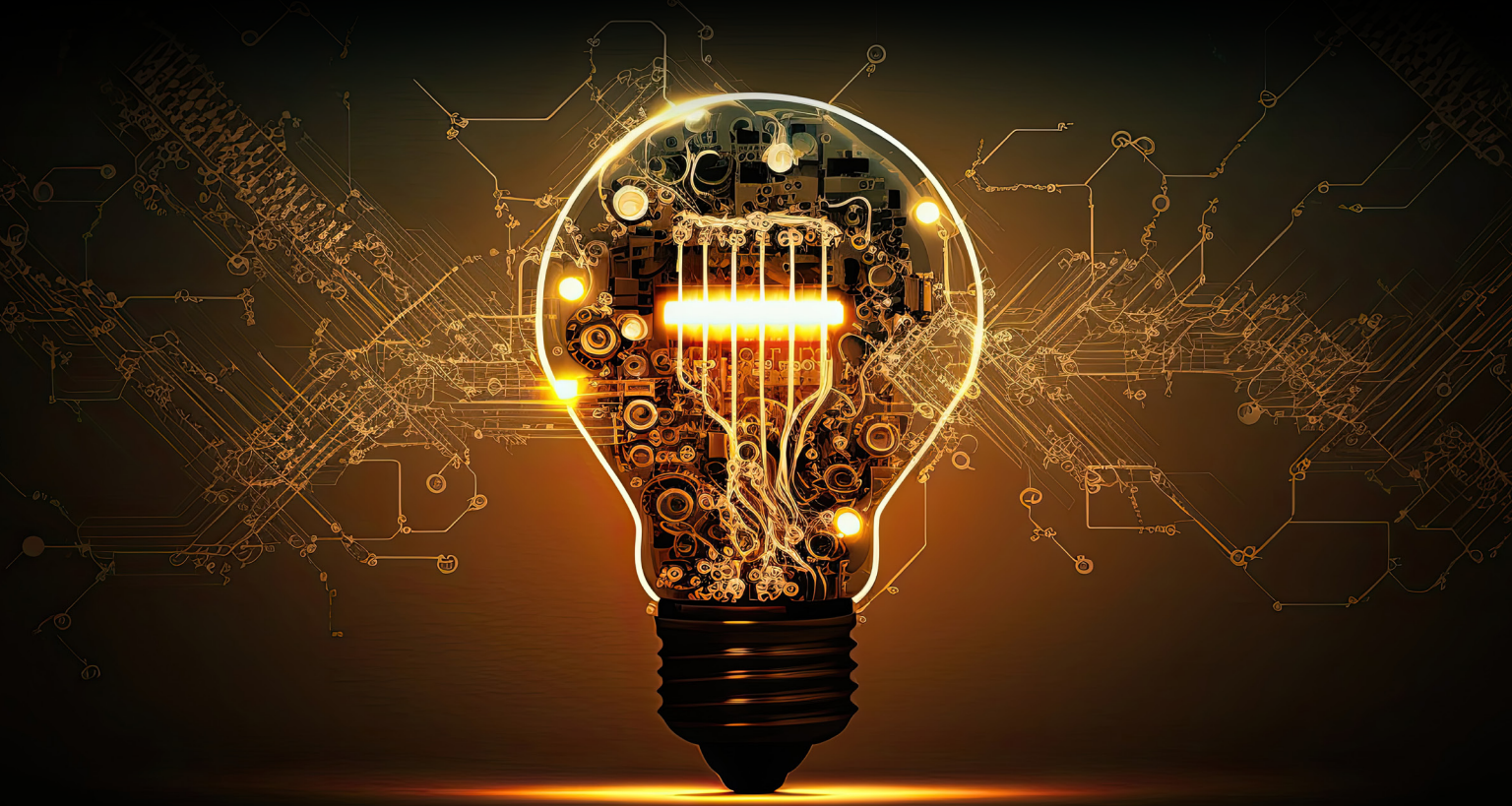
When we look at existing IPC standards, we see that most were created and intended to communicate and clarify expectations for superior quality, reliability, and consistency in electronics manufacturing. At first glance, their connection to sustainability is not obvious.

Yet as we continue to evaluate existing IPC standards against sustainability reporting best practices or requirements for companies in the electronics value chain, there are more than a dozen IPC standards that address important and relevant sustainability topics.

For example, training and education—a relevant and important industry sustainability topic covered by GRI standards—is represented in popular IPC standards, including IPC-A-610, *Acceptability of Electronic Assemblies;* IPC J-STD-001, *Requirements for Soldered Electrical and Electronic Assemblies;* and IPC-7711/21, *Rework, Modification and Repair of Electronic Assemblies;* and the certification programs built around these standards.

The GRI (Global Reporting Initiative) standards focus on the environmental, social, and economic impacts of a company in relation to sustainable development. They represent global best practices for reporting publicly. GRI is just one of four frameworks sustainability disclosures identified as a driver caus-

SMART FACTORY DESIGN



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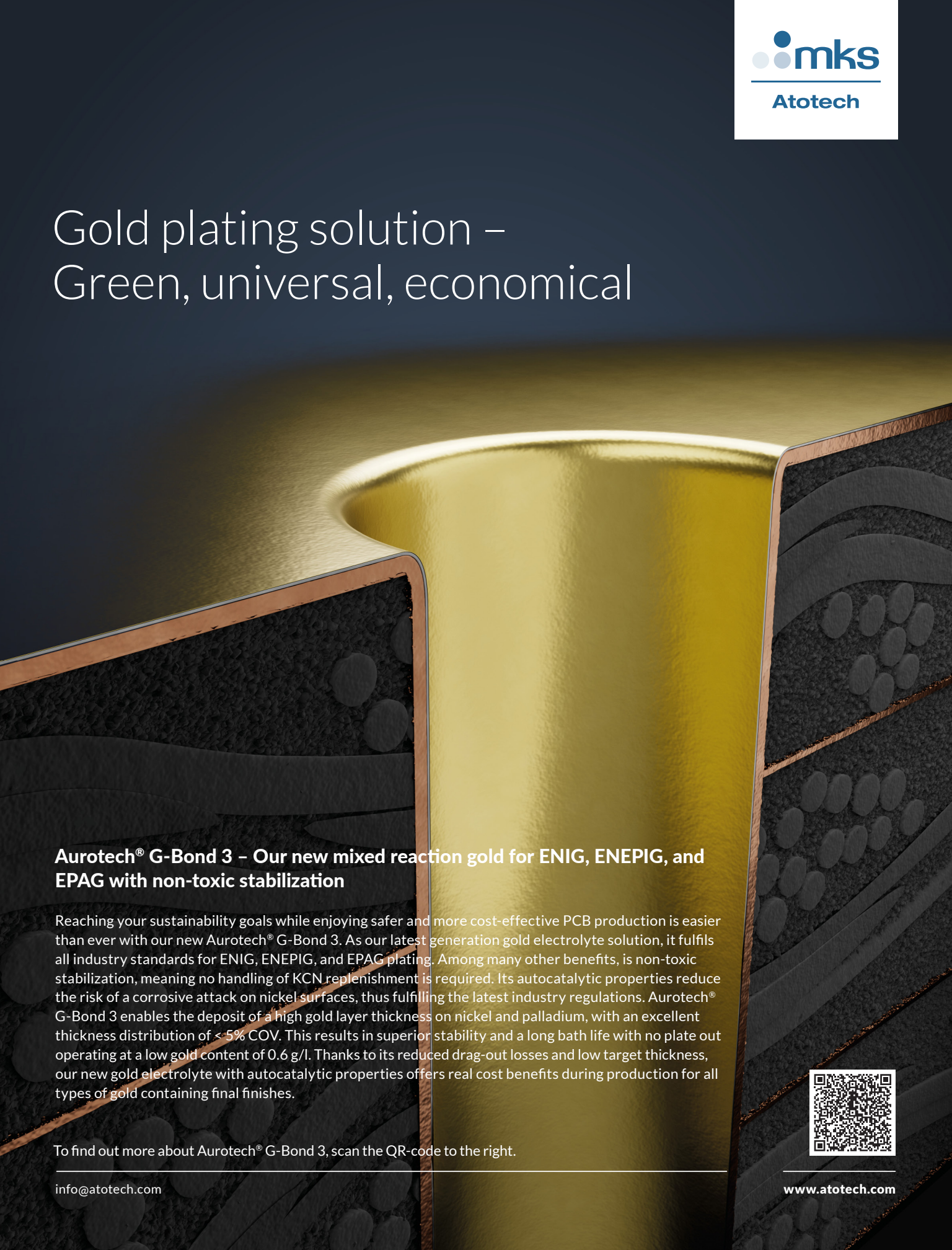

Aurotech® G-Bond 3 – Our new mixed reaction gold for ENIG, ENEPIG, and EPAG with non-toxic stabilization

Reaching your sustainability goals while enjoying safer and more cost-effective PCB production is easier than ever with our new Aurotech® G-Bond 3. As our latest generation gold electrolyte solution, it fulfils all industry standards for ENIG, ENEPIG, and EPAG plating. Among many other benefits, is non-toxic stabilization, meaning no handling of KCN replenishment is required. Its autocatalytic properties reduce the risk of a corrosive attack on nickel surfaces, thus fulfilling the latest industry regulations. Aurotech® G-Bond 3 enables the deposit of a high gold layer thickness on nickel and palladium, with an excellent thickness distribution of < 5% COV. This results in superior stability and a long bath life with no plate out operating at a low gold content of 0.6 g/l. Thanks to its reduced drag-out losses and low target thickness, our new gold electrolyte with autocatalytic properties offers real cost benefits during production for all types of gold containing final finishes.

To find out more about Aurotech® G-Bond 3, scan the QR-code to the right.

info@atotech.com

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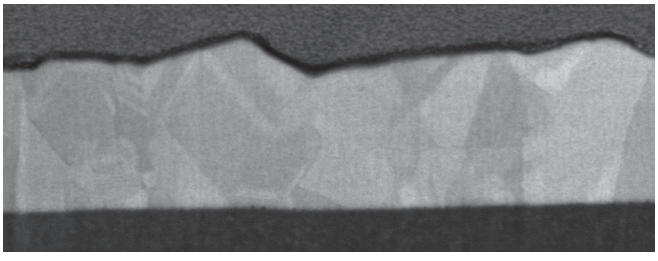
Revolutionizing gold plating for superior ENIG-corrosion prevention and environmental safety

In the dynamic world of printed circuit board (PCB) manufacturing, where innovation is paramount, Atotech's Aurotech® G-Bond 3 emerges as a breakthrough solution in Electroless Nickel Immersion Gold (ENIG), Electroless Nickel Electroless Palladium Immersion Gold (ENEPIG), and Electroless Palladium Autocatalytic Gold (EPAG) plating processes. This revolutionary solution not only surpasses its predecessor, Aurotech® G-Bond 2, but also introduces innovative features, such as a non-toxic stabilization. It therewith sets new industry standards and addresses environmental concerns.



Defect-free gold layer and interface

Superior protection and longevity

The G-Bond 3 electrolyte has remarkable autocatalytic plating properties that powerfully mitigate potential corrosive attacks on the underlying nickel layer. This feature allows for high gold thicknesses of up to 300 nm and more during the plating process. The autocatalytic nature of the process represents a significant step forward in corrosion-free gold electrolytes. It meets the industry's demand for increased reliability.

A safer and greener approach

A key advantage of the new solution is its non-toxic stabilization. By eliminating the need for hazardous potassium cyanide (KCN) replenishment, the process significantly improves user safety. The removal of toxic substances streamlines process handling, reducing risks and enhancing overall operational safety measures. This move towards a completely KCN-free stabilizer aligns with the industry's commitment to environmental sustainability.

A cost-effective solution

The Aurotech G-Bond 3 electrolyte also revolutionizes cost-competitive manufacturing. It optimizes production costs with a low gold content of 0.6 g/l and an exceptional thickness distribution of less than 5% CoV. This cost-effective solution not only minimizes drag-out losses but also allows for a low target thickness, thereby effectively optimizing overall production costs. The process builds on the advantages of its predecessor, Aurotech® G-Bond 2, by introducing an unprecedented level of stability and further improving bath life by up to 10 MTO. These improvements result in reduced maintenance and lower operating costs, making it an economical and efficient choice for manufacturers.

Flexibility for manufacturers

Versatile use in plating processes, including Ni/Pd/Au and Pd/Au deposits, is possible due to the unique composition of the new process. As a result, system operators benefit from greater flexibility in their final finish production. This potentially saves space and time and reduces warehouse stock.

Corrosion mitigation in ENIG

In response to industry demands for corrosion mitigation in ENIG processes, the autocatalytic properties of the Aurotech G-Bond 3 solution significantly reduce the risk of corrosive attacks on the nickel layer. It meets industry standards with an outstanding > 95% level 0 corrosion rating according to IPC 4552B.

The Aurotech G-Bond 3 electrolyte represents a paradigm shift in corrosion-free gold electrolytes for ENIG, ENEPIG, and EPAG plating processes. Its autocatalytic plating behavior, non-toxic stabilization, and versatile applications set new industry standards. Manufacturers benefit from improved stability, reduced maintenance efforts, more versatile shopfloor management, and cost-competitive manufacturing. This places the new process at the forefront of electroplating technologies. The innovative solution not only ensures enhanced efficiency but also prioritizes environmental safety, making it a top choice in the evolving surface finish landscape.

Sandra Nelle
Global Assistant Product Manager
Atotech Deutschland GmbH & Co. KG
Materials Solutions Division
MKS Instruments

ing companies in the industry to disclose data and information on various sustainability topics and targets. A recent exploratory materiality study of dozens of industry sustainability reports revealed that GRI, along with SASB, TCFD, and CDP, was strongly preferred and most used of the four.

I provided an overview of a recent exploratory materiality study that evaluated dozens of industry sustainability reports to determine the drivers for disclosing data on sustainability targets.

Companies reporting against the GRI 404 Training and Education requirements, for example, must document their approach to training and upgrading employee skills, including training programs inside or outside the company. The IPC standards I've mentioned require personnel proficiency at tasks, and associated IPC training programs ensure industry-traceable certification. Companies should consider these IPC standards and certification activities when they are compiling data and information for their sustainability reports in the topic area of training and education.

A new IPC standard, IPC-1402, *Standard for Green Cleaners Used in Electronics Manufacturing,* applies to direct-use chemicals to clean electronic products or components, as well as to clean manufacturing machines or tooling during operation and maintenance. It establishes practical criteria for cleaning products used in electronics manufacturing workplaces that can be efficiently applied by decision-makers and purchasing parties to protect workers. IPC-1402 is used as a baseline to determine qualifications for programs aimed at promoting safer chemical alternatives.

Companies reporting against the GRI 403 OHS requirements must demonstrate commitment to worker health and safety—the prevention of harm and promotion of health through processes that assess risks and apply methods to eliminate or minimize those risks.

Given the expertise and financial resources necessary to complete hazard analyses and more comprehensive risk assessments necessary to meet this GRI requirement, it is useful to have an industry standard that enables efficient risk evaluation. Companies should consider this IPC standard when looking to move toward safer chemical cleaning products and demonstrate their commitment to prevention.

There are many other relevant sustainability topics, including product life cycle management, product security, and procurement practices, that can be addressed using existing IPC standards. We continue to evaluate them to determine their utility in documenting sustainable practices for your company. Please contact me if you have questions about IPC standards and their applicability to sustainability requirements. **PCB007**

This article originally appeared in *IPC Community,* Vol. 1, Number 4.

ALL EPISODES AVAILABLE

sustainability podcast

From logistics, manufacturing, and personnel, to cloud-based applications, there are many aspects of sustainability that should be considered. I-Connect007 brings to our listeners a six-part series on Sustainability. Siemens topic experts explore how each of these areas are impacted by the effort to go green.

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The Importance of Standards for the Chip Packaging Industry

Material Insight

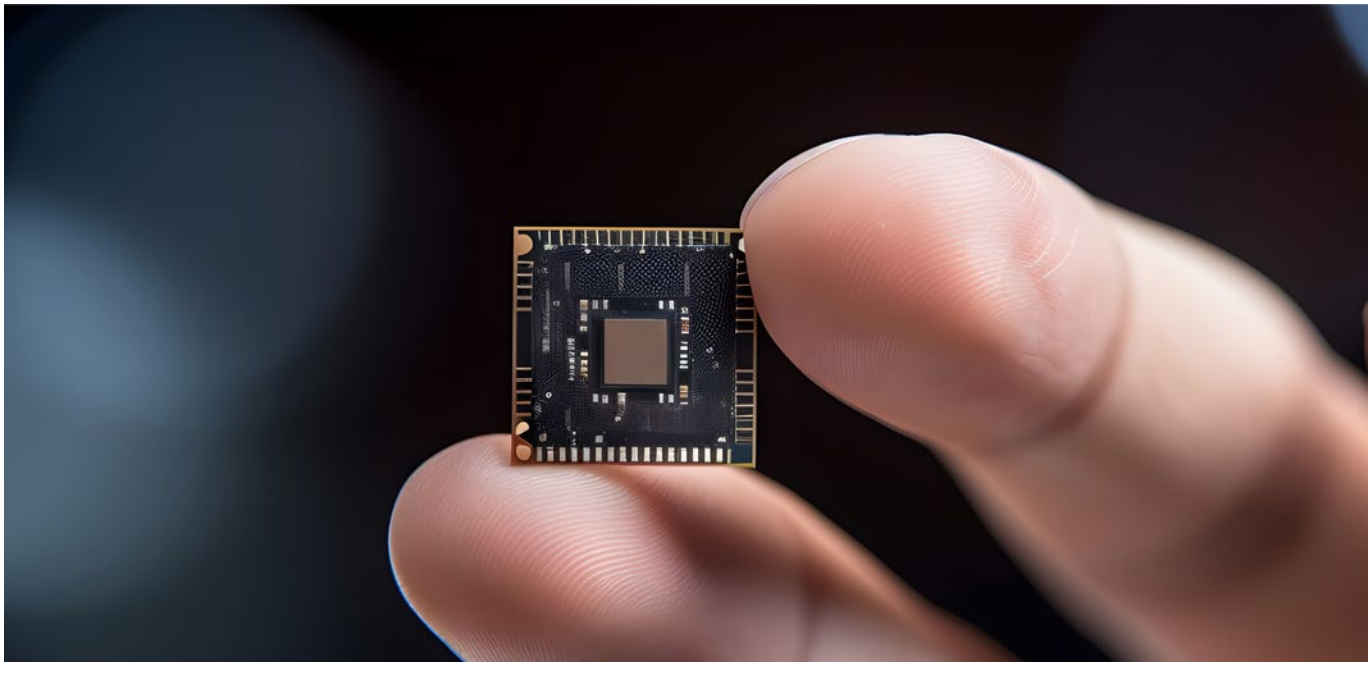
by Preeya Kuray, Ph.D.

I had the great pleasure of recently attending the National Institute of Standards and Technology's (NIST) CHIPS R&D Chiplets Interfaces Technical Standards Workshop. The purpose was to bring together technical experts across industry and academia to deliberate one of the most pressing technological matters of 2024: chip packaging standards.

In the semiconductor industry, monolithic chips are widely employed. Herein, all elements of the integrated circuit (e.g., transistors, resistors, interconnects, etc.) are built onto a single chip. By incorporating all aspects of the integrated circuit onto the same chip, the monolithic design or "system on chip" (SoC) simplifies design and can allow for high performance. Meanwhile, "system in package" (SiP) offers a different approach. SiPs employ chiplets where segmented processors (CPU, GPU, memory, etc.) are manufactured as separate chips, and then assembled onto an interposer at a tight pitch (or stacked on top of each other) to form a single, cohesive system.

The benefit is that SiP opens an entirely new world for semiconductor chip design: the ability to mix and match specialized chiplets onto a single package. This allows for greater selection and integration of components for customized applications. SiP also offers a faster time-to-market than SoC because designers can select pre-existing components and integrate them into a single package, streamlining the design process.

But while the concept of SiP is not new to the packaging world, most companies that design products with proprietary interfaces



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do not allow for interoperability, or the mixing and matching of chiplets from different manufacturers onto a single package. So, where do standards come into play? Standards for interoperability ensure that chiplets from different manufacturers can work together seamlessly without compatibility issues. When chiplets adhere to common design specifications, it becomes easier to integrate them into a single package or system. This is critical for designers who want to mix and match components from various sources to create customized solutions.

"Ideally, we would want the chiplet ecosystem replicating the PCB ecosystem," says Dr. Ganesh Subbarayan, professor of mechanical engineering at Purdue University. "In other words, it's procuring chips from multiple vendors and being able to arbitrarily integrate them very close to each other, because the problem comes from a system that consists of multiple chiplets from different sources. If there is no metric, there is no way to understand how any singular changes made in a component can affect the system as a whole."

Ultimately, the creation of open standards for chiplets would allow for interoperability, lowered barrier to innovation, and encourage the growth of a healthy chiplet ecosystem. Therefore, the purpose of the NIST workshop was to deliberate the development of open standards for the chip packaging industry.

The most pressing topic area from the conference was creating standards for safe data sharing. "Data sharing is not very robust in the sense that different tools from different ecosystems collect and format their data differently," said one official from the U.S. Department of Commerce. "The lack of standards makes it difficult to share the data across different ecosystems. NIST has done a fair bit of work in this space of data sharing. One thing we propose to do in the near term is to have another workshop that will essentially revisit this idea of data sharing. There are tons of data across the different ecosystems of chip packaging. We need to find a system that facilitates data sharing across these ecosystems. There are currently ongoing activities centered around distributed ledger technologies, such as blockchain technology for sharing data. This is one of the areas we will need to put a lot of effort into."

As data moves across the chiplet ecosystem, it will inherently pass through several hands. Blockchain technology refers to a decentralized and distributed system for storing and recording information. It allows multiple parties to have a secure, transparent, and tamper-resistant record of transactions without the need for a central authority. While the implementation of blockchain in chip packaging standards is a complex process requiring collaboration among industry participants, the technology has the potential to bring increased transparency and trust to the chip packaging ecosystem.

In other words, if companies are assured that their IP will be protected, the dream of interoperability can become a tangible reality. How far are we from that reality?

"It is going to be sooner than later," the commerce official stated. "The chiplet-based packaging ecosystem is already here. The question is, how do we harmonize the ecosystem such that we can take a component from one company and marry it to something from another? When the market starts demanding better performance, cost, and availability, we should be ready to help facilitate that change with the appropriate chip packaging standards."

While there is still much work to be done, the scientific community understands the value of developing these standards. The horizon for chip packaging looks promising. **PCB007**

Preeya Kuray, PhD,
is a material scientist.
To read previous columns, click here.

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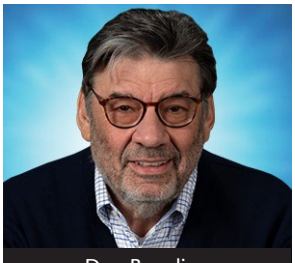
TOP TEN

EDITOR'S PICKS

What PCB Fabricators Should Know About IPC APEX EXPO 2024

In this article, we focus on how bare board fabricators can maximize their time and investment at the show. We visited with Matt Kelly, IPC chief technologist, and Julia Gumminger, IPC professional development and events manager, as well as Udo Welzel and Stanton Rak, the chairs of the technical program committee, to discuss the technical depth and breadth that the 2024 show will bring to fabricators and professionals all along the supply chain.

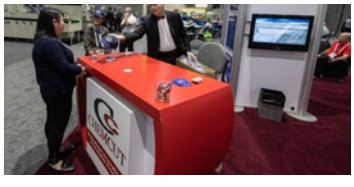
It's Only Common Sense: Seeking the Possibility of Opportunity



Dan Beaulieu

We are often so immersed in what we are doing that we don't have time to lift our heads and open our eyes to the possibility of opportunity. Why is this a problem? It's because being open to opportunities is crucial for success in sales. The absolute best way is to always have an open mind. You must also be able to connect the dots, to see something a company is doing that makes them successful and whether you can apply it to your own business—no matter the industry.

The Chemical Connection: An Exhibitor's View of IPC APEX



When I learned this issue would be dedicated to optimizing the bare board fabricator's experience at IPC APEX EXPO 2024, I thought it would be an easy column to write. With more than 40 of these shows under my belt, I didn't think it would be too difficult to come up with a list of dos an don'ts to make your visit to an exhibitor's booth worthwhile. The whole point of being at the show in the first place is to introduce new products, meet and talk with old customers, and introduce yourself and your product to potential new customers.

Trouble in Your Tank: Processes to Support IC Substrates and Advanced Packaging, Part 4

In a previous column, the critical process of desmear and its necessity to ensure a clean copper surface connection was presented. Now, my discussion will focus on obtaining a void-free and tightly adherent copper plating deposit on these surfaces. After the desmear process, the task is to insure a continuous, conductive, and void-free deposit on the via walls and capture pad. Today, there are several processes that can be utilized to render vias conductive.

Real Progress Toward Solving U.S. Workforce Problems

IPC achieved a landmark in 2023 by creating an apprenticeship program approved by the U.S. Department of Labor. With such a registered framework in place, industry can work through IPC to secure local, state, and federal dollars for workforce development in a way they've never been able to do before.

American Made Advocacy: Congress Must Handle Supply Chain Challenges in 2024

It's easy to get distracted in an election year. A constant stream of polls, primaries, and political prognostications will surely dominate the media cycle. Elections are important, but they should not distract the 118th Congress from the important work of securing our fragile supply chains and rebuilding microelectronics manufacturing capacity on our own shores.

Ups and Downs in the World Market

The keynote session for the EIPC 2024 Winter Conference addressed several topics, ranging from applications for superconductivity to the fluctuating European financial mar et and the importance of IC substrates. The conference took place in late January at the IHK Academie in the city of Villingen-Schwenningen, on the eastern edge of the Black Forest in southwest Germany.

Testing Todd: Why 4-wire Kelvin?

As William Thomson (Lord Kelvin) once said, "If you cannot measure it, you cannot improve it." This is truer today than ever before. With the advances in microelectronics and nanoelectronics, HDI, and buried active/passive components, the signature of the printed circuit is critical. High-speed substrates rely on signal transmission to be as pristine as possible. Minor changes can cause impedance changes in standing wave ratio (SWR) elevation, which leads to degraded performance.

Women in Electronics Reception

Women comprise about 47% of the workforce and are statistically underrepresented in STEM fields, yet the number of women in STEM positions has steadily increased. In 1970, women comprised 8% of STEM roles. Today, they represent 27%. This jump is an encouraging sign for aspiring women in tech, but it shows there's still a long way to go in ensuring the tech and STEM industries reflect the general workforc .

Build Tariff Planning into Product Development Strategy Early

An attorney at DesignCon? I wasn't sure I heard that right either, but it's true. I sat down for an interview with international trade lawyer James Kim of ArentFox Schiff LLP. James was at the show to present a session entitled "Chips, Batteries & Charging Stations," which highlights the Biden administration's steps to secure the supply chain for the EV industry.

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- Support existing sales logistically and commercially
- Provide field assistance to distribution accounts
- Liaise with suppliers
- Grow sales through increased market share and the conversion of new business opportunities into sales
- Develop and maintain account plans to achieve sales targets and objectives
- Forecast sales projections and provide regular reports on market activity
- Regular travel within the territory is required

Experience

Ideal candidate has technical sales experience in the PCB industry.

About EMX US Inc.

EMX US Inc. is a distributor of consumable materials to the US printed circuit board industry. We strive to provide unparalleled service and support to our customers. EMX US Inc. is located in Manchester, NH.

Please submit inquiries to
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Field Service Engineer (or) Field Service Technologist

SCHMID Group is currently in search of a Field Service Engineer or Field Service Technologist for its USA subsidiary SCHMID Systems, Inc. (SSI). This position acts as an advocate for the company providing worldwide customer service on-site or remotely.

General scope of duties includes machine installation, commissioning, maintenance, and repair of PLC and PC-controlled systems primarily in the company's proprietary industrial machines within the wet chemical processing industry as well as automation technology.

This is a full-time exempt position with limited supervision. SSI provides full-time employees different options for benefits including medical, dental, vision, fl x, 401K, and more.

Contact Bob Ferguson:
Ferguson.ro@schmid-group.com

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Career Opportunities

GARMIN

Senior Printed Circuit Board (PCB) Designer

Garmin is seeking a full-time Senior Printed Circuit Board (PCB) Designer in our Olathe, KS, Cary, NC or Salem, OR location. Relocation allowance provided.

Essential Functions

- Partners with Product Design Engineers and Mechanical Engineers to produce loosely defined compl x PCB Designs that are timely, robust, and economical
- Key technical contributor and ECAD/MCAD interface expert in the design of new or challenging PCB designs or projects bearing directly on organizational objectives
- Leverages thorough knowledge of Garmin processes and procedures through leadership of major research or product development projects consisting of multiple modules or sub-projects that align the team with Garmin and departmental mission and vision
- Leads the advancement of team capabilities through identification and testing of new PCB design technologies for ECAD software
- Connects engineering teams, communicating effectively with all project sta eholders (ex. Electrical, Process and Mechanical Engineering)
- Serves as an expert in PCB Design and Engineering processes including mentoring one or more PCB Designers

Basic Qualifications

- Associate's Degree in Electronics Technology or related field AND a minimum of 10 years relevant experience performing similar consumer electronics industry duties OR an equivalent combination of education and experience
- Demonstrates expert proficiency using Garmin's ECAD tools (Cadence Allegro)

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Garmin is seeking a full-time Lead eCAD Librarian in our Olathe, KS or Cary, NC location. Relocation allowance provided.

Essential Functions

- Ability to define library solutions with a cross functional understanding of the overarching library impact
- Manages/delivers a global library database solution within established Garmin standards
- Develops reliable solutions for exceedingly complex eCad Library parts which require the regular use of individual thought and creativity
- Verifies/validates schematic symbols and physical footprints for parts created by other librarians for accuracy
- Leads advancement of team capabilities through identification and definition of AD Library technical strategy
- Expert in evaluation of new eCAD features and capabilities as they relate to the eCAD Library
- Ability to define e AD Library process for new technologies and capabilities
- Ability to mentor one or more eCAD Librarians

Basic Qualifications

- Possess a minimum of 15 years experience in an eCAD librarian position OR an equivalent combination of education and relevant experience
- Demonstrates expert proficiency of e AD Library best practices and design standards for all PCB technologies used in current Garmin designs
- Demonstrates a working knowledge of all types of electronic components
- Demonstrates proficiency to interpret Manufacturer Data Sheets
- Demonstrates proficiency of PCB manufacturing processes

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Career Opportunities

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Sales Manager, Remote

Location: North America

Experience: Minimum of 4 years in the PCB industry

Job Description: We are looking for a highly motivated and experienced sales manager to join our team. The ideal candidate will have a minimum of 4 years of experience in the PCB industry and a proven track record of success in sales. The successful candidate will be responsible for developing new business and sales network, maintaining existing accounts, and achieving sales targets. The candidate must be able to work independently, have excellent communication and interpersonal skills, and be willing to travel.

Qualifications:

- Minimum of 4 years of experience in the PCB industry
- Proven track record of success in sales
- Excellent communication and interpersonal skills
- Strong technical process background
- Ability to work independently.
- Willingness to travel

Education: Technical or related field preferre

Compensation: Competitive salary and benefits package

Pluritec develops high end equipment for the printed circuit board (PCB & PCBA) manufacturing industry. We offer a wide range of equipment including drilling and routing, wet processing, spray coating and more. We are a global supplier with more than 3,000 systems installed worldwide.

Contact Nicola Doria
nicola.doria@pluritec.org to apply.

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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 offic staff to further our customer-oriented mission.

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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 sta , following established procedures to accomplish assigned tasks.
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- 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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Career Opportunities

TAIYO AMERICA

Europe Technical Sales Engineer

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

ESSENTIAL DUTIES:

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

QUALIFICATIONS / SKILLS:

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

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

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

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

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Experience: Electronics Manufacturing: 5+ years (Required)

License/Certification: IPC Certification Preferred, Not Required

Willingness to travel: 25% (Required)

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Sales Representatives

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

Reasons you should work with Prototron:

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- ITAR
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Interested? Please contact
Russ Adams at (206) 351-0281
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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 fl xible, collaborative environment and promotes professional growth.

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

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Career Opportunities

MivaTek Global

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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
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- Training and certifications provided and maintained by EPTAC

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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, rout , 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/Genfl x CAM tooling software.

PHYSICAL DEMANDS

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

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