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GOOD FOR THE INDUSTRY

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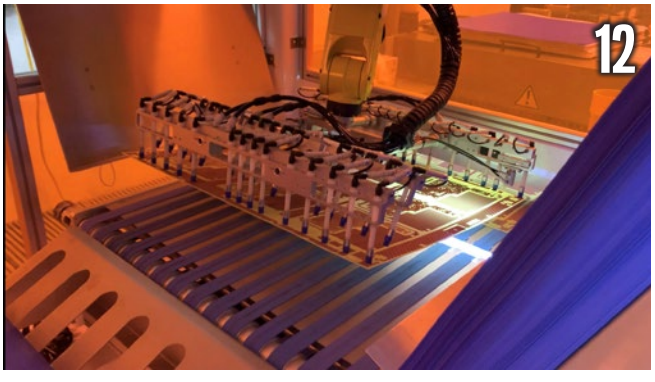
Continuous Improvement: $X = X_c - 1$

In this issue, we kick off with coverage of continuous improvement, a topic we'll be focusing on throughout 2021. We'll be exploring smarter processes, smarter equipment, automation, and operational efficiencies. This month, we begin by establishing why continuous improvement, in the form of smarter processes, is so critical to our industry.



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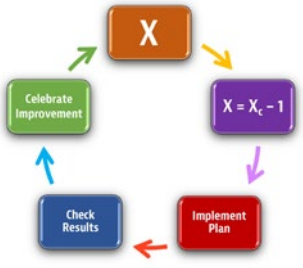

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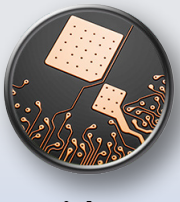

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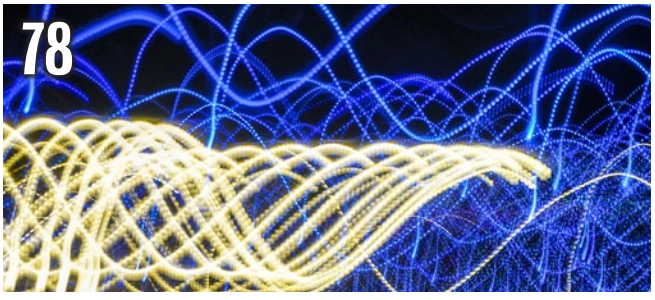

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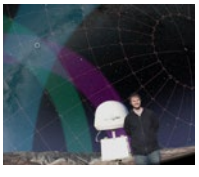

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Continuous Improvement, Smart Processes

Nolan's Notes

by Nolan Johnson, I-CONNECT007

In my column for *SMT007 Magazine* earlier this month, I wrote about continuous improvement and digitalization. My point was that "the future" is here in many ways: "When the 'future of digitalization' becomes part of our daily lives; when our grandparents are using science fiction technology to maintain (or cultivate) closer relationships with their grandchildren who might be across the continent or simply in lockdown across town; and when digital stops being a novelty and becomes automatic, that is the tipping point."

But what exactly is this new technology enabling? The technology itself isn't changing anything specific; the technology isn't what's revolutionary. It's how we use it, how we build new processes around it.

A West Coast friend recently told me about videoconferencing with their 3-year-old niece, who lives across the country. This friend described what it was like to be a handheld playmate. You see, my friend was treated just like a sentient favorite doll. They got a tour of the backyard, and spent time swinging on the swings from the nausea-inducing perspective of a cellphone in the hands of a small child. My friend slid down the slide repeatedly (the word they used to describe the experience was "endlessly"), to the delight of their niece. At the end of the virtual play date, as my friend's sister took over the call once more (on a cellphone undoubtedly scuffed and scratched from all the fun), my friend's realization was that technology can bring us so

many new ways to do traditional things, and it can be so very, very immersive. But only if we want it to be.

Conversely, I've sat through tedious meetings (I'm sure you have, too) that have become even more unbearable for having been moved to a videoconference platform. Boring, poorly led meetings simply become all the worse when moved from the physical world and flattened into 2D. I've stopped attending the monthly meetings for one community group I belong to, simply because the group's meeting priority is to socialize more than achieve the club business. Socializing certainly happens, but the business often does not. I argue that we shouldn't blame the video teleconference venue; we must blame the meeting process being used. For those of us who have learned a thing or two about how to run an effective video teleconference, those new practices will transfer into doing a better job in face-to-face meetings as well.

But what does all this have to do with printed circuit board fabrication?

That question leads us to the theme of this issue of *PCB007 Magazine:* smart processes. No, not smart factories, but smart processes. You may be considering smart factory automation for your company. Just as teleconferences took a bad meeting and made it worse, automating inefficient and wasteful processes will not eliminate waste, it will simply make you wasteful at a faster clip. It's up to you to eliminate the waste from your process. The challenge that faces you is to optimize your processes before you automate. Even if automation isn't on your technology roadmap, eliminating waste from your processes means that you'll make more revenue on less expense; no bad can come of that.

In this issue, we kick off our continuous improvement coverage, which continues through 2021. We'll be exploring smarter processes, smarter equipment, automation, and operational efficiencies. We will consider "$X = X_c - 1$" from all angles. This month, we begin by establishing why continuous improvement, in the form of smarter processes, is so critical to our industry.

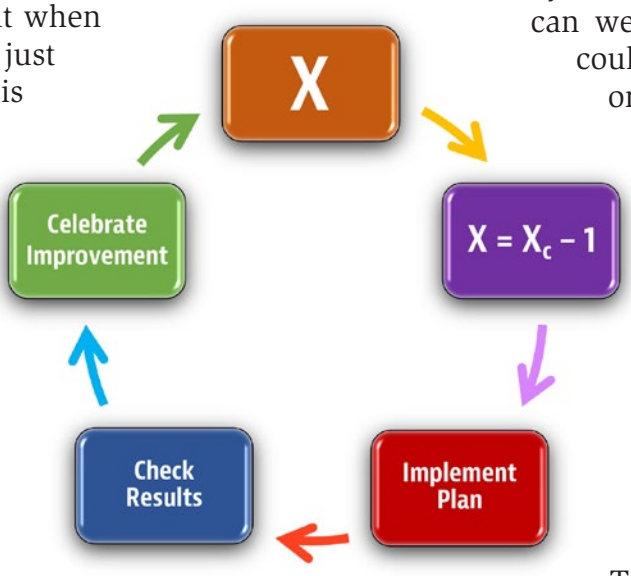
As always, we value talking to our readers. If you have a story of your own related to "$X = X_c - 1$" to share, we'd love to hear it. Reach us at editorial@iconnect007.com. **PCB007**

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

Your Greatest Competition is Yourself

Feature by Barry Matties
I-CONNECT007

It really doesn't matter who you think your external competitors are, because the only competitor that really matters is you. Of course, you will look externally to stay on top of latest trends, but when it comes to competition, just competing with yourself is a win. When you look at yourself as your greatest competitor you will start with a huge advantage: you already have great intel on how "your competition" thinks. Ask yourself, "What can I do to displace my 'competitor' and create something much better?"



Process efficiency: The first area in which to compete is process efficiency. If you can perform your processes in a more efficient way, you will begin to add capacity, increase employee happiness, enjoy higher productivity, and find greater customer satisfaction. This will lead to more sales and ultimately higher profits.

And when we talk about process efficiency this includes all processes: how you answer phones, make sales, process orders, manufacture your products, do your accounting, shipping, filling out paperwork and every other process step in your business. When doing these tasks in your business, think differently. Think in terms of crushing the competition.

Albert Einstein said: "We cannot solve our problems with the *same thinking* we used when we created them." So, if you are busy chasing your so-called external competition, you will miss the greatest opportunity sitting right in front of you—the opportunity to think differently and compete with yourself.

Use the formula: As we start the new year—what we are calling the year of continuous improvement—it's a good time to start with the simple process improvement formula: $X = X_c - 1$. When you look at any current process (X_c), the question you want to ask (and have your coworkers ask) is, "How can we reduce (X_c) by (1)?" It could be one day, one hour, one minute, one less piece of material, one less percent of scrap, one less form to fill out, or it could even be lowering a risk factor or other even less tangible things. By reducing (X_c) by (1) we now have a new (X) and the process starts over.

The tricky part can be deciding what to choose for your first (X). In the early phases of process improvement, the common advice is to start with small improvement projects and grow from there. By doing so, you and your team will be able to feel and celebrate the success and benefits gained.

$X = X_c - 1$ is perhaps a new way of thinking for some. In any case, $X = X_c - 1$ focuses you and your team to really compete with your greatest competitor—yourself. **PCB007**

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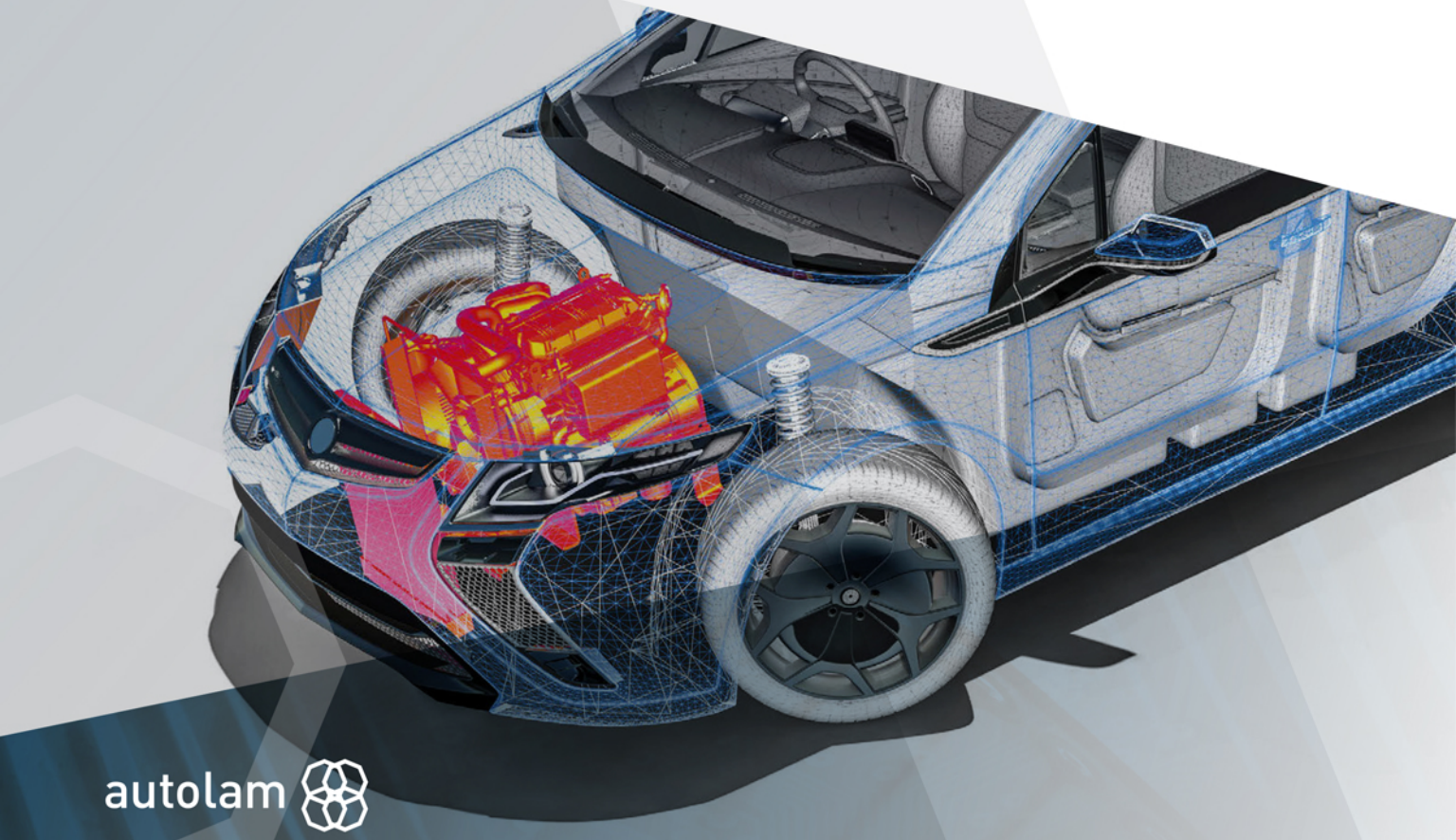

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Focus on Smart Processes, Not Just Smart Factories

Feature Interview by Nolan Johnson
I-CONNECT007

Nolan Johnson talks to Audra Thurston, Todd Brassard, and Meredith LaBeau about how Calumet is focusing on smart processes, and not as much on smart factories. While modern manufacturing equipment and next-gen technologies can be impressive, so much innovation still hinges on human beings. Calumet believes by investing in their workforce and instilling a culture of innovation throughout their company and supply chain, they'll see faster advancement.

Nolan Johnson: Right now, there's a whole lot of discussion about smart factories and equipment that help you automate your manufacturing processes. But right behind that is all the "basic blocking and tackling" work that needs to be done to manage processes. How do you tackle process improvement to make them more efficient and make them better?

Todd Brassard: A relevant question, especially if the resurgence in domestic manufacturing continues. There is pressure, newfound interest, and good reason for U.S. OEMs to manufacture leading electronics technologies within the United States. Much of this new interest is coming from increasing security concerns as other countries rapidly advance their technical capabilities—at times through forced technology transfer, intellectual property theft, or other nefarious methods—which in many cases already exceeds the manufacturing capabilities of the U.S. electronics industry.

Sure, there's good reason to bring electronics manufacturing back to U.S. soil, but lawmakers' focus on advancing and protecting exclusively microelectronics, as opposed to the greater surrounding ecosystem, has ended in a domestic electronics industry that can readily conceive and design, but not adequately manufacture, the most advanced electronic systems at home in the United States. Through direct and frequent interactions, we know de-

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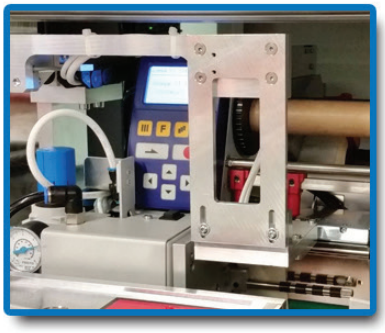

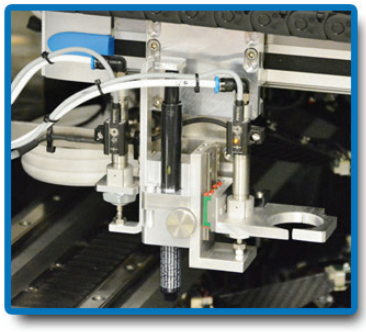

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Lay Mayra, a research and development engineer, works with the French fusion press in the lamination department.

fense, aerospace, and even some commercial U.S. OEMs are casting about the country seeking circuit board manufactures that can provide viable technological solutions for novel leading edge electronic systems to fulfill their government contract commitments within the next two to three years. Often, with little success, according to their representatives on the calls.

Money solves problems by enabling manufacturers to acquire modern equipment, attract talented people, and sustain a capable workforce, but unlike the state-sponsored circuit board manufacturers common in China, the U.S. government cannot and will not come to rescue the U.S. circuit board manufactures with a sweeping injection of funding. Manufacturers must play with the "cards they been dealt" and make incremental improvements from there.

How then can U.S. circuit board manufacturers begin the journey toward becoming a smart factory? Is becoming a smart factory a good strategy based on what the U.S. market is now asking of its electronic manufacturing industrial base? Is there a middle ground between traditional manual processing and smart factories, say with smarter processes?

You need to answer a few basic questions to know how far to take automation. How diverse is your product mix? What are your volume requirements? How quickly and often will your manufacturing environment be required to pivot significantly? Is it important that your factory can readily produce one-off designs? Are the product types being produced stable or rapidly evolving as you work to meet customer need?

When producing stable designs at high volumes, a smart factory with automation offers efficiencies. When operating in an environment with high design diversity and continually evolving complexity, especially at low volumes, excess automation may reduce efficiency, agility, and flexibility.

Meredith LaBeau: I don't believe the future of electronics is going to be reliant on robotics as a holistic system. We've always talked about utilizing an employee's mind over their body, intelligence over labor. This allows a duality, more advanced robotic processes with the intelligence of the human who's making the choice, "Okay, this lot needs a little more thickness. This does not need…" and so on. To me, that's the real advancement in smart manufacturing for the future. Questions like: What is the right chemical to use? What is the right brush to use for this process? Are the brush and chemicals meant for a commodity-based product, or are they intended for a high technology product? How do you tune those processes with constant process control to advance the technology that the customer needs?

That direction is not going to come from a fully automated machine. It's going to come from the use of a specifically tuned chemistry, process control, and a complete understanding of the process's limitations. It's going to come from operators and engineers utilizing their critical thinking skills to tune processes,

to achieve the desired end result. Smart really is—instead of the hands—the intelligence of the workforce.

Brassard: One great thing about highly motivated and ingenious human minds is they can pivot very quickly to solve problems or take on new challenges. The code and scrips that comprise the basis of automation, however, are inherently non-intelligent, no matter how much forethought a programmer tries to build in at the onset of the systems architecture. Circuit board manufacturers make significant investments in their pre-production automations, using complex design for manufacture (DFM) software tools to reduce errors and speed up the pre-manufacturing process. As the level of technology manufactured in the United States continues to advance more rapidly, these automations quickly become inadequate or obsolete. If the market demands agility and flexibility from its manufacturers, if your company needs to pivot and take a hard right turn, your standing automations may not turn so readily. Simple automations can be quickly reprogrammed, but complex automations take time to change.

Audra Thurston: We have parts right now that we have been working on with the team where there are necessary manual processes required to ensure form, fit and function—completely specialized. I don't think entirely automated equipment works for very high technology boards and special processes that are unique to certain designs. You must be able to flex and have the human brain power to figure out how you're going to do these specialized processes for these advanced designs.

Johnson: We've got a couple of different ideas. One of them is that the ability to flex or pivot with the technology that comes out of human knowledge—engineering knowledge—more than the equipment. At the same time, while you can invest a lot of time and money in automating processes, and bringing robotics into the factory, there's still opportunity to look at human factors: what you do with the workflow, and what you do with the actual labor being done on the manufacturing floor, to still optimize that and find ways to make that smarter.

If you can remove one iteration in a step, in a work order, a small change that then builds up over time with efficiencies and capacity, there may be hundreds of thousands, or millions, of dollars invested in changing your workflow with equipment. To change your processes often is a very small investment, the benefits of which drop to your profitability.

Brassard: I agree. I've had the privilege to witness our company go from somewhat lagging in capability decades back to being closer to the forefront of product realization. There are no "aha!" moments. You just don't feel or internalize the progress because you're always working on the next thing. But in those retrospective moments, you recognize it usually comes down to motivated people in all roles and at all levels doing their best to move the organization forward. Automation is cool and modern manufacturing equipment is often a game changer, but even the most modern equipment provides little value without great people making the most of it, whether programming or simply operating.

Perhaps a middle ground between overly automated smart factories and traditional process improvement is smart processes, although I believe a better term is "dynamic processes." As designs become more complex and tolerance requirements stack up, the need to fine-tune process parameters on a step-by-step basis becomes critical. Dynamic processes is where product is evaluated in each step of a process and subsequent steps are fine-tuned to maintain as much of an open tolerance as possible for subsequent steps. This combats the challenges that come with stacking tolerance requirements. For example, several OEMs are allowing additional layers of substrate to be added in the mid-production route to tune final thickness. The stackup is not fixed, but dynamic.

LaBeau: Where does innovation come from? A robot isn't innovation. As we look at the U.S. business climate today—the NDAA, onshoring, COVID, and what/where your sup-

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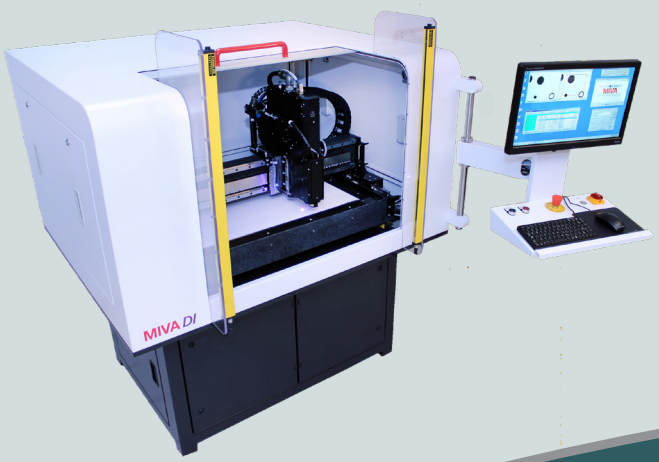

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Max Panel : 24 x 24	●	●	●	
Max Panel : 24 x 30	●	●	●	
Max Panel : 30 x 60 or 42 x 60		●		
Panel Index Capable	●	●		
Dry film resist	●	●	●	●
Soldermask	●	●	●	●
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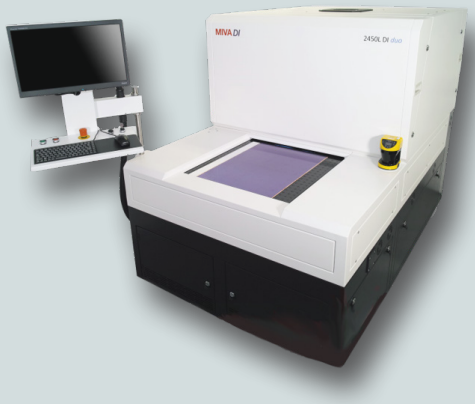

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ply chain is—the United States needs innovation. We once were an innovation leader. It's debatable where the United States is today. To innovate, we need intelligence—the humans. The humans have to work in concert with advanced manufacturing equipment to develop robust technological solutions that surpass the technology of other countries for DoD and commercial market segments.

We need people in the factory who are watching and learning the process, understanding how to iterate through that process, and then understanding the process control to make the adjustments for reliable and robust product or inventing that next generation technology. We fundamentally believe that humans are the future, coupled with great machinery.

Don Nicely, factory manager, works with an ALTIX Adix SA UV LED direct imaging machine in the solder mask department.

Brassard: Obviously, there is a space where innovative automation techniques are necessary, say when manufacturing 500,000 iPhones a day—an easy example. Once a product design is stable and released to mass production, the art and profits are in the manufacturing techniques. But the demand from defense OEMs for domestically manufactured circuit boards are designs rich in complexity at very low volume, 250 to 500 boards a year per design. Is the value of enterprise automation the same in this scenario? Less so. Again, to solve the immediate problems for the U.S. OEMs with plans to manufacture leading edge electronic systems domestically, we're right back to highly motivated and capable people who are using advanced equipment and dynamic processes, but not necessarily striving just yet for the smart factory ethos.

Johnson: Let's talk about innovation within Calumet. How do you approach innovation? You've changed what you've done. You're much more sophisticated and doing higher tech work than you were before. How did you get there? How did looking at your processes and making them smarter help you get there?

LaBeau: We are not a company that requires engineers operating within a tight management structure. We say, "Here's the process, how are you going to control it? How are you going to innovate it for greater tolerances and advancing product?" Challenge yourself. The engineers and technicians are allowed freedom to make process choices. They're allowed to fail, too. Failure is the best teacher. Of course, we try to limit their failures, but if they don't fail, they will never understand the full process. We have a culture where failure is acceptable, if you ultimately learn and advance from it. In addition, we include these young engineers in business conversations, so they understand the need to advance and innovate daily, not just accept the mediocrity that exists across a lot of manufacturing.

Thurston: To Meredith's point, it's not only the engineers, but also our managers on the floor. A great example is our soldermask department. A few years ago, the previous manager of the LPI department retired and the company promoted a relatively young supervisor to fill the role. Encouraged to get out of the box, he started making changes and improvements to make the workflow more consistent, drawing on world class manufacturing techniques. That department went from working

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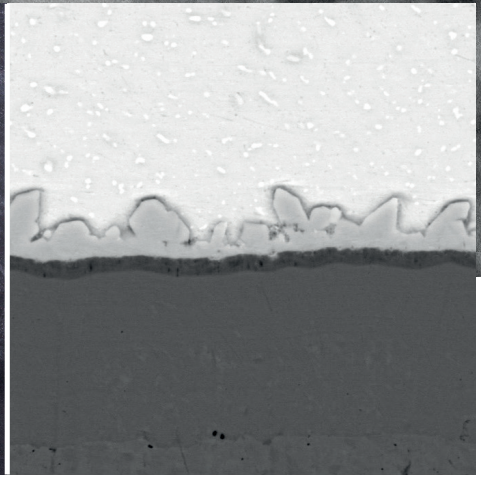

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Calumet young engineers at work: (Left to right) Cole Van Camp, engineer 1; Chris Davis, engineering intern; Audra Thurston, R&D engineer manager; Rob Cooke, director of design engineering and Engineering Services; and Ian Huibregtse, senior engineer.

every weekend just to keep up with other departments, to smoothly running 800 to 1,000 panels per day, keeping up with other departments. Couple the engineering efforts to dial in those processes cutting out waste on the engineering side, with a manager doing likewise on the production workflow side, and you can really drive out the waste working in tandem creating the start of smart processes.

Johnson: That's a great example. Did that create a sense of urgency to do similar things in other departments? Has this spread?

LaBeau: It has spread, although it's not contagious yet. We have a significant number of operators, young and old, working on reducing waste and increasing efficiencies within their workflow. And we are continuing to do this daily coupled with advancements in machinery and smart processes.

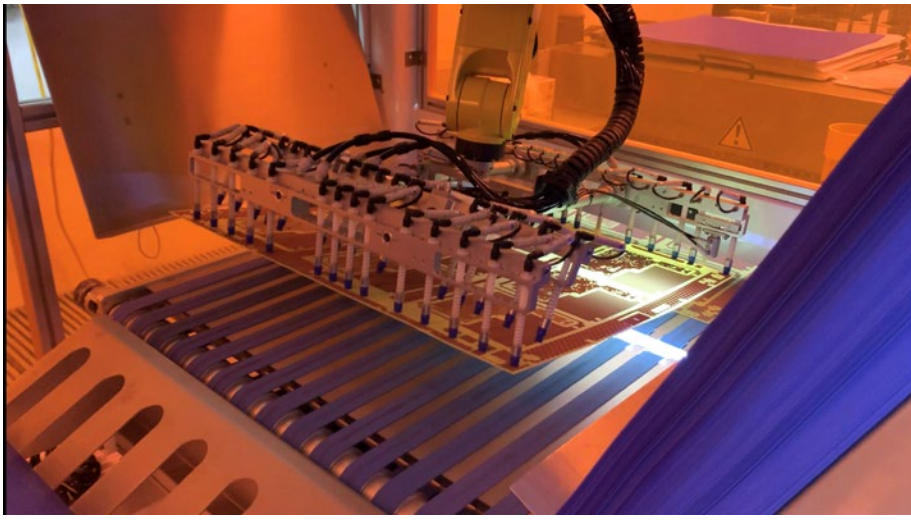
If you don't allow young engineers to participate at the supply chain level, then they're not going to learn or innovate. Audra and her team have direct channels into any equipment supplier, especially our material suppliers. We must extend the innovation cycle all the way down to the raw materials since this is a holistic ecosystem for advancing technologies. We work with suppliers to do supplier technology summits where we collaborate on new technologies to advance solutions for all our end customers. If you can harness this culture in the supply chain, then you're going to advance faster and develop smart engineers, technicians and operators.

Johnson: You're staffing with young, motivated engineers who have a different perspective and aren't weighted down with the tradition of the industry. Then, you're giving them problems to solve with room to fail as long as it's failing forward. How do you integrate longtime industry expertise into this process?

Thurston: I am still a young engineer and there's another generation coming up behind me, but one thing that has helped our young engineers, myself included, is just asking questions. We don't always know why we are doing something a certain way in a 50-year-old business. If a senior engineer can't give a great answer, it also opens their eyes. We both question why we are doing it this way. Then, the teams works together to answer the question or develop new systemic ideas for traditional processes. I am also asked these types of questions and sometimes I can't answer them either. That's when we take the time and dig in and find out if this is the right way to do it. Can we do it in a different way? Is this the smartest way? Let's find those answers together.

LaBeau: When we started bringing in new engineers, we moved every engineer into a new process. The engineer may have been managing that process for the last 15 to 20 years, and we decided it was time to continue the ever-evolving learning process and move them to a different factory and to open their eyes

to something different. Suddenly they can look through a different lens, applying new and old knowledge to continue to advance processes while deeply understanding processes up and downstream. We have a goal that a process engineer will not stay in that process area for more than three to five years, and then we're going to step to the right or step to the left. The idea is that we're constantly challenging their notion of process engineering and process management.



The Benmayor Technosystem Unloader with Fanuc Arm.

Johnson: Have you seen measurable results from that approach?

LaBeau: It has been quite effective. First, it's just using a new lens in a different department. For example, Audra has been really effective in our solder mask and surface finish department peeling back the layers of the problem and developing more systemic, smart solutions for advancing processing and board technology. The other engineers that pivoted have been able to draw on a wealth of knowledge to innovate in these new departments, often reducing scrap and bringing in new technologies quickly and effectively.

While there will always be stumbling blocks, the next generation is ready to take on the innovation that's needed in the domestic PCB industry. The constant evolution, teamwork, and opportunity to innovate has developed much stronger problem-solvers because they're not doing it every single day; they can look outside the box to provide the next solution.

The results are measurable with some of the best solutions yet to come. We believe it takes maybe two years for someone new in the building to start understanding the printed circuit board engineering and manufacturing process; we're still in that discovery phase.

Johnson: Human behavior is that we do things that get us a reward. How does the Calumet company culture reward or give recognition for that sort of innovation?

Brassard: Let's not forget that domestic circuit board manufacturers took crippling damage from 2001 to 2018. The telecoms crash, housing market crash, and the true killer of our industry—rampant offshoring of circuit board manufacturing by U.S. OEMs to low-cost regions, such as Asia. First pushing manufacturing, then supply chain, then R&D offshore, until the U.S. industry was characterized as "dying on the vine" in an early 2018 report by the Department of Commerce and "aging, constricting, and failing to maintain the state of the art" in a report to the executive branch later that same year. Throughout this period, U.S. circuit board manufacturers struggled to survive—let alone invest in—the future to maintain state-of-the-art capabilities and wage stagnation certainly turned-off workforce interest in careers in electronics manufacturing across the nation.

Regardless of the driving forces behind the renewal of U.S. electronics manufacturing, it's easy to understand how the most immediate reward for a manufacturing company and its workforce is to simply be once again making forward progress after a two-decade drought. Progress with investment in workforce and equipment, and to be meaningful and relevant in the marketplace, with people solving problems for customers with interest in U.S. manufacturing, regardless of their motivations.

Calumet demonstrated resiliency through these difficult times bolstered by OEMs and

CMs who remained committed to domestic manufacturing by resisting the lure of low-cost circuit boards from offshore suppliers. We also continue to learn important lessons about the principles of world class manufacturing, empowering people and reducing waste. The concepts of world class manufacturing do not go out of style in the face of smart factories. The concepts of the smart factory are a subset of the principles of world class manufacturing, not the other way around. A smart factory is a subset of world class manufacturing, not a superset.

The smart factory may take system integration, automation, and dynamics to the Nth degree, but it still must follow the principles of world class manufacturing, where the best measure of overall performance is manufacturing cycle time. As a company adopts the principles of world class manufacturing, priorities shift, new measures emerge, counter-intuitive methods are learned, work in process drops, feedback rates increase, yields improve, stress is reduced, cycle times drop, and margins improve. It's a lot of work, and the journey is never finished, but the results are tangible.

Crystal Hodge, manufacturing operator, works with the Benmayor Technosystem Unloader with Fanuc Arm.

To a workforce who is applying maximum effort every day to be successful in their careers, experiencing new levels of success is rewarding. As the company improves, so do the career opportunities at the company. Regardless of the level of automation, a smart factory, and a manual factory have something in common—both require great people.

Johnson: That's very astute; factory automation is not a superset to smart processes, it's a subset. If you automate an inefficient, ineffective process, you're just doing something inefficiently faster or in a more automated way. It's still inefficient. It just makes me think of the old joke from used car dealer commercials, "We lose a little on every sale, but we make it up in volume." Automating a dumb, inefficient process is just going to make it worse.

Brassard: One of the pillars of world class manufacturing is simply to reduce waste, and waste comes in many forms. We're not talking just about scrap. We're talking about motion, movement, inventory, untapped employee potential, and all of the different factors. The goal of the smart factory is to eliminate certain types of waste to improve yields and reduce manufacturing cycle time. Of course, smart factories also introduce new types of waste that may negate some of the gains.

Thurston: I think we've pushed that culture of reducing waste from the top down. I've had interactions with line operators who say, "Hey, if I had a marker pen sitting right here, it would make my job a lot easier." You wouldn't think a simple marker pen in the right place would reduce waste, but it does; it prevents them from having to leave their line and go find it to fill out the form. Our motto is no matter how small it is, it's going to make a difference; "fix what bugs you," and over time, that's going to reduce a lot of waste.

Johnson: It can be as simple as paying attention to the number of steps you take. What are the

simple solutions to iterate and improve? It grows up from there, all the way up to the top of the organization and then out into the industry.

Brassard: With people, an attitude of "fix what bugs you" is a great place to start. When you have a few hundred employees each fixing something that bugs them once a month, that adds up to a lot of small improvements over time. The ideas are there, you just need a culture that allows people to act on their ideas. Small reversible changes are best, but the bigger ideas must get due consideration. Everyone is happy when they are contributing to the betterment of the company by making improvements.

Manufacturing operators Travis Carney (left) and Ron Winnie hold ventilator circuit boards.

If you're interested in the concepts of a "smart factory" or "smart processes," start by adding machine readable QR codes to your panels to eliminate the time and errors associated with an operator manually keying in filenames for equipment. Your process just got a little bit "smarter" and the principles of world class manufacturing are being followed by saving the operator time and aggravation and reducing the possibility of error, which reduces stress.

Webster tells me that "smart" means "having or showing a high degree of mental ability." I don't believe that the smart factories and smart process of today or the future are going to have any sort of "mental ability." But people on the other hand, they can be very smart. Let's put human smarts to work and develop the right tools and the right scale to solve problems for our customer and our country. Let's keep learning and evolving.

Johnson: Meredith, over the next 12 months, do you have a sense for how this sort of culture, this sort of process, is going to change what's happening at Calumet? What do you expect to see at the end of 2021?

LaBeau: The foundation is set and now we are using this foundational knowledge to support the domestic supply chain. At Calumet, our technology is evolving and transitioning us into new markets thanks to the progressive leadership and innovation of our engineering teams. Calumet strives to be the solution that the United States needs, not just for prototyping, but for volume as well. We're on the precipice of something exciting and novel. Calumet is continuing to work with DoD primes to develop that reliable and robust next generation solution, harnessing the minds of our employees, creating smarter processes.

Johnson: Do these changes then percolate into a different attitude for your sales department?

LaBeau: Absolutely, it gives them the confidence to continue to push boundaries and transition from the traditional transactional sales relationship into a strategic relationship. We're getting engineering involved right away; the CAM team phrase is "design with manufacturing" instead of the aged old concept "design for manufacturing." By providing strategic, smart solutions, we develop robust supply chains for PCBs, the backbone—the DNA—of the electronics industry.

Johnson: Thank you everybody! PCB007

This article first appeared in SMT Magazine, January 2021

2021: The Year of $X = X_c - 1$

Feature by Nolan Johnson
I-CONNECT007

Throughout 2021, I-Connect007 will focus on our theme, "$X = X_c - 1$," in which we will explore continuous improvement in a practical way. Get talking about continuous improvement as a business method and the conversation often hinges around large programs and grand transformations. "Company culture" and "corporate transformation" are terms that often appear in these conversations. Often, it seems, continuous improvement is simply a huge undertaking.

The good news is that not everyone sees continuous improvement in this light. Continuous improvement methods can be scaled down; smaller, more manageable goals can be set. Continuous improvement can be implemented at a departmental level, team level, even an individual level. In their paper "How Continuous Improvement Can Build a Competitive Edge," McKinsey & Company authors Carolyn Dewar, Reed Doucette and Blair Epstein write, "Continuous improvement is an ongoing effort to improve all elements of an organization—processes, tools, products, services, etc. Sometimes those improvements are big, often they are small. But what's most important is they're frequent." [1]

Maggie Millard writes in her blog, "Improvements are based on small changes, not only on major paradigm shifts or new inventions… By approaching change in small, incremental steps, the continuous improvement model reduces the fear factor and increases speed to improvement." [2]

Jon Terry writes, "Sacrificing quality can rarely be justified by the ability to do something faster or cheaper. To maintain quality standards while cutting time and cost, companies turn to Lean ways of working, including continuous improvement." [3]

In fact, if your company is pursuing ISO9001 certification, continuous improvement is one of the eight key principles for ISO9001.

Continuous improvement "is all about 'doing' but it isn't something that you do. It's how a company operates. Continuously improving means creating a culture that promoted

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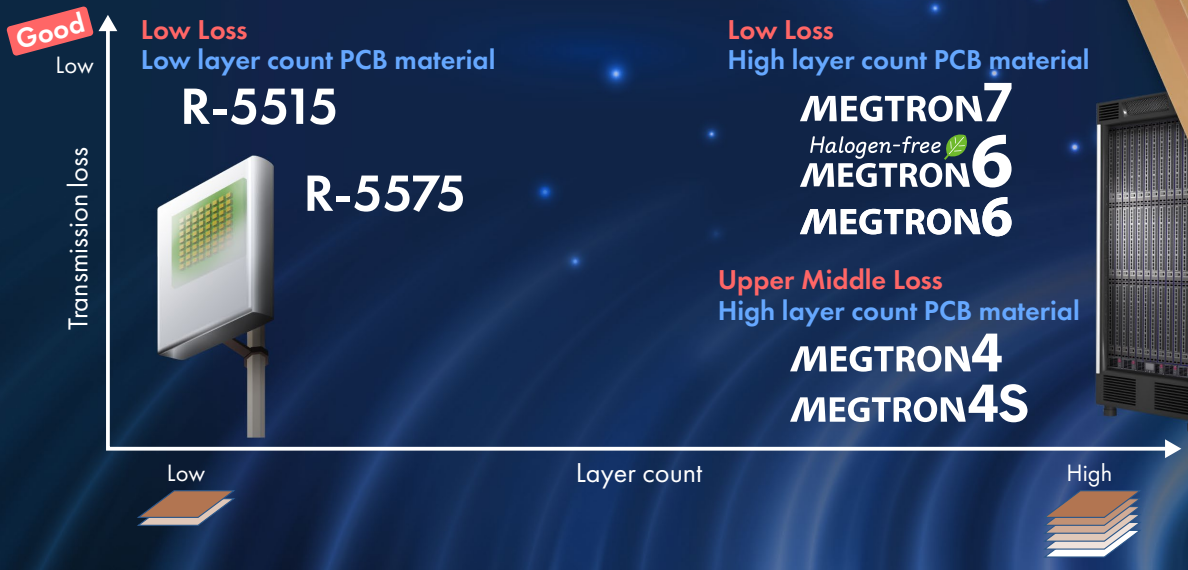

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R-5575	High thermal conductivity Stability under high temperature storage	3.6	0.005	
MEGTRON7	Ultra low loss laminate High layer count	3.4	0.002	12GHz Balanced-type circular disk resonator
Halogen-free MEGTRON6	Halogen-free type Stability under high temperature storage	3.4	0.003	
MEGTRON6	De facto standard material in industry Stability under high temperature storage	3.4	0.004	
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improvement. As odd as it may sound, employees might be more aware of company processes than the management. Hence, it's important to take everyone on board when it comes to improvement. The concept is simple, the process should include employees." [4]

In fact, Dewar, Doucette and Epstein point out, "Companies that excel at continuous improvement start with the belief that success comes from:

- Innovating "how" they do what they do (big and small)
- Engaging all employees in sharing knowledge and generating improvement ideas
- Exploring better ways to deliver to customers and respond to changes in the external environment." [5]

Here at I-Connect007, we've tagged this concept "$X = X_c - 1$." We're presenting the idea that incremental improvements can happen at any level and can be of any size. We posit that a significant number of small, easy-to-implement, no- or low-cost incremental improvements can add up to a significant increase in operational efficiencies, improved quality, and profitability. The "X" could be anything: steps between repetitive work tasks on the shop floor; the number of design respins needed to get a working prototype of a new product; or maybe a routine process in the accounting department. Further, this kind of incremental improvement need not necessarily require top-down company mandates to change company culture.

How Can We Recognize it?

The "$X = X_c - 1$" dynamic may already be in place in your company. In a blog post, Daedalus Howell writes, "In its essence, continuous improvement is the practice of honing every aspect of your company's processes in a manner that enhances your offering's value to your customer while diminishing any activity that proves wasteful along the way." [6]

What if continuous improvement is being employed within your company organically, at the individual or team level? Does that count? Millard thinks it does. She wrote, "Continuous improvement can be viewed as a formal practice or an informal set of guidelines."

One way to sniff out organic continuous improvement is to listen for complaints and watch to see how those complaints are resolved. Millard advises us to "embrace them [complaints] as opportunities for improvement. If a team member notices something amiss and says something about it, that's a good thing. That's the beginning of the improvement cycle." [7]

Do You Suffer from Performance Transparency?

Once a complaint about an inefficiency in the process has been identified, and then monitored to learn how the complaint was resolved (or was it?), you also get a sense for the performance transparency in your organization. Was the inefficiency identified? Was a root cause determined? Was the root cause then addressed? And was the resolution communicated to others?

Millard says, "Constant feedback is an important aspect of the continuous improvement model. Open communication during every phase of executing an improvement is critical to both the final results of the improvement and to the maintenance of employee engagement." [8]

With respect to feedback, Dewar, Doucette and Epstein add, "Making goals public and cascading those goals (typically a balanced mix of financial and operational metrics) in a way that is tailored to individuals at all levels of the organization. Progress toward goals must be transparently tracked to give the frontline and management clear visibility into what is working and what needs work." [9] This is entirely reasonable when attacking continuous improvement on a larger scale. But does this work on a smaller scale?

For example, how does one achieve transparency when working alone, or when optimizing one's individual contributions to the overall flow of a team? To whom do you hold yourself accountable?

These methods can, and do, scale down. Inspiration can be found in Millard's comment that "to achieve real improvement, the impact of change must be measured. This makes it possible to determine if the change can be applied successfully to other problems." [10] Perhaps it is enough to be accountable to oneself? Measure the improvement by posting metrics at your workspace, or on the machinery, where others might notice. Regardless of the scale, Millard counsels, "Proving positive ROI also helps keep the organization aligned around improvement."

Do You Share Knowledge?

At this point, problems are being identified and measurement of baseline and attempted improvements are in process. Sharing results more widely is the next step toward continuous improvement. When tackling continuous improvement on a larger scale, Dewar, Doucette and Epstein share that it is "critical to scale best practices across (and up and down) organizations." They point out, "One of our clients became adept at deploying small cross-functional teams against any problem to break down the organizational silos that had previously prevented knowledge sharing."

Remember, the change need not be dramatic. Small improvements in highly repetitive work tasks accumulate into significant gains over time.

This is a key point: to get knowledge sharing to be effective, create teams with representatives from all affected departments. It's the involvement of the upstream, downstream, and administrative teams as well that help make a change effective and improve the permanence of the solution.

Do You Have Employee Involvement?

Employee involvement is a key factor. The stories are that Deming required his continuous improvement training to start at the top and be taught down the organizational chart by the managers themselves. This method certainly assures that the methods being taught come with an automatic approval from higher up. Yet it's the staff at the "action end"

of the organizational chart who can be expected to have the most practical insight. In fact, Dewar and team disclose, "Frontline employees are closest to the work, and thus typically have the richest insights on how their work can be done better. Capturing their perspectives is critical."

Millard concurs, "The continuous improvement model relies greatly on employees, not only top management, to identify opportunities for improvement. This bottom-up improvement is effective because employees are closest to the problems, and thus better equipped to solve them."

And then, Millard rings the "$X = X_c - 1$" bell by suggesting, "Ask people what improvement they could make that would save them 5 minutes a day. Then empower them to implement that improvement, and spread it to everyone else in the organization doing the same process. In this way, you can take a small idea that anyone could come up with and drive a big impact."

Benefits

Techniques for implementing continuous improvement strategies are well documented elsewhere; expect that we will visit some of these sources throughout the year. In the meantime, "$X = X_c - 1$" opportunities come at all levels of the organization and fall into some common categories. Continuous improvement benefits can be categorized as follows.

Streamline Workflows

"Working to constantly improve is the number one way in which many businesses reduce operating overhead," writes Jon Terry. "For example, projects that involve shifting deadlines, changing priorities and other complexities are usually filled with opportunities to improve. It's just that no one has acted on that opportunity. The gateway to streamlined workflows is frontline worker involvement.

Millard points out that changing habits is a difficult thing to do, adding, "Know what makes it easier? Rolling out changes that originated from the front lines. When people come up with the ideas to improve their own work, they intrinsically see the value of the changes. Knowing that improvements come from their peers inspires faith in the necessity of the changes much more so than does a decree from senior leadership."

Reduce Costs

Labor is a significant expense, and easy to lose track of, especially at the microtask level.

"For this reason," notes Terry, "most project management offices benefit from knowing the amount of time it takes to get certain types of work done." Labor waste, therefore, is a natural area to practice continuous improvement.

It doesn't take extensive studies and consultants to analyze whether a job function can reduce the number of repetitive walking steps an operator must take, or whether solder paste pot time can be optimized to increase material utilization as well as labor time loading in fresh solder paste. Frontline employees, in fact, are ideal sources for this type of optimization. Millard says, "Employees tend to focus on small changes that can be accomplished without a lot of expense. In fact, many ideas from employees involve eliminating processes, rather than adding them."

But frontline involvement is not always limited to small changes. I-Connect007 has recently shared customer stories in which management was planning to buy a new line to increase capacity, only to have frontline workers present a study showing that the existing line still had more than enough capacity to run the extra work, provided that the company make some changes to their material flow processes. Small changes (relative to purchasing and installing an entire line) were made, and the needed capacity was achieved. This, of course, leads to increased profits.

More Profits

Most often, reduced costs (and increased capacity for sale) translate directly to improved margins and more profit. Whether the company keeps this profit or returns it to the customer in the form of reduced prices, is up to the company. Just keep in mind that, as the team at Rever Inc. says, "The purpose of every small change is to make the business more profitable."

Employee Morale

It is a general truth that we all just want to make a difference in our world. On this topic, Jane Goodall has often been quoted as saying, "What you do makes a difference, and you have to decide what kind of a difference you want to make."

When employees are encouraged to point out process problems, effect change, and then not only have the successes from those changes shared across the company, but perhaps also see the monetary value of that change to the

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organization, there is little more management can do to demonstrate an employee's worth. Henry Ford understood this. The anecdote goes that when a consultant, upon seeing one of Ford's employees sitting with his feet up on his desk, asked Ford why he paid that man $50,000 a year, Ford replied, "Because a few years ago, that man came up with something that saved me $2 million. And when he had that idea, his feet were exactly where they are now."

Greater Agility

Continuous improvement future-proofs your business. Incremental changes to adapt and optimize are at the core of creating an agile company. There is a close relationship between continuous improvement and company evolution that requires the presence of human observation.

In a recent conversation on the topic of smart versus automated processes, Calumet Electronics' Dr. Meredith Labeau said: "You're not going to get there if you completely remove the humans who are watching and learning the process, understanding how to iterate through that process, and then understanding that process control enough to say, 'I can move it this way and get this result.' And, 'Hey, that result, while it was out of process, is next-generation technology.' We fundamentally believe that humans are the future, coupled with some really great machinery."

Grow the Business

All these benefits contribute to growing the business. By doing more with fewer resources, and doing it more efficiently, small changes add up incrementally to big results. The knowledge that comes from consistently analyzing, improving and measuring processes contributes directly, allowing the business to grow.

The Rever team states, "A lack of visibility will prevent you from reaching your goals. Remember that no business can grow without realizing what's causing it to stop growing."

Conclusion

As quaint as it may sound, continuous improvement is never-ending; it's continuous. Change is continuous, too. A recent example from the U.S. entertainment industry helps make this point. Blockbuster was a video rental company (it technically still is, with one remaining Blockbuster retail outlet in Bend, Oregon). Sources say that, at its peak, Blockbuster had 9,000+ stores and employed 58,000+ people worldwide. Blockbuster had a good business model and dominated the video rental industry. No surprise, then, that Blockbuster management was reluctant to change even as the market changed around them.

Enter companies like Netflix and, a bit later, Redbox. Netflix began in 1997 as a DVD movie rental service, operating through mail-order and a website instead of a storefront. The Netflix subscription model—a flat monthly fee with unlimited rentals and no late charges—changed how its customers consumed the content they rented. The convenience of having a DVD show up in the mail, ready to watch, without rental restrictions, created deep customer loyalty to which Blockbuster did not adequately respond. When Netflix further evolved in 2007, introducing the streaming option, Blockbuster's unchanged business model was simply unable to compete. In contrast, Netflix intentionally innovated new distribution methods that were not only less expen-

The last Blockbuster store on the planet is located in Bend, Oregon.

sive, but also more convenient for customers. Netflix improved continuously into a market leadership position, toppling an industry giant in the process. Ironically, in the early days of Netflix, Blockbuster had a chance to buy the company for $50 million, and passed. Today, Netflix's reported annual income is more than $20 billion.

But there is another lesson in the Blockbuster/Netflix story. Netflix not only adapted business operations to be more competitive and nimbler, but they also adopted innovations in electronic distribution. Netflix went digital; that changed everything. Netflix was able to grow as it did because the company had already improved upon its business practices continuously, so that when they went digital, the efficiencies scaled.

The electronics manufacturing industry is embarking on a transition to Industry 4.0, a transition for us that is not unlike the Netflix transition. To fully utilize their investment in smart factory equipment, real-time data for process control, and the benefits of the digital twin, manufacturers must first ensure they are automating optimized processes, then continuously improve them.

With the tagline "$X = X_c - 1$," we're representing the idea that incremental improvements can happen at any level and need not be large. I-Connect007 will devote regular attention in 2021 to the ideas of continuous improvement—both incremental and large-scale. **PCB007**

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The Eight Principles of ISO9001:

1. Customer focus: Organizations can establish this focus by trying to understand and meet their customers' current and future requirements and expectations.

2. Leadership: Organizations succeed when leaders establish and maintain the internal environment in which employees can become fully involved in achieving the organization's unified objectives.

3. Involvement of people: Organizations succeed by retaining competent employees, encouraging continuous enhancement of their knowledge and skills, and empowering them, encouraging engagement, and recognizing achievements.

4. Process approach: Organizations enhance their performance when leaders manage and control their processes, as well as the inputs and outputs that tie these processes together.

5. Systematic approach to management: Organizations sustain success when processes are managed as one coherent quality management system.

6. Continuous improvement: Organizations will maintain current levels of performance, respond to changing conditions, and identify, create and exploit new opportunities when they establish and sustain an ongoing focus on improvement.

7. Factual approach to decision making: Organizations succeed when they have established an evidence-based decision-making process that entails gathering input from multiple sources, identifying facts, objectively analyzing data, examining cause/effect, and considering potential consequences.

8. Mutually beneficial supplier relationships: Organizations that carefully manage their relationships with suppliers and partners can nurture positive and productive involvement, support, and feedback from those entities.

MivaTek's New Technology and Market Drivers

Feature Interview by Nolan Johnson
I-CONNECT007

I recently spoke with Brendan Hogan about the upcoming new product releases from MivaTek. The conversation flows naturally from the new product's market drivers to the $X = X_c - 1$ idea that is at the core of the market drivers.

Nolan Johnson: Brendan, I wanted to follow up and get your take on what is happening with imaging from your spot in the industry. Additionally, our 2021 theme at I-Connect007 is continuous improvement. We are using the tag line "$X = X_c - 1$." The idea is that when we take one iteration out and improve those small steps throughout, we can start to create more efficiencies, better margins, more throughput. And when we've done it once, chances are good we can do it another time.

Brendan Hogan: Our point of development is right in that mix. Direct imaging eliminates several steps in the manufacturing process—phototools and manual registration is now obsolete. With the advent of Miva's Quad-wave technology the same machine can "image anything" and without significant operator intervention. Direct imaging brings a certainty to the imaging process. Most of Europe and North America, let's say, have some form of direct imaging which has improved the imaging process and capabilities. What Miva is focused on is solving the next element in the certainty question; total process certainty with digital imaging can influence plating quality, adapt to new scaling issues that result from the exotic material sets that are increasingly becoming less than "exotic." How are we going to handle the technical demands three to five years out?

Miva Technologies has a great track record of working with companies and institutions developing new methods of manufacturing for technologies that will be on factory floors in the 3-5-year range.

Miva Technologies intended to demonstrate and announce its next technology offering at the IPC APEX EXPO in March. Unfortunately, due to COVID, a live trade show isn't going to happen for the first time in my 35-year career. Miva Technologies and its sister company

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Johnson: What can you tell us about the next offering from Miva Technologies?

Hogan: Our new offering will go way beyond the current concept of direct imaging. It is a broad re-thinking of the notion of digital imaging to establish tools for the factory floor that allow users to correlate multiple processes in a highly efficient approach to make wider process windows and total process control a reality.

Brendan Hogan

Miva Technologies has been very active in development through a span of products from PCB to microelectronics. For example, at the University of California's Center for Environmental Implications of Nanotechnology we are now producing 2-micron line and space for additive technologies. The registration challenges we faced in substrate imaging were the catalyst to this new technology we will be introducing.

Johnson: If readers are starting to work with some of the newer exotic materials and applications, especially those that are sensitive to dimensional stability—some of them are quite flexy—that becomes critical in this case, doesn't it?

Hogan: Yes. Our thought process originates from trends we see in PCB and our experience in microelectronics. The requirements and considerations are of the two markets which are starting to collapse into each other. The densities are getting tight. The early materials, FR-4, pretty much move linearly. If you are in the press, that's going to have a coefficient of expansion and it's going to move a certain amount. It is pretty predictive as a system. But the new exotic materials with exotic prepregs, copper weights, and the demands that the circuit board industry has today, it is not linear, and it is not as predictive.

Couple the material set issues with increased drill and line/space density and you have an unsolvable scaling equation. Miva's new technical direction will provide the tools to solve the equation.

Johnson: What is the general approach you are using?

Hogan: As you know, direct imaging systems already collect a lot of data through vision systems and a literal measurement of every panel processed. The issue with most systems is granularity of the data (resolution), direct experience with adaptive software development, or the limitations of the PCB design due to the non-linearity issue that is beginning to present itself. Miva's new technology will approach the problem more holistically with involvement of all affected processes in the solution. Too often the factory floor is littered with equipment that has blinders on. The modern factory floor can directly interact with other processes that also collect data; to have total process control, data collection must be integrated.

Johnson: That is the cutting edge of the Heterogeneous Integration Roadmap, isn't it?

Hogan: The CHIPS consortium at UCLA is just an outstanding organization for futuristic development; it's been a big investment for a company of our size to make. We became Platinum Members of the consortium, but we have already altered our paradigm of thinking on where we need to go from a technological perspective. We must step up and build the research sources internally to capitalize on that. But we did not stop during the pandemic; we worked around the clock. We built machines, developed a whole new technology, and advanced the company without the benefit of air travel and in-person meetings.

Obviously, this year was challenging across the board from a logistics point of view, but

I was very pleased to see our overall performance. Our team provided our customer base with excellent technical support and ultimately shipped the same number of machines this year as last despite periods of full quarantine. During the lull of the quarantine, the team was provided with the opportunity to work more creatively in ways that otherwise might not have occurred previously. You do not get opportunities like that as a company to get everybody on board and have all arrows pointed at a project. We have rolled out our new technology at a few key customers deploying this new technology and we are preparing for a big unveil sometime in March or April.

Johnson: So how does this new offering directly deal with our "$X = X_c - 1$" model?

Hogan: Total process control means that, for the imaging steps at least, the bounds of circuit production will be better controlled, understood, and inspected to an increased certainty. It targets transitioning "science project" panels to production panels through improved data collection and integration. It also captures and recognizes process missteps earlier in the process such that material scrap rates should be reduced.

Johnson: This is more important when you start dealing with the weird, non-linear materials that don't scale well.

Hogan: Yes. The idea is that we are at a point in digital imaging where we have the ability to alter a process on the fly. You cannot do things like that in develop or in etch because the processes are not responsive. You can do it in drill, in imaging and, theoretically, you can do it in CAM. So, the idea of data collection to create a process control that is meaningful is, I think, the key to reducing the failure modes for first pass panels.

Johnson: And these concepts came out of the Heterogeneous Integration Roadmap at the UCLA CHiPS program?

Hogan: Yes, the fundamental issue being solved with the UCLA CHiPS organization as well as a similar program at the University of Stuttgart are the problems the PCB fabrication market will experience in the next decade. At CHiPS we produce 2-micron features to directly receive the pads of the die itself—without packaging. The registrations issues are daunting. The method used to solve that unique problem set us on a line of discussion that will now be applied to the PCB fabrication segment.

Johnson: With the technology and the approach you are describing, doesn't the interposer become the new breadboard?

Hogan: That's right. And downstream, the interposer just disappears because the interposer becomes a silicon-based substrate like the PCB but at much higher resolutions: $X = X_c - 1$. If you think about a classic motherboard on a computer, you get your memory devices, your copper line and then you've got a controller.

Higher reliability, increased performance—it is the direction we all must go.

Well, there's lag that happens. The controller sends—it's microseconds—but it sends a signal across copper where the transition of materials causes a latency so that now the travel distance might only be an inch, but the travel distance and materials induce latency. Now, if you've got it all on silicon, it's all similar materials and there's no latency. The memory becomes faster, you can use cheaper memory for certain applications and all of these other flexible tools come into play. Higher reliability, increased performance—it is the direction we all must go.

Johnson: When you started your career did you ever think we would be at this point in manufacturing?

Hogan: Thirty-five years ago, my first project in the industry was working with dry film solder mask, smallest pads were 50 mils not microns. I have immense respect for everybody in the circuit board industry because it's the millions and millions of hours of circuit board engineers working and toiling away that make the iPhone interconnect possible, but somehow Steve Jobs gets all the credit. That's okay; it's part of our deal in the circuit board industry—people are not amazed at how our industry has evolved. My kids look at a new iPhone and say, "Look, they doubled the resolution of the screen, it's five times faster, it's got more memory and it's only $1200, isn't that great?" That's the sum total of the amazement they have. They don't think about how it came to pass that Apple manufactures 63 million iPhones per quarter at an almost 100% yield (laughs).

But where we live here at MivaTek, we see both ends of the spectrum. We see the issues of the microelectronics guys and the circuit board guys, and we essentially use the same technology. So, we can see where these things are going, over a decade or more, to collide and intermingle in a way that I don't think the market is really seeing yet.

We can see where these things are going, over a decade or more, to collide and intermingle in a way that I don't think the market is really seeing yet.

Johnson: Does data security play a part?

Hogan: Absolutely. There are two sides of this coin. The first thing that matters to OEMs is the design data, the CAM data, the raw Gerber file—how to build something. The second is the know-how of building this unique product—that's the IP that needs protecting. Data security is important but the majority of the data that we're collecting is the result of manipulations to their initial design data. By the time we take action on the data file it doesn't resemble their data file anymore because we generate our own proprietary file formats; in general terms you could not reverse engineer into the design of the product.

Johnson: That makes sense. After all, by the time it gets to your machine, really, it's just a string of Cartesian coordinates.

Hogan: That's right. Our data doesn't contain anything about the finished product. It has no correlation to reality. It's correlated to a job with several other pieces of information; separating the lock from the key is the security element. That's one of the beauties of the heterogeneous program, and that is one of the reasons why so many security-driven companies are members of CHiPS. If you think about how defense electronics are manufactured, at some point all the information is in one place right now: how to make the chip, how to assemble the chip. With the heterogeneous approach, the lock is separated from the key. Very complex integrated systems will be manufactured with true compartmentalization.

Johnson: It's going to be very interesting to watch what happens after the 2020 presidential election process has completed.

Hogan: Hard to say at this point which path the country will choose regardless of who is elected. It's unfortunate that with the access to information we have as Americans so little of it is policy driven. Facts now have agenda and perspective—they are not just facts.

The last four years have bluntly tried to deal with serious trade issues on a global political scale. I think more than anything it demonstrated just how difficult global trade problems are to solve. It is a complex problem that must encompass technology transfer, IP protections aside from basic economic interests. The main outcome, I think, for the large-scale producers is a recognition that diversification

of the manufacturing base is essential going forward.

Johnson: How would you characterize COVID's effect on your part of the industry?

Hogan: It's interesting because the industry, and specifically our customer base, were far more agile than I expected. When COVID took hold, I thought, "Oh, we're not going to sell a machine for a year." With capital equipment, people want to run samples and tests, touch it and kick its tires. But our customers need the product so they're adapting and finding a way. We used a range of technology to conduct demonstrations and produce samples and worked hard to maintain the same level of technical support to the customer base. Our team worked hard to be sure the customer base was supported without being able to go into their facility. Everybody had to be flexible. All our customers, I believe, were very happy with all the things we did to keep them running, because they're all essential businesses to us.

Johnson: And that seems to be true for the whole industry. That's something that I would grab on for a 2020 retrospective point of view. The pandemic and social distancing pushed a lot of the manufacturing folks into taking action, finally buying in to smart factory, digital, etc. One argument is that because, for the foreseeable future, they won't be able to put the same number of people on the manufacturing floor and as close together as before, you have to do something else.

Hogan: Yes, with the staffing of the factory alone, how does that work now? What are the alterations? Are we going to go full automation now in the U.S.? I think one of the outcomes of our technology is to create more data channels so that the direct imaging system will process engineer itself. Regardless of what panel you are making, the entire process is controlled in an automated intelligent process. That's what Factory 4.0 is all about: trying to eliminate minute-to-minute engineering to make the whole process work as one.

Johnson: The staff is moving from being operators on the floor to being engineers on the carpet.

Hogan: That's right, analytics. That's where it's at.

Johnson: I've been asking, when is the analytics industry really going to be able to take all of this data and turn it into something that is intelligible?

Hogan: When you think about the cycle, data collection is inexpensive. Our product is infinitely upgradeable. This new technology offering we are releasing will be upgradeable to all 60 U.S. customers, for example. We see our mission as extending the useful life of technology equipment. Further, once implemented, the process should improve the performance of plating, develop and etch. The buzz word of "artificial intelligence" requires data as an input to result in an intelligent process correction or output. The reason AI is vital is the ability to dynamically analyze data and react.

The reason AI is vital is the ability to dynamically analyze data and react.

2020 will forever be known for COVID, but the side story may prove even more impactful in the long term: the shift of the public and the business world to rapidly adopt new technologies out of necessity. Major shifts that would normally take decades have occurred in a single year. I will say it's an interesting time right now.

Johnson: Brendan, thanks so much!

Hogan: My pleasure, Nolan. **PCB007**

Electronics Industry News and Market Highlights

Vishay Aluminum Capacitors Increase Design Flexibility, Save Board Space ▶

Vishay Intertechnology, Inc. introduced a new series of low impedance, Automotive Grade miniature aluminum electrolytic capacitors that combine high ripple currents up to 3.36 A with high temperature operation to +125°C and very long, useful life of 6,000 h at 125°C.

Qualcomm IoT Services Suite Aimed to Enable Digital Transformation of Smart Cities ▶

Qualcomm Technologies, Inc. has announced the Qualcomm® IoT Services Suite, which delivers comprehensive, end-to-end, IoT as a Service (IoTaaS) solutions to enable the digital transformation of smart cities and smart connected spaces globally.

Veritone Launches Automated Studio to Accelerate AI-based Digital Transformation Initiatives ▶

Veritone, Inc., the creator of the world's first operating system for artificial intelligence (AI), aiWARE, has announced the public launch of Veritone Automate Studio, a low-code, web-based workflow designer tightly integrated with aiWARE.

Siemens Government Technologies Honored as a Top Technology Company by NVTC ▶

Siemens Government Technologies (SGT), Inc.–the federally focused U.S. arm of technology powerhouse Siemens–is honored to announce that the Northern Virginia Technology Council (NVTC) has selected SGT for its 100 most innovative technology companies in 2020, as well as recognized SGT President and CEO Tina Dolph as a NVTC Tech 100 Executive.

Soter Analytics Using Smart Wearables to Reduce Injuries at Giant Eagle Supermarkets ▶

Turning to smart wearables, Giant Eagle have seen a 31% reduction in injury risk, using the Soter Clip&Go solution. The fully autonomous wearable provides real-time biofeedback to workers and measures and captures up to 10 different hazardous movements that lead to musculoskeletal injuries.

Samsung Tells its 5G Story ▶

Samsung didn't just help introduce 5G to the world–they've been setting new records. An October 2020 report from Strategy Analytics revealed that the Samsung Galaxy S20+ 5G was the best-selling 5G device by revenue for the first half of 2020, accounting for 9 percent of global revenue.

Waylay's Digital Twin Revolutionizes Provisioning in Industrial IoT ▶

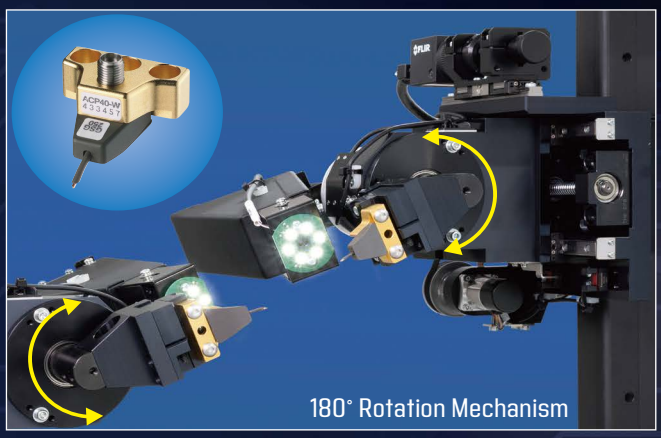
IoT automation and analytics software company Waylay announced its new industry first zero-code provisioning portal based on digital twins of equipment for time efficient retrofitting of legacy assets.

Connecting World 'Intelligent' Vehicle to Build Industrial Highway ▶

Supported by the People's Government of Guangzhou Municipality, World Intelligent Vehicle Conference 2020, co-sponsored by the International Cooperation Center of National Development and Reform Commission, Development & Reform Commission of Guangzhou Municipality, Tianhe District People's Government of Guangzhou Municipality, and IDG Asia, was closed in Guangzhou on December 4.

Automated VNA Measurement

E2V6151 [VNA Tester]



• High Frequency Probe Unit

The high frequency probe unit is equipped with a rotation mechanism which allows close proximity between probes enabling testing of various pad arrangements. High frequency probes such as the ACP series by Form Factor (formerly Cascade Microtech) and many others are supported.

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Finding Process Improvement Opportunities in Training

Feature Interview by Nolan Johnson
I-CONNECT007

Nolan Johnson speaks with Leo Lambert of EPTAC about training the next generation coming out of high school and vocational schools, and how his company continues to improve processes, grow, and adapt to changing requirements while fulfilling its mission to deliver technical certification training.

Nolan Johnson: Leo, what's happening in the training space lately? Have our recent pandemic-driven restrictions changed how you deliver your product? Have your instructors found success in this environment?

Leo Lambert: They must all have the same interpretations from our end, so to speak. But to get our teachers involved in the new technologies, most of that happens in conversations with our customers. What's going on? Well, the technology itself from assembling components on printed circuit boards and soldering those components in place is one thing, but the technology has improved relative to density of the product, such as cellphones, for example, and all that is packed into that product. Then of course, there's the technology of the components themselves.

We did an SMTA tour at one of the major military contractors in the area. Their boards were very low technology, but the technology of their product was based in their componentry. So, while this customer may not need new technology for board circuit design and assembly, we still try to bring them up to date, relative to the new processes being used in fabricating boards, new soldering technologies, and new metals to replace the high temp alloys with the new lower temperature ones that are starting to come out.

There are a lot of new soldering irons today that are much better than the previous ones, so we cover the use of those new tools. We've changed all our soldering irons, simply because it shows the students what they can do with the new equipment, and specifically since the components are getting smaller. Additionally, there's a lot of new information that comes from the component manufacturers as to how to secure their componentry on printed

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circuit boards. They don't want soldering irons at very high temperatures touching those components because they're going to crack.

The intent is to be able to teach the new technology to the students. Initially we taught through-hole and hand-soldering techniques. We still teach those processes for through-hole technology, but since then, the component sizes have shrunk down to the size of a speck of pepper. The methodology of assembling those, and the specific paste required, has changed. We need to have conversations with the component and the material suppliers as to how to apply and use their materials. Our knowledge is developed with two conversations, one being with the clients who are in the training room and the process developments they're doing. Secondly, it's with the people making the material—paste and solder manufacturers like Indium, AIM and Alpha—and finding out what they're doing, because they must be developing new products for the new technologies in process.

The other conversation is in the relationships from the cleanliness programs. There are a lot of issues going on with cleanliness. Historically these processes used solvents for cleaning printed circuit boards, and when aqueous cleaning came into vogue it created an entirely new process with new materials. The question then was, how are those materials going to be used and processed so they don't harm the product or harm the individuals who are using them? That's how we developed our knowledge of the new technologies that are evolving. As trainers we don't get too involved with the electronic functionality portion of the circuits, but rather the assembly of those electronic circuits.

Johnson: What I'm hearing is that, while the basic skill set that you teach might be the same, is, at the same time, more complex because of so many factors. You have to be concerned with more things. I mean, back in the Dark Ages, it was through-hole, one kind of board, and one solder, and there was plenty of room to do that and if you didn't learn how to solder, well, you were good enough. That's not true anymore.

Leo Lambert

Lambert: Correct. One of the things that happened is the laminate materials changed. Today there are many microwave products being developed, and we need to know how to handle those versus the traditional FR-4 materials, and so on. We have to learn how to handle those new laminates, and then know how to teach that to the students.

Johnson: Right. There's the skill set around different materials, much smaller components, cleanliness, and even contamination becomes much more of an issue. This is becoming much more like a cleanroom kind of semiconductor application—at least, semiconductors 20 years ago. That certainly adds complexity to it and skill set; I get that. Keeping track of the interactions between the packages and materials and so forth, for the people you're teaching—whose job is that? Is that the job of the person who's doing the soldering to know that information? Or is that something they should be leaning on their management to tell them?

You train on this technique and there are interactions between materials and components, and you're teaching them that? That's a part of the instruction?

Lambert: Wow. That's a tough question. One of the ways that I'm involved, and I think that's one of my functions, is to work with the customers. I'm on the board at the University of Massachusetts for the advisory committee for the mechanical engineering programs. I'm also on the board of the local vocational school. One of the questions that always crops up is, "How do we teach the kids coming out of school and the students coming out of college? What are they going to need to know so when they go to work for those types of companies—be it government contractors, general assembly houses or electronic manufacturing facilities—to be valuable employees as they walk in?" This is something the educational facilities must keep asking.

There's a lot of information that is not being taught to these students. They come out of college knowing the theory about electronics, mechanical measurements and things like that, but how do they put all of that together? They should also have a background in design criterion so they can design these electronic products. What makes it go? How do you figure all that out? Therefore, it becomes a problem because these courses are not offered in many colleges. For example, local companies are hiring electrical engineers, mechanical engineers, industrial engineers, material scientists, etc. This protects their future, however they have to work on existing processes while also developing the next generation of products, so where do they get this training and knowledge needed for their growth? For example, materials is a great degree to pick up in college because there are so many things going on with the materials development and usage. Are we going to play with plastics? What kind of alloys are we going to use? How about composite materials? In a business like ours, we need to be involved in that knowledge development. We bring that knowledge to our instructors and offer them the opportunity to pick up the information on how the new materials are coming about.

But students coming out of college today will be working on products that probably haven't even been created or developed yet. So, we deal with what exists and how to put it together. Question being asked by all the educational facilities I'm involved with are, "What do we need to teach students so they will be valuable employees? How do we get the students up to that point?" Then, once they're hired, how do you keep them employable? What enticements will be necessary to keep them working for your company, i.e., retention? Because employees often work in teams, we need to be aware of the different philosophies and work ethics of different generations so they'll be successful at their jobs and life environments. We need to ask, "What do we need to do to accommodate those various work ethics and how can the industry get them to work together?"

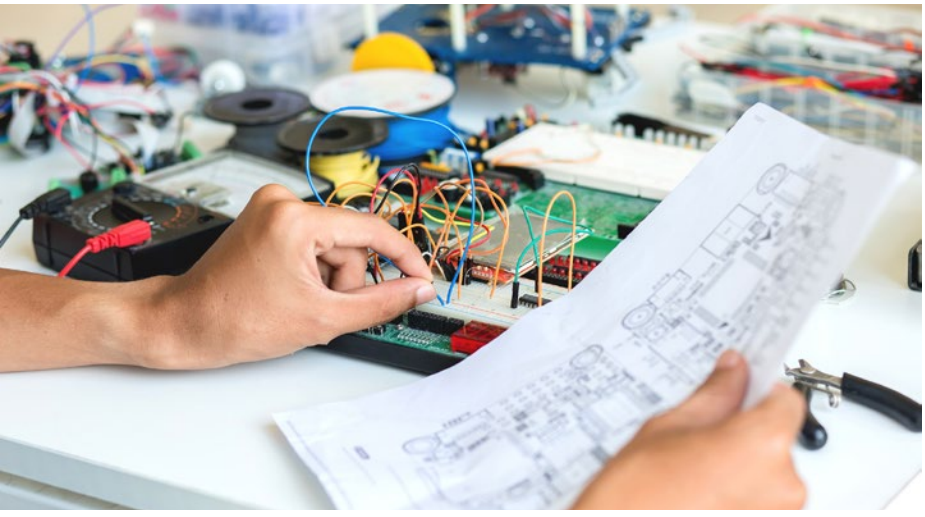
How do you develop the training, ethics and work habits so that when people start working for these companies they stay around? The enticements to keep them, the programs and amenities that you offer them—this is all something that they're working on in schools. When I was in school, it seemed like all the engineers were introverts, but now, because they work in teams, they have to be extroverted. As a matter of fact, I'm doing some work now to review curriculum changes—developing teams so they're handling various parts of the projects. Hopefully, perhaps a company will hire four or five students out of a university so they're working as a team. Or maybe they'll select the same disciplines from different schools so that they can work together and interface; but that's more of an extroverted type of thing. When you look at the professors trying to work this out, and the people in the industry trying to help them, that is difficult but it's what we're facing today.

Johnson: How do you train them for today, and at the same time train them in a way that's going to have a shelf life they can use for a while?

Lambert: Exactly.

Johnson: You said you're on the board of a technical school?

Lambert: Yes, the Greater Lowell Technical High School.



Johnson: Where you sit, Leo, doing training at the industrial level, the commercial level for IPC skills and standards and certifications, and what's happening that you can see going on in the technical schools, maybe the community colleges at that level—does the IPC certification program belong in the vocational school or after?

Lambert: Great question. At the vocational schools, EPTAC has trained the instructors so they are certified instructors for IPC programs. In the process of training the kids, they're going through the electronics program. They have two programs: the electrical program where they're wiring houses, and the electronics program, where these students are building robots and then they're learning all about the electronics, how the sensors are going to work on the robots, doing all the soldering for the robots, etc. There are also other classical types of programs so when these kids graduate from school, they will have an IPC certification on soldering and board inspection.

One course being offered is an Oracle course. This provides the students an understanding of software and how to work the software to develop the robot. Plus, there are a couple other certificates they can earn that will help them get employed with companies like BAE, Raytheon, Lockheed Martin, and the big employers in our local area. We train the instructors, and they, in turn, train the students in the new things that are coming up. As a member of the advisory board, we get involved with the tools available and what new tools will be needed. We provide support in the development of the budget to buy new equipment and programs that the students will use once they get into the workforce.

Now, with IPC there's an education group that is working with various universities, colleges, and high schools to start introducing these programs so that when students leave school and get jobs, they have some knowledge of what's happening in those environments. Years ago, when I worked for Digital Equipment, I was sent to the university to interview the students—chemical engineers. And some of these students, honest to goodness, would come in and it was the first time they wore a suit. And you'd ask them, "Why do you want to work with Digital Equipment?" They would say, "We have no idea, that's an electronic computer company, you have no use for chemical engineers there." But others would come in and say, "I worked at a board shop in New Hampshire for a couple of summers, and you guys make boards, and there's a lot of chemistry involved there." As part of a co-op program, they knew what went on in the company. That knowledge moved them right up the ladder as a potential hire.

That's how we're trying to educate the students, whether they're in colleges or vocational schools. I think companies like ours need to train the students, and from there, we need to train the educational facilities that are training these students so when they leave school, they come into a company with some knowledge and skills for the work required. I know that's a lot, but it all has to tie together because that's the only way you'll get continuity.

Johnson: What's your take, Leo, for those post-secondary vocational schools that are prepping their students to go into the industry and work in an area such as electronics manufacturing? The question always seems to center on how

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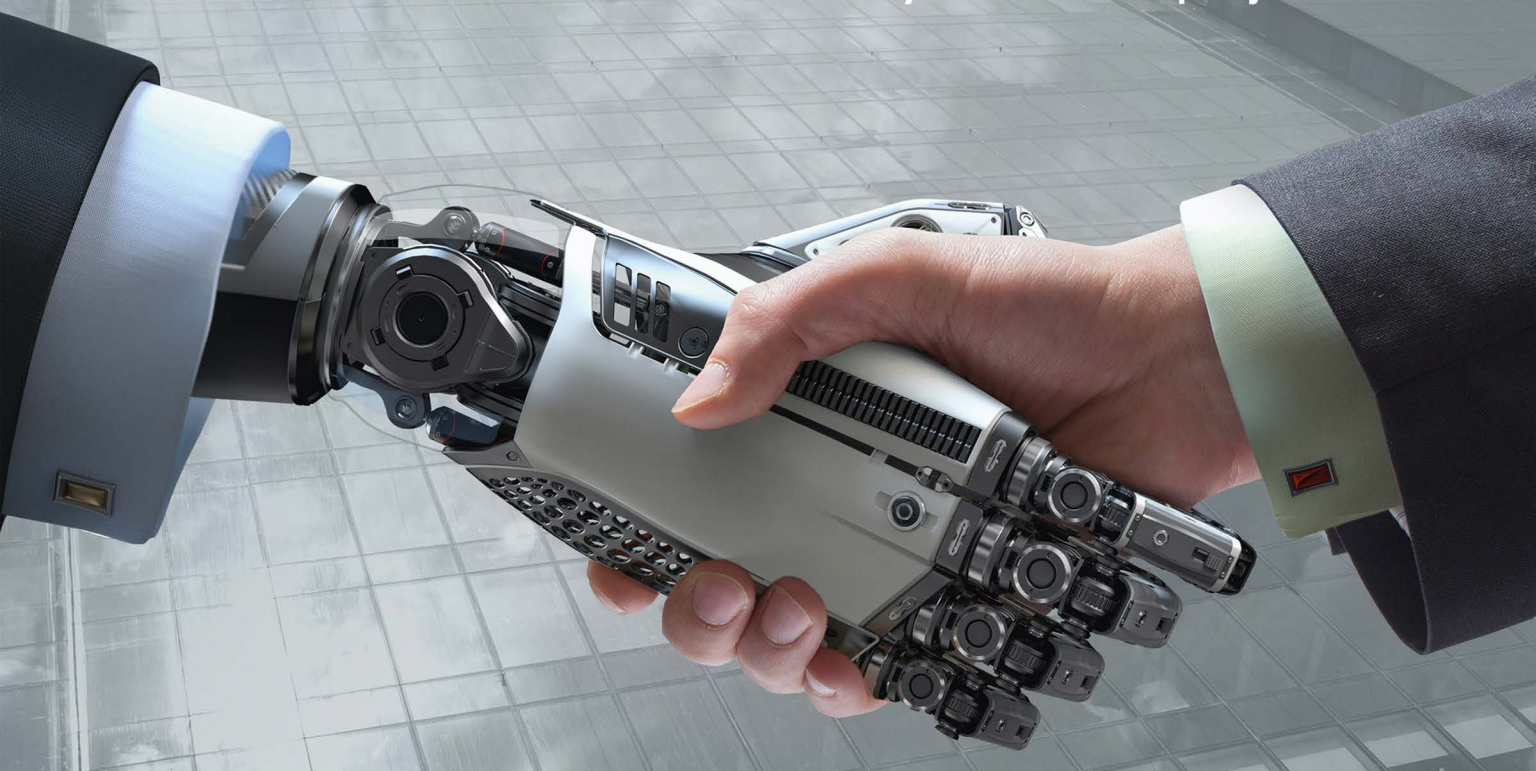

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much of the academic education to include in their program. Is it important for those students to know some of the basics of what's going on in the chemistry, even if they're not getting a four-year chemical engineering degree? Or is it better to put together a program that really teaches them how to work on a manufacturing floor, how to work the machinery that they're going to find on the line, how to troubleshoot that, and really focus on the specific details of doing the job?

I ask this because, in doing this research over the past couple of months, I've seen vocational programs that take both approaches. For some, the focus is, "We're going to put you in the lab. We're going to teach you about the machinery. We're going to give you lab time where we inject problems and you're going to figure out how to diagnose them, triage them, fix them, put the line back running and that's going to be the basis of your degree." And, you also have more of the academic learning involved. Do you see one program that seems to be a better approach than the other?

Lambert: I think the students coming out of colleges have been changing some of the mandatory courses that we used to have and substituting those with specific electives that are more conducive to the work environment. The students have a better chance of success because now schools are letting the students take more courses that are related to what they want to do. For example, in the mechanical engineering program, you might see courses like "strength of materials" and "physics 4"—which was an electromagnetic physics program—and the university may say, "Well, that was mandatory 10 or 20 years ago, but now we're making that an elective because you might want to take a machine course or you may want to take a lab course." The universities are offering more of these changes in their syllabi to get the students more accustomed to working in teams and becoming well-rounded.

At UMass, the students have these Capstone programs and are mentored by people from the industry. The professors are involved and connected with the local industry, and when the students need something, they can go to local industry and get assistance with designing a program or a piece of equipment. If they have to cut something or make something, they have use of the machine shop or the computer labs that develop the computer programs. These programs must define the whole system, and when they do that, they're working different pieces of the program. They could be working the software piece, or maybe the mechanical piece, and it's very similar to cross training employees working in a manufacturing environment.

With these efforts, the students graduate with a lot of knowledge. They might not know the best of all the things, but at least they have some idea of the process and products, and that's the thing. Training and education have to create that interest. The students need to see the need. They need to see and be able to answer the question, "What am I going to get out of this?" You're not going to come out of college and be at the top of a company. You're going to step in and you're going to find out that you have to get your hands dirty, especially in engineering. It's not all book work; it's getting involved and coming up with something, seeing it work and piquing their interest. The vocational schools do the same thing, but they're starting at a technician level.

Johnson: Do you see that same dynamic for your more commercial students when you're doing IPC training, soldering training, certification training for a company with their staff—not in educational, but in industrial? Do you see that same need to connect with a reason?

Lambert: The students that we get are not necessarily young; they're typically a different age bracket, and they're working for different reasons, and to maintain their jobs they have to get trained. That keeps them employable, and it makes them employable at other companies.

English as a second language has become a big deal for us. Everybody can read a picture: explaining what to do first, then using the second picture for the next step and so forth, then they will understand the process. It takes patience! Occasionally, in some of my classes, a student says, "Well, I just got out of the military academy and I've got a job working at a local company. They want me to come to this class to understand what goes on with boards." I say, "Great." And the way that person receives and understands the material is completely different than a student who's 50 years old. Recently graduated students who come to our classes still have the knack of studying and their minds absorb anything new, whereas the 50-year-old needs different methods to fully understand the knowledge being delivered.

But having that diversity in our classroom really makes it interesting. We've got some classes where we have PhDs as students and our instructors are asking them, "How do I handle this? You know a heck of a lot more than I do." I remind our instructors they're the teacher, and the PhD needs a certificate, so give them the information and let them take it. Although these PhDs are very smart, they also need to pick up new material, so when you talk to them, you make sure your notebook is open, because you're going to take some notes from these students.

Johnson: We've been dealing for an extended period time with the pandemic and changes in business habits; what do you see for the next 12 to 24 months? Even if it didn't change the

business we do, everybody has been affected, especially as to how we connect. How has the training business changed because of it?

Lambert: We have 17–19 instructors scattered all over the United States and Canada, and we still conduct classes at the facility in Manchester, New Hampshire. But most of them are the hands-on, workmanship-type skills development classes. Last March when this thing hit, it clamped down on everybody. Everybody said, "What are we going to do at this point?" That's when we decided, "Let's see if we can do something online."

We set up a studio, allowing our instructors to teach their classes online from home. It's interesting because it allowed students to attend from anywhere. You could have a kid in a class from California and another from Europe. It offers and provides the students that opportunity.

As a matter of fact, we recently had a meeting with all the instructors, and we talked about this situation. We told them that we're going to continue online courses because it syncs with the school programs that you see in various communities; we're going to do both online and hybrid classes. The online thing has been working very well for us.

We're also looking at programs that we've developed, not simply waiting for IPC to come up with other programs. These new programs could be in the form of a very short video or answer a question, that type of thing.

We believe online classes will be a big deal in the next year because of the cost savings to companies. You don't have to send people to

a class somewhere, and you don't have to pay the airfare or their hotel for the week. Online is a lot less expensive, so that's a big positive for the customers.

One caution, however, is the internet bandwidth available in your community may not be large enough to deal with the speed and total time frame of the class. For example, it may be noontime and everybody's at home, getting online to do whatever they're doing, and you can actually feel it in the presentation. Both the industry and communities will need to address this situation in some fashion.

Johnson: We have our own internet rush hours nowadays.

Lambert: That's right! I don't think it's going to go away, we'll just develop new techniques, new methodologies. For example, at EPTAC, we've talked about "Death by PowerPoint." How do we clean that up? We need to be able to make a PowerPoint presentation that's exciting, with videos, perhaps, colorful and such. We want to avoid, "Oh man, I have to listen to this for three days?" There are new things coming out that we're playing with and we're learning.

Johnson: After years and years of having a strong in-person, front-of-the-classroom technique, now you're all learning to be video presenters. And you're finding value in that, as well. What is the training staff learning about doing their jobs in this environment that helps them grow?

Lambert: We've preserved the ability to get together often and to share the experiences of teaching the class online. If you're teaching a class in-person, internet interruptions are not a problem. But if you're teaching online and the system hiccups, then you're shut down. How do you recover and go back? I finished a class recently and right after the class finished, I heard an explosion outside and the power went out for four hours. How do you handle something like that? How do you treat the students? How do you get the students involved?

Every month, we have a staff meeting, and we do two things. One is an instructive meeting on the technologies, the problems that occurred in class, the registration and so forth. The next is we have a life coach, training us on how to relate to people, how to interact across the screen. You can't be a dictator in front of the class; you've got to get the flavor of what's going on in the video portion of the program. We spend a lot of time on that, and we've been doing that for a year. It's how we're training our people. It works whether you're in class or you're online.

Johnson: How do you engage your students in that multi-day interactive TV show?

Lambert: We do it through conversations we're leading with our students. One of the tools that we use is the introductions: "This is who I am, this is what I do." We get to know everyone. "I work in a board shop." "Well, I work in an assembly house." "I'm a materials guy. I just build cables. I don't know why I'm here." As an instructor you take notice. You talk to the board shop guy and—if you're doing a boards class—you say, "Don't go too far away. If I've got a problem, I'm going to ask you about it, and you can help us out." That gets them involved as an expert too.

Johnson: Leo, thank you for sharing.

Lambert: You're welcome. PCB007

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What's Driving Price Increases for CCL and Prepreg?

Article by Mark Goodwin
VENTEC INTERNATIONAL GROUP

As we reach the end of a difficult year managing the many challenges caused by the COVID-19 pandemic, another series of challenges is rapidly coming into focus for EMEA and North American PCB manufacturers and their supply base.

Increased demand, static capacity, and industrial accidents have all come together to cause longer lead-times, reduced availability, and upward price pressure for key raw materials. These factors are likely to have a mix of long-, medium- and short-term effects on the outlook for CCL and prepreg (PP) prices, but the pressure is building for significant and, in the case of copper foil, sustained price rises that would start coming into effect in early 2021.

Copper Foil and Copper

Demand for copper foil is increasing (Table 1) from both PCB and battery production for e-mobility, leading to an upward price pressure for copper foils as post lockdown pent-up demand starts to exceed capacity. Lead times are stretching and prices increasing, particularly for heavy copper foils (2 oz./70 micron and above) as capacity is repurposed to maximize square-meter output for lightweight foils to increase capacity for lithium battery production.

With the forecast growth for battery demand, long lead times, and high investment costs to increase copper foil manufacturing capacity, this situation is unlikely to ease given the

Copper Foil Capacity Utilisation 2020 YE (T/Year)			
	CCL and PCB	**Lithium Battery**	**Total**
2020 YE Capacity	549600	283000	832600
2020 YE Demand	545000	255000	800000
2020 YE Utilisation	99.16%	90.11%	96.08%

Table 1: Copper foil capacity utilization. (Source: Ventec International Group)

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China Market Lithium Battery Demand for EV Cars			
	2020	2025	2030
Requirement (Gwh)	62.4	322.1	1097.3
Copper Foil Requirement (T/Year)	56,160	289,890	987,570

Table 2: Every Gwh will consume 900 tons of copper foil. (Source Ventec International Group. Data sources include Co-tech Development Corp. and Taiwan Copper Foil Manufacturing Association)The trends are already evident in the pricing data for raw copper (Figure 1). Since March 2020, prices have continued to rise rapidly and have now even significantly exceeded pre-pandemic lockdown highs.

policy statements and green agendas of most governments for the coming 5–10 years. The lithium battery forecasts for China alone give a strong indication of the impact on supply and demand, and price pressure for copper foils in the coming 10 years (Table 2).

Similar conclusions were made in a recent report by Goldman Sachs, which predict a sustained bull market for copper: "[A] bull market for copper is now fully underway with prices up 50% from the 2020 lows, reaching their highest level since 2017. This current price strength is not an irrational aberration, rather we view it as the first leg of a structural bull market in copper." [1]

Goldman Sachs analysts raised their 12-month forecast for copper to US$9,500 per metric ton, up from a previous estimate of $7,500. The Wall Street bank said it now expects a sustained, higher average price for 2021 and 2022. It has estimated copper prices will average around $8,625 next year, before climbing to an average of $9,175 in 2022. By the first half of 2022, Goldman Sachs analysts noted, it is "highly probable" copper would test the existing record highs of $10,170 set in 2011.

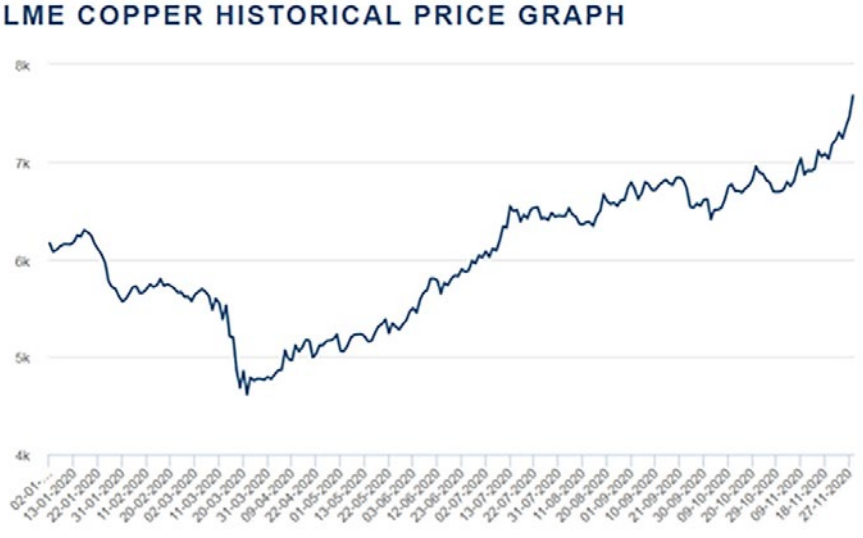

Figure 1: This chart details the historical price of LME copper. (Source: London Metal Exchange.)

Aluminum

Demand for aluminium in insulated metal substrates (IMS) and metal-backed printed circuit boards (MPCB) continues be driven by the demand for thermal management solutions for high-powered LED general and automotive lighting applications, as well as power conversion applications associated with e-mobility charging infrastructure and green energy generation, as well as the competing industrial and consumer applications. As demand from these sectors starts to pick up pace, post-pandemic lockdown prices are starting to rise above their pre-pandemic levels, introducing price pressures to the supply chain. See Figure 2 for a graphic representation of these levels.

Epoxy Resins

High demand for epoxy resins for green energy applications (wind turbine blades) in China, coupled with recent industrial accidents at volume resin manufacturing facilities in China and Korea has led to shortages and signifi-

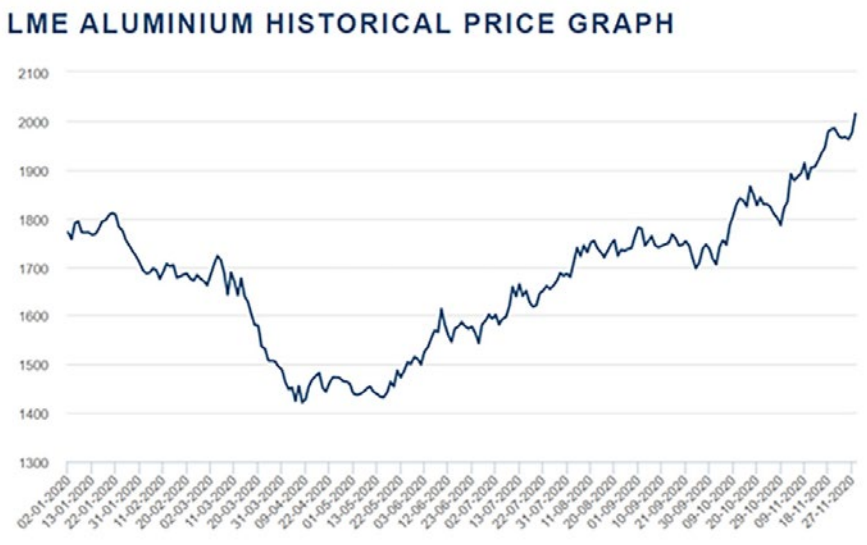

Figure 2: The price fluctuations of aluminum over time. (Source: London Metal Exchange)

cant (60%) price hikes for CCL manufacturers in the last two months. The impact is mostly felt in standard (130-135°C Tg) FR-4 laminates and PP production costs and has already fed through to December 2020 price increases of 15–20% at the factory gate.

These increases will be felt in Europe and the U.S. from early Q1 2021 as inventories in these markets are replenished with higher cost stock. Upward price pressure has also been building for mid- and high-Tg phenolic cured FR-4 since the end of August 2020. The cumulative effect to date is around 15–20%, which will equate to 5–10% increases for CCL and PP in early Q1 2021.

Glass

High growth in consumer and green energy applications is also pushing up glass yarn and glass fabric prices and limiting availability, particularly for heavyweight fabrics such as 7628 and 2116. Glass fabric manufacturers tend to follow the demand for those materials which have lower quality demands and command higher market prices than those demanded by the PCB industry. The CCL manufacturers expect that this trend will cause laminate shortages, particularly for rigid materials. High year-end enquiries and order levels in Asia are always a solid precursor of both availability limitations, and significant price increases in early 2021. This has already been confirmed by market price increase warnings issued by the global market leaders in rigid CCL production.

Supply Chain Logistics

Supply chain logistics are another cause of concern as demand picks up post-pandemic lockdown. There are significant capacity constraints affecting the availability of both sea and air freight. Market data shows that air freight demand is close to returning to 2019 levels, but the available capacity is down by 24% due to the lack of passenger flights. Price levels are down from the early pandemic highs of 4–5X pre-pandemic rates. However, the price trend is upward from summer 2020 levels of 1.5X pre-pandemic rates and currently sitting at 2–2.5X pre-pandemic rates due to very high seasonal demand. They are expected to remain high in 2021 and until a significant increase in passenger air traffic increases available cargo capacity.

For sea freight, demand is high due to a post-pandemic lockdown rebound in demand, leading to two major issues: a shortage of both dry and refrigerated containers, and a high differential in pricing on Asia-to-Europe/UK and Asia-to-U.S. shipping routes. This differential toward more profitable U.S. routes is driving up prices for container traffic between Asia and Europe/UK, and freight rates to the U.S. are already very high.

Any comments on logistic pressures would, of course, not be complete without some mention of Brexit. Congestion at UK ports was already building prior to the UK's departure from the EU at the end of December 2020. This is leading to non-negotiable congestion surcharges, which for now can be absorbed to some degree, but with other price pressures building, if they continue for the long term, they will need

to be passed on to customers. Additionally, inland transportation costs are increasing as the number of available drivers and vehicles for moving containers from port has reduced as continental drivers return to mainland Europe ahead of the UK's December 31, 2020 departure from the EU.

Today more than ever, suppliers who own and control the complete supply chain of PCB materials including laminates and prepregs from end-to-end have a clear advantage. Maintaining carefully managed inventory in various locations worldwide gives the flexibility to adapt to these unforeseen events outside normal control—such as pandemics or industrial accidents.

Building a supply chain capable of handling the challenges we all encounter—those we can control and those we cannot—is ultimately dependent on the quality of dialog between supplier and customer. The more we can work together and establish those close, strong, and enduring relationships to the benefit of all parties involved, the easier it will be to navigate these challenging times. **PCB007**

References

1. "Goldman says copper bull run 'fully underway,' sees potential for record high," CNBC, Dec. 2, 2020.

Mark Goodwin is COO of EMEA and the Americas for Ventec International Group.

New Research Will Use Space Telescopes to Monitor Buildings' Energy Efficiency

Dr. Ian Parry of Cambridge's Institute of Astronomy has been awarded funding for high-resolution thermal infrared space telescopes for monitoring the energy efficiency of buildings.

Thermal infrared (TIR) earth observation telescopes in low earth orbit can monitor the energy output of buildings. Parry and his collaborators will build and develop a prototype for the continuous alignment required for a space telescope, as well as developing end-user climate change cases for TIR telescope.

"This technology can give us a global health check to let us know if the world is on target to meet its carbon emissions targets. It also makes it clear who needs to act and what they have to do if the targets aren't being met," said Parry. "It's a bit like trying to get someone to give up smoking. The person knows it's bad for them and they have good intentions and make promises, but they still fall short of what they need to do until they get a worrying wake-up call from a medical examination."

Governments sign up to agreements but it's the behavior of organizations and individuals that will deliver—or not—the required actions. This technology will allow governments across the world, including our own, to deliver what was promised.

The technology will identify anything bigger than about five meters across that is using large amounts of energy, such as buildings, houses, aircraft, ships or trucks.

(University of Cambridge)

MilAero007 Highlights

The Government Circuit: Looking Ahead to 2021: ▶

Before the 116th Congress adjourns for the holidays, IPC expects to secure some policy victories for the electronics manufacturing industry and keep its policy agenda moving forward. Read on—and watch this space—to learn how it all turns out.

Understanding MIL-PRF-31032, Part 6 ▶

Concluding this six-part discussion on understanding the military printed circuit board performance standard MIL-PRF-31032, Anaya Vardya discusses the remaining procedure required to address the unique requirements of the military.

IPC President John Mitchell Releases Statement on NDAA Final Passage ▶

IPC President and CEO John Mitchell released a statement on final passage of the National Defense Authorization Act.

Raytheon and United Technologies Merger: Stronger Together ▶

The 2020 merger of Raytheon Company and the United Technologies Corporation aerospace businesses brought together two companies with distinctive legacies of developing and deploying advanced technologies to solve some of the world's most pressing and complex challenges.

IPC Applauds U.S. House Approval of Defense Policy Act With Pro-Electronics Provisions ▶

Follow the link below to view a statement by John Mitchell, IPC President and CEO, on the vote by the U.S. House of Representatives to approve the final version of the Fiscal 2021 National Defense Authorization Act (NDAA).

Stephen Chavez, Happy Holden on Designing Reliable Vias ▶

Andy Shaughnessy and Happy Holden speak with Stephen Chavez, a staff engineer with an aerospace company and chairman of the Printed Circuit Engineering Association (PCEA), about designing vias for greater reliability. They also address several areas where they can look to improve reliability, a variety of steps that designers should take to help ensure more robust vias, and some testing and educational resources that PCB designers and design engineers should be aware of.

2021 Symposium on Counterfeit Parts and Materials Call for Abstracts ▶

The Surface Mount Technology Association (SMTA) and CALCE University of Maryland are inviting the industry to submit technical papers for presentation at the VIRTUAL 2021 Symposium on Counterfeit Parts and Materials. The event will be held on August 3–5, 2021.

Defense Speak Interpreted: What's a VITA? ▶

Ever wonder how military electronics users could swap out circuit cards rapidly and keep their defense systems running? What about a "hot swap" of a circuit card that was questionable? The Department of Defense started to worry about those issues over 30 years ago and has helped private industry develop a highly sophisticated set of standards for circuit card input/output (I/O) to make quick change possible.

A Martian Roundtrip: NASA's Perseverance Rover Sample Tubes ▶

The tubes carried in the belly of NASA's Mars 2020 Perseverance rover are destined to carry the first samples in history from another planet back to Earth.

Getting 'Lean' in 2021

Testing Todd
by Todd Kolmodin, GARDIEN SERVICES USA

Welcome to 2021! We made it! I hope you all had a happy holiday season. Unfortunately, we are still in the midst of the worst healthcare crisis of modern medicine. My heart goes out to all those who have lost loved ones and have been directly affected by this tragic pandemic. I offer my sincere gratitude to all the front-line medical personnel who have tirelessly cared for the overwhelming cases we have been faced with.

Many companies and individuals had to make life-altering adjustments in 2020 because of the pandemic, including reduced hours, telecommuting, and examining how we do things in this "new normal." Although the circumstances causing these changes are tragic, it forced us into becoming lean.

However, becoming lean isn't a bad thing. In fact, it's a focus of continuous improvement. So, it seems fitting that we open this new year talking about becoming lean as a part of continuous improvement. Let's look at what we have done already.

It seems that 2020 took command, particularly in how we go about our daily lives, both personally and professionally. Depending on where you live, restrictions, closures and interaction restrictions may all be a part of your life. To survive, we had to adapt, adjust and emerge strong. So, when we talk of "lean," you may not be aware that you have probably already implemented some lean philosophies without even knowing it.

Where did you become leaner? There is no question you have adjusted to reduce costs. You may have reduced some manufacturing hours and workforce. Business travel may have been reduced or eliminated based on company policy and guidelines. These are direct bottom-line cost reduction measures. However, what we have also done is adapt. We may not be able to travel but we have embraced technology (albeit forced) and taken our meetings into

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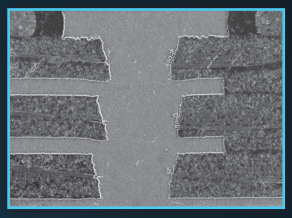

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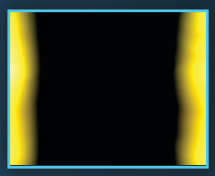
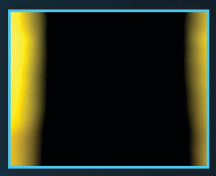


M-Activator AP
Ionic Activator



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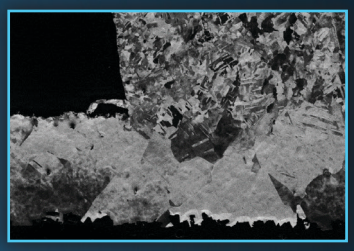

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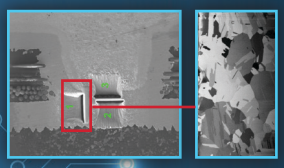

ViaDep 4550 +
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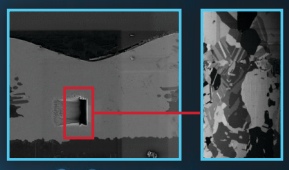

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virtual formats. In-person meetings have gone to cloud-based platforms such as Zoom, Microsoft Teams and other options. Telecommuting has reduced cost and studies have shown actual improvements in productivity. Virtual business has become extremely popular as worldwide meetings can take place with no travel required. In short, it's working.

In manufacturing, many companies have been forced to reduce staff and hours while still providing the service their customers and partners expect, especially in the sectors deemed as "essential." This requires adjustments with reduced staff. Cross-training and multi-tasking with the reduced force is another example of becoming leaner.

Becoming lean is a discipline of evaluating tasks, processes, layouts and inventories to identify waste and capitalize on removing the waste and streamlining. This is all part of the continuous improvement process. As you begin 2021, review how you have become leaner during 2020. See what you have done as a reaction due to mandated restrictions, and then apply that proactively now that you had to plunge into it without thought. Now you can take a better look at becoming lean and take advantage of what this discipline can provide. Cheers to 2021! Be safe. Let's go! **PCB007**

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

A Magnificent Burst from Within Our Galaxy

A suite of radio antennas, including those making up Caltech's STARE2 (Survey for Transient Astronomical Radio Emission 2) project, together with other ground- and space-based observatories, have captured overwhelming evidence to help unlock the mysterious cause of cosmic blasts known as fast radio bursts, or FRBs. These ultrafast radio flashes originate from distant galaxies, but until now, no one could say what was causing them. Researchers now demonstrate that the answer to the riddle likely involves a dead magnetic star called a magnetar.

Magnetars are spinning stellar remnants, left over from the explosion of massive stars. Magnetars stand out for their extreme magnetic fields: more than 100 trillion times stronger than Earth's magnetic field.

STARE2 consists of three radio receivers, each about the size of a large bucket. They are located at Caltech's Owens Valley Radio Observatory; the Goldstone Deep Space Communications Complex operated by JPL; and near the town of Delta, Utah. STARE2 is not nearly as sensitive as CHIME but has a wider field of covering the whole visible sky and observes radio frequencies twice as high as those seen by CHIME.

In addition to radio waves, other telescopes in space detected electromagnetic radiation coming from the same area of the sky, specifically from a magnetar called SGR 1935+2154 (SGR 1935 for short). NASA's Swift and Fermi observatories, for example, which observe X-rays and gamma rays, respectively, picked up rumblings from the magnetar on April 27, the day before the massive radio blast. Other telescopes observed X-ray bursts simultaneously with the radio burst.

(Caltech)

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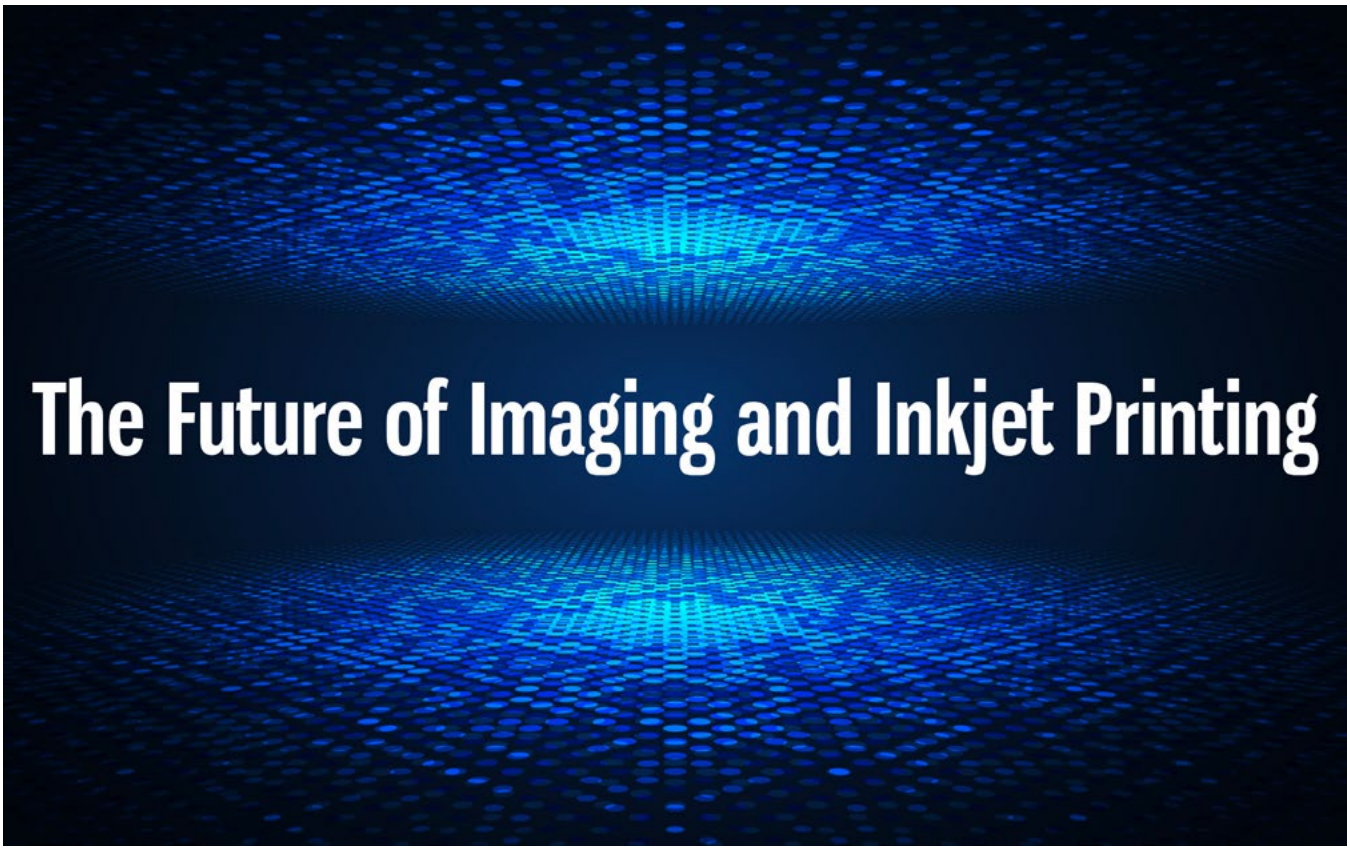


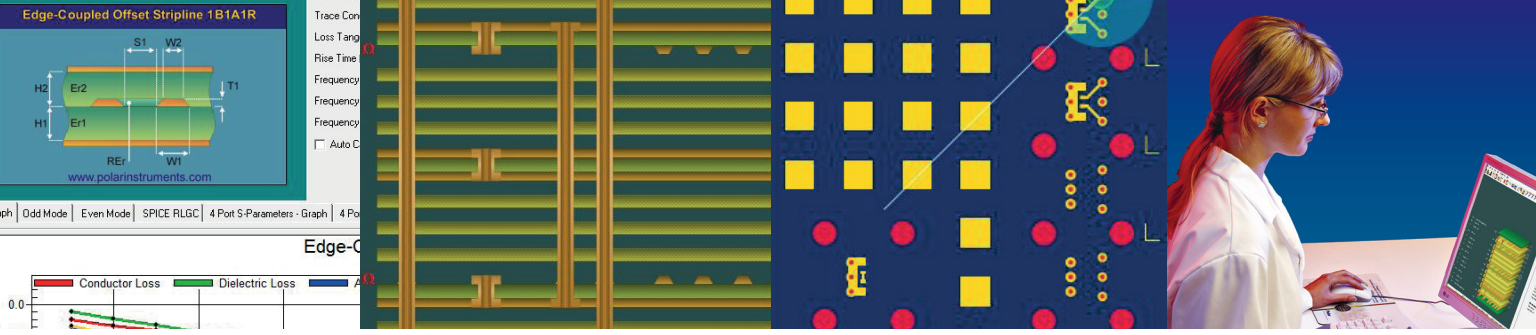
Interview by the I-Connect007 Editorial Team

We recently spoke to Ed Carignan of Technica, who outlines the current landscape for both direct imaging and inkjet printing and describes how the technologies have evolved over the years. He also details what's next on the horizon.

Nolan Johnson: A lot seems to be happening for imaging. I would even go so far as to say that it seems that what's now being called imaging is changing. How would you describe the landscape for imaging currently? How is it changing, and what's on the horizon?

Ed Carignan: The biggest change that happened over the last decade was a large-scale conversion from standard phototool-based imaging to direct digital imaging (DI). The technology instantly allowed fabricators to improve registration accuracy, improve productivity, and reduce their reliance on individual operator skill. The change also benefitted PCB designers who could begin to reduce tolerance budgets for higher component densities. A variety of equipment manufacturers now populate this market, driving competitive pricing downward and made the adoption rate very widespread by both large and small PCB fabricators. The two significant contributors to the current success of DI were the development of the equipment platforms (laser-based, UV LED/DMD-based, etc.) and formulation changes made in dry film resist and solder mask materials to reduce photo speeds, allowing for fast exposure times.

What is new are inkjet-based systems used for the direct and additive placement of solder mask on the PCB panel. Inkjet systems for direct digital printing of legend inks have been available and in use by fabricators for many years. However, further improvements in platforms and print head technologies have made the potential for solder mask printing a reality. Similar to the DI development, this technology requires a careful match between the solder mask ink and the equipment's ink delivery components. A key quality issue for PCB fabricators, assemblers and the end customer



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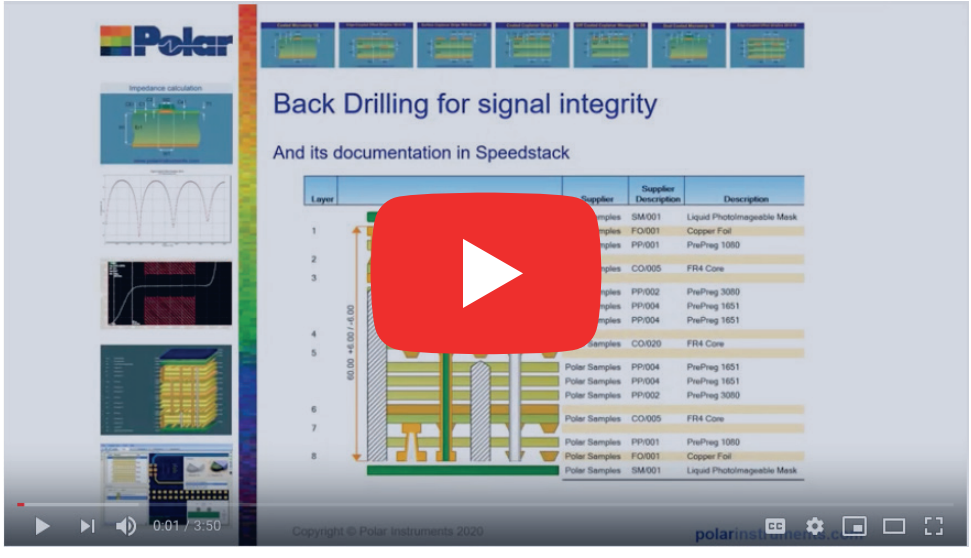

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is that droplet placement by the piezoelectric, drop-on-demand print head engines negate unintentional placement of solder mask ink on solderable pads. With the development of print heads capable of jetting sub-6 picoliter droplet sizes, it is becoming viable to print solder mask inks directly in place of what was previously done in direct imaging and in an additive process, while also reducing the number of process steps in the bargain.

What will be exciting to watch is how much of that market will be transitioned to inkjet systems over the next decade as more equipment suppliers and more early-adopters ramp-up. There will likely always be a place where both direct imaging and inkjet systems co-exist for various PCB designs and constraints. At Technica, we represent solid partners in both technology spaces: CBT (Taiwan) (Figure 1) for DI solutions and SUSS MicroTec (Netherlands) for inkjet equipment.

Johnson: As inkjet supplants direct imaging or photoimaging, what are the advantages of using inkjet? Why would you want to do direct or inkjet? They don't entirely overlap.

Carignan: I agree that these two technologies do not entirely overlap and there are going to be PCB designs and products which will favor one over the other.

For direct imaging, the process replaces phototools (and their inherent instability) and enables precise registration control by actively scaling the image data to "fit" the panel through the acquisition of multiple fiducial targets. Also, the DI units can image solder mask inks that are already approved by the fabricator OEMs.

On the inkjet side, the advantages are that it is an additive process and, similar to DI, it allows precise registration control through fiducial acquisition, scaling and printing. It also eliminates several process steps such as screen or spray coating, tack curing and development. All these eliminate power, water, chemistry and wastewater treatment costs as well as the associated labor and equipment maintenance.

Feinberg: Once you get the image on there, how is it cured? Is it air-dried, baked, or photocured? What is the typical curing procedure for an inkjet image?

Carignan: That's a good question. Following the inkjet print head in real-time is a UV LED cure unit. This allows the equipment to quickly "pin" the droplets in place to reduce droplet spread and removes the ink "tackiness" so you can directly print side A followed immediately by side B, i.e., you can process both sides of a panel.

Feinberg: It's kind of like a standard UV cure or a 360 nanometer.

Carignan: It uses an array of UV LEDs as large as the print head assembly. The solder mask material requirements define the range of light emitted within the UVA range.

Johnson: There's a business operation benefit to moving to the latest. The ability to do this work becomes more process and less art, if you will, by moving to direct imaging and then to inkjet and additive. Can inkjet just drop into a traditional prototype shop, or is this something that lines up more with the mSAP/SAP type of processes? Are there some restrictions as to where you can use inkjet?

Carignan: Adopting inkjet technology will, in many cases, require customer approvals (and UL qualification) as the inks used are a unique formulation. There may be a period of delay as OEMs validate the change in material. Over time, however, these inks will become well known and understood.

Some manufacturing process flows may not be compatible with inkjet applied solder mask such as in cases where hole tenting is used, but a very large percentage of PCB designs should be a "drop in."

It's still very much the beginning for inkjet solder mask systems; I know of maybe six or more units installed in the U.S. and a few in Europe. When we talk to board fabricators, most are eager to better understand this tech-

Figure 1: CBTech's fully automated Titan 8400D UV LED/DMD Direct Imaging system.

nology and know that they will evolve quickly over the next several years. Some early adopters are moving forward today strictly for the reduction in their water and power usage in regions where rates and/or restrictions are high.

Johnson: In the case of a greenfield facility, where you build and set up new equipment, would you recommend going straight to inkjet? Are they going to be giving up anything if they take on that strategy?

Carignan: Careful consideration of your current (and future) product portfolio should be assessed in order to go direct to inkjet technology, I believe. Even with the present sub-6 picoliter print heads there are some limitations if you're trying to do very small features in the ≤ 50 micron range. It will always be challenging to print perfectly square features with round dots. I believe inkjet solder mask adoption will primarily be done by users that have an established solder mask process that likely includes DI but want to migrate as much of their PCB products to inkjet in order to take advantage of cycle time and cost reductions. If 70-80% of the production could transfer to inkjet solder mask, then that could represent a large savings.

Johnson: Is there still room for direct imaging?

Carignan: Yes, I believe these two technologies will co-exist for a very long time in our industry. Not as well explored today is the use of inkjet-printable etch and plating resists for general PCB manufacturing. This frontier is fast approaching, however, and will accelerate as fabricators become increasing confident in the benefits of inkjet solder mask printing.

Johnson: What's in the gap for inkjet?

Carignan: One is market acceptance, and it has two interpretations. First, there is visual acceptance of the printed solder mask. This might differ from what traditional technology delivers; still, this is a strength. The appearance is a consequence of the printing strategy; and printing strategies can change upon specification. For example, print strategy fine-tuning offers different levels of shine or matte, as well as solder mask thickness. Actually, designs can specify appearance topology, enabling real digital solder mask definition. Second is commercial acceptance; equipment throughput does not yet match the traditional technology. Furthermore, print heads are expensive and the motion control platforms need to be precise.

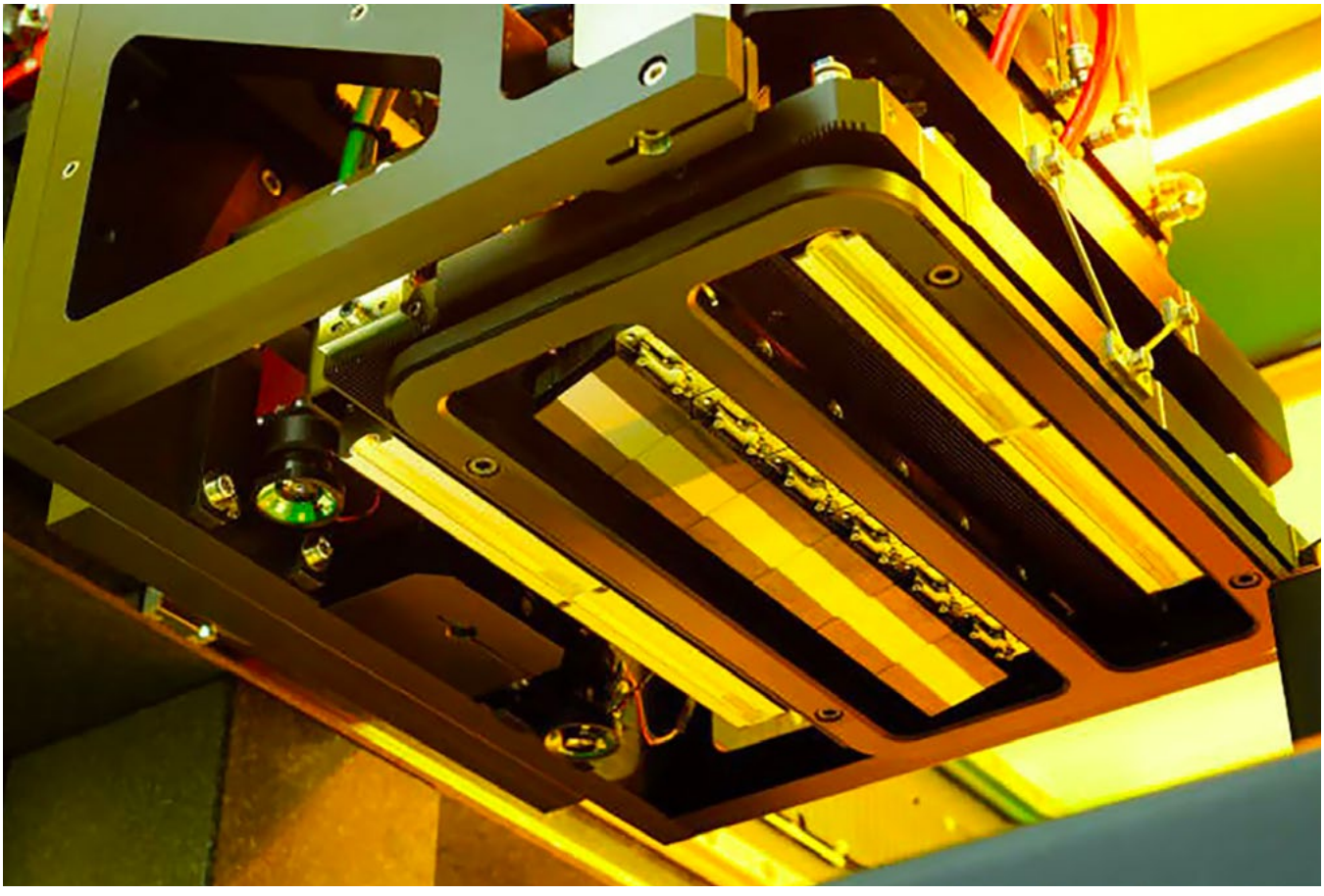

Figure 2: SUSS MicroTec print head assembly with front to back UV LED cure units for bi-directionality.

Of course, the business case is still there with high utilization; otherwise, we would not be talking about inkjet. However, now the technology is new and volume manufacturing of the equipment and components is still small; this makes the build costs high, but the future is bright. With growing adoption and general acceptance, equipment manufacturers will enjoy better buying leverage in the future. This was a similar cycle in the early days of direct imaging.

Happy Holden: Can you comment on the use of the DMD engine for direct exposure vs. the inkjet engine? These DMD engines don't come from our industry; the DMD engines have the advantage that they're showing up in projectors and many other applications. I don't know if inkjet engines are showing up in diverse industries, but maybe they are. As DMD engine use grows, they're a technology that continues to improve without us having to put in the money from PCBs. That makes for a healthy future because they don't seem to be going obsolete. Can it be similar to inkjet?

Carignan: You're absolutely right. DMD technology started long ago with products such as digital projectors and grew into many diverse applications in both the visible and UV range. As micro-mirror sizes became increasingly finer and DMD formats larger, more applications were developed accordingly. A similar trend happens with print head technology, industrial inkjet tools use print heads from the B2B graphical industry. These address large format (billboards) or high definition (>1,000 DPI) needs– a very large industry that continuously provides technological advantages (better print heads, better ink recirculation systems, better electronic control of pH, etc.). Furthermore, SUSS MicroTec has long since been using inkjet platforms to provide equipment in the semiconductor and photovoltaic panel markets.

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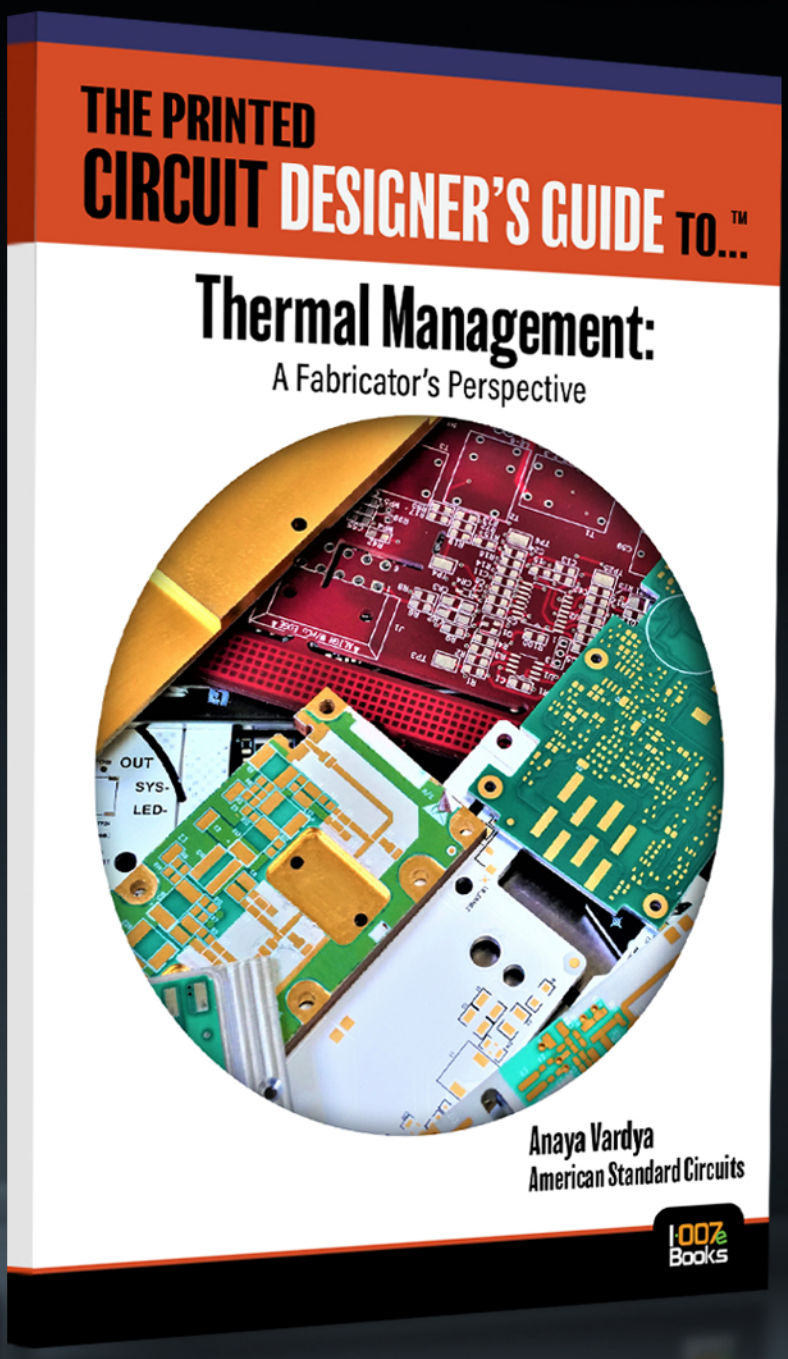

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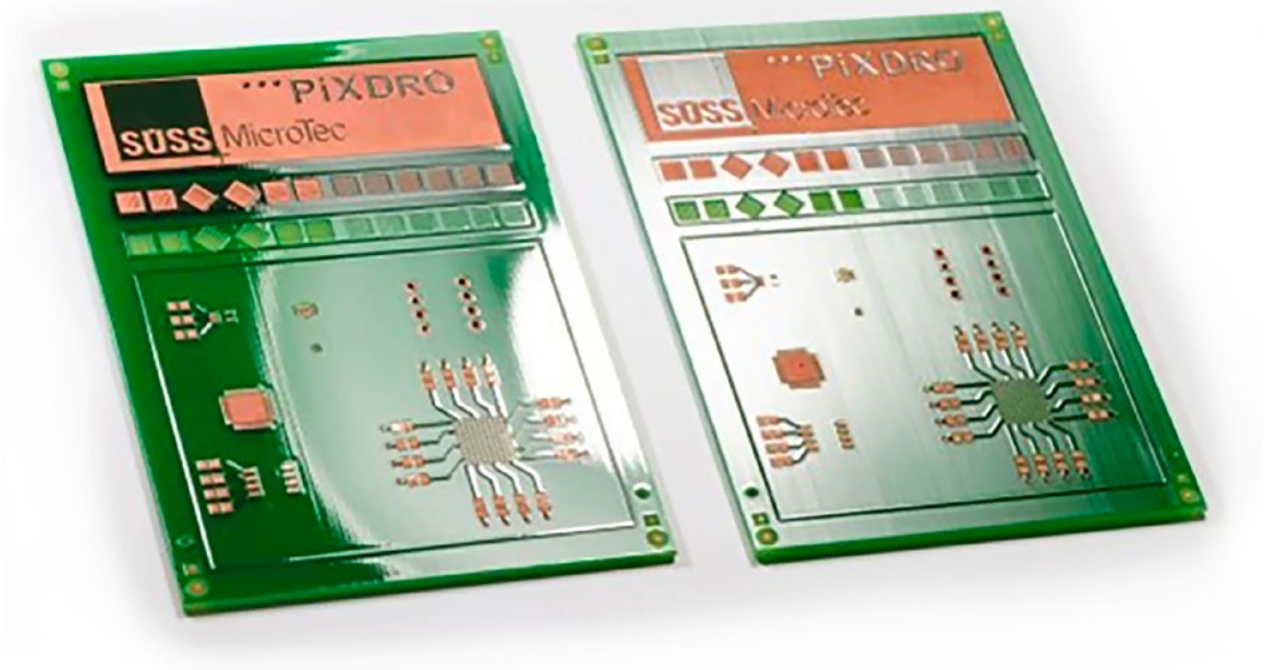

Figure 3: Inkjetted solder mask PCB, shiny (L) and matte (R) (SUSS MicroTec PIXDRO/Electra Polymers ELECTRAJET EMJ-110 ink).

Holden: I didn't realize there's a change when you go from the visible light to the ultraviolet for those engines.

Carignan: There can be. For DMDs used with illumination in the UV range there are some special considerations. Solarization, for example, is a phenomenon that can occur over time which can degrade light transmission and intensity as the DMD glass lens becomes saturated in the UV spectrum. Therefore, certain components in the manufacture of DMD products in UV range are unique.

Holden: There was software in the camera systems to figure out where the holes were for registration. Has that been duplicated by others in the direct exposure area?

Carignan: Being able to acquire images, targets and fiducials differs somewhat from one manufacturer to another. CBT (Taiwan), for example, uses a patented method to precisely acquire front-to-back alignment for inner layer printing on their DI equipment without requiring any fixed target at all. This method is widely known for being extremely accurate. For outer layer and solder mask alignment, the techniques used are very similar among suppliers and are used by inkjet solder mask alignment systems.

Holden: Is there some group or some company that particularly dominates that kind of software, or does everybody have to develop it on their own and go through the evolution of improving it?

Carignan: I am not able to say with certainty what level of customization each equipment supplier exerts on their image acquisition software. What is clear is that fiducial recognition must be robust enough to account to variations in the PCB process and material types, and accurate enough to repeatedly locate the center of the feature without exception. Once the alignment process is complete, the next critical step for outer layer and solder mask steps is for the software to apply linear/non-linear corrections to the CAM data, i.e., to scale the data to precisely fit the panel features.

Holden: In 1980, we put together an inkjet legend system at HP using our thermal ink-

Figure 4: Fully automated SUSS MicroTec PIXDRO Inkjet Solder Mask System.

jet because we wanted to serialize every single individual board with a unique serial number for traceability. That was always a nightmare until we came up with building our own big inkjet printer and board handler, but we made the cartridges. We got involved with changing the formulation of the white ink because we helped develop the inkjet heads, which are electroformed nickel. They repaid the favor by modifying some of the inks for us to be not as good as solder mask or as thermally cured legend, but at least it got the job done.

Carignan: Today for inkjet solder mask, you can buy proven inks from several well-known sources including Taiyo, Electra Polymers, Agfa-Gevaert and others. These have been formulated to work well in the application and pass IPC specifications for solder mask acceptance. In addition to the functionality, thanks to the digital nature of inkjet, the same ink can be printed to look shiny or matte, or as you were mentioning, serialization can be introduced in the solder mask level on-the-fly.

Johnson: Who is doing the etch resist and plating resist?

Carignan: I do not know of any PCB fabricators using this yet, although there may be some. Lithojet™ from Dupont, and DiPaMat from Agfa, are just two examples of what you can buy today with several plating resists and etch resists types. It is printable by most of the major equipment manufacturers and is wax based. There is a long history of inkjet print head systems in use with these formulations but not as prevalent today in the general PCB manufacturing market yet. It represents an exciting next step as it is adapted for use.

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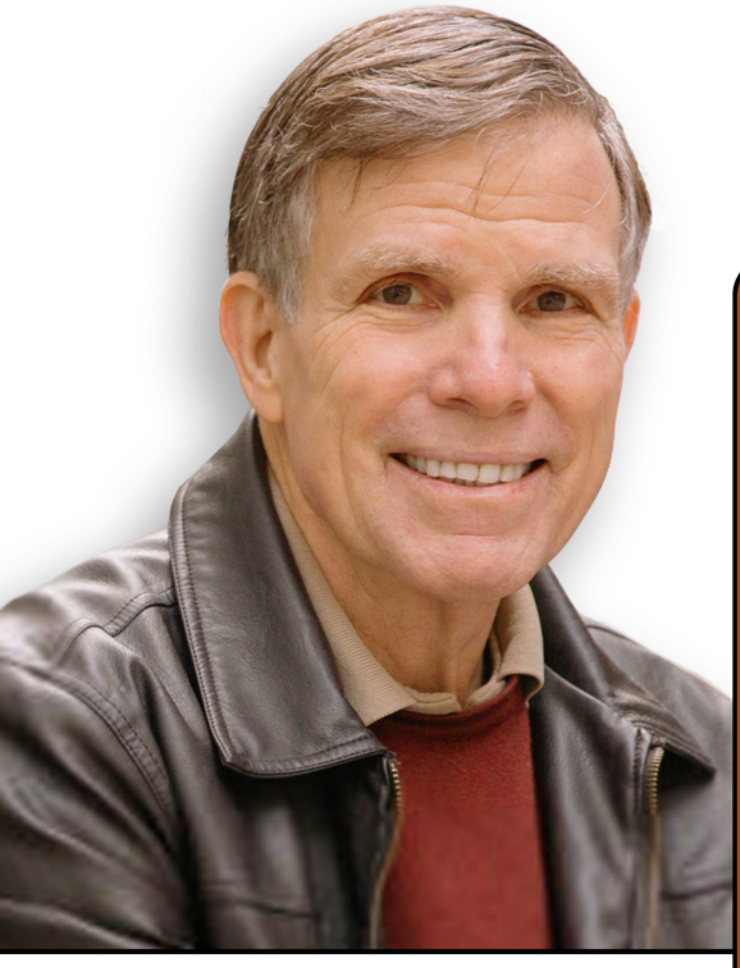

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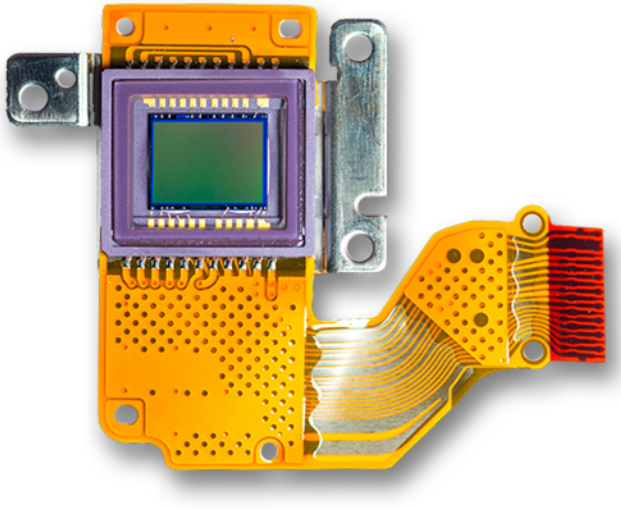

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Holden: But it's also finding a home in printed electronics.

Carignan: Correct.

Johnson: In the U.S., our fabrication is typically lower volume, higher mix, higher complexity. This sort of machinery lends itself well to that. How would this technology work in a much higher-volume production facility like you see in Asia?

Carignan: I believe quite well, due especially to its environmentally friendly footprint and its seamless integration in the production floor. Many suppliers, like SUSS MicroTec's PIXDRO inkjet unit, offer options for full automation to increase efficiency and productivity and are well designed for continuous printing environments. I foresee that print speeds will become faster over time, both in terms of the number of print heads and operating frequencies.

Johnson: What other partnerships are you developing?

Carignan: In the context of this conversation, Technica continues to develop partnerships that allow us to offer our customers complete solutions in the digital printing arena. Direct imaging, through CBT (Taiwan), has been a key partner of Technica for nearly a decade. In late 2019, an alliance with SUSS MicroTec (Netherlands) gained inkjet solder mask as a technology offering. We also represent Electra Polymers (UK) for consumables in solder mask and other engineered inks.

Johnson: I have to assume that you have a team that can act as a consultant for any prospective customers. Is there some pre-sale consultation expertise that customers can take advantage of?

Carignan: Technica has trained regional salespeople, most of who come directly from the PCB fabrication or assembly markets; they understand the processes very well. The typical engagement we do with our customers is to educate them on new technologies as they become available and to provide detailed pre-sale technical communication including directly with the equipment and material suppliers we represent. Technica also employs trained service technicians and applications support personnel which is a critical benefit to our customers after a system is in place and operational.

Holden: If someone in the fashion industry came to you and said, "We want to experiment with wearable electronics. We're interested in what fabrics are compatible. Where do we find the ink and the machine that somehow can print conductive or other electronic components or circuits on a fabric and cure them?" Could they come to you?

Carignan: I believe we are in a very good position to offer support in this area in multiple ways. SUSS MicroTec placed an inkjet system at Electra Polymers and several other ink manufacturers for exactly this reason; so, the ink manufacturer could directly print on various substrates and be capable of analyzing the results and make recommendations for clients. SUSS MicroTec also has a complete R&D center in the Netherlands.

Holden: The fashion industry would dwarf the PCB industry.

Carignan: That's the promise of wearable electronics; monitoring an individual's vital signs for medical reasons is but one example. Many wearables today also count steps you have taken, have GPS devices to track location, etc. Despite some feelings for the risk of revealing too much data, I don't see how this trend will slow down much over the coming decade. Overall, there are more positives than negatives.

Johnson: This was incredibly helpful. Thank you for your time today.

Carignan: Thank you. PCB007

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Supplier Highlights

Elite Material Co., Ltd to Acquire 100% Equity stake of Arlon EMD Specialty Materials ▸

Elite Material Co., Ltd announced that EMC will acquire all outstanding stakes of EMO Specialty Materials LLC, a Delaware limited liability company doing business in the U.S., through its 100% owned subsidiary EMC Special Application Incorporated. Consummation of the transaction will be subject to the relevant regulatory approvals.

Ventec's California Facility Receives ISO 9001:2015 Certification ▸

Ventec International Group Co., Ltd. is proud to announce that it has passed the ISO 9001:2015 audit for its Quality Management System at its U.S. facility in Fullerton, following an audit by certifying body Intertek. This follows the certification of Ventec's Chicago facility in 2020.

New Orbotech Flex PCB Manufacturing Solutions Enable Future Generations of Advanced Electronics ▸

Orbotech, a KLA company, announced two new roll-to-roll (R2R) manufacturing solutions for flexible printed circuits (FPCs), enabling the design and mass production of new generations of electronic devices, including 5G smartphones, advanced automotive and medical devices.

MKS Sees Strong Sales for its Latest Flexible PCB Laser Processing Solution ▸

MKS Instruments, Inc., a global provider of technologies that enable advanced processes and improve productivity, announced that a leading PCB manufacturing customer in the Greater China region has purchased 80 units of the company's ESI CapStone system for near-term delivery.

Rogers Corporation Appoints Megan Faust, Keith Larson to Board of Directors ▸

Rogers Corporation has announced that its Board of Directors appointed Megan Faust and Keith Larson to serve as members of the Company's Board.

Ucamco Webinar Explores Benefits of Front-End Automation Tool ▸

I-Connect007's Pete Starkey has known the Ucamco people for over 30 years and recognises the company as an industry-leading provider of PCB CAM and pre-CAM software, as well as laser photoplotters and direct imaging systems. The team has always endeavoured to understand customer needs—often to anticipate them—and to respond with innovative solutions.

PV Nano Cell Introduces 7 New Digital Conductive Inks ▸

PV Nano Cell Ltd., an innovative provider of inkjet-based conductive digital printing solutions and producer of conductive digital inks, has announced that it is introducing additional digital conductive inks meant for solar, ceramic, glass, LIFT and generic applications. The newly introduced inks are meant for the following digital conductive printing technologies: inkjet, aerosol and Laser Induced Forward Transfer.

Atotech Launches New DynaSmart Plating Line for Corrosion Resistant Coatings ▸

Atotech, a leading global supplier of specialty surface-finishing solutions, announced the global launch of its innovative and patented DynaSmart® plating line for corrosion resistant coatings. This addition to the company's product line was engineered in Germany to address the increasing demand for advanced surface-finishing equipment in our industrial end markets.

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Leadership 101: Leadership is Hard

The Right Approach
by Steve Williams, THE RIGHT APPROACH CONSULTING

Introduction

Good leadership always makes a difference; unfortunately, so does bad leadership. It can be the difference between average (or worse) and exceptional organizational performance. Leadership is not easy to learn; if it was, everyone would be a leader. This Leadership 101 series will provide practical leadership tools and principles that can be applied immediately with your team.

The Biggest Leadership Mistake

I wrote about my personal journey in my October 2016 column citing three pivotal (and painful) lessons I learned early in my career. I have been in leadership positions for most of my 40+ year career, but as I discussed five years ago, it has not always been a smooth and natural relationship. One thing I have learned, working with some of the biggest and brightest companies in just about every custom manufacturing industry, including ours, is that everyone struggles with leadership in some way.

The biggest mistake most companies make is to promote their best employees on the floor into supervisory positions. Making your best drill operator the drill supervisor may sound like a good idea, but without providing leadership training you will most likely just lose your best drill operator. Sometimes your best drill operator should remain your best drill operator.

Figure 1: Effective leaders inspire others to get the work done because employees have bought into the vision.

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Leadership is Hard

An effective leader needs to possess a unique skill set to manage people, schedules, equipment problems, and quality issues. The people part is the most difficult because the success of a leader is based on their ability to inspire others to follow them. There is a significant distinction between a "manager" and a "leader."

While the measure of success of both is based on the ability to accomplish things through others, the differentiator is in how each does this. A manager can direct others to do something based on their managerial title, whether the others want to. A leader gets things done through others because the others have bought into the leader's vision freely and sincerely want to do what is being asked of them.

Considering this, remember that a leader can be a manager, but a manager cannot be a leader. As my fellow author and friend Warren Bennis once told me, "A manager does things right, a leader does the right thing."

If It's Lonely at the Top, You're Doing Something Wrong

A couple of months before I wrote the October 2016 column, I had just ended 18 months of intensive training to become an independent certified leadership coach, teacher and speaker with the John Maxwell Group. John Maxwell is an internationally recognized leadership expert who has sold more than 13 million books and trained more than two million leaders worldwide. One of the first lessons I learned was regarding the relationship of a leader "being at the top."

In both your personal and business life you will always run across others who are willing to give advice on things they've never experienced. Let's use an example most of can relate to: using a travel agent. They may sell you an expensive vacation package and say, "I hope you enjoy the trip," then you never see them again. In contrast, good leaders are like tour guides. They know the lay of the land because they've been there before, and they do everything they can to make the trip enjoyable and successful for everybody. A leader's credibility begins with personal success, and it ends with helping others achieve personal success. To gain credibility, you must consistently demonstrate three things:

1. ***Initiative:*** You have to get up to go up.
2. ***Sacrifice:*** You have to give up to go up.
3. ***Maturity:*** You have to grow up to go up.

Key takeaway: If you show the way, people will want to follow you. The higher you go, the greater number of people who will be willing to travel with you.

Leadership is Influence: Nothing More, Nothing Less

The core principle of leadership in the John Maxwell leadership philosophy is this statement. After spending six years studying, learning, and now training leadership teams with my clients, I have come to realize that any other definition of leadership is just fluff. Lead-

Figure 2: The best leadership comes from inspiring and helping others achieve greatness.

ership is influence. Period. When writing my October 2016 column, another a-ha moment for me was realizing (unknowingly) that I had come to this same conclusion during my leadership journey, prior to John Maxwell. Early in my career I was an autocratic manager that got things done through the power of my title. This is not leadership. Using brute force and intimidation is not leadership; it is not even being a good manager. Inspiring and helping others achieve greatness is leadership. The brilliance of this is that the fastest path of success for a leader is by helping others become successful.

The Journey Continues

I ended my 2016 article, "The lessons learned were far too many to cover in even a year's worth of articles," which has stuck with me as unfinished business. This Leadership 101 series is my chance to fix this. I hope you join me as the journey continues. **PCB007**

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

Green Materials Could Power Smart Devices With Ambient Light

We are increasingly using more smart devices like smartphones, smart speakers, and wearable health and wellness sensors in our homes, offices, and public buildings. However, the batteries they use can deplete quickly and contain toxic and rare environmentally damaging chemicals, so researchers are looking for better ways to power the devices.

One way to power them is by converting indoor light from ordinary bulbs into energy, in a similar way to how solar panels harvest energy from sunlight, known as solar photovoltaics. However, due to the different properties of the light sources, the materials used for solar panels are not suitable for harvesting indoor light.

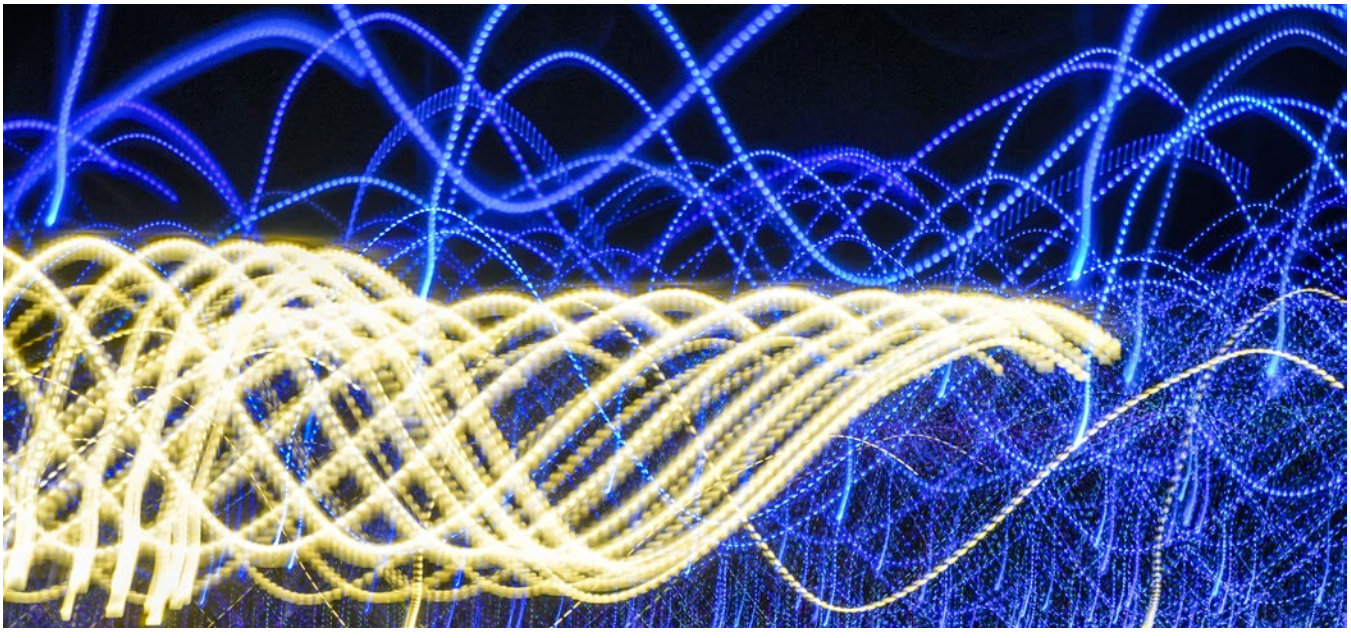
Now, researchers from the University of Cambridge, Imperial College London and Soochow University in China have discovered that new green materials currently being developed for next-generation solar panels could be useful for indoor light harvesting. They report their findings in *Advanced Energy Materials.*

"By efficiently absorbing the light coming from lamps commonly found in homes and buildings, the materials can turn light into electricity with an efficiency already in the range of commercial technologies," said co-author Dr Robert Hoye from Imperial College London. "We have also already identified several possible improvements, which would allow these materials to surpass the performance of current indoor photovoltaic technologies in the near future."

The team investigated perovskite-inspired materials, which were created to circumvent problems with materials called perovskites, which were developed for next-generation solar cells. Although perovskites are cheaper to make than traditional silicon-based solar panels and deliver similar efficiency, perovskites contain toxic lead substances. This drove the development of perovskite-inspired materials, which are instead based on safer elements like bismuth and antimony.

Despite being more environmentally friendly, these perovskite-inspired materials are not as efficient at absorbing sunlight. However, the team found that the materials are much more effective at absorbing indoor light, with efficiencies that are promising for commercial applications. Crucially, the researchers demonstrated that the power provided by these materials under indoor illumination is already sufficient to operate electronic circuits.

(University of Cambridge)



Integrated Optical Waveguides in Printed Circuits

Article by Happy Holden
I-CONNECT007

Editor's note: The original version of this article was published as a paper in 2006. This version includes updated information.

High density interconnect (HDI) printed circuits are now being designed in ever-increasing quantities for very high-speed applications. The challenge of opto-electronics and integration of photonics into the printed circuit has started to take off. With photonic integrated circuits forecast to grow at a CAGR of just under 40% through 2025[1], we can expect photonic circuit boards to keep pace.

This paper looks at the issues, materials and current processes being researched to create this integrated OptoElectronic Circuit Board by European, Japanese and North American organizations. In addition to reviewing the global players in polymer photonics, this paper will review the current programs of three groups globally:

- GuideLink™ (Dupont, HP, OpticalinterLink, USA)
- TOPCat (NIST, 3M, Goodyear, USA)
- Truemode (Terahertz-UK)
- OptoBump (NTT-JP)
- JIEP (JP)
  - * EOCB (Univ. of Ulm, Fraunhafer Inst, Daimler-Chrysler, Siemens, EU)
  - * Terabus Project (IBM, Avago, USA)
  - * Integrated Optical and Electronic Interconnect PCB Manufacturing (UK)
- PhoxTroT: Photonics for high-performance, low-cost and low-energy data centers, high performance computing systems: Terabit/s Optical Interconnect Technologies (EU)

Introduction

It is difficult in this paper to expose fully all the progress and details in optical board developments since 2003. A very good summary is found in the eBook, *Handbook of Fiber Optic Data Communication: A Practical Guide to Optical Networking*. Paper 26, "Optical Back-

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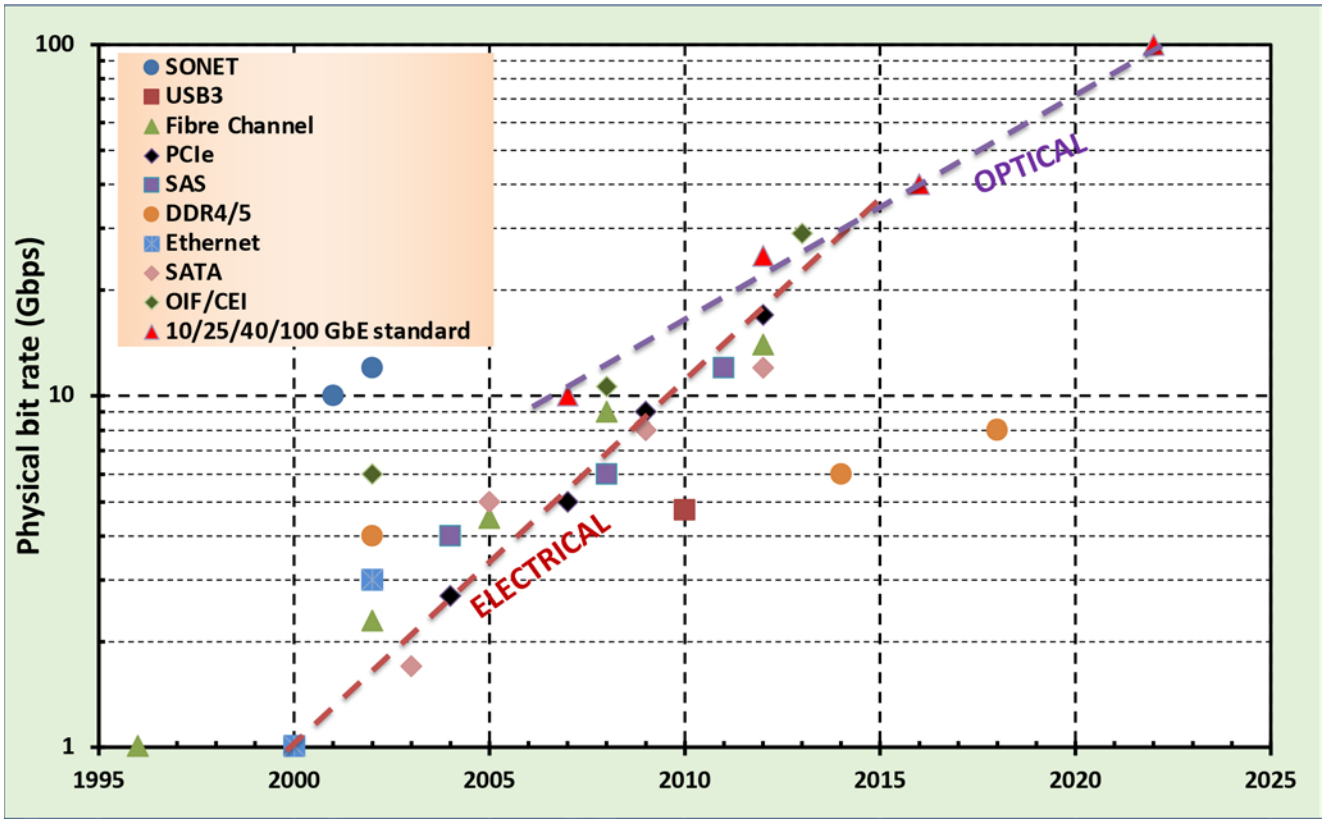


Figure 1: Internet bandwidth and IP traffic trends place a greater load on communication infrastructures. (Source: CISCO VNI, 2010)

planes, Board and Chip Interconnects," contains a very good summary up to 2008 and has 43 excellent references[2].

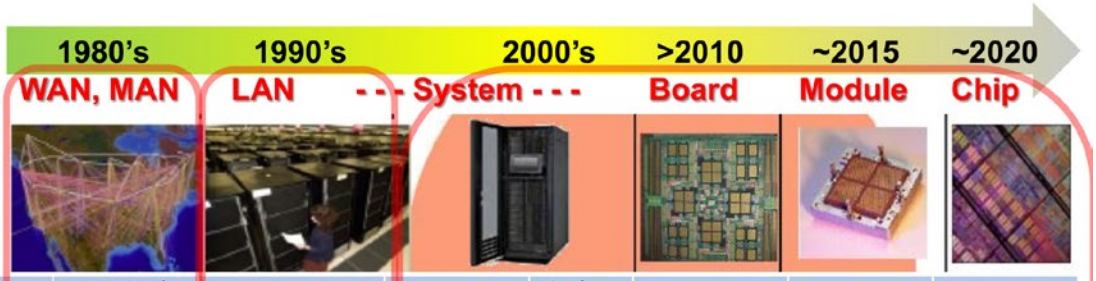
Opto-electronics printed circuits are based on HDI-microvia technology. In addition to the extremely high-frequency electrical signals, the need now includes the requirement for integrated-optical waveguides. Finally, increasingly restrictive cost targets are compounding problems associated with today's smaller, denser, lighter and faster systems. When working with opto-electronics, the need for the integrated waveguides is a major program.

Photonics and Electrical Performance

The performance of the conventional electrical interconnection technology is limited through the underlying physical properties. These are major hindrances to the five growing challenges in advancing electronics:

- Bandwidth of the internet for "packets"' and the growing volume of data (Figure 1)
- Challenge of the future for "massively parallel computing cores" needing to communicate
- Weight and power reduction for aerospace, space and automotive
- Limited data-rate-length product caused by attenuation and dispersion, mainly affected by the high frequency skin effect and the frequency dependent loss factor tan of the dielectric materials
- High number of single interconnects (pin-count) at component level and connector level caused by the limited data rate per single interconnect, and bringing chip I/Os up to the speed of the CPU

The popularity of wireless devices and increasing applications that demand high bandwidth have placed an enormous burden on the Internet. Take, for example, the per-lane data rates of the PCIExpress (PCIe®) interface that has increased from 2.5 Gbps for Gen 1.0, to 8.0 Gbps for the current Gen 3.0, and is



	Long-Haul, Metro	Local Area Networks	Rack-to-Rack	Card-to-Card	Module-Module	Chip-Chip	On-Chip Buses
Distance	Multi – 100s kms	10 m – 2 km	<10 m intra- <100 m inter-	<1 m	0.1 – 0.3 m	0.5 -10 cm	< 20 mm
# of lines	single	tens	100s	100-1000's	1000s	10,000s	100K-10M
Cost ($/Gbs)	1000	100	10	1	0.1	0.01	0.0001
Power (MW/Gbs)	500	50	10	5	1	0.5	0.05
Density (Gbs/mm²)	10^{-3}	10^{-2}	1	10	100	1000	10,000
Technologies	Internet Protocol, SONET, ATM	LAN/SAN Standard (Ethernet, InfiniBand, Fibre Channel)	Design-specific system buses, SAN standards (InfiniBand)		Design-specific. Some standards (PCI/PCI-X/3 GIO)	Standard and design specific components	IC design-specific
Optics or Copper	Optics ubiquitous since '80s or early '90s	Optics common since late '90s: Fiber standards in Enet, IB, FC	Optics coming in 2005-2010, with effort		Optics possible cost-effective vs. copper in 2010-2015	Standard components beyond 2012	Integrated optics beyond 2015

Telecom
Datacom
Computer-com

Figure 2. Breakdown of optical interconnects based on distance and structure. Terabus Program focuses on the "board" levels. (Source: ITRS)

expected to increase to 16 Gbps by Gen 4.0. Figure 1 shows the internet and IP traffic demand trends.

The IBM optical transmission roadmap is designed to meet this coming future need. For "cloud computing," the IBM Roadmap (Figure 2) shows the past progression of global networking, to metro/local networking, continuing down to rack-board-module and then chip.

To accomplish these higher speeds above 10 Gbps, optical connections seem to be the solution. The growth of optical interconnect cabling for IBM super computers, grew from 5,000 fiber cables in 2006 to more than 540,000 for the P775 in 2011. The next machine, Blue Water, will have over 5 million fiber-optic cables[3]. In these last two implementations, instead of the fiber terminating at the PCB card edge, the Agilent and Avago MicroPODTM optical connector actually extends onto the central-processor module (as seen in Figure 18).

The competition between electrons and photons (copper versus waveguide) is now down to the last 100 meters. Looking at a roadmap from the Terabus Program[4], the number of optical lines is increasing, along with the density of those lines, and correspondingly, the cost and power is coming down as well. Currently, the focus is on board-to-board channels of < 1 meter, < 10m for the "intra-system," and < 100m for the "inter-system."

Electrons Versus Photons

Why the focus on photonics? It's probably because Gene Rodenberry told us that was the technology of the USS Enterprise on Star Trek back in 1966! But aside from science fiction, the photon has inherent advantages over the electron. First, it does not generate magnetic fields, nor is it affected by a magnetic field, which is a big advantage in noise reduction. A second advantage is its density. It is much smaller and more compact than electrical cables. Third, individual tracks (waveguides) and connectors can be packed closer together without generating noise or crosstalk. These advantages are expressed by IBM's Optical Roadmap (Figure 3)[5].

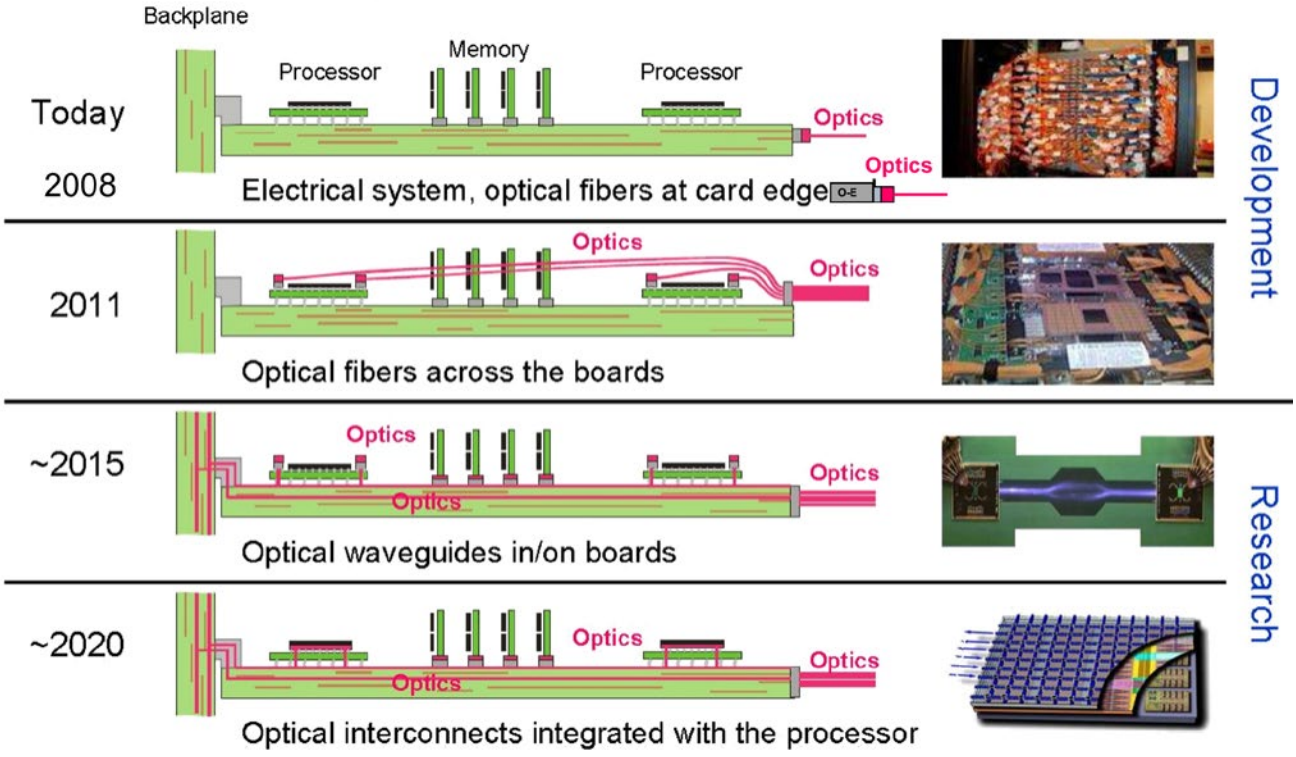


Figure 3. IBM Optical Interconnect Roadmap. (Source: IBM[4])

In 2006, their supercomputers used a single optical cable at the card edge, and multiple optical fibers to the card edge and across the board to individual connectors at the processors (Figure 3d—MicroPODs). Reportedly deployed in the 2015 timeframe were integrated optical waveguides on the card and backplane with optical connectors and sockets. The predictions were that by 2020, optical interconnections would be on the chip and between cores and memory, as well as board and backplane.

For the foreseeable future, systems will be a mixture of electrical circuits with high-speed optical and slower electrical data busses. This architecture is seen in Figure 4[6]. In the far future, the actual circuit elements may be photonic computing, memory, encryption and analysis as well as data distribution, effectively realizing the predictions of science fiction writers.

Photonics and Waveguides

While an electrical signal can be multiplexed on a single wire or trace, many laser frequencies can be multiplexed on a single waveguide. This results in a 1,000X increase in information handling while not being influenced by magnetic and electrical fields like electronic signals.

The integrated optical board and backplanes are predicted to have a steady growth over the years. The predicted growth forecast by ElectroniCast is that by 2020, the value of rigid and flex photonic boards will be $3,965 million. The need to route long-line optical signals in an efficient manner and at lower cost has created the interest in integrated optical waveguides and methods of optical routing. The current method of signal routing is to convert the optical signal to an electronic signal, interrogate it, switch it to its next destination, and then convert it back to an optical signal. All of this forms what the industry calls "Terabit Routers" and can require up to 42 large, complex multilayers. With integrated optics, this can probably be done by one or two unique PCB assemblies. The "board-to-board" optoelectronic system will probably look like the illustration in Figure 4.

It has to be considered that the design process is of the same importance within the val-

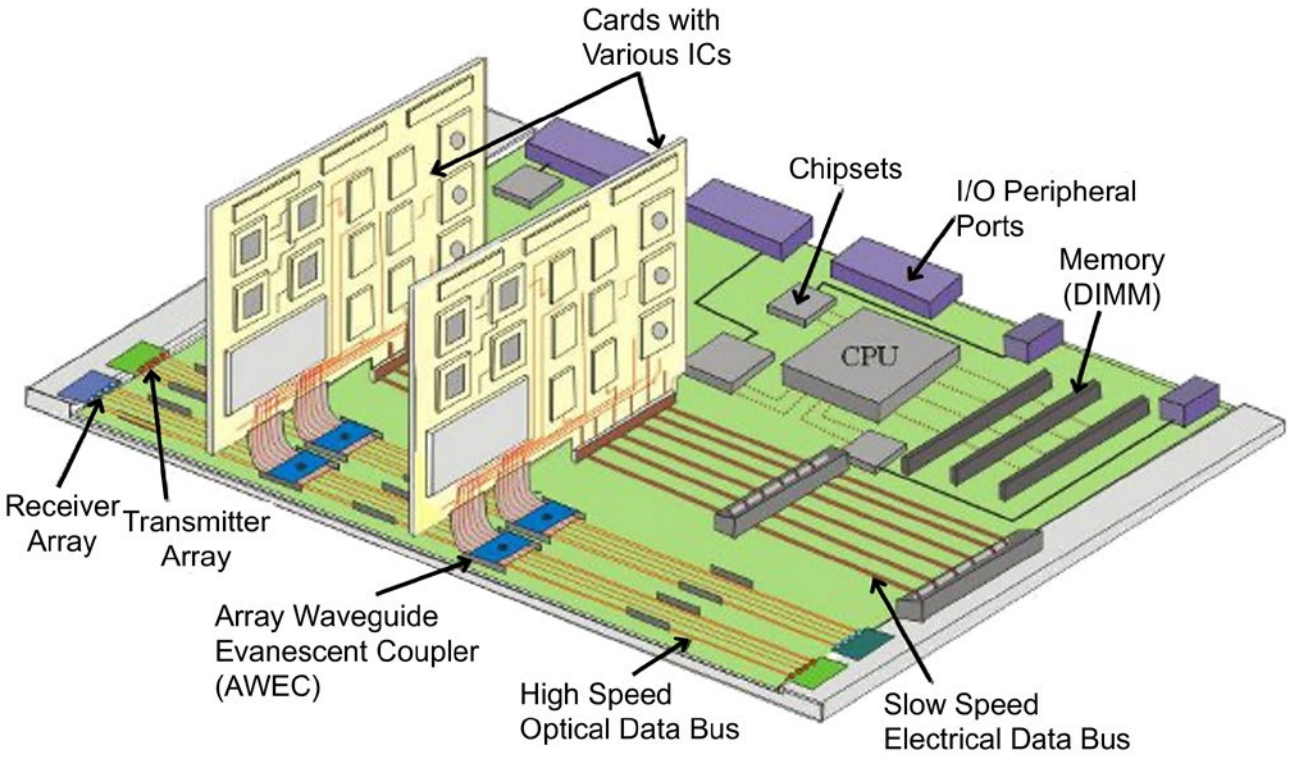


Figure 4. Board-to-board optical interconnections details including inter-connects.

ue supply chain as the manufacturing process. The most important components and manufacturing technologies to be developed are:

- Optical waveguides and techniques for integrating them into printed circuit boards
- Electrical-optical and optical-electrical converters for realizing optical transmitters and receivers, and
  - Robust coupling concepts to realize optical component-to-board connectors
  - Board-to-board connectors
  - Board-to-fiber connectors

The following tools, models, algorithms and methodologies are necessary to provide an efficient design of electrical-optical printed circuit boards:

- Simulation models and algorithms to enable time domain
- Simulation of optical interconnects
- Routing and general design rules for optical interconnects and entire electrical-optical printed circuit boards, and methodologies for the analysis and optimization of electrical-optical printed circuit boards in respect of functional, technological, and cost requirements.

Numerous techniques are under development for: multimode waveguide lamination, through-hole light coupling, surface finishes and soldering connectors.[7]

This integrated opto-assembly will have a number of factors new to PCBs:

- Optical waveguide materials
- 3D fabrication techniques
- New components
- 3D assembly techniques

Optical Waveguide Materials

The optical materials currently being considered for integrated waveguides are polymers. Polymers have a number of advantages:

- Stability—High thermal stability and long-term photostability. Bellcore Telecordia compliance (i.e., 1209, 1221) tested for > 600 hrs. at 85°C/85 RH, solder temperature > 230°C and degradation temperature > 350°C

Manufacturer	Polymer Type	Patterning Techniques	Waveguide Optical Losses (dB/cm)		
			840 nm	1300 nm	1550 nm
Allied Signal	Halogenated Acrylate Acrylate	Lithography, RIE Laser	0.01 0.02	0.03 0.2	0.07 0.5
Amoco	Fluorinated Polyimide	Lithography	-	0.4	1.0
Asahi	Epoxy-NanoSU-8-50	RIE	-	0.3	-
BF Goodrich	Polynorbornenes	RIE, Laser	0.18	-	-
Dow Chemical	Benzocyclobutene Silesquioxane	RIE Lithography, Laser	0.8 0.031	1.5 0.05	- 0.5
Dow Corning	Siloxane	Lithography, Laser	0.02	0.4	-
DuPont	Teflon AF	RIE	-	0.4	-
Exxelis	Halo-Polyacrylate	Lithography, Laser	0.025	0.4	0.8
Fujitsu	Polysiloxane	RIE	0.17	0.43	-
General Electric	Polyetherimide	RIE, Laser	0.24	-	-
Hitachi / NTT	Halogenated Acrylate	RIE	0.02	0.07	1.7
ILFA / Wacker	Polydimethylsiloxane	Lithography	0.023~.027	0.3	-
JDSU / R & H	Acrylate	RIE	0.015	0.110	0.6
Nippon Paint	Polysilane Film	Lithography bleaching	0.02	0.1	<1.0
Optical interLink	Acrylate Monomers	Lithography	-	0.6	-

RIE= Reactive Ion Etching

Source: Alcatel/Lucent Technologies, Loughborough University

Table 1: Candidate polymers for optical waveguides. (Source: Lucent Technologies and Loughborough University.)

- Well established—A huge body of data was obtained over the last 100 years on polymers including all the popular photoresists
- Useful—Unique properties you cannot get anywhere else (such as bend radius, modulators, and index tuning); and unique processing options (such as photolithographic, RIE, direct laser writing, molding, and printing)

Polymers also have a number of disadvantages:

- Unstable—Many have low thermal stability (POF below 80°C) with photodegradation and are sensitive to delamination, moisture and chemicals
- Unknown—New materials require new processes, equipment and experience
- Useless—Some polymers have losses of POF of 20 dB/km, while optical glass is < 0.1 dB/km. The packaging cost of polymers is 80% of the cost in devices

Candidate materials are acrylates, halogenated acrylates, cyclobutenes, polyimides and polysiloxane. Some of the most popular are listed in Table 1. The optical losses of the polymers (dB/cm) are in the lower wavelengths near 840nm.

Industrial Optical Waveguide Materials

Six materials have emerged in the literature from seven commercial companies:

- PDMS (polydimenthylsiloxane) from Wacker
- Chamie and Dow Corning- OE4140
- Photodefinable acrylate from Exxelis-Truemode

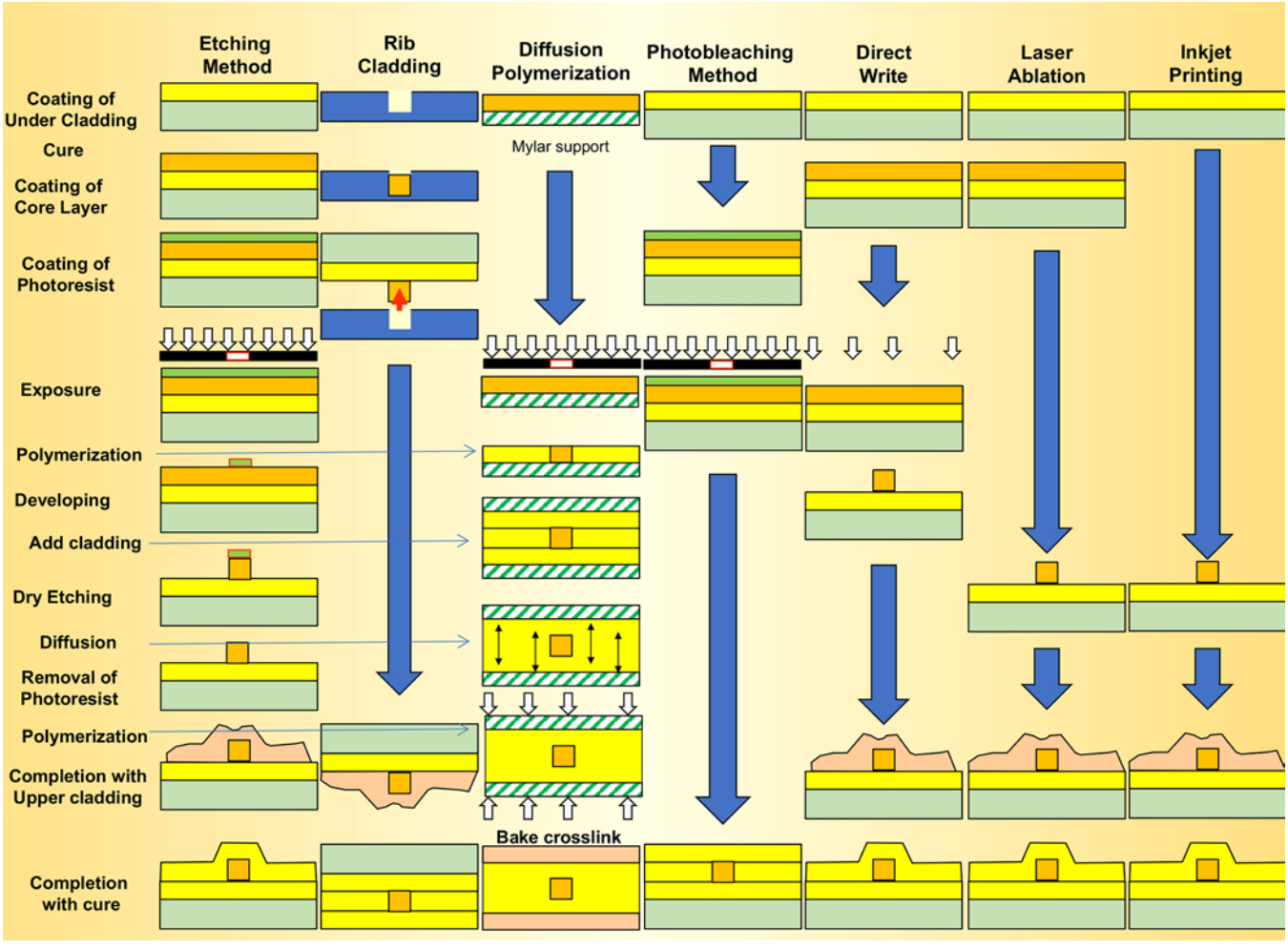


Figure 5: Seven processes for defining polymer optical waveguides.

- Photodefinable epoxy from MicroChem-NanoSU-8-50
- Photodefinable acrylate film from Hitachi Chemical
- Photodefinable acrylate monomer on Mylar from OpticalinterLinks called GuideLink™

Two waveguide materials seem to predominate: PDMS and acrylates.[8] The fabrication processes can be summarized in Figure 5.

EOCB (Electrical Optical Circuit Boards)

This work is part of the German projects Electrical/Optical Circuit Board and Opto-Sys, which are supported by the German government's Department of Education and Research (BMBF) under grants 16SV802/6 and 01BP801/01. (Dortmund, Ulm and the Fraunhafer Institute for Applied Solid-State-Physics in Freiburg are participating on a suborder basis.)

The progress in Germany is typical of that in the UK and USA, moving from the laboratory at universities to industrial companies building prototypes and the infrastructure. The EOCB (electrical optical circuit board) typified by C-Lab of Siemens in the last update is now replaced by commercial firms like VarioOptics AG of Villingen, Switzerland (spin-off of Varioprint AG of Heiden, Switzerland), and tested/qualified by Microtec GmbH laboratories [Pusch-2006]. Microtec tested and reported on the EOCB performance along with failure mechanisms and failure predictions. This provided new information for standards and prequalification actions.

Figure 6 shows this concept which provides the required compatibility concerning the design and manufacturing processes. It also en-

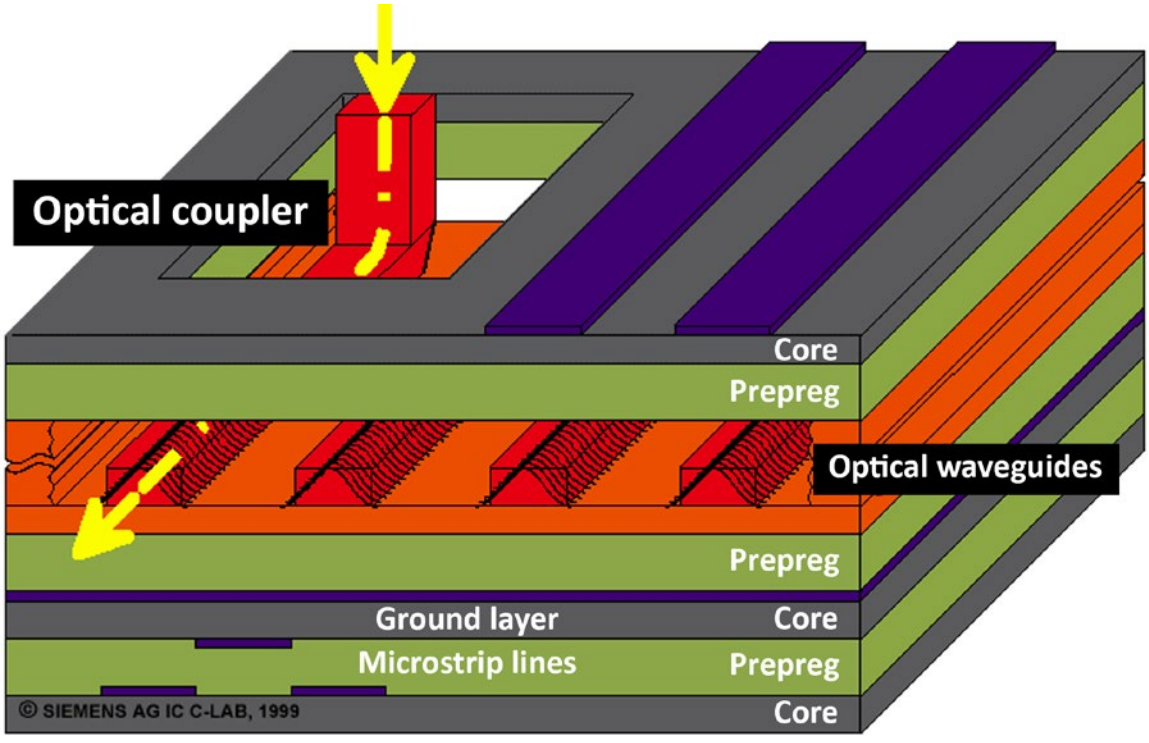


Figure 6: Concept of a printed circuit board with an integrated optical layer containing optical multi-mode waveguides.[6]

ables the required free optical routing. The optical waveguides are part of separate optical layers resulting in an EOCB.[6-10]

This process uses an embossing mold (shim) to hot emboss the foil structure of the waveguide. Topas, the optical material, fills the deformed core. After curing, the core is laminated into the EOCB.

A hot embossing process, which is one possible way of fabrication, is based on first manufacturing rib waveguides, which are laminated in a second step on a polymer substrate. Finally, the optical layer is obtained after filling with the over-cladding. In order to meet the high temperature requirements already mentioned, high-Tg materials such as COC or special polycarbonate can be used.

An example of the European program can be seen in Figures 7 and 8. These show the Siemens C-Lab test vehicle, called OptoSys, fabricated by a collaboration of Siemens AG, Infineon Technologies AG, ILFA Feinstleitertechnik Gmbh, Daimler Chrysler.

The EOCB is a consortium of Andus, Fraunhofer IZM Berlin, ILFA, Mikropack, OECA, Robert Bosch, Siemens and the University of Paderborn. They are now replaced by commercial firms like Vario-Optics AG of Villingen, Switzerland, and tested/qualified by Microtec GmbH laboratories [Pusch-2006]. Microtec tested and reported on the EOCB performance along with failure mechanisms and failure predictions.[11] This provided new information for standards and pre-qualification actions.

A new opto-interconnect program has started in the EU. PhoxTroT (Photonics for high-performance, low-cost and low-energy data centers, high performance computing systems, Terabit/s Optical Interconnect Technologies) is a two-year, $10 million Euro program to extend the performance of optical interconnections and infrastructure.

Integrated Optical and Electronic Interconnect PCB Manufacturing

In the UK, a large team of university and industrial companies collaborated under EPSRC's leMRC, and OPCB, namely University College London, (UCL) Instigator, Principal Investigator and Technical Project Leader; the School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh; and

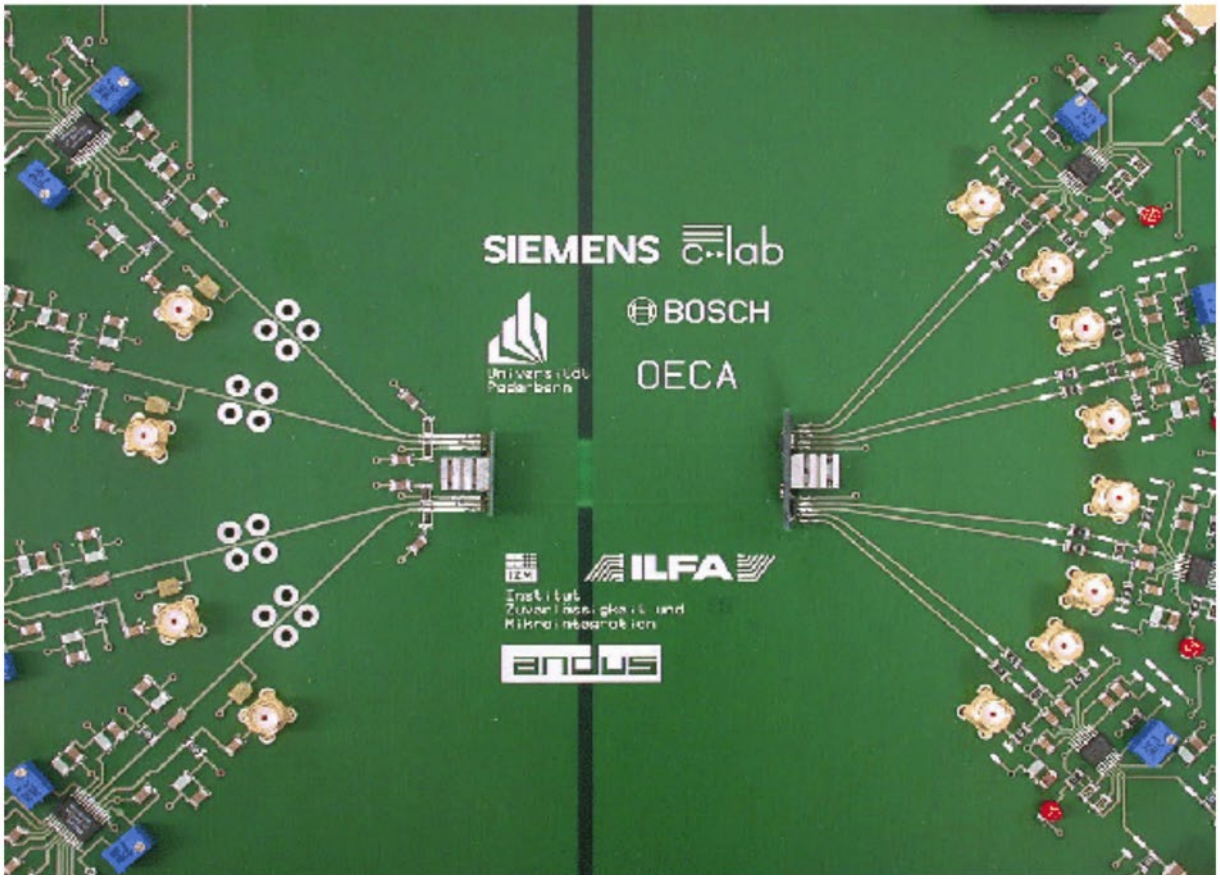


Figure 7. Siemens C-Lab test vehicle for optical waveguides.[6]

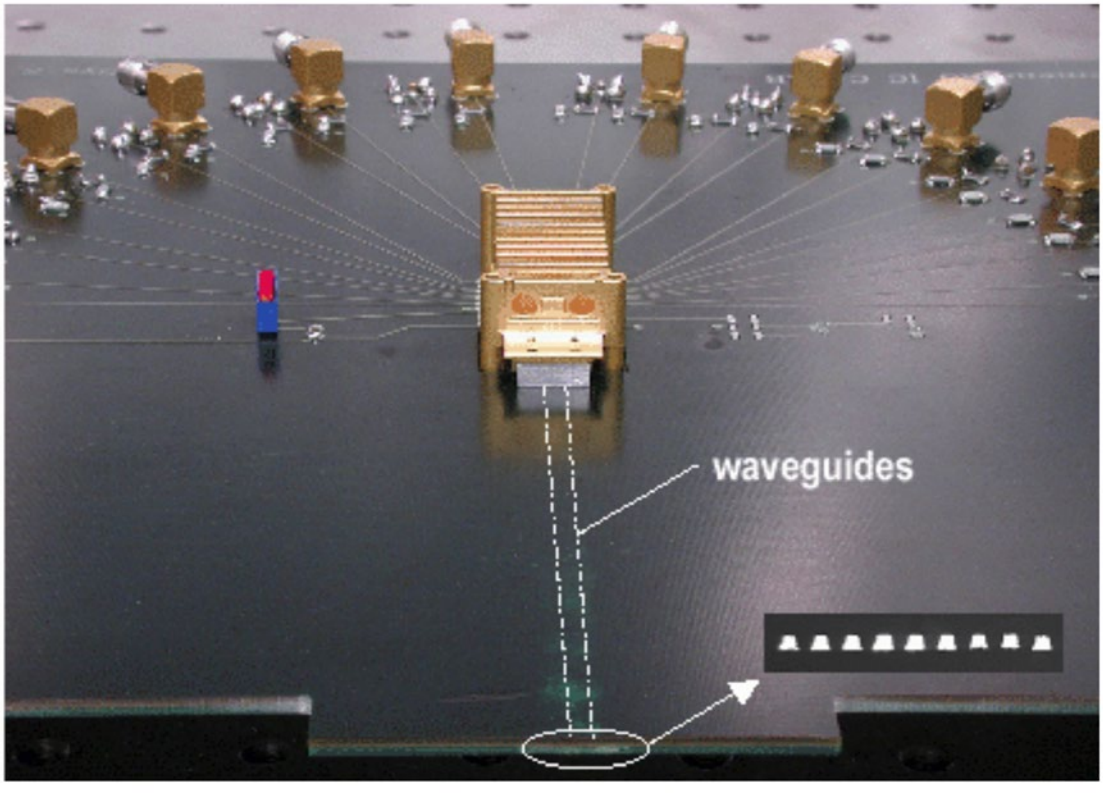


Figure 8. Close-up of the VCSEL laser transmitter for the Siemen's C-Lab test vehicle.

the Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University. They joined eight companies: Xyratex Technology (project manager and manufacturer of petabyte data storage systems); BAE Systems (global aerospace, security and defense company); Renishaw, Dow Corning USA (polymer supplier); Exxelis (polymer supplier); Stevenage Circuits Ltd. (PCB manufacturer); Cadence Design Systems (PCB layout software supplier); and National Physical Laboratory (national standards laboratory).

The simple research in polymer waveguides that started in 1998 at Heriot-Watt University is now a very large program involving four UK universities and ten industrial firms. The current reference [OPCB-12] has no less than 35 references published from 2005 to 2010. The purpose of this program is to develop manufacturing techniques for integrated optical and electrical interconnects in standard FR-4 PCBs. In particular:

- To establish waveguide design rules for several different manufacturing techniques and to incorporate them into commercial design rule checker and constraint manager layout software. PCB designers can easily incorporate optical connection layers without detailed knowledge of the optics involved in their designs
- To investigate and understand the effect of behavior of light and the effect on waveguide loss
- To develop low-cost manufacturing techniques for OPCBs. To develop and to compare the commercial and technological benefits of several optical PCB manufacturing technologies—photolithography, direct laser writing, laser ablation, embossing, extrusion and ink-jet printing—for high-data rate, small and large (19 in.), rigid and flexible PCBs so that it will be clear which technology is best for each type of PCB
- To characterize the behavior of optical waveguide backplane systems in real-world conditions, including temperature cycling, high humidity, and vibration
- To design a commercial, low-cost, optical connector (dismountable, passive, self-aligning and mid-board) as the next stage from the prototype demonstrated in an earlier project (Storlite Project) (Figure 9)
- To develop novel connector designs suited for interfacing flip-chip lasers and photodiodes to OPCBs, and OPCBs to OPCBs through a right-angle connector

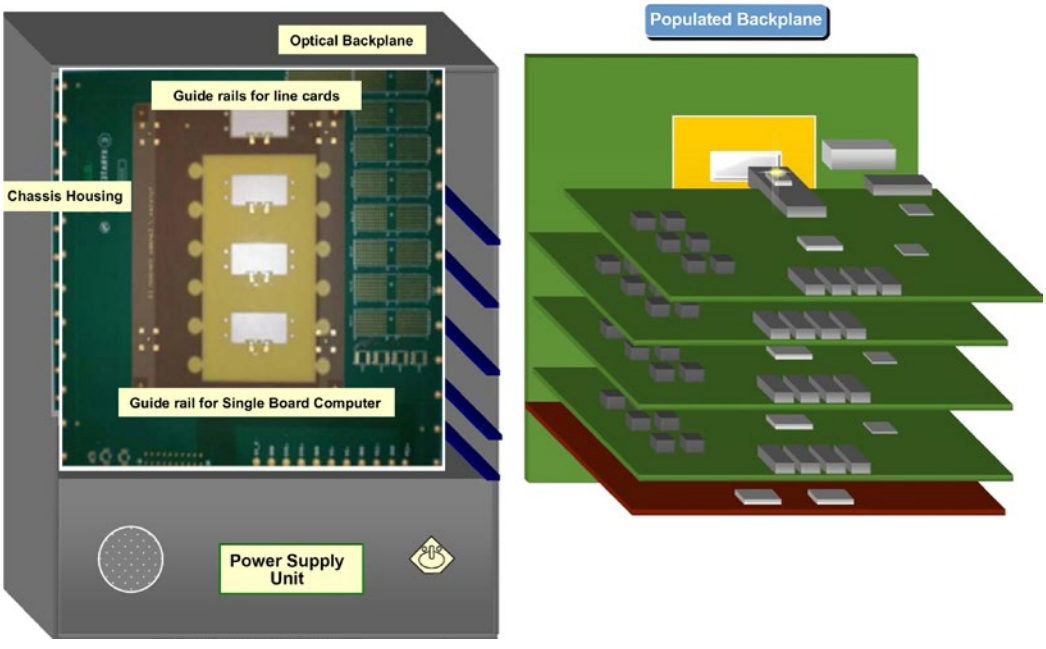


Figure 9. Demonstration of optical backplane and optical connector components.

Loughborough University is developing and testing polymer waveguide fabrication methods including:

- Direct laser write
- Laser ablation
- Inkjet printing

The fabrication process is done by Stevenage Circuits and assembled by Xyratex.

This culminated with the building of a hybrid integrated optical and electrical inte connected test system backplane incorporating multiple layers of copper tracks and polymer waveguides to demonstrate bi-directional error-free interconnections using 10 Gb/s ethernet digital traffic, as seen in Figure 10.

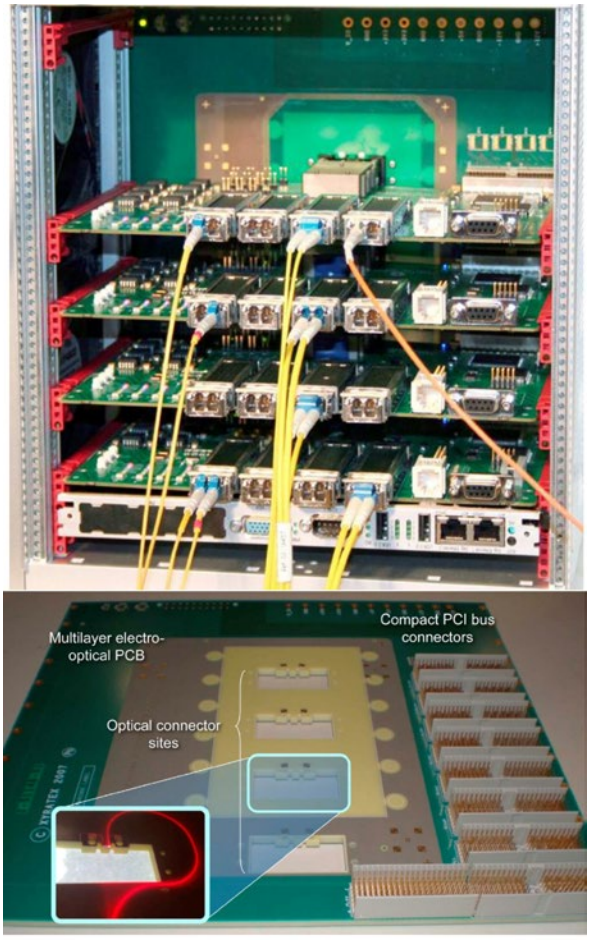


Figure 10: The [OPCB-12] Project finished test system with daughter cards (8x8 crosspoint switches), optical array connectors and mating optical connector in the multilayer electro-optical midplane. The closeup of the midplane shows the cut-outs for the optical connections and waveguide path.

Terabus Project (IBM's Optocard)

IBM Research has invested heavily over the years in optical printed circuit board technology based on multi-mode polymer waveguides. This is now referred to as Optocard. This research was partially funded by the U.S. Government (DARPA) as the Terabus Program [4,9]. IBM believes this technology will be needed to provide the bandwidth for future server generations (clouds), allowing highly integrated electrical-optical links of waveguides, flex and fiber between systems, modules, boards, and chips. Agilent (withdrew in 2005), Emcore, HP Labs and Avago also participated. A typical high-performance computer (HPC) has a chip-module-board structure seen in Figure 12a. The bandwidth limits are characterized in Figure 12b. The electrical packaging technology is mature and there is not enough space or pins (including per-pin BW) to get past the "chokepoint" at the module-to-circuit board interface, which is only 12.6 Tb/s. What is needed is a more miniaturized structure proposed in Figure 12c, using optical TX and Rx along with waveguides (OE Modules) and optical bussing on the PCBs. This raises the

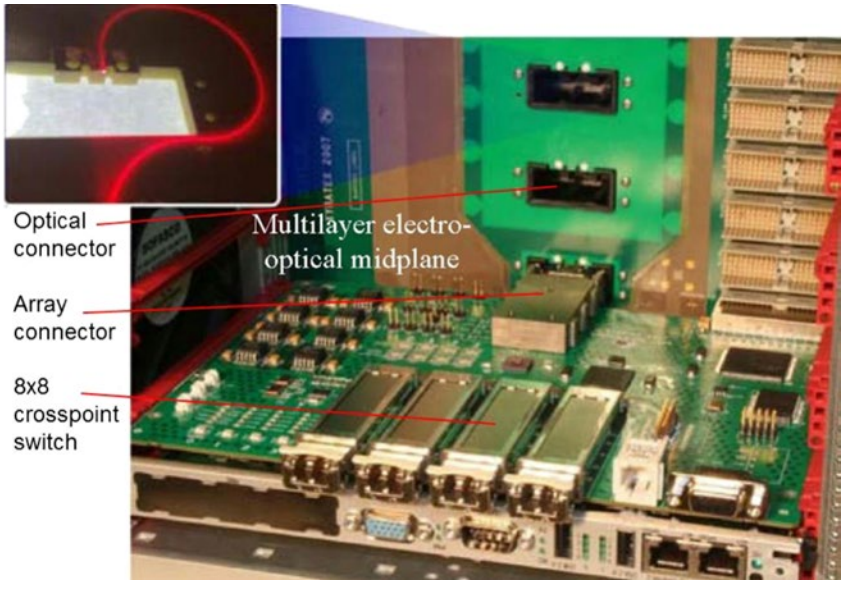


Figure 11, OPCB-12 UK project.

bandwidth to 76.8 Tb/s. The organic OE Module is seen in Figure 12d[11].

IBM's OE Module progression is detailed in Figure 12. The goal is EXABIT computing (1015 bytes/sec) and on the short term from 2008 to 2012, the progress for the Optochip from 240 Gb/s to 480 Gb/s. The second step uses the OPCB with the polymer waveguides and the third step includes direct optical connections to the OE Module.

Which brings us back to where we are today. A look back at Figure 3 shows the progression from 2008 to the current architecture of the P775 supercomputer. The optical interconnects go directly to the processor module and use a 48 channel times 4 (48x4) operating at 12.5 Gb/s. These are supplied by Avago and, soon, others. This allows the nearly 540,000 optical channel connections required for the system. BLUE WATER will require over 5 million optical connections.

The optical connections and cables are seen in Figure 13. This 192-channel flexible waveguide is an optical backplane operating at 850 nm and 12.5 Gb/s. The flex material is polyimide with 12 WGs per tail with 250 nm pitch.

The fabrication of the Optocard flex cables and rigid waveguides was conducted by Endicott Interconnect Technologies (EIT) of Binghampton, New York[12]. These were fabricated by direct deposition of the waveguide material (Dow Chemical XP-5202A) onto a hybrid PCB substrate of Upilex polyimide with a layer of resin-coated copper (RCC) laminated on both sides and to a frame. The copper is etched away to leave the resin bonded to the Upilex. This resin improves the adhesion of the wave-

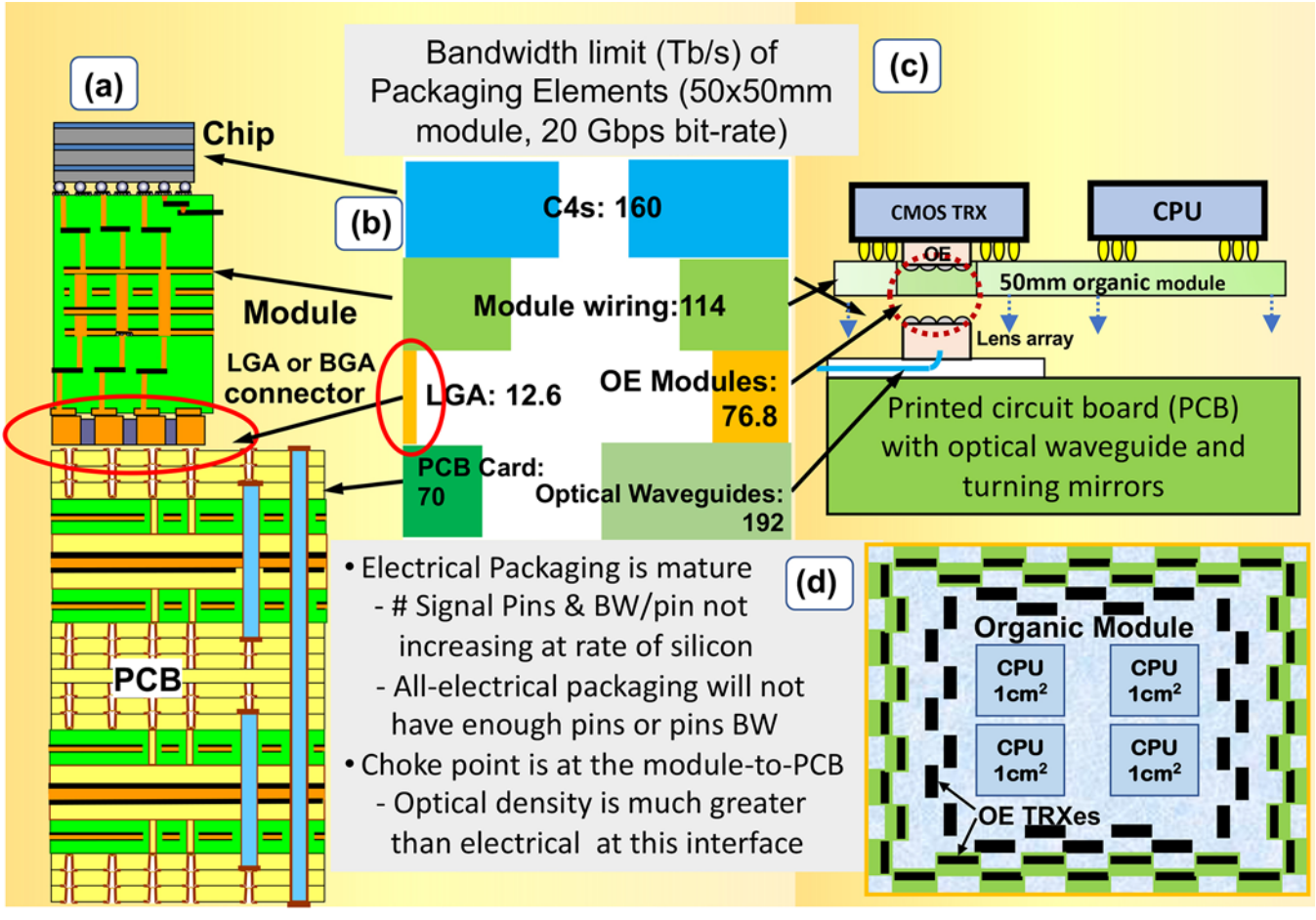


Figure 12: (12a) Structure, (12b) performance (bandwidth limits) of 'chip-module-board' structure, which is only 12.6 Tb/s for today's structure. What is needed is a more miniaturized structure proposed in (12c), using optical TX and Rx along with waveguides (OE Modules) and optical bussing on the PCBs. This raises the bandwidth to 76.8 Tb/s. (12d) The organic OE Module.

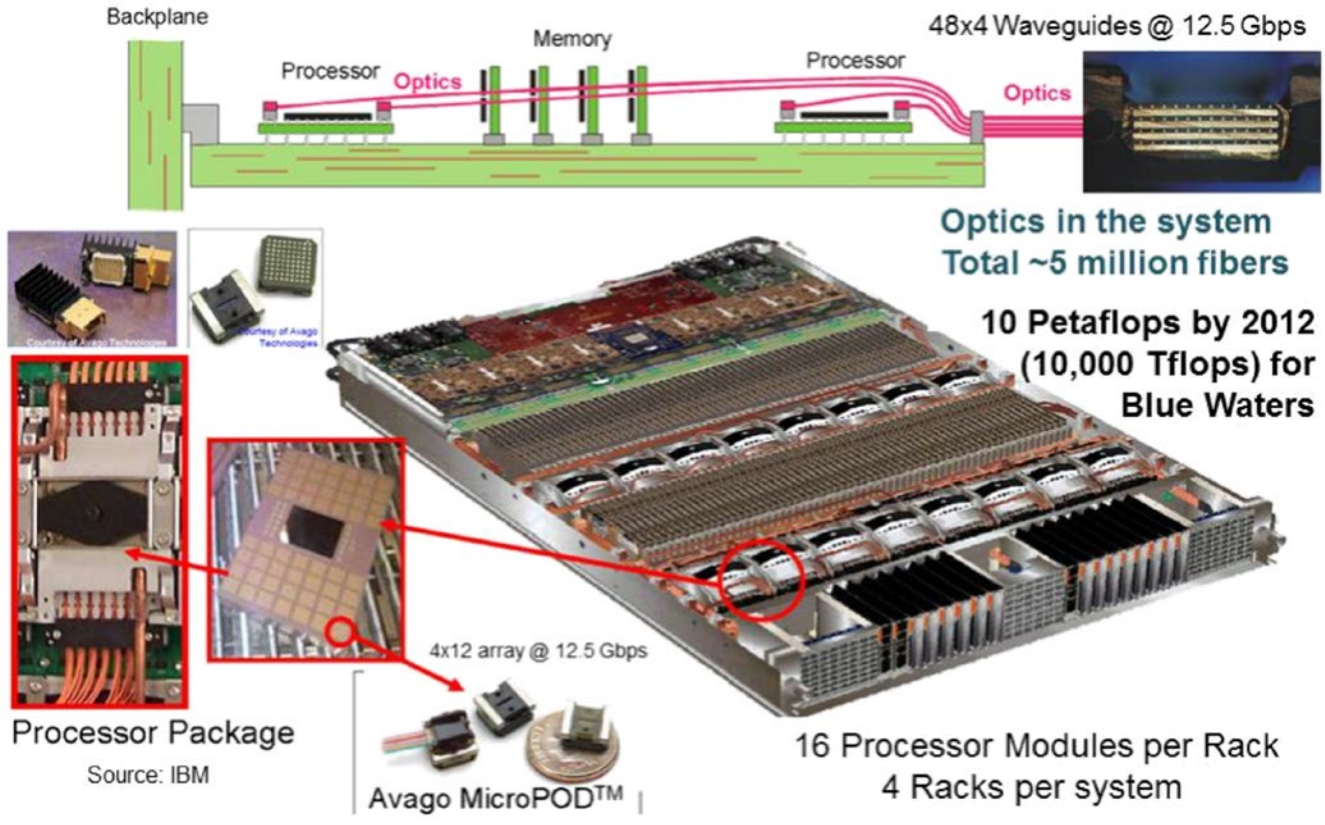


Figure 13: IBM opto packaging strategy: a 2011 strategy of grouped waveguide cables to CPU Modules, CPUs processor package and Modules that individual MicroPOD optical connectors rack with 16 Processor Modules: 4 racks per system. (Source: IBM) [17]

guide material. After the copper is etched from the backside, the top side is circuitized with copper pads.

The Terabus project wants to create a dense, hybrid packaging structure made up of "Optochips," "Optomodules" connected with flexible waveguides to create the "Optocard" with additional waveguides in a backplane between Optocards. This is shown in Figure 14. The future vision is for an "optically-enabled MCM" as seen in Figure 3d (~2020 Roadmap figure) with performance projected into the 2014 to 2016 era[9].

Other flex optical cabling is ThunderBolt from Apple. Similar to Intel's LightPeak, Thunderbolt is a combined electrical/optical connection standard.

Figures 14a, b, and c show these flex polymer waveguides in the Optocard. A frame is employed to address the need of flat working surfaces that are required during optical fabrication, as seen in Figure 14a. The flex assembly is aligned to the Optomodule and Pyralux and is used to laminate them together. The entire assembly is then baked under pressure to cure the Pyralux. The fully assembled structure is shown in Figure 14b. The attachment process is repeated at the other end of the waveguide flex to complete the Optocard, as seen in Figure 14c. EIT also employed inkjet printing of the waveguides successfully [11].

The Terabus Structure consists of the Optomodule connected to the HDI PCB (Optocard seen in Figures 15 and 16a), with integral or flex waveguides (Figure 16b), patterned by the process in Figure 16c and showing its cross-section seen in Figure 16d, e, f, and g. The Optomodule is an organic HDI chip carrier (known in IBM as SLC) with the Optochip containing optical VCSEL and PD chips aligned by Optochip lens array to waveguide lens array on the Optoboard.

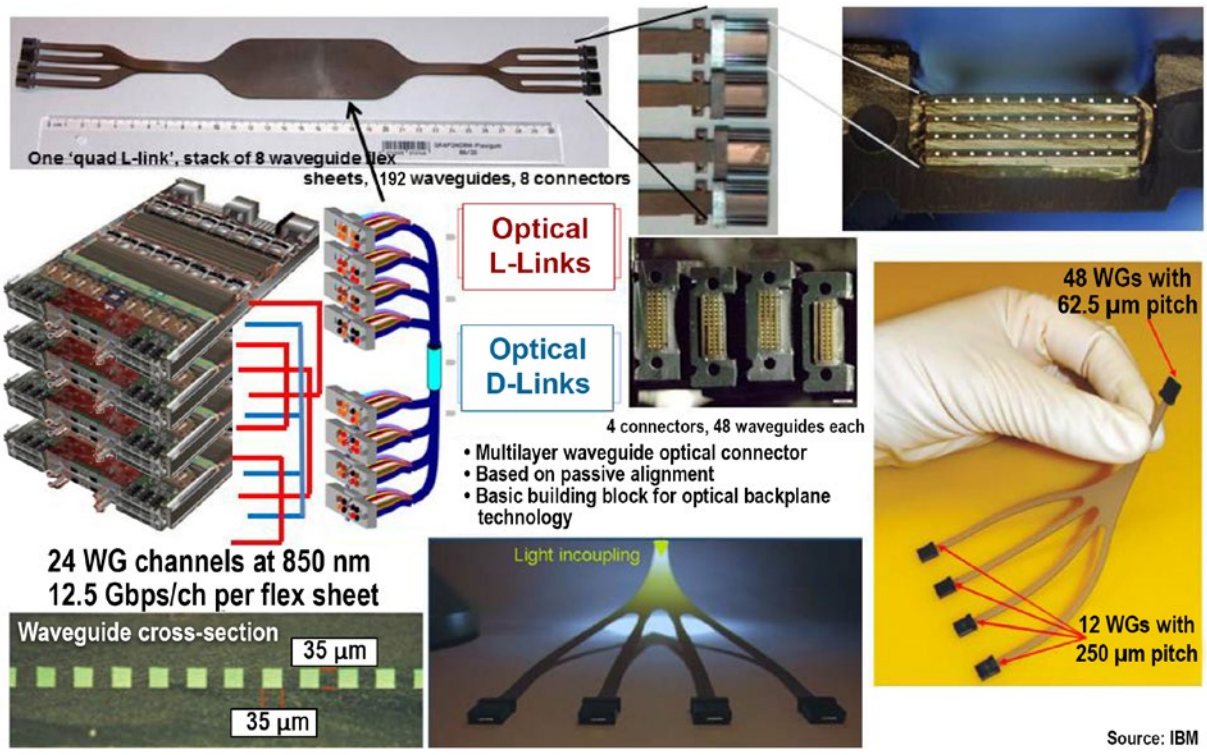


Figure 14: The details of the optical cabling and backplane consisting of 192 waveguides, fabricated as eight flex conductor sheets of 24 WGs, divided into four connectors with 48 waveguides each; the L-Links and the D-Links operating at 850 nm and 12.5 Gbps [13].

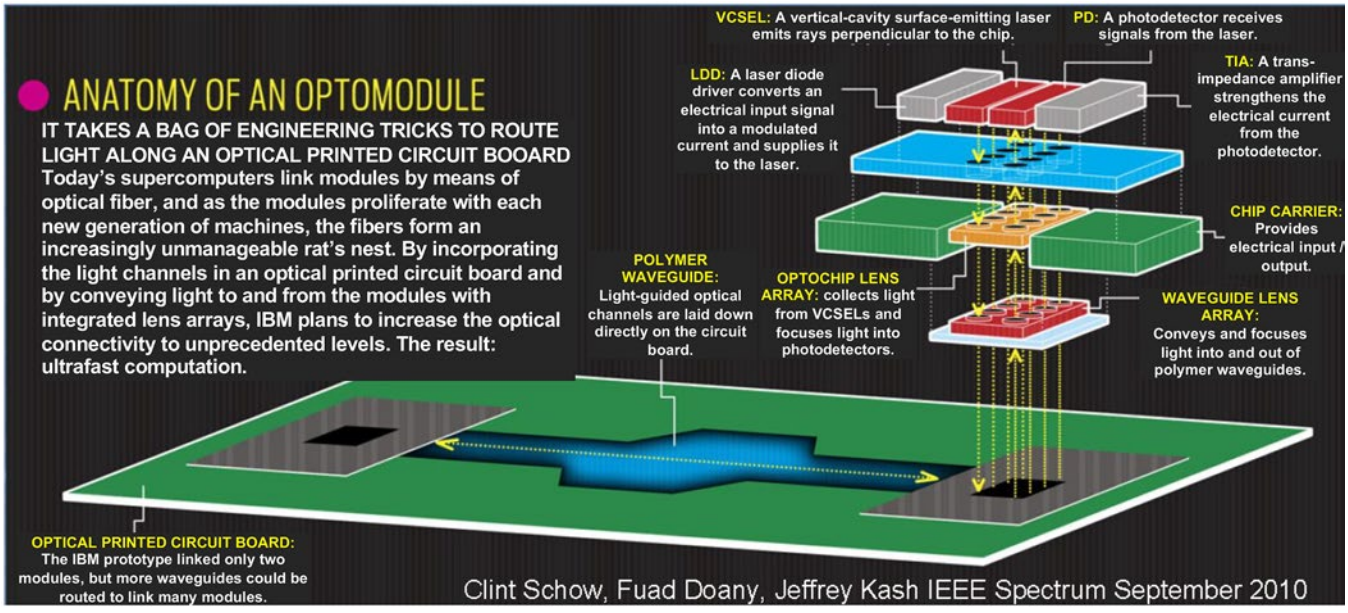


Figure 15: The details of the optical system IBM is working on Optochip, Optomodule and Optocard connected by the polymer waveguides [13].

3D Assembly Techniques

With these new optical components, new 3D assembly techniques are going to be required. Many optical components require micron-level tolerances to create the proper optical alignment. Key to these assembly capabilities will be the Z-axis plateau tolerances of the printed circuit. X-Y-angular alignment will be new kinematic mounts that provide micron-precise alignments.

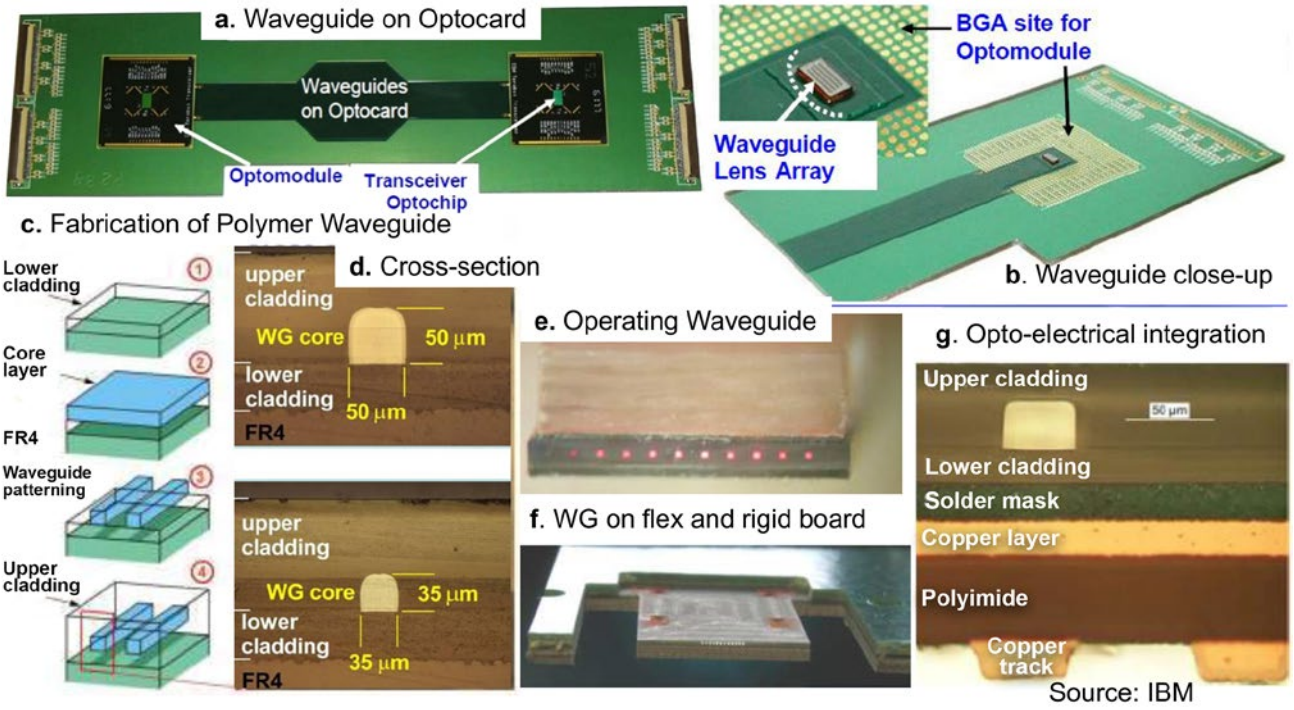


Figure 16: Optocard fabrication. (Waveguide on Optocard, 16a), with integral or flex waveguides (16b), patterned process, 16c; cross-sections 16d; operating waveguides in the rigid board, 16e and f; and opto-electrical integration cross-section, 16g. The Optomodule is an organic HDI chip carrier (known in IBM as 'SLC') with the Optochip containing optical VCSEL and PD chips aligned by Optochip lens array to waveguide lens array on the Optoboard. (Source IBM)

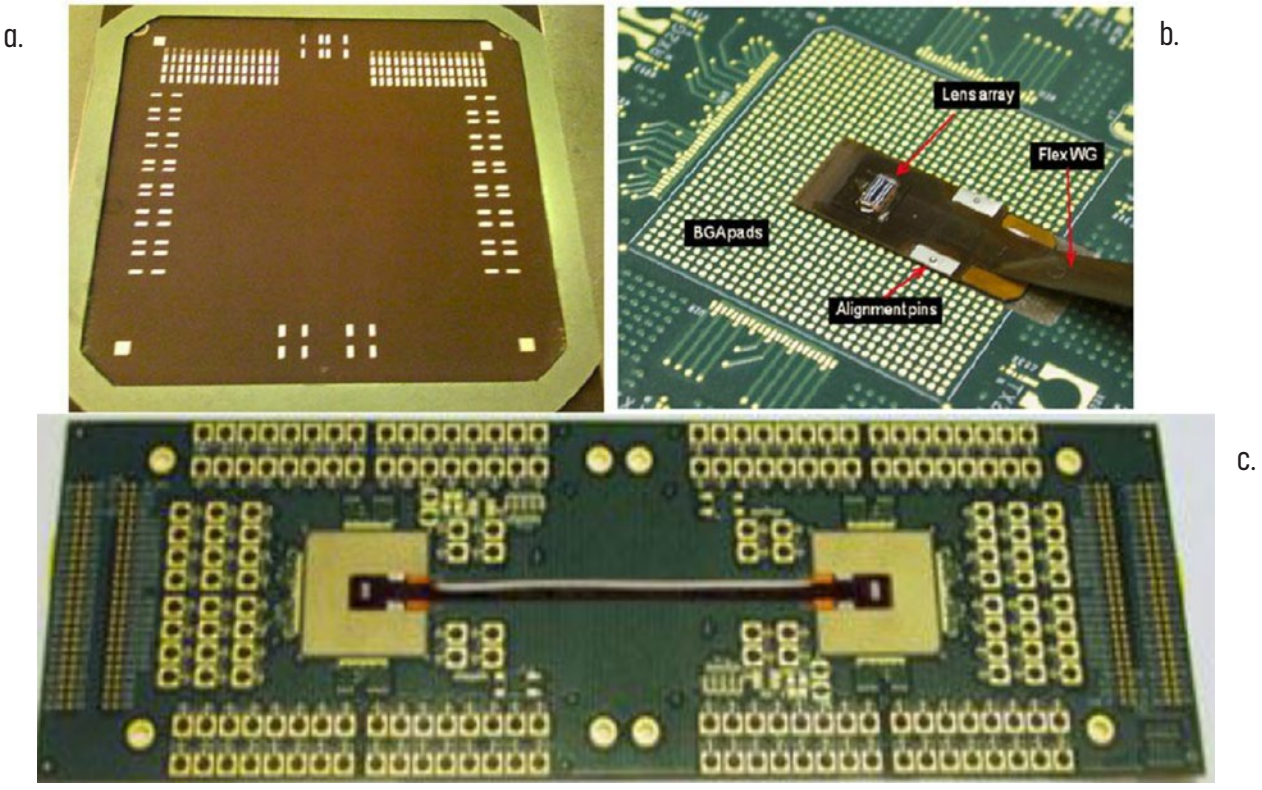
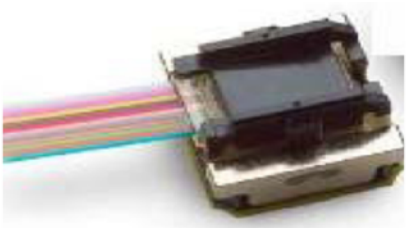


Figure 17: Optocard with flex waveguide attached (a) flex waveguide during fabrication; (b) waveguide laminated to Optomodule; (c) completed Optocard [10].

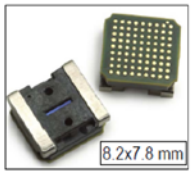


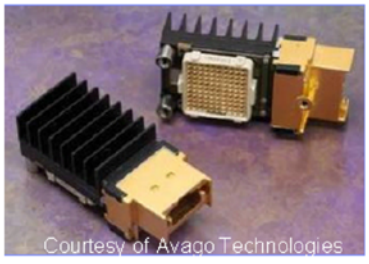
Provides Some MicroPOD details; close ups of the bottom BGA pattern; a top view without the 45° connector and ribbon fiber; an array of MicroPODS with the ribbon fiber and connector illustrating the fiber management.

The MicroPOD features include:

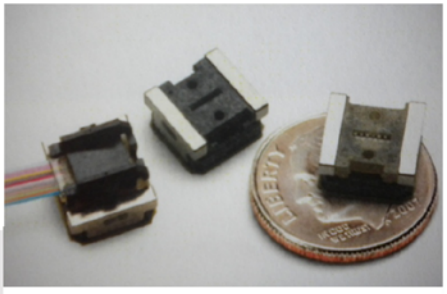
- Footprint is 7.8 mm x 8.2 mm
- 2 types are made; Tx and Rx
- Consumes 25mw/Gb/s
- 81 I/O in a grid array footprint
- 12 multimode fiber ribbon
- US Conec optical connector
- Light turned 90 degree in an optical element that interfaces with the connector
- 850 nm VCSEL for each channel
- Photodetector for each fiber ~ 1.5 watts/ module
- If mounted in an array, the ribbon fiber stacks nicely

- >10-Gbps 12-channel transmitter and receiver modules.
- Avago 850-nm VCSEL/PIN technology
- Avago-designed IC's for superior signal integrity and extended feature set
- Novel top-attach PRIZM™ LightTurn™ optical connector by USConec for cost (vs MPO/MTP™), fiber management, and dense tiling.
- µLGA electrical interface for signal integrity and density
- Full digital diagnostics.
- Optimized for dense high-bandwidth applications with tight coupling to the host IC.





Avago is the semiconductor spin-off of Agilent & Agilent was spun out of Hewlett Packard in 1998



A close up shot of the top of the MicroPOD with and without the 45° connector and ribbon fiber.

Figure 18: Additional discreet components are also part of the integrated optical waveguide systems. Eight parabolic mirror structure, pluggable optical connector and FPGA optical interfaces.

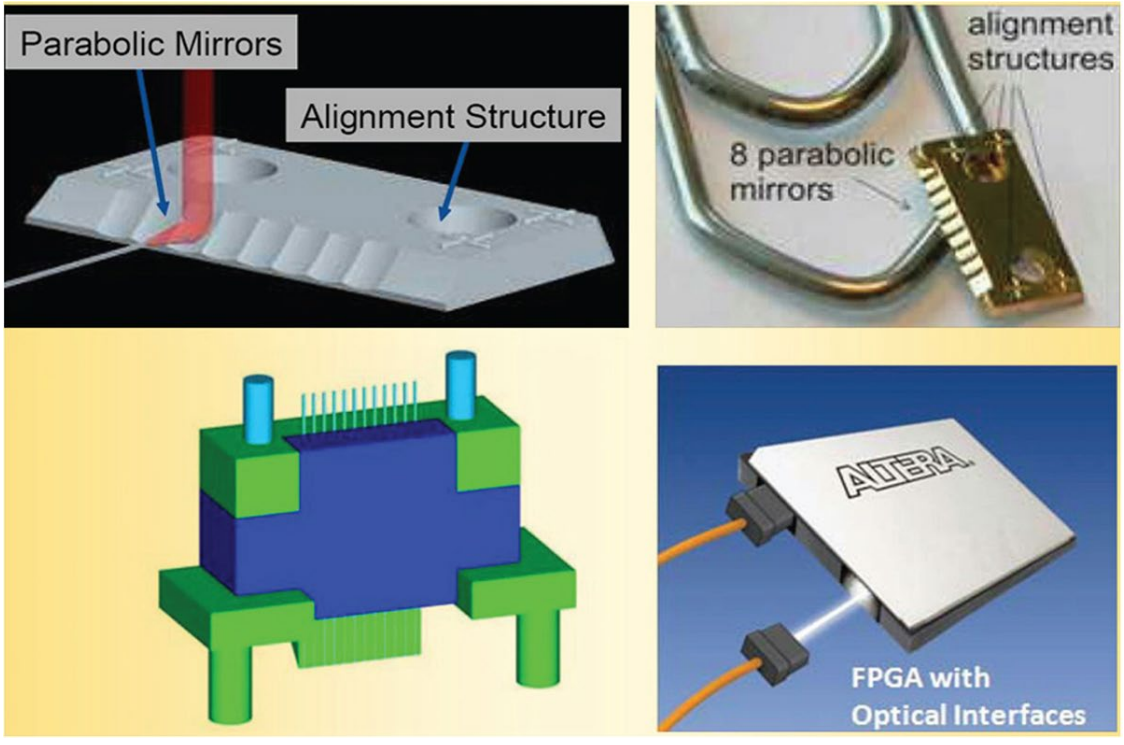


Figure 19: Additional discreet components are also part of the integrated optical waveguide systems. Eight parabolic mirror structure, pluggable optical connector and FPGA optical interfaces.

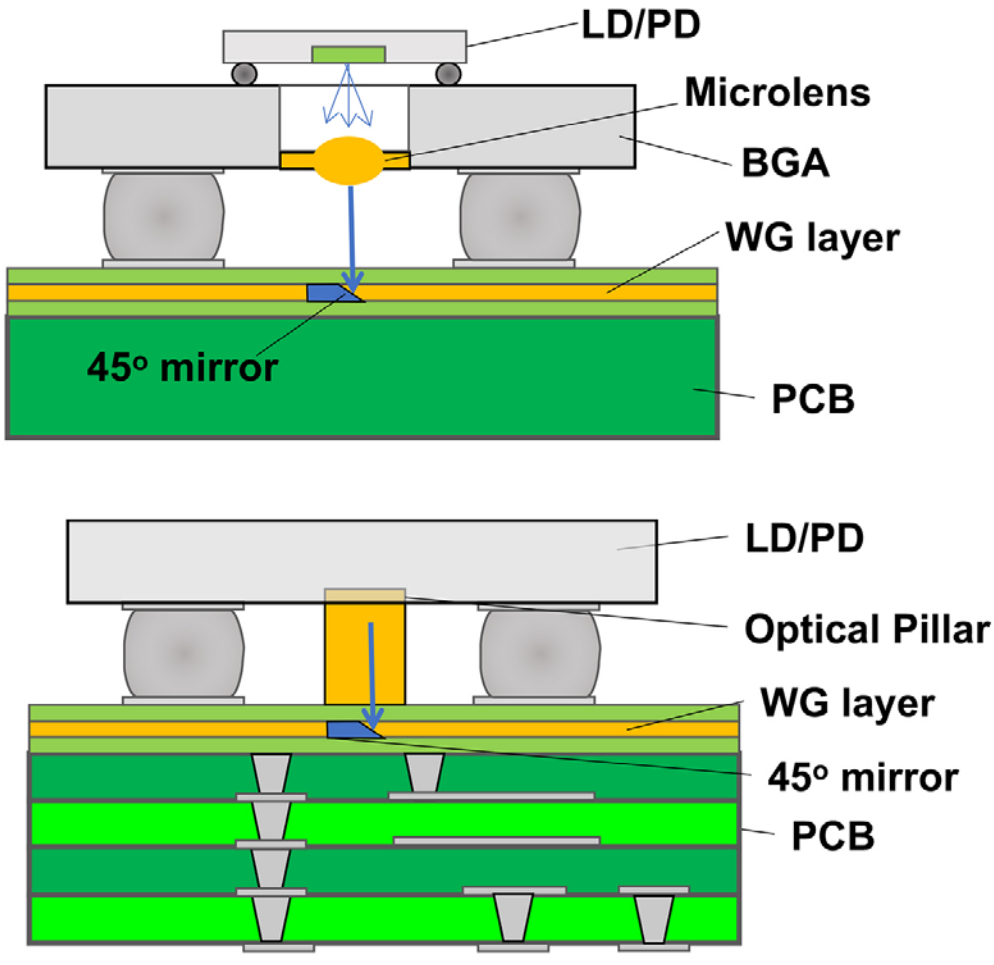


Figure 20: Alignment of VCSEL and the mirror in an embedded waveguide will require a new level of SMT precision. Various approaches are being researched to find the most cost effective.

As mentioned, the "integrated waveguide" is a major fabrication challenge, but equally as challenging is the "alignment" of the VCSEL lasers and the optical sensors to the embedded PCB waveguide. This was addressed by UCL and Xyratex in the UK (Figure 19).

Embedded optical waveguides in printed circuits have progressed aggressively in the last few years due to cooperation between university and industrial partners. There are now several polymer materials available, several fabricated by industrial firms capable of building these boards in production. The 10 Gb/s threshold per channel has been achieved and now the 16 Gb/s and 25 Gb/s are in progress. Soon, the 40 Gb/ s channel will also be achieved.

A second, but similar approach was used by IBM for their 12x10 Gb/s optical link demonstrator (Figure 20). A high-speed flex-cable containing the silicon optical components (VCSEL or photodiodes-TIA) are passively aligned with MT fiber ferrules.

Conclusion

Telecommunication rates continue to improve; long-line optical communications is the standard. The challenge now is to bring faster optical communications rates into the Metro area and to the individual or commercial user.

The performance limitations of electrical interconnections and wires (traces) due to their physical field limitations can be overcome with optical interconnections. The basic technologies are optical waveguide materials, waveguide fabrication, low-cost optical components (transmitters and receivers) and optical assembly. These technologies can be made compat-

ible with existing printed circuit board design and manufacturing processes and tolerances. Soon both electrical and optical interconnections can be fabricated into a single board with significant improvement in end-product performance. **PCB007**

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Further Reading

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

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A Process Engineer's Guide to Etching Defects, Part 3

Trouble in Your Tank

by Michael Carano, RBP CHEMICAL TECHNOLOGY

Introduction

While troubleshooting everyday processing issues, final etching touches on many downstream processes. These include surface preparation, imaging, and copper surface quality. There are concerns with the etching process itself and how process issues and operating parameters impact the circuit formation quality. In this month's edition of "Trouble in Your Tank," the subject of etch-outs, undercut, and line width reduction will be presented.

Overview-Etch Factor and Undercut

Electrical engineers and circuit board designers are not thrilled if, as fabricators, you don't give them the line width and spacing (as well as the circuit geometry) that was initially intended. Issues such as undercut and overetching will detract from the circuit trace quality. However, the constant battle is minimizing undercut while ensuring the unwanted copper is completely removed during the etching process.

Let's discuss the difference between the undercut and etch factor. The undercut is the difference between the width of the developed resist line (it could also be the design line width) and the final width of the etched circuit across the top. Expressed another way, undercut is the amount of copper that was removed laterally as the etchant did its job of eliminating unwanted copper as it etches downward (Figure 1).

The etch factor is the ratio between the difference in the widths of the copper trace at the most expansive and narrowest parts of the feature after etching is completed and the metal's thickness (copper) etched. The etch factor can be easily expressed as a ratio by dividing the copper's thickness etched downward by the amount of copper removed laterally.

Please note that Figure 1 describes conditions related to print-and-etch (typically known as

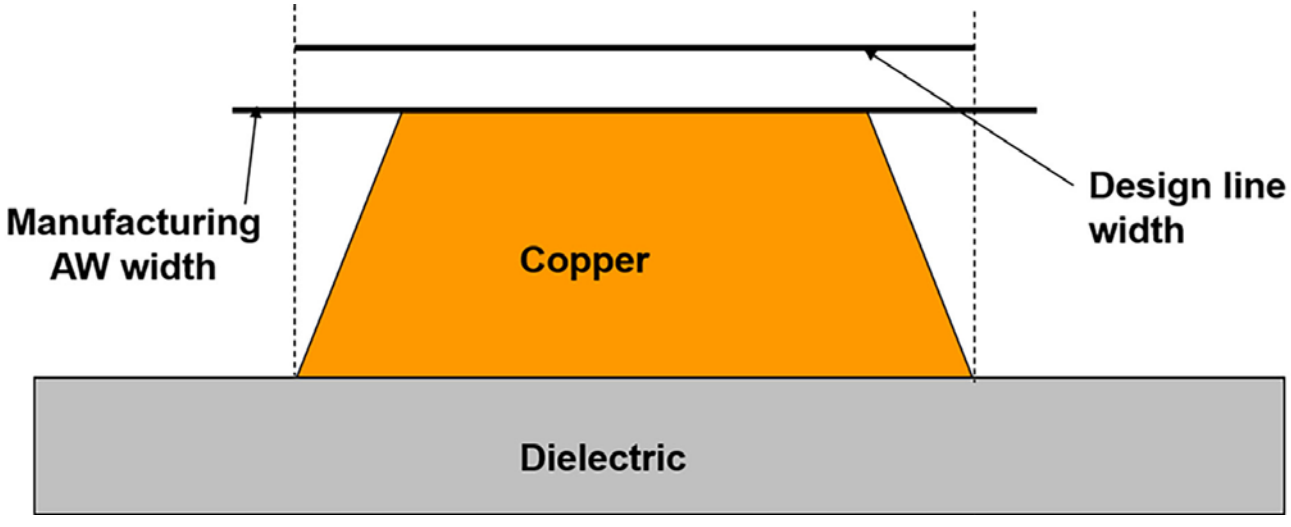

Figure 1: Illustration of undercut (AW = adjusted width in artwork if allowed).

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Figure 2: Illustration of undercut related to outer layer. Note metal etch resist overhang.

image-develop-etch); the same concepts apply, only with a slightly different twist where outer layer technology is concerned. With a metal etch resist and final etching as typically seen with outer layer technology, undercut continues to be an issue. However, excessive undercut and the overall etch profile (Figure 2) leads to the overhang of the plated etch resist. The concern here is the excessive undercut may allow a metal sliver to break off during processing and cause additional issues, such as a short. Regardless, the factors at play remain the same.

One can review the requirements in the IPC-A-600 detailing issues with metal overhang.

Again, process engineering needs to pay close attention to the etching process to minimize the undercut both on inner layers and outer layers.

The undercut is exacerbated when the thickness of the copper foil and plated copper is thick. Think of 1-ounce copper foil (typically 1.4 mils thick) along with a minimum 1.0 mil of electroplated copper. In practice, the electroplated copper is often considerably thicker than 1.0 mil, further increasing the undercut opportunity.

Alkaline Etching

What can be done then, from a process standpoint, to minimize undercut? And in a worst-case scenario, what can be done to reduce significant line width reduction or complete etch-out (open)? To answer these questions, one must consider all the factors that can influence undercut and overall etching speed.

It has been established that undercut factors are grouped into three categories: etching chemistry, etching equipment, and other effects that are not due to either chemistry or equipment. These include surface preparation, exposure, development, etc. More on that later.

The process control of the chemical and other operating parameters (temperature, specific gravity, pH, etc.) of alkaline etching is paramount to ensuring consistent quality and high yields. Cupric chloride etching (acid-based) has several other critical chemical parameters that affect undercut and etch rate.

There are two specific parameters concerning alkaline etching that have a significant (read: heavily weighted) effect on the undercut and etch rate. Unfortunately, the etch rate and undercut move in opposite directions. A slower copper etching rate, while a drag on productivity, allows for the reduced undercut. Keeping the pH in a tight range of 8.0-8.2 is ideal when alkaline etchants are employed for print-and-etch applications. Some formulated alkaline etchants can operate at a pH of 7.9. While this is ideal for minimizing undercut, if the pH drops further, there is the risk of the etchant sludging out.

Conversely, as copper concentration builds in the etchant chemistry, specific gravity increases. A combination of low pH and higher specific gravity provides a positive benefit in reducing undercut. However, the reduced undercut comes at the expense of slower copper etching speeds. Indeed, higher operating temperatures will increase etch rates with a corresponding increase in the undercut.

Outer Layer Etching

There are several additional concerns when employing etching as part of the strip-etch-strip process (in preparation for SMOBC—solder mask over bare copper). First, one cannot use cupric chloride as a final etchant on metal etch resist processed circuit boards. Thus, one can default to alkaline ammoniated etching technology. However, there are additional challenges related to etching pattern-plated outer layers. These include the need to etch through thicker copper (copper foil thickness plus the pattern-plated copper on top of the foil copper). As the reader recalls, the greater the copper thickness that the etchant must

Figure 3: Outer layer after etching. Note the excessive overhang.

remove in the Z-axis, the greater the potential for undercut. As the plated copper increases or if the foils used are more than one-ounce foils, undercut increases. All the process engineer can do is maintain tighter controls on the operational and chemical parameters.

First and foremost, if undercut is minimized, there is less opportunity for overhang (Figure 3). In this case, the undercut is somewhat excessive. We can see how the etching solution affects the copper while leaving the tin plating intact. The strip of tin that is left floating at the edge of the feature represents the etching factor. The etching factor is the difference of dimension between the film and the final width of the features.

In a future column, we will delve further into the interrelationship of final etching, electroplating, surface preparation, and imaging. **PCB007**

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

Autonomous Boats Could Be Your Next Ride

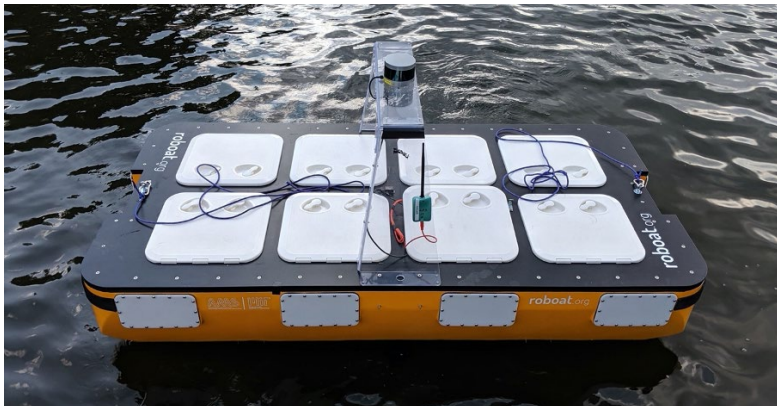
In an update to a five-year project from MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) and the Senseable City Lab, researchers have been developing the world's first fleet of autonomous boats for the City of Amsterdam, the Netherlands, and have recently added a new, larger vessel to the group: "Roboat II." Now sitting at 2 meters long, the new robotic boat is capable of carrying passengers.

"Roboat II navigates autonomously using algorithms similar to those used by self-driving cars, but adapted for water," says MIT Professor Daniela Rus. "We're developing fleets of Roboats that can deliver people and goods, and connect with other Roboats to form a range of autonomous platforms."

Self-driving boats have been able to transport small items for years, but adding human passengers has felt somewhat intangible due to the current size of the vessels. Roboat II is the "half-scale" boat in the growing body of work, and joins the previously developed quarter-scale Roboat, which is 1 meter long. The third installment, which is under construction in Amsterdam and is considered to be "full scale," is 4 meters long and aims to carry anywhere from four to six passengers.

"The development of an autonomous boat system capable of accurate mapping, robust control, and human transport is a crucial step towards having the system implemented in the full-scale Roboat," says senior postdoc Wei Wang, lead author on a new paper about Roboat II. "We also hope it will eventually be implemented in other boats in order to make them autonomous."

(MIT News - Robotics by Rachel Gordon)

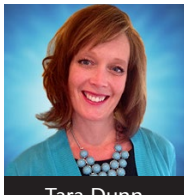


Editor Picks from PCB007

1 ECWC15 Virtual Conference Keynote: 5G PCB Technology and Material Challenges ▸

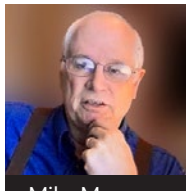
The second day of the Electronic Circuits World Convention began with a keynote from Dr. Shiuh-Kao Chiang, managing partner of Prismark, describing the PCB technology and material challenges presented by the introduction of the fifth-generation cellular wireless communication network—the roll-out of which was continuing in spite of the coronavirus pandemic. Technical Editor Pete Starkey has more.

2 Just Ask Tara Dunn: The Exclusive Compilation ▸


Tara Dunn

We asked for you to send in your questions for Averatek's Tara Dunn, and you took us up on it! We know you all enjoyed reading these questions and answers, so we've compiled all of them into one article for easy reference. And if you'd like to hear more from Tara, be sure to view her Flex007 column series "Flex Talk."

3 Batteries and Data Centers ▸

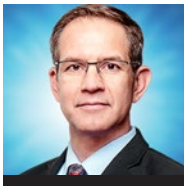

Mike Mosman

Mike Mosman recently sold his engineering company CCG Facilities Integration; he is now the vice president of electrical engineering in mission-critical facilities for Morrison Hershfield. In this discussion, Mike explains how evolving battery technology and a strong demand are playing a key role in this area and others.

4 Prices of Copper-Clad Laminates Continue to Rise ▸

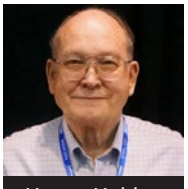
Recently, two major explosions at epoxy resin plants in China had a great impact on domestic resin suppliers. Prices have risen steadily in 2020, with leading CCL manufacturers announcing price increases of 20-30% recently. As the cost of raw materials such as electronic copper foil, resin and glass fiber have risen, the cost for manufacturing CCL has taken off as well.

5 Dr. John Mitchell on IPC APEX EXPO Going Virtual ▸


John Mitchell

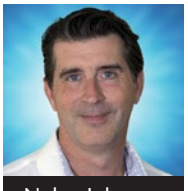
On Monday, December 14, 2020, Barry Matties and Dr. John Mitchell, IPC president and CEO, discussed the decision to move IPC APEX EXPO to an all-virtual platform. In this interview, Dr. John Mitchell confirms that IPC is committed to delivering a cutting-edge experience, including a strong technical program, exhibitor and visitor support, multiple keynotes and a wide variety of online networking events.

6 Happy Holden: ECWC15 Virtual Event a Success ▸


Happy Holden

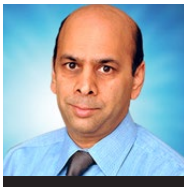
The HKPCA hosted this year's conference and they kept up the fine tradition of collecting outstanding keynotes, nearly 60 technical presentations and myriad poster papers. HKPCA was also kind enough to provide English slides and translations. It is still possible to sign up and view the presentations.

7 Pacothane on the Future of Laminate Technologies ▸


Nolan Johnson

Nolan Johnson recently spoke with the Pacothane Technologies team about the current drivers of circuit board technology and how that has influenced and increased their product development of lamination and lamination assist products.

8 Standard of Excellence: Going Public With Your Partner ▸


Anaya Vardya

One aspect of a great partnership with your vendors is to show the world how you are working together. Demonstrating how a great partnership can serve both your companies well and is beneficial to your industry too. Anaya Vardya shares nine ways to go public with your partner.

9 Chapter 2 Excerpt from the Book *'Thermal Management: A Fabricator's Perspective'* ▸

When metal is attached to a PCB, the bonding material can either be thermally conductive but electrically isolative (IMPCBs or MCPCBs), or in the case of RF/microwave circuits, the bonding material may be both electrically and thermally conductive.

10 It's Only Common Sense: Planes, Trains, and Automobiles ▸

On the Wednesday before Thanksgiving, my family watches the classic "Planes, Trains, and Automobiles." We all end up shouting suggestions at the characters, encouraging better choices. This movie came out in the '80s, and it's stunning to realize today how many things have changed since then. There have been changes in terms of technology, services, and travel. Think if they'd had cellphones. Their lives would have been so much easier.

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- Stays current with related manufacturing trends. Develops and enforces a culture of strong engineering discipline, including robust process definition, testing prior to production implementation, change management processes, clear manufacturing instructions, statistical process monitoring and control, proactive error proofing, etc.
- Provides guidance to process engineers in the development of process control plans and the application of advanced quality tools.
- Ensures metrics are in place to monitor performance against the goals and takes appropriate corrective actions as required. Ensures that structured problem-solving techniques are used and that adequate validation is performed for any issues being address or changes being made. Develops and validates new processes prior to incorporating them into the manufacturing operations.
- Strong communication skills to establish priorities, work schedules, allocate resources, complete required information to customers, support quality system, enforce company policies and procedures, and utilize resources to provide the greatest efficiency to meet production objectives.

Education and Experience:

- Master's degree in chemical engineering or engineering is preferred.
- 10+ years process engineering experience in an electronics manufacturing environment, including 5 years in the PCB or similar manufacturing environment.
- 7+ years of process engineering management experience, including 5 years of experience with direct responsibility for meeting production throughput and quality goals.

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Now Hiring

Process Engineering Manager

A successful and growing printed circuit board manufacturer in Orange County, CA, has an opening for a process engineering manager.

Job Summary:

The process engineering manager coordinates all engineering activities to produce quality products and meet cost objectives. Responsible for the overall management, direction, and coordination of the engineering team and leading this team to meet product requirements in support of the production plan.

Duties and Responsibilities:

- Ensures that process engineering meets the business needs of the company as they relate to capabilities, processes, technologies, and capacity.
- Stays current with related manufacturing trends. Develops and enforces a culture of strong engineering discipline, including robust process definition, testing prior to production implementation, change management processes, clear manufacturing instructions, statistical process monitoring and control, proactive error proofing, etc.
- Ensures metrics are in place to monitor performance against the goals and takes appropriate corrective actions as required. Ensures that structured problem-solving techniques are used and that adequate validation is performed for any issues being address or changes being made. Develops and validates new processes prior to incorporating into the manufacturing operations

Education and Experience:

- Bachelor's degree in chemical engineering or engineering is preferred.
- 7+ years process engineering experience in an electronics manufacturing environment, including 3 years in the PCB or similar manufacturing environment.
- 5+ years of process engineering management experience, including 3 years of experience with direct responsibility for meeting production throughput and quality goals.

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Career Opportunities

BLACKFOX
Premier Training & Certification

IPC Instructor

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

Independent contractor, possible full-time employment

Job Description

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

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

Qualifications

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

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

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

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

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SUMMIT INTERCONNECT

Our Summit Anaheim, CA, division currently has multiple open positions for planning engineers.

The planner is responsible for creating and verifying manufacturing documentation, including work instructions and shop floor travelers. Review lay-ups, details, and designs according to engineering and customer specifications through the use of computer and applications software. May specify required manufacturing machinery and test equipment based on manufacturing and/or customer requirements. Guides manufacturing process development for all products.

Responsibilities:

1. Accurately plan jobs and create shop floor travelers.
2. Create documentation packages.
3. Use company software for planning and issuing jobs.
4. Contact customers to resolve open issues.
5. Create TDR calculations.
6. Assist in the training of new planning engineers.
7. Review prints and purchase orders.
8. Create stackups and order materials per print/spec.
9. Plan jobs manufacturing process.
10. Institute new manufacturing processes and or changes.

Education/Experience:

1. High school diploma or equivalent
2. Minimum five (5) years' experience in the printed circuit board industry with three (3) years as a planning engineer.
3. Must be able to cooperate and communicate effectively with customers, management, and supervisory staff.
4. Must be proficient in rigid, flex, rigid/flex, and sequential lam designs.

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Career Opportunities

MacDermid Alpha ELECTRONICS SOLUTIONS

We're Hiring!
Connecticut Locations

Senior Research Chemist:
Waterbury, CT, USA

Research, develop, and formulate new surface treatment products for the printed circuit board, molded interconnect, IC substrate, and LED manufacturing industries. Identify, develop, and execute strategic research project activities as delegated to them by the senior research projects manager. Observe, analyze, and interpret the results from these activities and make recommendations for the direction and preferred route forward for research projects.

Quality Engineer:
West Haven, CT, USA

Support the West Haven facility in ensuring that the quality management system is properly utilized and maintained while working to fulfill customer-specific requirements and fostering continuous improvement.

For a complete listing of career opportunities or to apply for one of the positions listed above, please visit us here.

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MacDermid Alpha ELECTRONICS SOLUTIONS

We're Hiring!
Illinois / New Jersey

Technical Service Rep:
Chicago, IL, USA

The technical service rep will be responsible for day-to-day engineering support for fabricators using our chemical products. The successful candidate will help our customer base take full advantage of the benefits that are available through the proper application of our chemistries.

Applications Engineer:
South Plainfield, NJ, USA

As a key member of the Flexible, Formable, and Printed Electronics (FFPE) Team, the applications engineer will be responsible for developing applications know-how for product evaluation, material testing and characterization, and prototyping. In addition, this applications engineer will provide applications and technical support to global customers for the FFPE Segment.

For a complete listing of career opportunities or to apply for one of the positions listed above, please visit us here.

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Career Opportunities

Manncorp™

SMT Operator
Hatboro, PA

Manncorp, a leader in the electronics assembly industry, is looking for a **surface-mount technology (SMT) operator** to join their growing team in Hatboro, PA!

The **SMT operator** will be part of a collaborative team and operate the latest Manncorp equipment in our brand-new demonstration center.

Duties and Responsibilities:
- Set up and operate automated SMT assembly equipment
- Prepare component kits for manufacturing
- Perform visual inspection of SMT assembly
- Participate in directing the expansion and further development of our SMT capabilities
- Some mechanical assembly of lighting fixtures
- Assist Manncorp sales with customer demos

Requirements and Qualifications:
- Prior experience with SMT equipment or equivalent technical degree preferred; will consider recent graduates or those new to the industry
- Windows computer knowledge required
- Strong mechanical and electrical troubleshooting skills
- Experience programming machinery or demonstrated willingness to learn
- Positive self-starter attitude with a good work ethic
- Ability to work with minimal supervision
- Ability to lift up to 50 lbs. repetitively

We Offer:
- Competitive pay
- Medical and dental insurance
- Retirement fund matching
- Continued training as the industry develops

apply now

Manncorp™

SMT Field Technician
Hatboro, PA

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

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

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

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

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Career Opportunities

LENTHOR ENGINEERING
MAKING THINGS FLEXIBLE IN A RIGID WORLD®

Sales Account Manager

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

Responsibilities

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

Qualifications

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

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

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

Contact Oscar Akbar at: hr@lenthor.com

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LENTHOR ENGINEERING
MAKING THINGS FLEXIBLE IN A RIGID WORLD®

Senior Process Engineer

Job Description

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

Position Duties

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

Qualifications

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

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

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

Contact Oscar Akbar at: hr@lenthor.com

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Career Opportunities

MivaTek Global

MivaTek Global: We Are Growing!

MivaTek Global is adding sales, technical support and application engineers.

Join a team that brings new imaging technologies to circuit fabrication and microelectronics. Applicants should have direct experience in direct imaging applications, complex machine repair and/or customer support for the printed circuit board or microelectronic markets.

Positions typically require regional and/or air travel. Full time and/or contractor positions are available.

Contact **HR@MivaTek.Global** for additional information.

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eptac

TRAIN. WORK SMARTER. SUCCEED.

Become a Certified IPC Master Instructor

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

Qualifications and skills

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

Benefits

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

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Career Opportunities

APCT, Printed Circuit Board Solutions: Opportunities Await

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

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

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

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

apply now

Sales Representatives (Specific Territories)

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

- Florida
- Denver
- Washington
- Los Angeles

Experience:

- Candidates must have previous PCB sales experience.

Compensation:

- 7% commission

Contact Mike Fariba for more information.

mfariba@uscircuit.com

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APEX EXPO IPC 2021

Virtual — Live and On Demand

Courses & Conference
Online Exhibition

March 8–12, 2021

TECHNICALLY SPEAKING:

IT'S THE PLACE TO learn

Kevin Kusiak
Electronics Engineering Senior Staff,
Lockheed Martin

IPC is the go-to association helping companies transform and modernize. IPC APEX EXPO 2021 is the place to plan for advancing and implementing **FACTORY OF THE FUTURE.**

Registration is Now Open at
IPCAPEXEXPO.ORG

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IPC Factory of the FUTURE

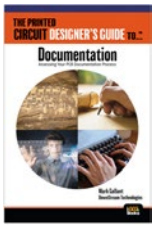
I-007e EDUCATIONAL RESOURCE CENTER

Webinar: For more information about the iamcam concept, please request the iamcam webinar video via presales@ucamco.com.

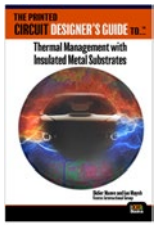
Roundtable: "Use of IMS Thermal Materials in Multilayer Stackups for Power Applications" with Ventec International Group and Excello Circuits.

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

Thermal Management: A Fabricator's Perspective, by Anaya Vardya, American Standard Circuits
Beat the heat in your designs through thermal management design processes. This book serves as a desk reference on the most current techniques and methods from a PCB fabricator's perspective.

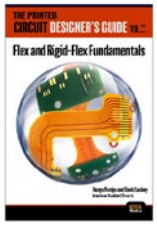


Documentation, by Mark Gallant, Downstream Technologies
When the PCB layout is finished, the designer is still not quite done. The designer's intent must still be communicated to the fabricator through accurate PCB documentation.



Thermal Management with Insulated Metal Substrates, by Didier Mauve and Ian Mayoh, Ventec International Group
Considering thermal issues in the earliest stages of the design process is critical. This book highlights the need to dissipate heat from electronic devices.

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



Flex and Rigid-Flex Fundamentals, by Anaya Vardya and David Lackey, American Standard Circuits
Flexible circuits are rapidly becoming a preferred interconnection technology for electronic products. By their intrinsic nature, FPCBs require a good deal more understanding and planning than their rigid PCB counterparts to be assured of first-pass success.

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

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