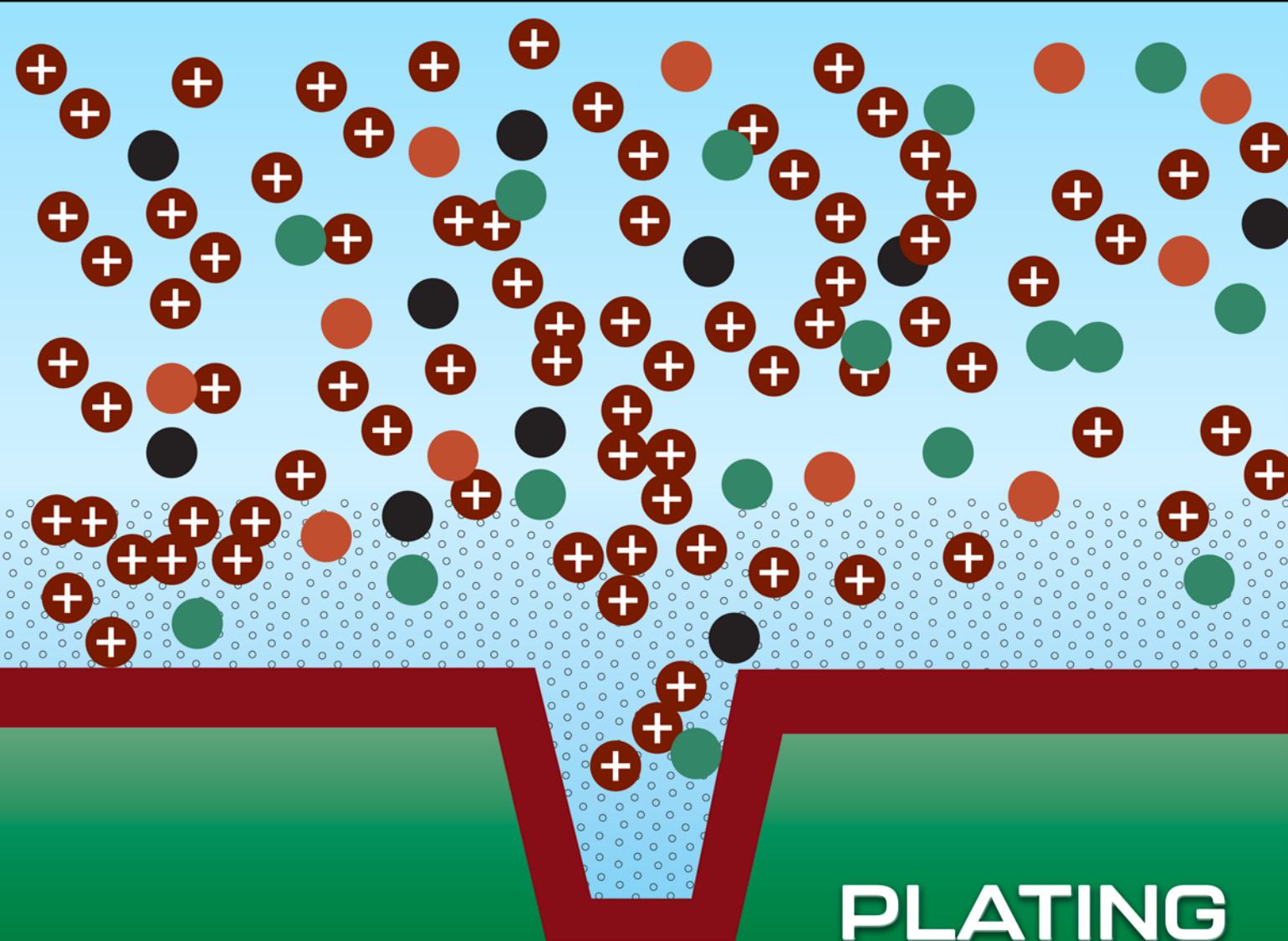


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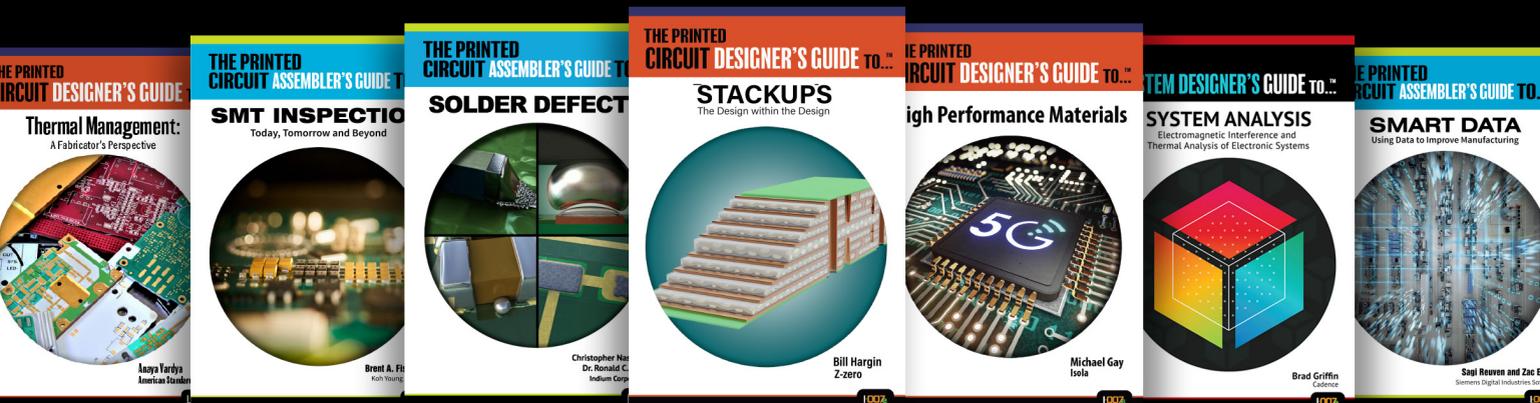
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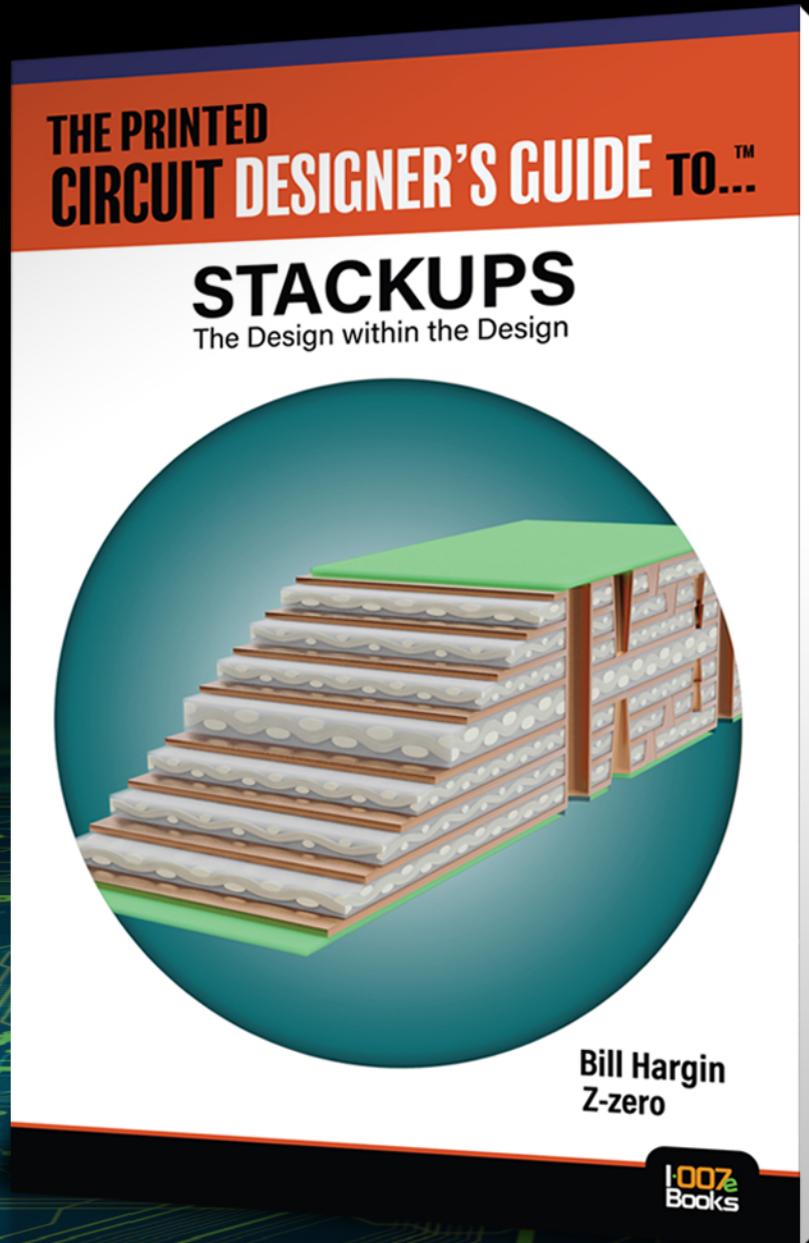
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The Plating Issue

In this issue, fabricators will learn strategies to optimize their plating processes to carry them into the future. Contributors will focus on plating trends in equipment, process, and chemicals, as well as challenges and opportunities for improvement.



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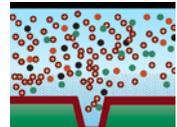


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Proper Plating

The Shaughnessy Report

by Andy Shaughnessy, I-CONNECT007

Joe Fjelstad once joked that if someone working in a board shop 50 years ago were placed in suspended animation and woke up today, they would recognize almost everything in today's board shop. They could theoretically go right back to work because so little of their work environment changed in those five decades. (After five decades, I'd probably want to take a week off and catch up on reruns of *MASH* and *The Bob Newhart Show*.)

True, the basic fabrication process hasn't changed much since 1972, but there have been tweaks along the way, especially in process control and measurement. And if you mentioned "environmentally-friendly waste processes" in a board shop before the 1990s, people probably would have looked at you funny.

Yes, many of the processes in our industry are what analysts like to call "mature." Take plating, the focus of this issue of *PCB007 Magazine*, for instance. In our research, we learned that plating technology predates the pyramids. The Egyptians developed a fairly advanced method for plating about 5,000 years ago.

They loved gold, but they really could work with anything. In the meantime, they also became experts at mining, refining, and metalworking. Mining is dangerous now; how would you like to be one of the miners working a few millennia ago?

The Egyptians, much like today's process engineers, were constantly experimenting and tweaking their processes. I wouldn't be surprised if we were to discover Egyptian pictographs that translate into "Plan, Do, Check, and Act." They also wound up developing some of the first metal wiring in history. Our industry owes more to the "technologists" of ancient Egypt than we realize.



Image: King Tut mask, Ronald Unger, Wikimedia Commons

As we found, though the plating process itself hasn't changed much over time, there have been several updates in the plating process, including process control, plating racks, and additives that enhance throwing power. Power supplies have come a long way in just the past decade or so, and newer tanks allow engineers to customize the amount of agitation and solution flow. A process engineer from 1972 would have quite a few questions about today's plating equipment, no doubt.

So, in this issue, our contributors share a variety of strategies for optimizing their plating processes to carry them into the future. We also look at current trends in plating equipment, processes, and chemicals, as well as challenges and opportunities for improvement, and areas for eliminating more waste. And we shine a light on measurement and instrumentation. In a segment where measurement is king, why hasn't the measuring equipment used to analyze the concentration of additives in chip manufacturing been tailored to the PCB segment?

We begin with a feature interview with I-Connect007 columnist Michael Carano. As he points out, even with developments in the plating process, the successful plating opera-



Image: King Tut back of mask, Tarek Heikal, Wikimedia Commons

tor must have a solid understanding of fundamentals such as Faraday's Law and Ohm's Law, as well as the ability to control every process as tightly as possible. In an interview, Christopher Bonsell provides an update on the latest in PCB plating, with challenges, opportunities, and what state-of-the-art means in this segment today.

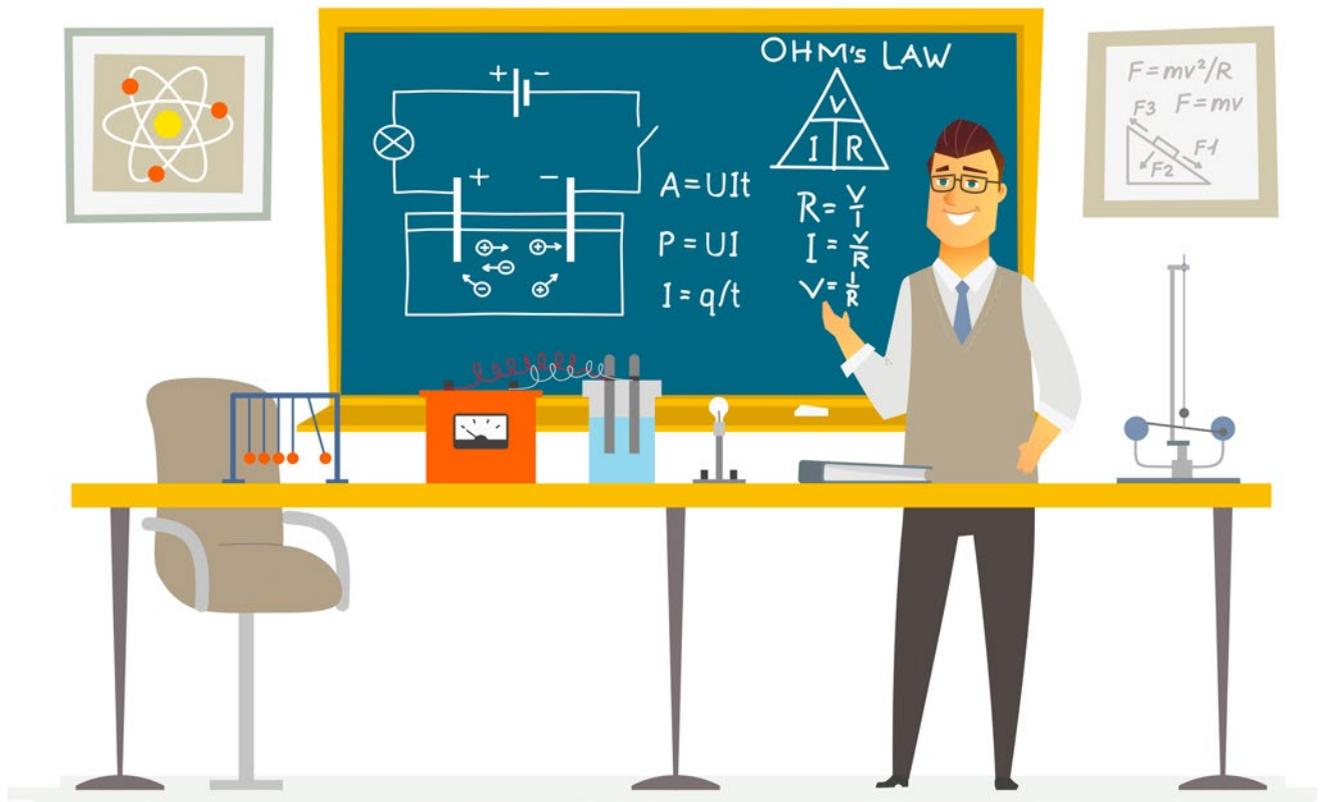
George Milad offers a primer on electroplating, electroless, and immersion plating techniques, and some advice for engineers facing difficulties in plating. Denis Jacques discusses an old process that's making its way back into the fold: silver plating. Finally, we have an

excerpt from Happy Holden's book, *Automation and Advanced Procedures in PCB Fabrication*.

We also have columns from our regular contributors Hannah Nelson, Christopher Bonsell, Happy Holden, and Dave Hernandez, who recognizes the work IPC is doing to advance manufacturing in Mexico. I think we would make the Egyptians proud. **PCB007**



Andy Shaughnessy is managing editor of *Design007 Magazine* and co-managing editor for *PCB007 Magazine*. He has been covering PCB design for 20 years. He can be reached by [clicking here](#).



PCB Plating Still Comes Down to Physics

Feature Interview by the I-Connect007 Editorial Team

For this month's plating issue, we spoke with I-Connect007 columnist Michael Carano, a longtime surface finish expert with years of experience at RBP Chemical and OM Group. He is now VP of Quality at Averatek. We asked him to discuss the latest innovations in plating equipment and chemicals, as well as some of the drivers in this segment, and the biggest challenges and opportunities he sees in plating today.

As Michael points out, despite all of the technological advances in this industry, process engineers still need a solid understanding of Faraday's Law and Ohm's Law to successfully plate PCBs.

Andy Shaughnessy: This is our electroplating issue, and I've heard you say that you know how to plate anything. What's the latest in

electroplating? What sort of innovations and challenges are you seeing in processes, equipment, etc.?

Michael Carano: If you go back 30 years, what's different in electroplating technology? Forget about electrodes for now. What's different about electroplating technology? I like to call it electrodeposition because we are attaching electrodes and we're running current through a tank. In the last 10–15 years, it hasn't changed much. But what has changed is the technology of the circuit board—smaller vias and thicker boards. Whenever you make a via smaller and you add more layers, what you do is you increase what they call the ohmic resistance through the via.

With Ohm's Law, $V = IR$; you apply a voltage to a plating tank. If you have a 10:1 aspect

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Michael Carano

ratio board and a 20:1 aspect ratio board, which one is going to be more difficult to plate? Very simple: the 20:1, because the resistance increases significantly down through the hole. From a technology standpoint, you've got to make

several adjustments, which the industry has. We've seen adjustments in tank design, plating rack design, process control, and the formulation of new additives that enhances throwing power and overall plating distribution.

It's always funny when someone says, "Why can't we just do this?" Well, you're violating Faraday's Law. There are only so many things you can do and you can't violate certain laws of the universe. Faraday's Law is one that you don't mess with. So you've got to manipulate the amperage, the voltage, and all the things that make a difference in getting chemistry into the hole.

That's significant. Then we went to periodic reverse pulse plating, which is basically electroplating except it uses a reverse current as well as a forward current. It makes adjustments in the wave shape using square wave vs. more turbulent type waves. That has helped tremendously to plate and improve the reliability of the thicker through-hole printed circuit boards.

Finally, one of the things that was borrowed from the semiconductor industry—we've all talked about what's new because sometimes it's not new, it's just re-cloaked in a new technology—is they learned to plate copper in narrow trenches. They call it damascene plating; they actually fill a trench with electroplated copper. Of course, the trenches are very minute compared to a blind via of a circuit board, but the circuit board industry and the suppliers, in my experiences, have been able to adapt to chemistry and, again, the agitation and other adjustments, to fill blind vias by electro-

plating copper in a via from what's called bottom-up filling, super fill, without necessarily overplating on the top. That has helped create HDI and ultra-HDI and allowed that technology to really blossom.

How do you fill blind vias when you're not going to put a component in them? You need to fill them with something. It's like the saying: A man digs a hole, and then he wants to fill it. Well, you must fill the hole in a blind via because you can't have air in a blind via if you're not going to put components in it.

You can use via fill paste, a polymer paste, or you can electroplate. I happen to be partial to electroplating because it can be done in some of the same equipment by just making adjustments. That's really what has allowed HDI and ultra HDI to truly blossom, in addition to all the imaging.

Dan Feinberg: As part of that, what do you have to control the most? Is it the wattage that's coming out or is it the voltage? It would seem that if your voltage was not in control and it was a quarter-volt or half-volt higher, you would have a problem with the evenness of the level of a plating.

Carano: Interesting, Dan. There are always two schools of thought and I've learned this from the metal finishing industry as well. People talk about two types of what you just mentioned—constant current and constant voltage. I happen to be a fan of constant voltage and letting the current rise.

But there are other factors. The additives themselves must be significantly altered in order to adjust so you can suppress plating on the surface. Think of a blind via as a vase: It goes wide on the top and gets down to a narrower base at the capture pad. You want the plating to fill that, whether it's 3 mils or 4 mils deep. You want it to come up faster and fill that via without leaving a void in the center of that area, all while minimizing overplating or mushrooming on the surface.

We do a lot of what we call the button plating. We put a image on the surface—essentially photoresist defining the pad and the via. And we go into our specially designed tank, where we alter the agitation, temperature, and solution flow, so we can get that suppression on the surface and then get that wrapping up filling. It's really done well. It's come a long way the last couple of years. Like I said, it's a big enabler when it comes to HDI.

Feinberg: Have you seen any improvements in power supplies over the last 15 or 20 years?

Carano: Sure, significant improvements. We've minimized and almost eliminated things like bipolar waves and we've eliminated things like loss. Everything is much improved. But I would like to give out some tips. Personally, when I troubleshoot at factories all over the world, one of the first things I do when someone says they're having trouble getting good via fill consistently or good throwing power, after analyzing the chemistry, is to say, "Take me to where your rectifier or your power supply is connected to your plating cells."

Here's a good example. At one shop I visited a year ago, all the rectifiers were located in the basement, and the plating cells were located on the floor above it. They had to run a cable from the basement a couple hundred feet up to the plating cells. They said, "What's wrong with that?" I disconnected it. I said, "Here, touch your hand to the cable." It was hot as hell because there was too much resistance.

The rectifiers and the cable should be as close to the plating cells as possible. Minimize that distance. Also, like I said, invest extra money in coaxial cables, which are a twisted pair. They will give you much more efficient current flow. I don't care whether it's pulse plating, via field plating, or it's conventional through-hole. Keep the distance as short as possible, keep the anode connection and the cathode connec-

tion as equal as you can. Use coaxial twisted pair of cables and you will minimize that current loss and something we call inductance, which when you run current through—especially if you have pulse plating, you run current—you get electromotive force that wants to oppose that current. You don't want that.

Shaughnessy: So, what are the biggest plating challenges right now for a typical American fabricator?

Carano: The biggest challenge is that they're still running plating cells that were designed 15 years ago. They have outmoded cabling, they don't really watch the anode-to-cathode ratio, and they don't use good quality anodes. As the technology changes, as they were asked to plate thicker boards and smaller holes, they really haven't changed the processes and the chemistry to go with it. That's where I see a lot of them falling down.

Second, you must have process control. I'll say it over and over again. The heart of process control and quality is how to control your processes. When you go into higher-technology and more complex designs, your controls must be much tighter. You must learn how to live in a narrower window because those are the rules. Just think about it: As you get up there in age, your lifespan is narrower and you must take care of yourself in a different way. It means not drinking six gallons of whiskey every day. You must tighten things up and that includes the controls and the processes.



Third, there's the challenge of finding and training people. I think the biggest problem in North America today is workforce development and getting people to understand how to troubleshoot and understand where problems come from. On my calls, I'll ask, "Why did this happen?" They say, "Well, I just turned this button on and I turned that button on." That's not good and it's not the answer that I'm looking for. I'm looking for what you're doing here and why you're doing it. Who's training you? That's the problem.

I think the biggest problem in North America today is workforce development and getting people to understand how to troubleshoot and understand where problems come from.

Feinberg: Two of the main areas of plating for making circuit boards are finger plating vs. through-hole plating. They're different. What do you see for someone who may be doing a really good job with finger plating and now they're going to through-hole plating? What do they need to think about?

Carano: As far as finger plating, get good tape. Tape tightly and go from there. That's the number one thing. If you can't plate fingers, you should find a job in a pizza shop because it doesn't get much simpler than that. You put the plating in a cell with a lot of agitation, and there's plenty of tape platers out there that deliver on current density and solution movement; it's conveyORIZED. All you have to do is tape and plate it. It's pretty simple.

When you put holes in the board, I don't care how many, but as the diameters get smaller, boards get thicker, layer counts get higher, the degree of difficulty becomes significant. You need to understand it's not linear, it's exponential. I'll give you an example. Let's take two boards, two designs. One of them is 0.125" thick with a 20-mil diameter hole, and the other board is 0.125" thick with a 10-mil hole. Now, you might say, "I'm only cutting my diameter in half so it should be easier." No, if you really look at the models that I've built and other models, you'll see that going from a 6:1 aspect ratio board to a 12:1 with the same board thickness, that the degree of difficulty becomes exponentially more difficult.

You need to readjust your parameters, your solution flow, and your anode-to-cathode spacing, making sure all the maintenance items are there with good cabling and proper rectification. You may have to go to pulse plating to get that current modulation that you need to get the throwing power into that thicker board. So it's not linear, it is exponential.

All you need to do is look at Ohm's Law, measure resistance, take a probe, take your ohmic meter, and just read the resistance between the boards. Two different ratios or two different thicknesses and you will see something significant, I guarantee you.

Happy Holden: One of the things I constantly experimented with was trying to use insulated mesh to create a grid between the anode and the cathode so that I could control the cations in terms of more universal distribution, much like on a triode vacuum tube. Will anybody ever be successful at controlling those cations?

Carano: Happy, you're talking about shielding. I've worked with adjustable shields my whole life, and that's very similar to shielding. You make the ions work a little bit harder so that you don't get overplating on the top or the bottom of the panels. But again, you can work with adjustable shields but there's enough

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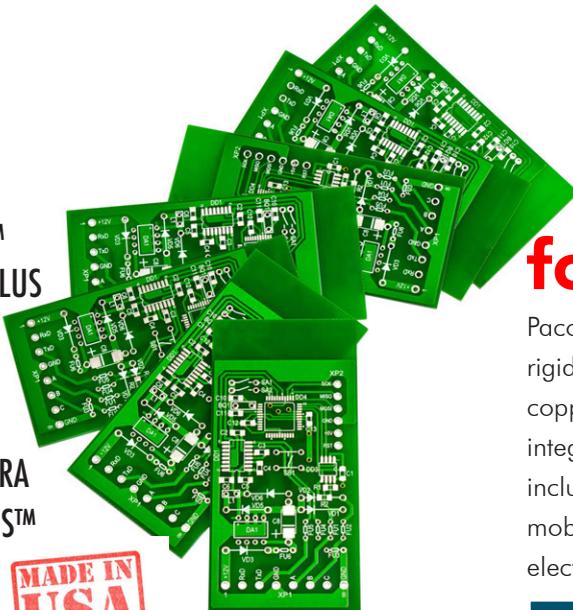
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out there in terms of adjustments, in terms of anodes, anode distance, and then solution impingement. I've gone to all eductor plating. I don't use air agitation anymore. I'm basically using solution movement in what I call laminar flow as opposed to air agitation, which causes a number of problems including air bubbles, which gives you turbulent flow. It doesn't give you a good movement across that diffusion layer. You must go across that cathode diffusion layer so the ions have a smooth path to the board.

Holden: Pete Pellegrino was the king of the flow motion plating with his 200 horsepower pumps on each side of the board. Fundamentally, I'd have to use refrigeration to cool the bath because there's so much energy being put in by those pumps, to create turbulent agitation.

Carano: Yeah, he did, but again, let me tell you, that's 20 years ago and I did a lot of work with Micro-Plate in the early '80s. The equipment was set up to process boards vertically using high current density plating. In those days they were using high-impingement (solution movement) plating at 100 or 125 ASF, and getting boards done in 10 minutes through a conveyor. We spent a lot of time optimizing the plating of high-aspect or medium-aspect ratio boards, but also at 100 ASF, 125 ASF. You don't do that today. Again, you can't violate Faraday's Law. There are certain laws to the universe that you need to learn that you can't violate.

Feinberg: If you want to increase your plating rate, are you increasing the amount of copper sulfate?

Carano: Yes.

Feinberg: So those are your choices— increase the copper sulfate level vs. the power consumption?

Carano: Whenever you increase your cathode current density, you are forcing the ions to move from the bulk solution to the cathode to be reduced. You achieve what is good or bad, it's called the limiting current density. It means, if you don't have enough concentration, you'll reach a limit to where no matter how high you go, you're not going to get any better plating. You're actually going to get terrible plating. So you must have a higher concentration of ions in bulk solution to meet with and work with that higher cathode current density.

But there's a caveat here. The higher the cathode current density, you favor the surface vs. the hole. You might say, "I'll plate at 40 ASF." That's great, raise the copper to double. Then you end up with two mils in the surface and six tenths in the hole. Is that what you want? No, I don't think so. Those are the trade-offs.

Feinberg: It's a cost and balance thing.

Holden: It's more than that, because you also have to think of the boundary layer. Agitation plays a big role in getting those fresh cations onto the surface of the cathodes.

Carano: That's the cathode diffusion layer which we just talked about. It's the finite thickness that builds up in front of the cathode and it becomes an area where the ions are either going to move faster or going to move slower depending on a number of factors like agitation and concentration. You have to remember, when you're plating, you have two types

of things going on. You can either have mass transport or diffusion control. When you have a conventional setup, you're really relying on diffusion control where the ions diffuse from the high concentration down to the low concentrations.

But when you get into higher aspect ratios, you've got to switch to higher convection which we call mass transport control. That makes a big difference in the type of throwing power you're going to get, so keep that in mind. Mass transport vs. diffusion control—what are you going to do, how are you going to do it; is it going to be governed by your current densities, your board designs, your tank setup, etc.?

I know there are companies, particularly on the semiconductor side, that make instrumentation that actually monitors the plating solutions constantly. They can analyze for copper, acid, additives. Why not do that for printed circuit boards?

There are companies out there that have these types of instruments that actually sample the working chemistry constantly and give you a concentration of all the additives, including the organic additives, and then makes adjustments based on set points. It's done in the semiconductor sector because obviously with semiconductors, it's very expensive to have any scrap in the semiconductor because it happens so fast. But why can't that be adapted to this industry? That's part of the problem. We tend to want to make things manual, just go do a titration. That's not enough today. I think that's what you should really look at: the whole package.

Look at training the workers about the materials, and then the equipment, the machines, everything, whether it's the tanks, the anodes, the controls. Do the fishbone diagram to show where all the bad things can happen, all the good things can happen, and you'll understand plating pretty well. They need to realize that it's a complex process. There are a lot of working parts.

Holden: Another thing I'm going to write about in a future column is palladium on copper.

I was looking over an older issue of *The PCB Magazine*, and there happens to be an ad in there for PallaBOND.

Carano: That is direct palladium over copper. Again, people are looking to eliminate that nickel layer if they can and get good solubility, also looking at eliminating gold. Unfortunately, the price of palladium has gone up, but again, if you can just put three to four micro-inches of palladium directly over copper, in my opinion, you'll have good solderability, you'll be able to attach your BGAs and almost any surface component QFNs to that and reduce your cost significantly.

Remember that the density of gold, Happy, is 19.32 grams per cubic centimeter. The density of palladium is 12.1. So, for every microinch of any of those metals you lay down, you're laying down a heavier amount of gold than you are palladium because of the densities. Obviously, the cost goes way up. Palladium does have an advantage, particularly for flex.

Palladium does have an advantage, particularly for flex.

Holden: I visited Photocircuits in the early '70s when they were supplying palladium on copper for the automotive industry. With the growth of electric vehicles and everything, I thought I'd mention that you can get away with palladium on copper, and it has advantages over immersion tin on copper or silver on copper or SMOBC.

Carano: Yes, because it plates directly on without any displacement reaction, whereas you can plate immersion tin or you can plate immersion silver but you also remove some copper. You have a galvanic cell going on. But

with the palladium, you're using a truly electroless palladium; therefore you're catalyzing it and you're not doing a galvanic cell. When you have galvanic reactions going on, a lot of things can happen: lifting the solder mask, trenching, creep corrosion where you exposed the copper underneath the solder mask, and if you're in a harsh environment, you end up getting what they call creep corrosion when it interacts with sulfur. That's why pure electroless tends to have some advantages over the immersion coatings. Immersion coatings are within what you call galvanic effect, so a battery cell, a very simple exchange reaction.

Holden: In your estimation, what's the current use of tab plating of gold on fingers vs. ENIG on fingers?

Carano: No, it's not ENIG anymore; it's still electrolytic nickel-gold. You need it for hardness. If you're going to use plug-in boards, and your boards are actually going to get plugged in, electroless nickel immersion gold is too soft and you'll just rub the gold right off. You need electrolytic gold and it's got to be thicker and harder.

Holden: I haven't seen an article about tab plating in 15 years. There are always a lot of articles about ENIG, so I was assuming that tab plating had drifted down in terms of its usage.

Carano: Again, Happy, it's about where the board is located and how it's going to be used. Think about the environment that it's going to be used in and the application, whether it's telecom, internet of things, harsh use environment, military, aerospace, office, etc.

Holden: Is there anything like ENIG that could be used for finger plating, or does it have to be electrolytic plating?

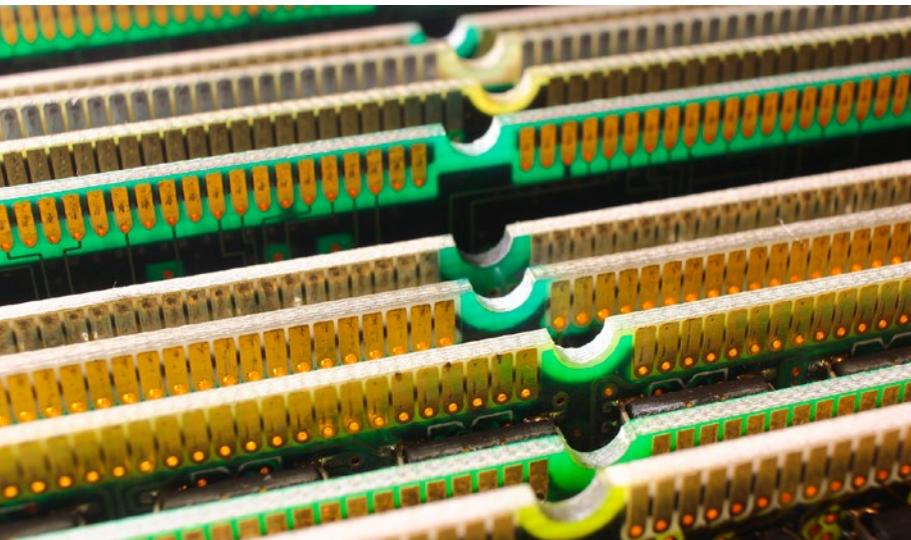
Carano: I wouldn't put ENIG on my fingers, not at that price. None of the people I work with do it either. They'll do it on BGAs or IC substrates when they want to do wire bonding and soldering, but not on fingers.

Shaughnessy: Mike, we're seeing some young people finally coming into the industry now. What advice would you give young process engineers coming in who are starting off in plating?

Carano: It's funny. I learned about plating in graduate school through a phone call from Happy. I was finishing my master's degree at 23 years old, and I was working in a lab, doing mostly metal finishing. Happy Holden called out of the blue and he wanted to know about this product of ours that he saw in a copper and brass mill in New England, which I knew plenty about.

It was a peroxide sulfuric micro-etch, used to clean copper and brass. He asked, "How would this work on a circuit board?" Of course, I said, "What's a circuit board?" Next thing you know we had a product called Cobra-Etch that Happy had implemented throughout Hewlett-Packard's five or six facilities in those days.

You know what's so exciting today? It's not just about surfaces of circuit boards anymore; it's plating on glass and silicon wafers and





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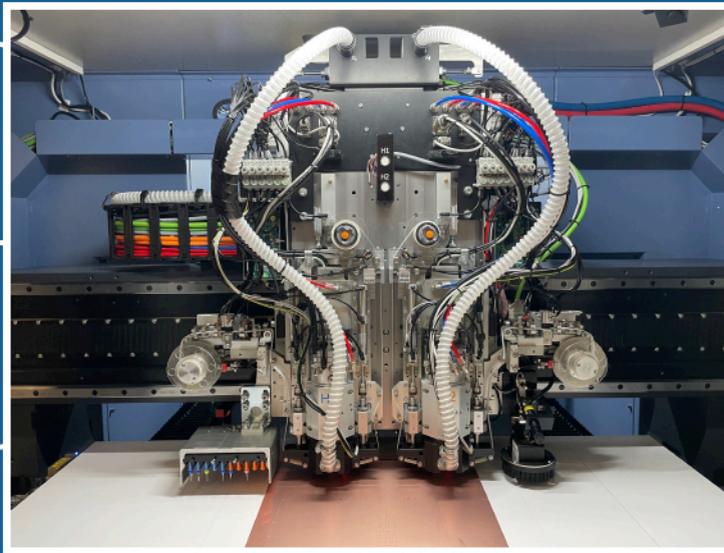
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the technology, the enabling. I was working with a company the other day on plating a glucose monitoring device to go into the human body. Certain parts had to be plated so that it could monitor the individual's sugar level. These medical breakthroughs are expanding into electronics, so it's not just circuitry. Today's opportunities, particularly in IC substrates, offer a great opportunity for young people to get into the electronics industry, especially with the CHIPS for America Act and supporting America's electronics industry.

I don't care if it's robotics or not, because it's all going to contain circuit boards anyway. Getting in on the ground floor of a circuit board fabrication facility that's really making headway is a great opportunity for a career. Then you start learning about imaging, solder masks, and board designs.

Just learn it, because you don't get a chance to learn that much in school. I love what IPC is doing, working with universities on outreach, and setting up student chapters. That's a great opportunity. There are some universities that offer a certificate program in printed circuit board fabrication like Michigan Technological University, and more are on the way.

Holden: One of the things that helped me a lot was joining the American Electroplaters Society, which spends a lot of time on electroplating. Living in the Bay Area, you had real theoreticians such as Lawrence Livermore Labs doing electroplating of thorium and other radioactive materials that were all electroplated. It was great to talk to those guys.

Carano: Absolutely. UCLA has an active metallization research program, as does the University of Arizona. Quite a few places are doing research in technology for metallization and thin films. It goes across many industries, but this is where some of the really cool stuff is happening as well.

Shaughnessy: Is there anything we haven't mentioned that you'd like to cover?

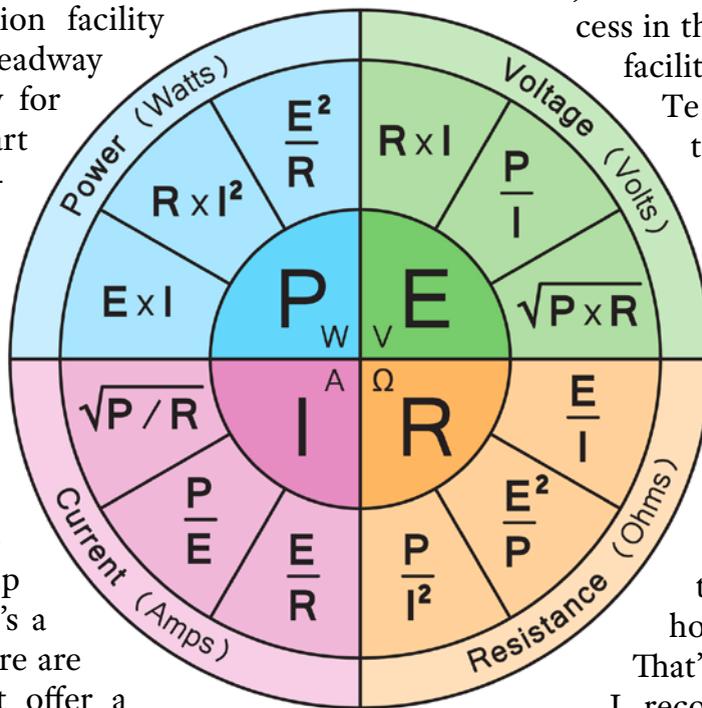
Carano: It's all about controlling processes. If you take any of my troubleshooting courses that I give through IPC or around the world, I talk about not just finding defects and solving them, but how to control every process in the printed circuit board facility and what to look for.

Temperature, concentrations, water purity, you name it—they're covered. It has to be done. That's the one thing that I see, sadly; when I work with fabricators, the majority of them don't know these things, even the engineers. They just put the boards in tech and hope they come out good. That's not good.

I recommend that you get involved from the ground floor and learn about metallization and electroplating, and learn about the physical chemistry aspects, because it's all physical chemistry. It's $V = IR$. At the end of the day, everything expands from there. Those are my parting remarks, folks.

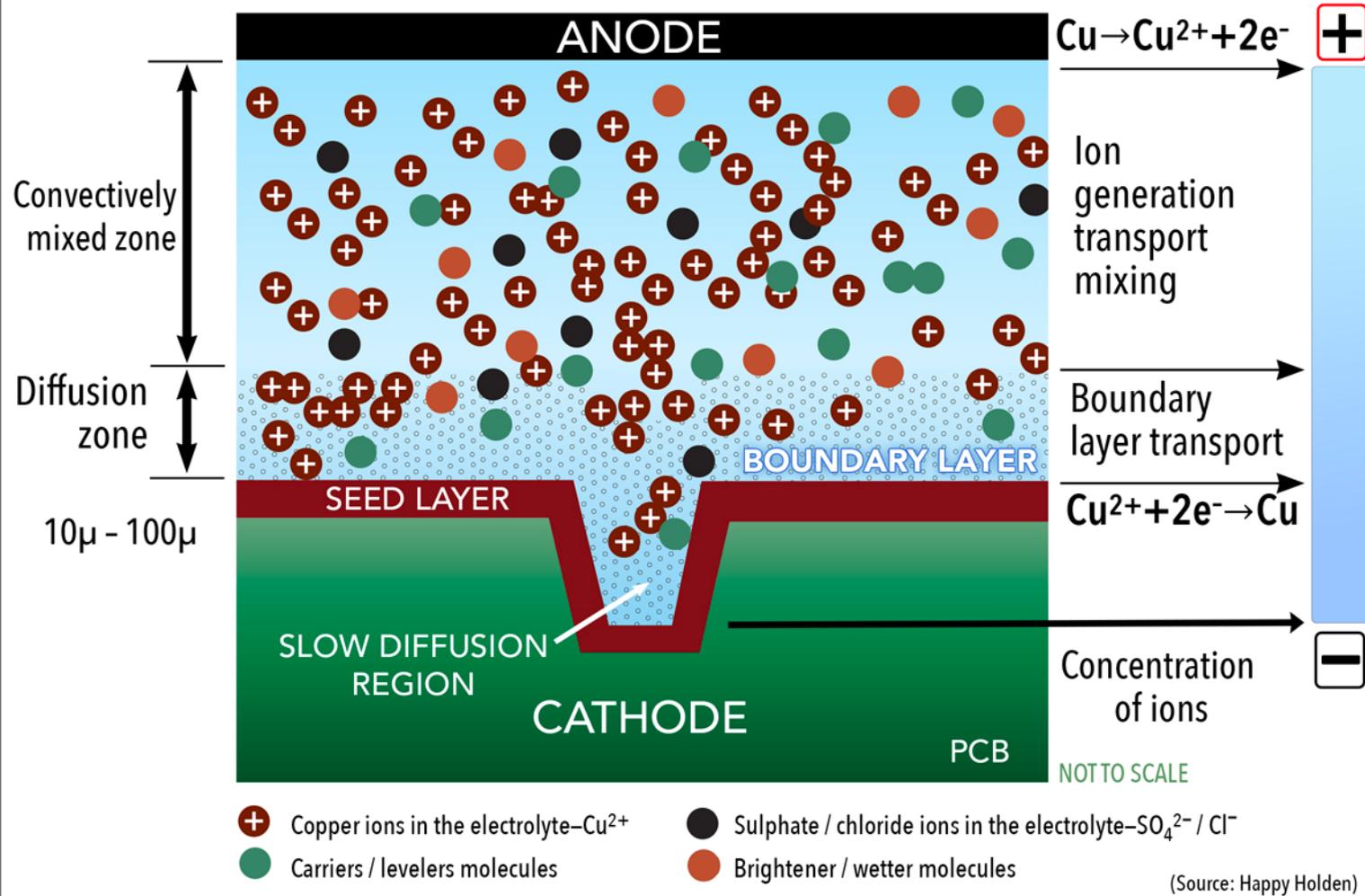
Shaughnessy: Thanks for your time.

Carano: Happy and Dan, good to see you. You too, Andy and Nolan. **PCB007**



PLATING KINETICS

Plating kinetics is all about getting copper ions to the cathode and penetrating the boundary area around the plating surface. Various organics are added to affect throwing power and the copper characteristics, but agitation (in various forms) is the physical force that has to overcome the resistance the boundary layer creates.



Current Density Distribution at the Cathode (Board)

As a function of anode spacing and 'anode-to-cathode' distance.

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

Where:

J = Local current density

J_{∞} = Current density if anodes were an infinite distance away

X = Distance anode to cathode (cm)

S = Width of anode (cm)

W = Distance between anodes (cm)

(Source: HP-Labs Research 1976, courtesy of Happy Holden.)



Plating Offers Plenty of Challenges—and Opportunities

Feature Interview by Andy Shaughnessy

I-CONNECT007

For this issue on PCB plating, I spoke with Christopher Bonsell, a chemical process engineer and author of an I-Connect007 monthly column, *The Chemical Connection*. I asked him to give us a rundown of the challenges and opportunities facing process engineers in the world of PCB plating today, and his advice to young process engineers beginning their careers in wet processing.

Andy Shaughnessy: Christopher, what are the biggest criteria for a fabricator to keep in mind when planning to invest in plating equipment and chemicals today?

Christopher Bonsell: Manufacturer and supplier reliability are the main factors you should seek when purchasing any processing equipment or chemicals. Getting equipment that helps you

meet your product specifications is one thing, but it is also necessary to know how available your provider is to help you. For complex processes like plating, it is important to have as much technical assistance as possible. Therefore, when you decide to purchase equipment or chemicals, you should ask yourself the following questions:

- Do they have significant knowledge and experience that they are willing and able to share with us?
- If something goes wrong with our equipment, or if we have questions, how quickly will they be able to respond or help?
- If we need parts for our equipment, how quickly can we get the parts we need from them?

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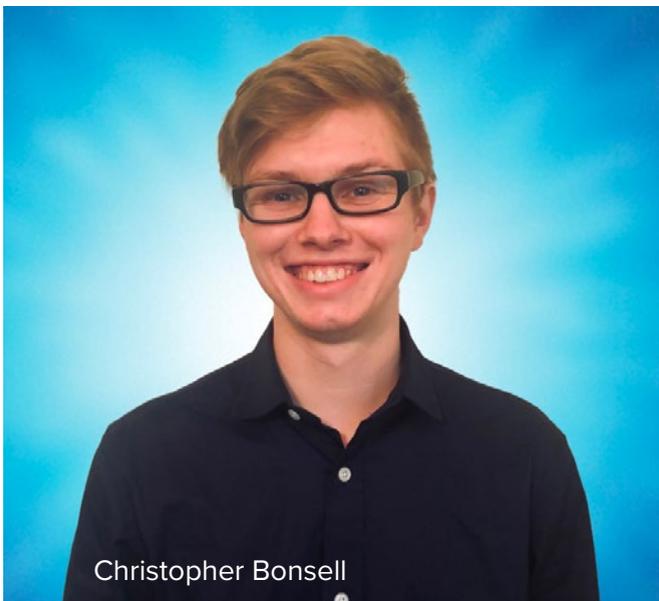
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Christopher Bonsell

Getting answers to these questions can tell you a lot about the supplier you are getting chemicals or equipment from. Whether they can provide the support you need can make a big difference. The last thing anyone wants is to be stuck with a piece of equipment, without training, to figure it out for themselves. Also, if something goes wrong with your plating equipment, you want to know that there is a way forward to receive help and fix the problem.

Shaughnessy: There's been a lot of talk about smart processes and increased automation in PCB fabrication. Are you seeing innovations like this in the industry today?

Bonsell: Yes. There has certainly been a surge in automation throughout the industry. Automation has been primarily adopted into the loading and unloading sections of processes like plating. Robotic loading/unloading systems have grown in popularity as they become easier to use. These loading systems offer great opportunities for maintaining product quality and boosting production while being relatively inexpensive.

Shaughnessy: What are the biggest challenges and opportunities in plating right now?

Bonsell: The biggest challenge in plating right now is overcoming the knowledge gap. Most of the knowledge in plating comes from the manufacturers/suppliers of plating equipment and chemicals—this is why I recommend going with a knowledgeable supplier. It is becoming more difficult to obtain engineers with hands-on experience in the plating process for PCB production. For this reason, engineers often need to be trained by the manufacturer or supplier. And as I mentioned, automation provides a variety of opportunities in this space.

Shaughnessy: Some of our readers are eyeing retirement, but we do see more young people coming into this field now. What advice would you give to young process engineers who are just starting out in plating?

Bonsell: The best advice I can give to new engineers is to network and document your learning and training.

If you want to learn more about plating, it is best to learn from the people who have experience with it. When you find someone experienced, you should try to maintain a connection with them so that you can feel free to ask questions and receive feedback on your thoughts. If you get the chance to work with someone experienced, you should observe how they approach problems. Any bit of insight that they can offer will be useful.

Don't just document your learning and training; record these steps in your ongoing education as if you are writing them for someone else so that they can understand. Writing this way will significantly help you track all the knowledge you acquired, and this will help you if you need to train someone else and get them up to speed.

Shaughnessy: Thanks for your time, Christopher.

Bonsell: Thank you, Andy. PCB007

[Read this month's *The Chemical Connection* column on page 58.](#)

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Plating in Electronic Applications

The Plating Forum

Feature Column by George Milad, UYEMURA

Plating is the deposition of a metal layer on a substrate to modify its properties. It occurs when the metal ion in an aqueous solution is reduced to the metal:



Plating can achieve numerous functional and aesthetic goals, including:

- Improve solderability
- Inhibit corrosion
- Increase hardness/durability
- Decorate objects (jewelry)
- Reduce friction
- Alter conductivity
- Improve IR reflectivity
- Provide radiation shielding

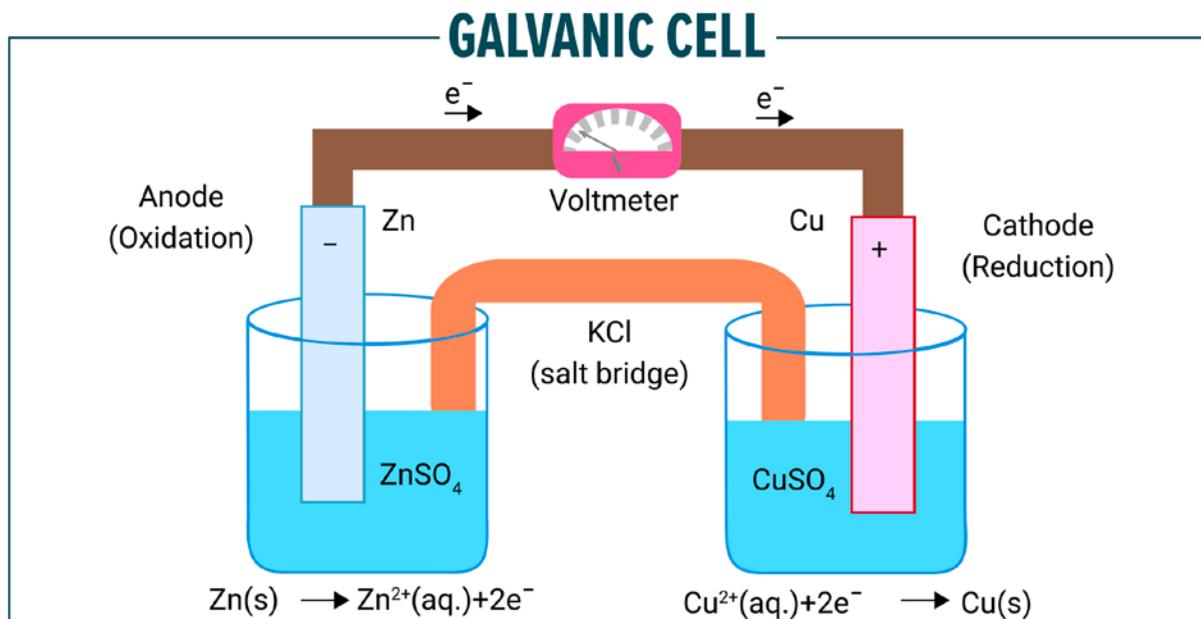
The reducing electron e^- can be supplied from these deposition reactions:

- Electroplating
- Electroless plating
- Immersion plating

Electroplating

This is a galvanic reaction that occurs when current is applied to an anode and a cathode immersed in the metal electrolyte. The anode is composed of the desired metal for deposition, typically copper, tin, or nickel. When voltage or current is applied, the metal at the anode will dissolve as a positive ion, leaving a negative charge at the anode.

At the cathode, the positive ion will be reduced to the metal, taking up electrons from



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the cathode which is rendered positive. The deposited weight depends on the current and the time, and is governed by Faraday's law. Electroplating requires connectivity. It is used to plate metal alloys, and in dispersion plating. The latter involves the uniform dispersion of a non-conductive entity in the electroplated metal.

Electroless Plating

In electroless plating, the negative electron is supplied by a reducing agent present in the electrolyte. The reducing agent is oxidized, and the metallic target ion is reduced to the metal. Plating continues as long as the reducing agent and the target ion concentration are maintained through replenishment. Electroless plating is independent of connectivity. Examples are electroless copper and electroless nickel, electroless gold, and electroless palladium.

Immersion Plating

In immersion plating, the reducing electron is supplied by the substrate where the deposition is occurring. The substrate metal is oxidized to the metal ion giving up an electron. The electron reduces the target ion to the metal for deposition. Only metals higher in the EMF series can replace metals below them. Immersion deposition is a displacement reaction and is limited to the availability of the substrate being plated. Examples include immersion silver, immersion tin, immersion gold, and others.

The general principles of all three methods are well understood and have been used for decades in electronics manufacturing. Refining the plating process to meet specific electronics requirements is the challenge faced by chemical manufacturers as complexity and miniaturization continue to increase. The following examples demonstrate how plating processes are modified and adapted to meet specific design requirements.

Copper Plating

Copper is a highly conductive non-precious metal. It is the conduit that carries the flow of current through printed wiring boards and semiconductors (integrated circuits) devices. Electroplated copper is the dominant method for plating traces and through-holes.

The challenge for electroplated copper in electronics is achieving consistent quality and thickness distribution throughout the part. Controlling the quality of the deposited copper (tensile strength and elongation) ensures that the deposit will not crack or fracture with the thermal excursion the parts are exposed to during manufacture and throughout their life cycle. Thickness distribution is critical for controlling impedance throughout the device.

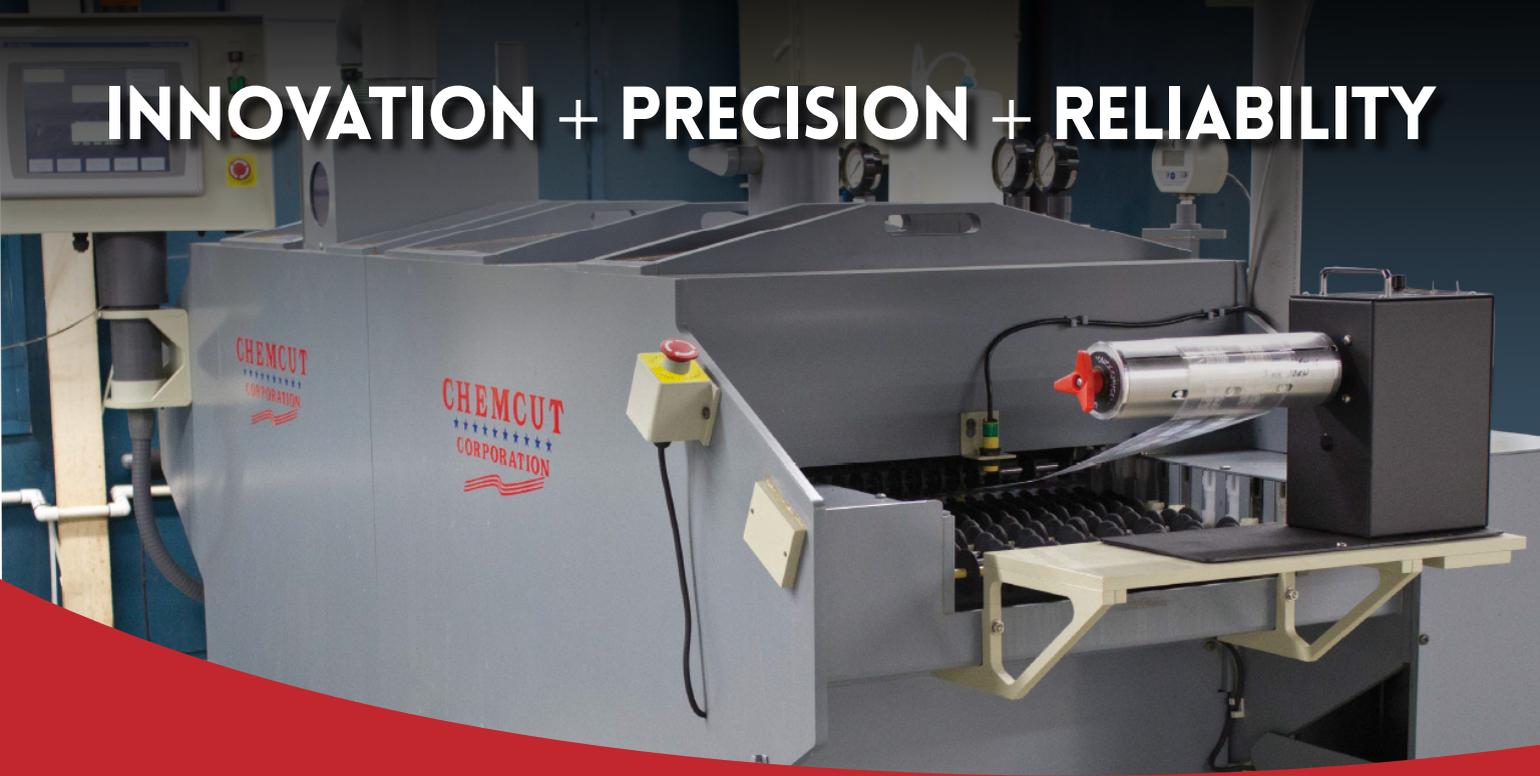
The use of additives (brightener, suppressor, and leveler) in the electrolyte, plating current density, and plating cell geometry are designed and manipulated to achieve a specific outcome, such as via filling, plating high aspect-ratio holes, and plating fine lines and spaces.

Surface Finishes

Surface finishing of electronic products is an integral part of manufacturing. It serves many functions, the most prominent of which is to create a solderable surface. It is also used as a corrosion barrier and an electrical contacting surface, as well as a wire bonding surface. One or more of the three methods of plating are used to create the desired surface. The layer may be a single component such as immersion silver, tin, gold, or palladium, or multiple consequential layers such as electroless nickel/immersion gold (ENIG), electroless nickel/electroless palladium/immersion gold (ENEPIG) and electroplated nickel/gold.

The choice of what thickness of metal to plate and what plating method to use is always based on meeting specific design requirements with the lowest cost. For example, solderable and gold wire-bondable finishes limit the choice of deposit. At the moment, the lead-

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ing finish for this application is ENEPIG. However, if the part is used for high RF (>20 GHz) signal propagation, nickel must be eliminated to avoid signal loss. This makes electroless palladium/immersion gold (EPIG) the appropriate alternative.

Automotive

As electric vehicles continue to grow in popularity, there is great demand for EV surface finishes that provide:

- Wear resistance and corrosion resistance
- High number of plugging cycles (10K+...)
- High electrical and thermal conductivity
- Elimination of lubricant
- Long-term, stable hardness (1000h → end of life)
- Temperature-stable hardness (150°C → 180°C)
- Extended contact/connector life

Silver is fundamental for electronic components used in electric vehicles, charging stations, and power grids, but to deliver the

capabilities required, silver must be modified. Studies of various alloys found none were able to meet the criteria listed above.

One of the ways to achieve the desired performance is dispersive plating, specifically with graphite as the dispersion element due to its availability and lower cost compared to alternatives. Dispersing graphite in the silver deposit produced the desired tribology attributes (wear friction and lubrication), hardness and conductivity.

Chemical suppliers to the electronics industry are continuously adapting the plating processes described to achieve the appropriate thickness of metal or metals (alloy or dispersion metal) in single or multiple consecutive layers. Meeting the design functionality at the lowest cost will always control the choice of plating material and plating options. **PCB007**



George Milad is the national accounts manager for technology at Uyemura. To read past columns or contact Milad, [click here](#).

NuSTAR Celebrates 10 Years in Space

Launched from a rocket strapped to the belly of an aircraft on June 13, 2012, NASA's NuSTAR

mission is celebrating 10 years in space. The mission, which detects high-energy X-rays, has made numerous

discoveries over the years about extreme cosmic objects, including black holes, supernova remnants, pulsars, our own fiery sun, and more. In this video, the mission's principal investigator, Fiona Harrison, who is also the Harold A. Rosen Professor of Physics and the Kent and Joyce Kresa Leadership Chair of the Division of Physics, Mathematics and Astronomy at Caltech, looks back on NuSTAR's journey and discusses where the future may lead.

(Source: Caltech)



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pcb 07 Supplier Highlights



Ventec to Host Live Webinar on Thermal Management with IMS ▶

Ventec International Group Co., Ltd., is pleased to announce that it will be hosting a live webinar on “Top design techniques for thermal management with IMS” on Thursday, June 23. Visit website for details.

Atotech, Schweitzer Engineering Laboratories Announce Business Partnership ▶

Atotech and Schweitzer Engineering Laboratories (SEL), an industry leader in the design and manufacture of digital products and systems that protect, control, and automate electric power systems, announced that they will partner at SEL’s state-of-the-art manufacturing facility under construction in Idaho.

Ucamco Expands Direct Presence With Official Subsidiary in North America ▶

Ucamco has established a subsidiary of Ucamco NV in North America. The subsidiary is presided by Luc Maesen, who has been working with the company since 1988 and was already in charge of Ucamco USA.

Nano Dimension Initiates Up to \$100 Million Share Repurchase Plan Process ▶

Nano Dimension Ltd. announced that its board of directors has authorized a one-year share repurchase plan (the “Repurchase Plan”) allowing the Company to invest up to \$100 million to repurchase its American Depository Shares (the “ADS”).

Element Solutions Declares Q2 Dividend of \$0.08 Per Share ▶

Element Solutions Inc. announced that its board has declared a quarterly cash dividend of \$0.08 per share of the company’s common stock to be paid on June 15, 2022, to stockholders of record as of the close of business on June 1, 2022.

Technica USA Presents WonderWise Atmospheric Plasma Equipment at Demo and Training Center ▶

Technica USA, in cooperation with Wise s.r.l. Parma, Italy, hosted Demo Week at Technica’s San Jose, Calif., Demo & Training Center during the week of May 9, 2022.

Chemcut’s Robotic Solution ▶

The I-Connect007 editorial staff spoke with Chemcut’s Jerry Reitz, and Atlantic Microtool’s Bruce Siemering and Neil Robinson about recent robotic automation advances, a specific robotic solution from Automata, and the changing factors tipping toward robotic automation in the current market.

Insulectro Hires Operations Expert Joe Harbour as Director of Operations, East & Midwest Regions ▶

Insulectro, the largest distributor of materials for use in manufacture of printed circuit boards and printed electronics, has hired industry veteran Joe Harbour as director of operations, East and Midwest Regions.



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My Interview With Happy Holden

The New Chapter

by Hannah Nelson, VALPARAISO UNIVERSITY/IPC STUDENT DIRECTOR

This past year, I set up several informational interviews with individuals across the industry. I saw this as an avenue to both enhance my own career and provide insight for my peers. To that end, I had the incredible honor of interviewing Happy Holden, the father of HDI PCBs. His insight into what it takes to be an excellent engineer and grow exponentially in this industry is unrivaled.

As students beginning an engineering program, we often have no idea what to expect.

In class, we're taught surface-level material, while the industry is much deeper than that. From Happy I learned that engineering principles are not the only aspect you will apply to the industry; you must know how to engage with business models and analytics. Before getting involved with IPC as a student liaison, I had limited knowledge of the industry business model. Now, several months later, and after speaking with Happy, I am so happy with how much my knowledge has increased.

The Happy Tale

From a young age, Happy understood the value of hard work. He was raised on a farm, where you quickly learn you don't get days off. He carried these characteristics with him throughout his career. Happy attended Oregon State University with a goal to study chemical engineering, but soon found himself delving into the world of electronics. He learned how to program and work with computers, which was quite unusual for a chemical engineer. He also decided to take on several technical projects while in school, which eventually led to a thriving career around the world. When he finished college, he was hired at Hewlett-Packard, where his first assignment was to develop the calculator. He accomplished this task with ease and was even given the opportunity to manage a \$4 million budget to advance the growth of his invention within the first year of work.

Another high point of his career was becoming chief technical officer for Foxconn. He's



Hannah Nelson met with Happy Holden during IPC APEX EXPO 2022.

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Hannah (right) with Wendy Gaston during IPC APEX EXPO 2022.

now retired, but he still engages with FIRST robotics, teaches at Michigan Technical, participates on IPC committees, and is a technical editor and columnist for I-Connect007. Happy has graciously volunteered to host informational discussions at Valparaiso, which helps our students learn more about what to expect beyond the classroom before entering their future careers. One thing I learned from Happy's stories has been to keep working hard and make a contribution through any opportunity you are presented with.

The Importance of Networking

Landing a job today can seem nerve wracking and almost impossible. Happy told me about the importance of networking even before you start looking for your dream career. Throughout his career, Happy never had to search for the next best job because, he said, "Somebody always pulled me to the next level." This happened because he understood the value of marketing himself first. He told me that as a student the best way to network is to build deeper connections with your professors; they can provide a valuable network and even help land a future career. Happy got his first job from one

of his professors who had handed his name off to HP. He feels this was because he took the initiative to build a close relationship with his professor.

Another way to network is by learning how to write effectively and creatively. Happy stated that you need to be able to describe a problem that you have dealt with and the alternatives you took to finding a solution. Then you need to put it out there. It's likely that many others have the same problems but have no idea how to find a solution. This helps you gain visibility by getting your name out in the industry. It opens opportunities for networking, which should open other doors for your career.

Develop a Broad Skill Set

Another important skill is to build your own tool set. One reason Happy excelled in this industry was because he had learned how to work with software, a skill that many other chemical engineers did not have. He purposely took courses on engineering statistics and plant design, which were unrelated to his major. These courses helped him develop a business plan to sell his first invention. Happy believes that it is incredibly vital to also develop your

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Hannah's FIRST robotic team received a safety award during a high school competition.

technical writing and journalism skills. Write the things you know the most about. This not only helps to get your name into the industry, but also builds a skill that is incredibly important among several engineering jobs.

Push Forward

When getting started, many individuals may doubt your ideas or the potential of your work. As a chemical engineer heading into the world of electronics, Happy did not have much knowledge about the industry, but “just because [he] didn’t know anything, [he] couldn’t let that get in [his] way.” When the first calculator at HP started to sell, Happy was told that he wouldn’t sell more than 400 in a month because they were too pricey. He persevered and ended up selling thousands within the first month of production.

Next Steps

Get involved in this industry! There are so many opportunities to build your skill set, such as joining an IPC committee. Becoming involved in this sector of the industry allows you to learn aspects of the industry outside your own limited area of expertise. Committees can also create an enhanced environment through the ability to share others’ ideas and opinions on topics in the industry.

Volunteering is another excellent way to excel in your career and encourage the next generation of engineers and technicians. One idea is to become a volunteer for FIRST robotics. When I started high school, I quickly became a part of our FIRST robotics chapter. I was surrounded by several mentors who guided me through engineering design processes. These individuals even helped develop my skill set with soldering and CAD. I looked up to my mentors, and they even encouraged me to become an engineer. There are 3,914 individual teams or 97,850 students within the FIRST Robotics Competition where you could make a difference as a mentor and help build the world’s future workforce. Please consider lending your expertise and mentorship to these students.

Encourage the next generation by reaching out to the IPC Education Foundation, which provides students with scholarships, credentials, professional development growth, and networking opportunities. The Foundation also helps students learn more about the different aspects of the industry, while growing professionally as individuals. Participate in webinars called “Forum Fridays,” which help students learn about different companies in the industry or invite students in for an industry tour that lets students see how a manufacturing facility works.

I have enjoyed and learned immensely from each informational interview this year and I’m so grateful to those individuals who spent time with me, including this phenomenal interview with Happy Holden. Now, I’m even more excited for the opportunities I can create for myself in the electronics industry, the skills I can contribute, and the chance to become a mentor someday as well. **PCB007**



Hannah Nelson is a student at Valparaiso University, and part of the IPC Emerging Engineer Program. To contact Nelson or read past columns, [click here](#).

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PCBAA Member Profile:

Dan Weber, TTM Technologies

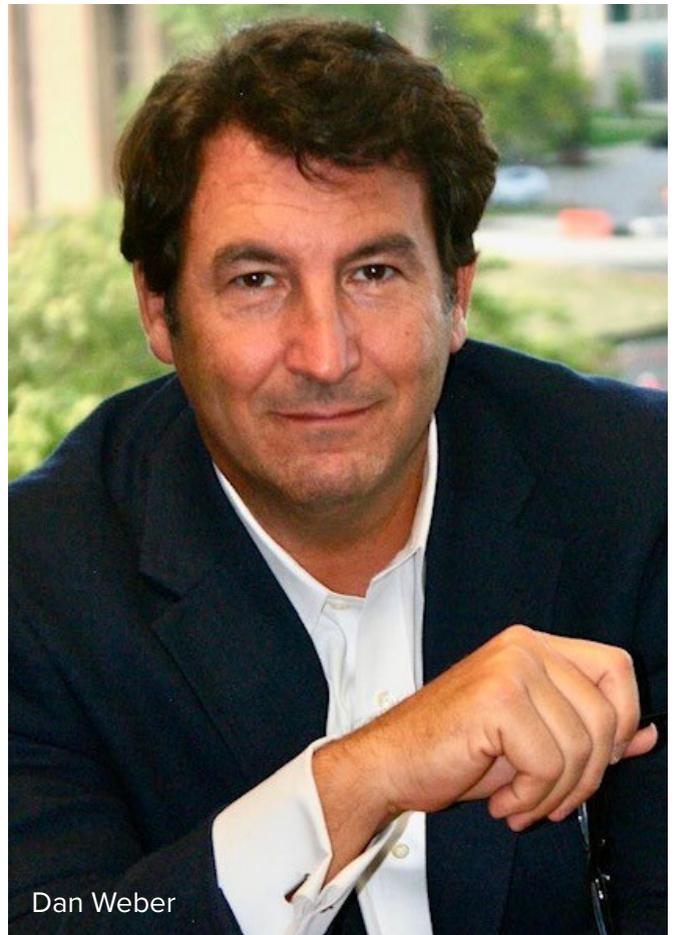
Dan Weber is executive vice president and general counsel for TTM Technologies. As part of this regular series, Dan answers questions about the benefits of membership in PCBAA.

Q: *After months of discussing why “Chips Don’t Float,” there is finally a bill on Capitol Hill focused on PCBs. Can you talk more about that?*

Dan Weber: It is gratifying to see our industry beginning to get the level of visibility it deserves. We are fortunate to have two champions in Rep. Anna Eshoo from California and Rep. Blake Moore of Utah. They jointly introduced HR 7677, the “Supporting American Printed Circuit Boards Act of 2022.” As proposed, their bill incentivizes the purchase of PCBs made in America, and provides funds badly needed for R&D as well as manufacturing workforce development training. We need to make up a lot of ground. America’s share of the global market fell from 26% to 4% over the last two decades and this bill is an important step in reversing that trend.

Q: *Doesn’t the CHIPS Act address our supply chain issues?*

Weber: The CHIPS Act is a great start toward making our microelectronic supply chains more secure and resilient. But this is a complex issue: Simply building more semiconductors in the United States doesn’t solve the larger problem in America’s electronics supply chain ecosystem. Today, the majority of PCBs are made in countries that are far away and where there is the potential risk of adverse political



Dan Weber

decisions or natural disasters that could cut off the supply of PCBs. Remember, without the PCB, a chip does not have a home. All those chips need a PCB to support an electronic system. PCBs need the same level of attention that semiconductors are getting because one doesn’t work without the other.

Q: *What is PCBAA doing to advance this legislation?*

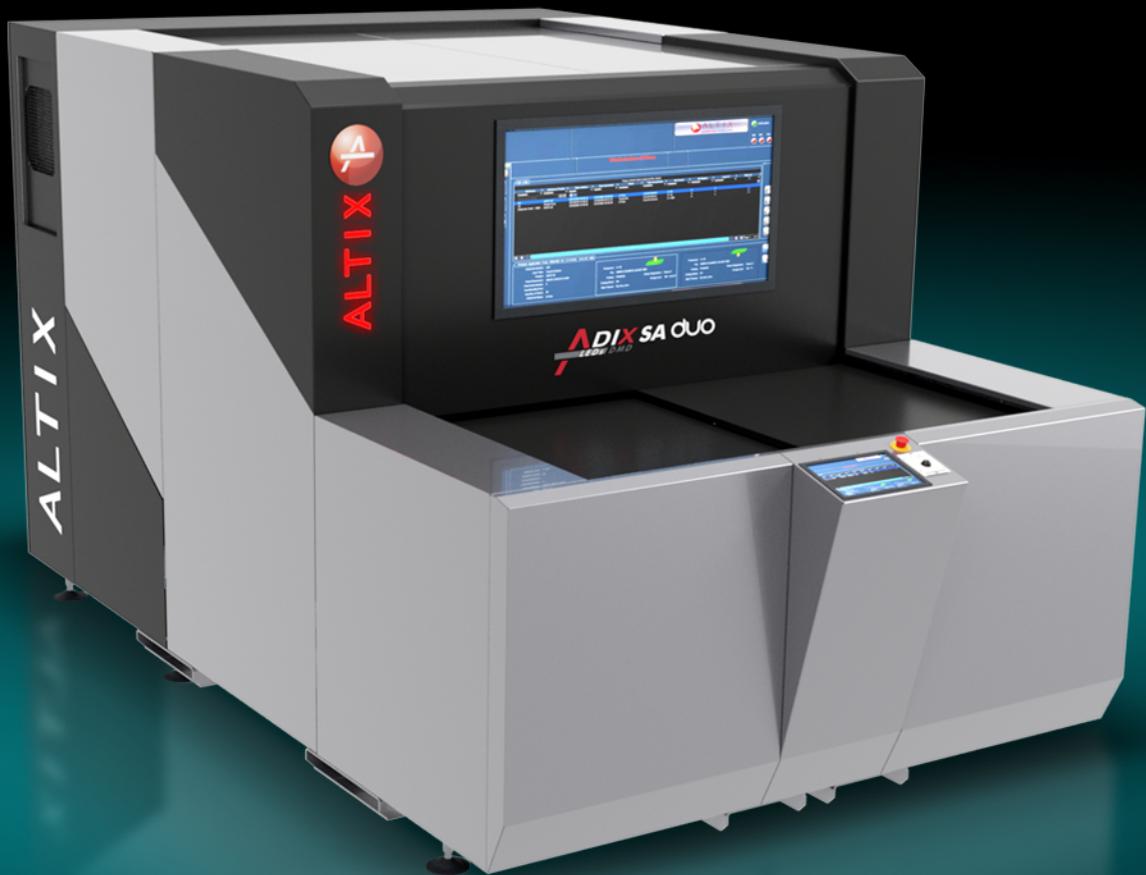
Weber: PCBAA has a three-pronged mission to educate, advocate and legislate for our industry. Recently, PCBAA leadership has been on Capitol Hill meeting with lawmakers and their



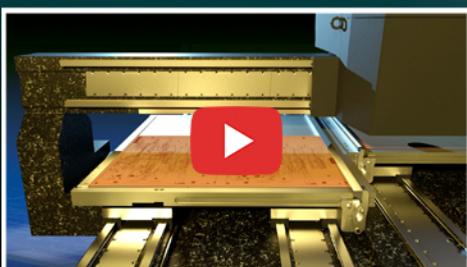
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staffs, think tanks, and reporters to explain how complex PCBs are and what needs to be done to revitalize our industry in America after decades of decline.

Q: How can industry members get involved?

Weber: I think anyone who's a part of the micro-electronics ecosystem should consider joining the PCBAA. The work PCBAA is doing is making a difference, but it won't be over any-time soon. The mission to educate decision-makers in Washington and around the country will never be complete as the players constantly come and go. Because there are so many issues competing for legislators' time,

we must keep our issue top of mind and keep pressure on decisionmakers throughout the agencies of government to support PCBs as part of the microelectronics ecosystem that supports everything from consumer electronics and telecommunications to electronics systems and weapons critical to America's national security. The more members we have, the louder voice we have in Washington. One thing we can all do now is make our individual voices heard by [using the online contact tool](#) that our partners at IPC have created. This contact tool sends a message directly to your nationally elected representatives to advocate for this critical legislation. It's easy to use and takes just a few minutes. **PCB007**

[Visit pcbaa.org to learn more.](http://pcbbaa.org)

Skyrmions on the Rise—New 2D Material Advances Low-Power Computing

Two-dimensional magnetic materials have been hailed as building blocks for the next generation of small, fast electronic devices. These materials, made of layers of crystalline sheets just a few atoms thick, gain their unique magnetic properties from the intrinsic compass-needle-like spins of their electrons. The sheets' atomic-scale thinness means that these spins can be manipulated on the finest scales using external electric fields, potentially leading to novel low-energy data storage and information processing systems. But knowing exactly how to design 2D materials with specific magnetic properties that can be precisely manipulated remains a barrier to their application.

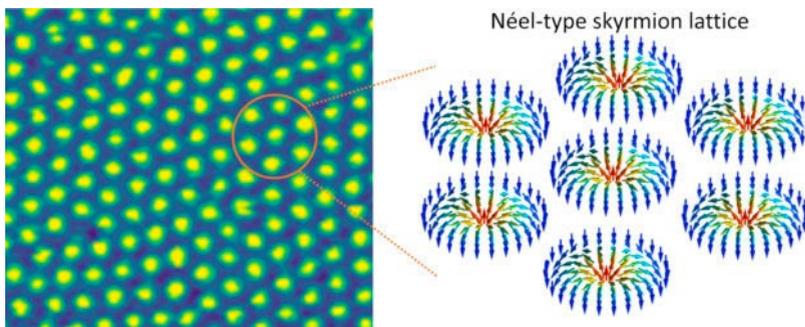
Now, as reported in the journal *Science Advances*, researchers at Lawrence Berkeley

National Laboratory (Berkeley Lab), UC Berkeley, Cornell, and Rutgers University have discovered layered 2D materials that can host unique magnetic features that remain stable at room temperature and could thus eventually be used in future everyday devices. Atomic-scale images of the material reveal the precise chemical and structural characteristics that are responsible for these features and their stability.

Berkeley Lab researchers have a track record of identifying unexpected magnetic properties in atomically thin layers of bulk crystals, many based on semiconductor materials doped with metal atoms. UC Berkeley graduate student Tyler Reichnadt, a study co-author, calculated just how the electronic structure of common 2D materials might

change by swapping out different atoms, in this case some of the iron for cobalt. This particular swapping results in a crystal structure that cannot be superimposed on its mirror image, and leads to the possibility of exotic, vortex-like spin arrangements called skyrmions, which are being explored as building blocks of future low-power computing.

(Source: Berkeley Lab)





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Plating on Silver: What's Old Is New Again

Feature Article by Denis Jacques
TECHNIC INC.

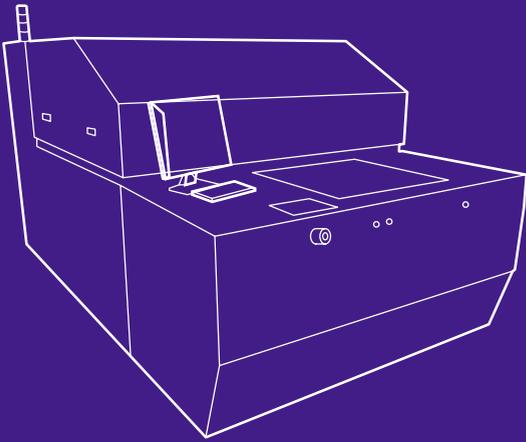
About three decades ago, immersion silver, a nitrate-based process, gained a lot of market share in the world of PCB final finishes. More economical than ENIG, flat, solderable, and conductive, it had everything going for it—everything but corrosion resistance in a harsh environment, that is.

Champagne voids were also an issue, along with line reduction. But the worst drawback, the characteristic that made the part short over time, was creep corrosion. A build-up of copper sulfide salt that grows in contact with a sulfur-rich environment, heat, and moisture resulted in failures in the field. This was enough to scar the process for good.

The market today for silver as a final finish is pretty meager and therefore does not justify much research. Fortunately, there is an alterna-

tive immersion silver, originally developed for other applications, that has proven to be a reliable solution. Immersion silver is nitrate-free, slightly alkaline, and deposits a slow, pore-free pure silver deposit. I had a strong feeling that this process would be a solid alternative to nitrate-based chemistry, yielding the benefits without the drawbacks.

Work started about 10 years ago with this product, on a very limited basis, because as mentioned before, the interest in silver is just not there. One of our customers raised the fact that their silver was acting somehow galvanic, and some isolated lines were reduced. The customer works in the RF field, and this was a major issue for them. I offered to test this bath, feeling that it could be a solution to the problem.



Orbotech Diamond™ 10W

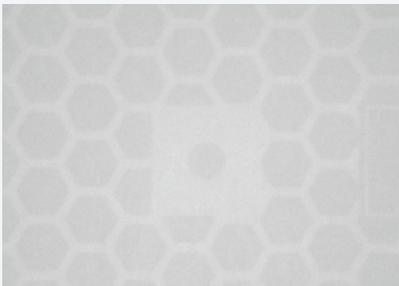
for White Solder Mask Direct Imaging



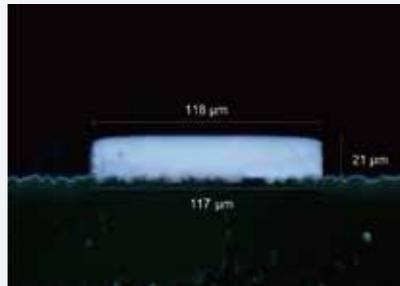
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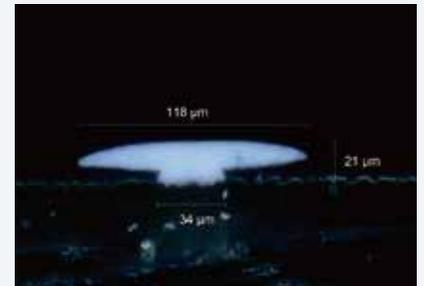
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- High accuracy with unique registration methods for white SM
- Field proven solution in multiple sites



Unique recognition of white SM covered targets



Orbotech Diamond 10W



Other SM DI solution

We had nitrate-free silver, which builds up about 10–15 microinches of silver in five minutes, so we tried simple tests with it. To our surprise, it solved all their issues, and they became an instant customer for this silver. They had had ongoing champagne voids and line reduction issues, and this silver solved that for them.

Strong on that success, we made a few installations where those issues were identified. As I mentioned, the silver market was slow, and we did not push because we did not know of any corrosion benefit yet. The nitrate-based process can deposit up to 20–30 microinches in one minute, and for us, that is the main issue. We felt that thinner, pore-free silver had to be better than thicker, fast deposited silver.

We had in mind to do a side-by-side bench comparison of these two silvers. The nitrate base is still dominating the market and is also directly related to the minuscule market share

of silver as a final finish. Then the pandemic hit, and I had a lot of free time to involve myself in that long-desired bench comparison study.

Some material manufacturers had begun to share their findings on 5G requirements and, based on the requirements of high-frequency PCBs, it looked like silver was the way to go. To make a long story short, high frequencies travel on the surface, and silver is practically as good as copper at precluding signal loss. Signal loss was the main problem for 5G applications as the component will stop working.

Compensating for insertion loss requires a more sophisticated material, or heat-resistant components, or signal boosters, all of which lead to higher costs to accommodate ENIG.

Or you could use alkaline nitrate-free immersion silver, at no extra cost. In this world, ENIG is the worst conductor due to its thickness and magnetic properties (Figure 1).

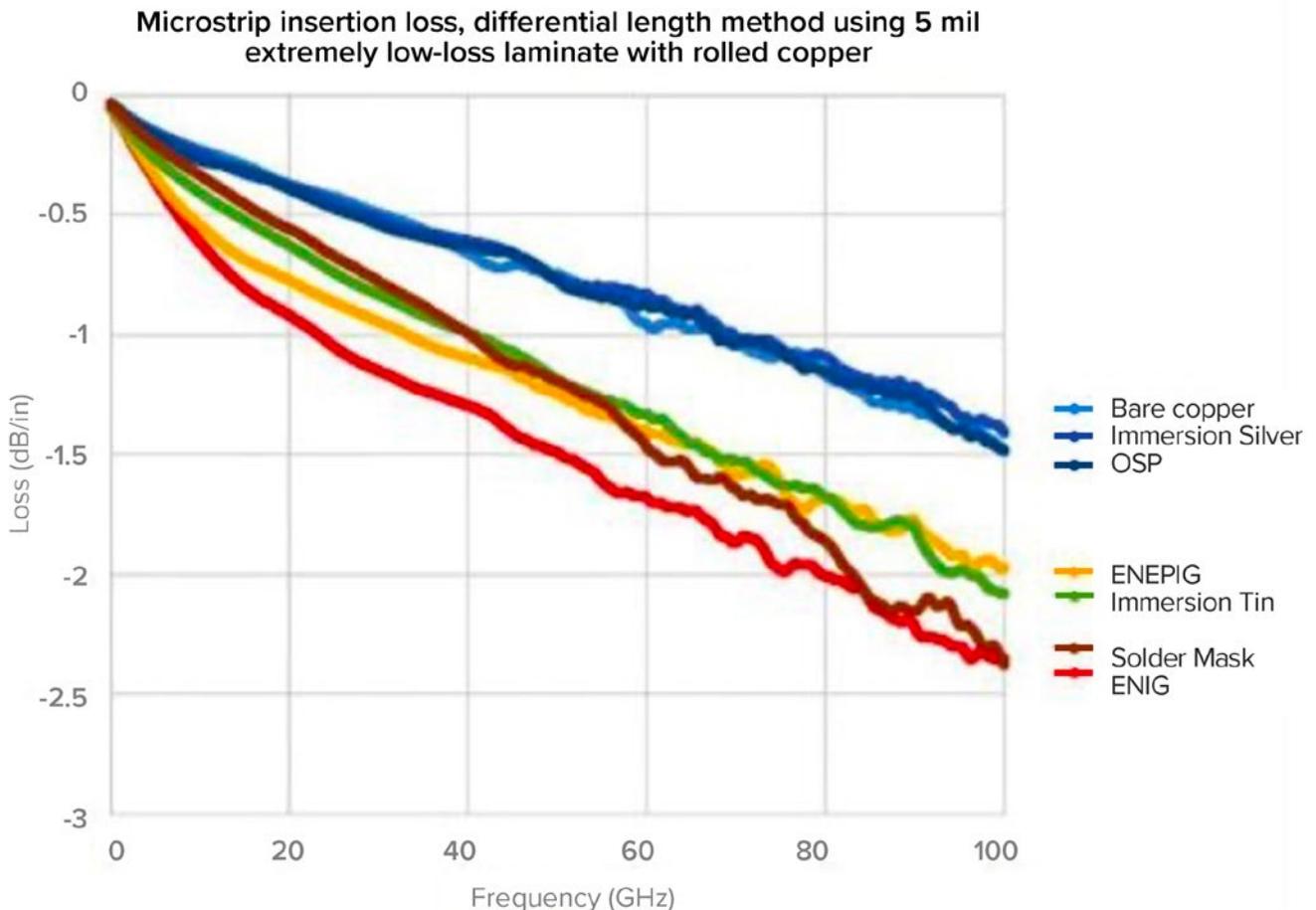


Figure 1: A comparison of various final finishes.

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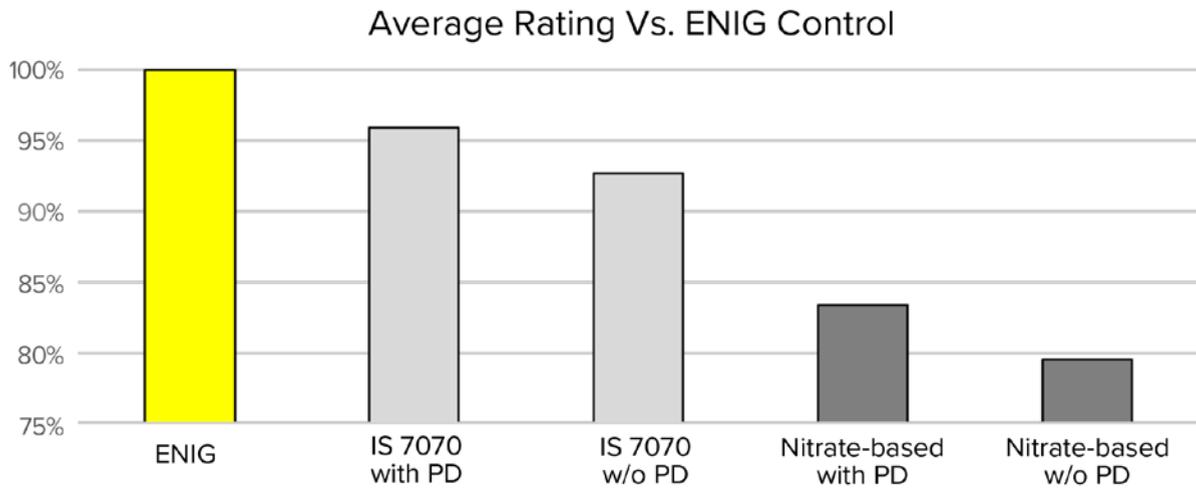


Figure 2: Corrosion test of ENIG, nitrate-based silver, and nitrate-free silver finishes.

This was what we needed to get started. In our internal study, we compared ENIG, nitrate-based silver, and nitrate-free silver against different types of corrosion. We wanted to prove our concept addresses corrosion issues and is superior to nitrate-based chemistry, much like the show *Mythbusters*. We believe we are better, let's do destructive testing to prove it!

The three processes were plated, using the same test coupons. They were all run as close as possible to best practice and we have tested the use of an organic post-dip for the two silvers. Then we compared all parts for cosmetics, adhesion, solderability, nitric acid dip/solderability, horizontal micro-etch cycle, and creep corrosion. As expected, the cosmetics and adhesion were all good. Even the nitric dip was good for three tests; the nitrate-based finish came out slightly yellow, but still solderable. It was during the next two tests that we got a nice surprise.

As expected, ENIG, came out perfect. But surprisingly, ENIG was followed very closely by the nitrate-free process using a post-dip. It was very close!

The horizontal micro-etch was removing about 15 microinches of copper with each pass. We processed the parts—inspect, tape test, and if it passed, on to the next round—for 10 passes. The creep corrosion test involves

putting cold parts in a hot clay, sulfuric environment for a 24-hour cycle.

When we plotted the results, ENIG was perfect, and the nitrate-free process with post-dip was extremely close. Traditional nitrate-based silver was far behind (Figure 2).

Since those findings, we reshaped the process, and do have a 5G solution for a final finish. It is economical, conductive, solderable (and in fact, multi-cycle solderable), and most beneficially, addressing all the issues immersion silver had with corrosion.

This new immersion silver process is a game-changer because cost, speed, and performance are all there. Today, ENIG is still dominating the final finish market, but this approach will not work in the very near future. 5G today is at one-tenth of its full potential, and as the signal speed increases, the options that can keep the cost down and performance high will become the new standards. **PCB007**



Denis Jacques is product manager of PWB products for Technic Inc.



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MilAero007 Highlights



Jahr Turchan Discusses Blackfox's Training Scholarships for Veterans ▶

Nolan Johnson recently interviewed Jahr Turchan, director of Veteran Services & Advanced Manufacturing Programs for Blackfox Training Institute. They discussed some of the new programs at Blackfox.

IPC: Rising Material Costs Remain Key Pain Point for Electronics Manufacturers ▶

Per IPC's May Global Sentiment of the Electronics Supply Chain Report, nine in 10 electronics manufacturers surveyed are currently experiencing rising material costs, while nearly four-fifths are experiencing rising labor costs.

Eshoo & Moore Introduce Bipartisan Bill to Bring Electronics Manufacturing to America, Strengthen Supply Chains ▶

Reps. Anna G. Eshoo (D-CA) and Blake Moore (R-UT) announced bipartisan legislation to bolster domestic PCB production and strengthen supply chain security.

Jabil Strengthens Additive Manufacturing Offerings with New PK 5000 ▶

Jabil Inc. launched PK 5000, an eco-friendly, powder-based additive material engineered to deliver improved strength, chemical resistance, and resilience in comparison to general-purpose nylon materials, such as PA 12.

BAE Systems Opens New Facility ▶

BAE Systems has opened its new engineering and production facility in Manchester, N.H., as the latest step in a series of strategic facility investments across the country.

Nortech Systems Announces New Board Member ▶

Nortech Systems Incorporated, a provider of engineering and manufacturing solutions for complex electromedical and electromechanical products, announced David Graff was elected to the company's board of directors.

Raytheon Missiles & Defense Ships First Lower Tier Air and Missile Defense Sensor to U.S. Army Test Range ▶

The first Lower Tier Air and Missile Defense Sensor, built by Raytheon Missiles & Defense, a Raytheon Technologies business, arrived at the U.S. Army's White Sands Missile Range on April 11.

U.S. Air Force and Lockheed Martin Successfully Complete ARRW Hypersonic Boosted Test Flight ▶

The U.S. Air Force and Lockheed Martin successfully conducted a hypersonic-boosted flight test of the AGM-183A Air-launched Rapid Response Weapon (ARRW) from the service's B-52H Stratofortress.

Powering the Moon: Sandia Researchers Design Microgrid for Future Lunar Base ▶

Sandia National Laboratories is well-known for designing reliable and resilient microgrids for military bases and vital city services. Now, Sandia researchers are working with NASA to design one for the moon.

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Happy Holden's *Automation and Advanced Procedures in PCB Fabrication*

When it comes to plating printed circuit boards, few people have more experience than our technical editor, Happy Holden. In this excerpt from his book *Automation and Advanced Procedures in PCB Fabrication*, Happy discusses the development of early automated PCB manufacturing at HP, including computer-controlled plating systems. He also outlines a plan for tracking ROI through automation, along with some of the many tradeoffs to be considered.

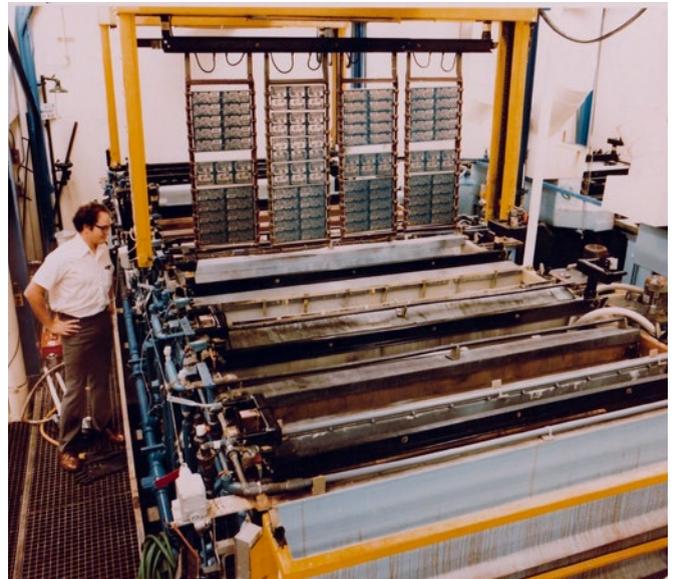


Figure 1: The author with one of the robot hoists controlled by the computer system.

Computers Come to Plating

Computers were first applied to PCB manufacturing at HP's Palo Alto facility in 1974. Figure 1 shows the computer-controlled plating system that included hoist control, current control, and monitoring for the plating tanks; chemical replenishment for the plating cells;

CAM System Hierarchy of Sunnyvale PC

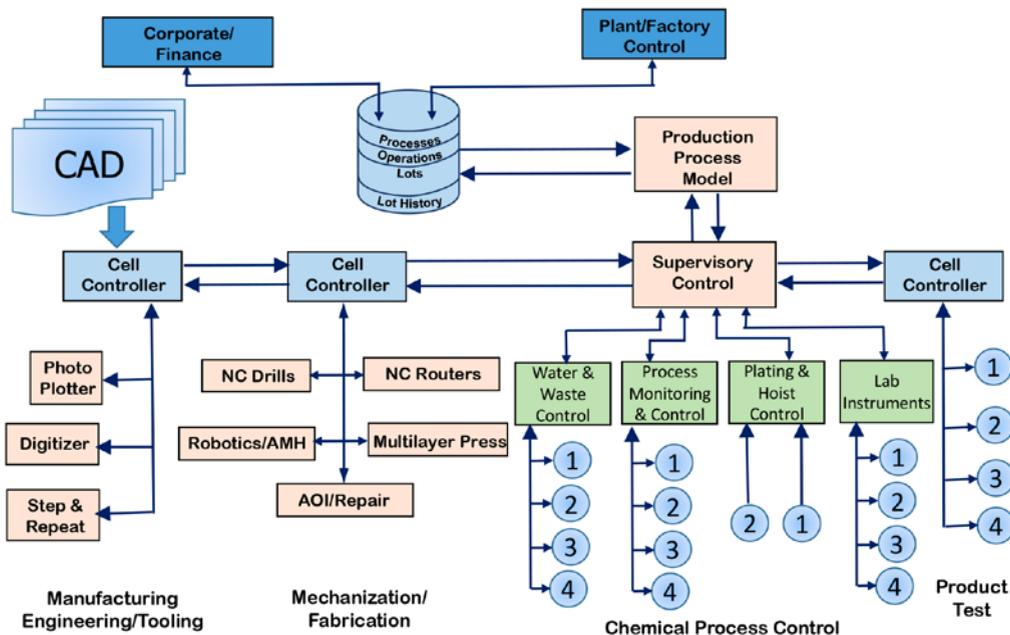


Figure 2: The HP-Sunnyvale PCB CIM system diagram.



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- * Overall process cost reduction.



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Copper Clad Laminate



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Rigid, Flex, Rigid-Flex



Card
Polycarbonate, PVC

Markets



Medical



Automotive



Aerospace & Defense



Networking & Communications



5G

Automation Return On Investment

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
(\$415,000.00)	\$46,764.80	\$163,873.60	\$177,251.92	\$191,363.39	\$206,246.59	\$288,342.10	\$304,892.58	\$322,342.87

PV=\$415,000

n=8

PMT = PV(crf-?%-8) = cash flows

PMT = cash flows/year

Figure 3: Cash flows for plating investment.

and multiple process sequence recipes (Cu, Sn/Ni, Sn, and Au) that HP used for all its different 23,000 separate products.

CIM Environment Used for the Sunnyvale PCB Factory

The PCB facility in Sunnyvale that was built in 1981 had even more factory automation than the facility in Palo Alto, Figure 2 demonstrates the hardware system diagram. This was the first implementation of HP's automation strategy, "The Manufacturers Productivity Network."

Automation ROI

The classical trade-off is between the purchase of an automated system and its advantages, and the continued increase in direct labor. However, quality, process yields, and wastewater treatment costs also enter into the calculation. Return on investment (ROI) is the calculation of the equivalent interest rate of the money invested based on the cash flows over the useful life of the equipment.

Example

A copper/tin pattern plating line with rack strip purchased at a cost of \$400,000 plus \$15,000 installation with an eight-year operating life and a five-year depreciation would result in the following:

- Capacity: 500 18" x 24" (450 x 600 mm) panels per shift
- Load: two rows of four panels
- Individual process steps: Load, microetch, water rinse twice, sulfuric acid, copper plate, dragout rinse, water rinse, fluoroboric acid, tin, dragout rinse, water rinse, dry, unload, rack strip, dragout rinse, water rinse, and load.

The equivalent interest rate that could be earned on the investment of \$400,000 + \$15,000 installation and startup is 35% interest, which is the ROI (Figure 3).

These tradeoffs can be seen in Figure 4 with a calculated cost comparison between manual production for electroless copper and electroplating copper/tin versus four automation strategies. PCB007

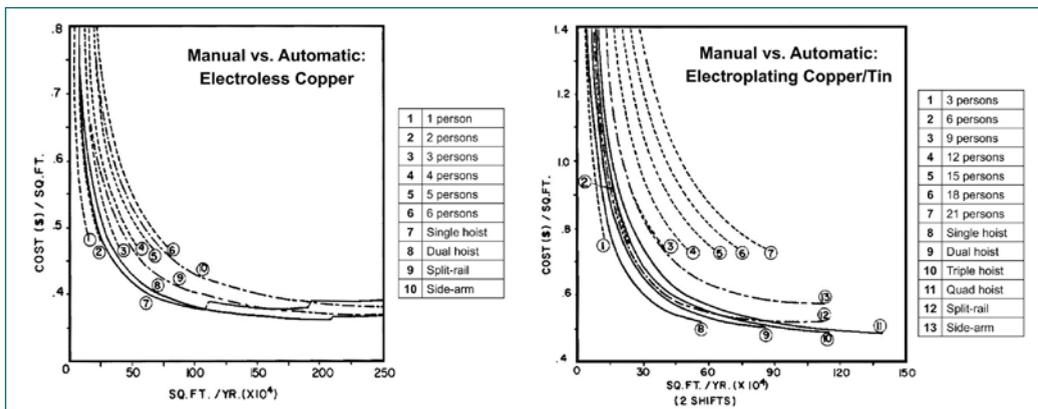


Figure 4: Curves of manual versus automatic cost per square foot: Electroless copper (left) and electroplating copper/tin (right).

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Atotech Sells 1,000th Horizontal Electrolytic Copper Plater

Atotech, a market leader in advanced electroplating solutions, announced the sale of its 1,000th horizontal equipment for electrolytic copper plating. The plater, which belongs to the company's Uniplate product family, will be installed at one of Taiwan's leading advanced package-substrate and PCB manufacturers. Atotech's Uniplate Cu18 plating line is designed for high aspect-ratio through-hole filling of core layers for advanced packaging of CPU and MPU for high-performance processing and computing.

"The 1000th horizontal electrolytic copper plater is intended to support our customer in Taiwan in complying with the increasing demand for more advanced IC substrate products," said Harald Ahnert, President of Atotech's Electronics segment. "For over three decades, we have worked with leading PCB and Package Substrate companies and have shaped the industry with our innovative, constantly improved Uniplate family. This is just another step in our continued success story, and we are all proud of the innovative capacity of our global engineering teams."

Key milestones of Atotech's horizontal electrolytic copper plater include:

- **1988:** Atotech sells its first Uniplate plater (DC plater with soluble anodes), revolutionizing the way PCBs are transported and processed by introducing horizontal electrolytic copper plating.

- **1998:** Atotech launches the next-level breakthrough with a system that has an inert anode and reverse pulse plating capabilities and uses a redox system for copper replenishment.
- **2002:** Atotech's engineering teams further enhance the company's flagship horizontal production system and launch "Uniplate InPulse 2", the next-generation copper plater. It features closer proximity between anodes and PCB, allowing improved surface distribution and requiring no shielding system.
- Over the years, the plater series is further optimized, and more innovations are added to the product family, incl. an extra-wide plater and an advanced plater for through-hole filling.
- Atotech's latest generation of the Uniplate plating system is used for high aspect-ratio through-hole filling of core layers for advanced package substrates. It is also used for mSAP technology as applied in the production of substrate-like PCBs, particularly flash copper plating and any-layer technology with BMV SuperFilling.
- Atotech is currently developing a new generation of its plater family with an expected market launch next year. Key features of this product will include its ability to transport much thinner materials, plate finer features, and it will come with an even more advanced surface-distribution concept for horizontal electrolytic copper plating.

- To date, Atotech has sold a total of more than 2,220 units across all its Electronics equipment systems.

The sale of the 1,000th horizontal electrolytic copper plater complements Atotech's horizontal lines from the 'Uniplate' family, which are already in operation at several flagship manufacturers worldwide. The order is in line with the current trend to ramp up production capacities for high-performance computing and advanced-packaging applications.

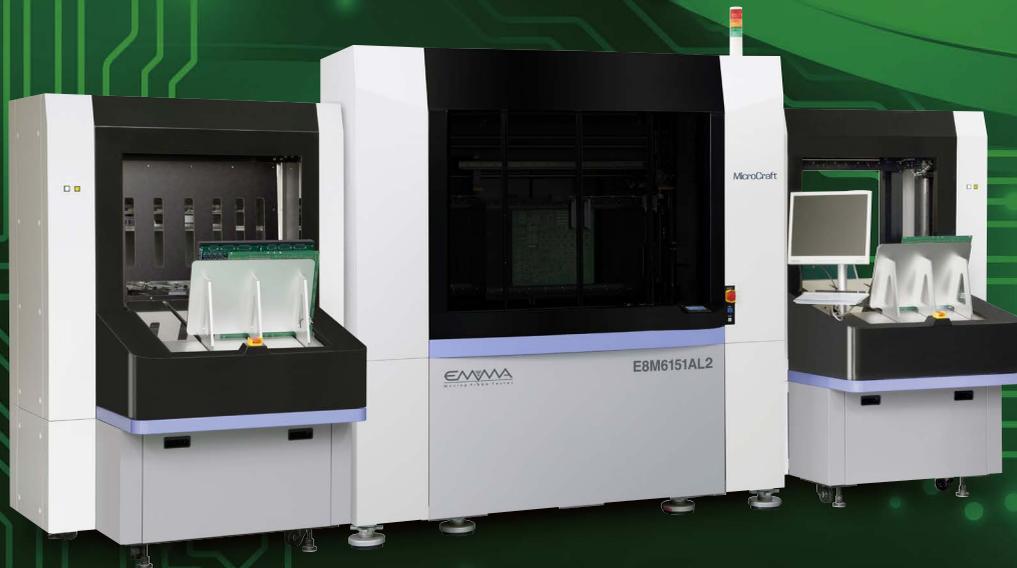
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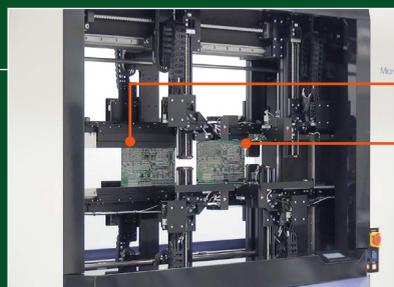
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200 pcs

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Increased Throughput

Transfer speed reduced by **37%**

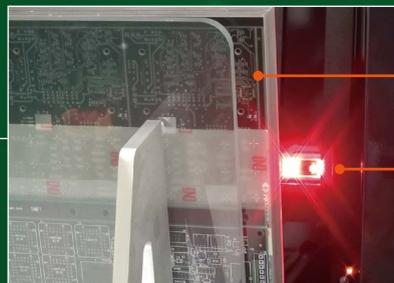


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Etchants of the Industry: Cupric vs. Alkaline

The Chemical Connection

by Christopher Bonsell, CHEMCUT

Chemical etching is a vital process for manufacturing PCBs. It is one of the most complex chemical processes next to plating. This is because there are many different variables that can affect your product and how efficiently it is produced. Although it is complex, etching of copper can be narrowed down to a handful of etchants that PCB manufacturers widely use. By far, the most common etchants are cupric chloride and alkaline cupric chloride, commonly referred to as “ammoniacal alkaline etchant.” There are other etchants for copper, such as ferric chloride, sodium persulfate, and alkaline ammonia sulfate, but they are not commonly used for PCB manufacturing and are often only used in “special cases.” I may touch on those other etchants a bit more in a future column, but this one will focus on cupric and alkaline.

About Cupric and Alkaline

Together, these etchants are used in the majority of PCB etch shops, with alkaline being the most popular. To provide a baseline of how they work, their etch reactions along with their corresponding regeneration reactions, can be found in Table 1.

One of the main reasons these two etchants are the most used is because of their regeneration capabilities. With regeneration, you increase the capacity of copper you can etch. It also helps keep the etch rate at a consistent value. To maintain mass production of PCBs, it is important to keep the etch rate steady but also high enough to maximize output. Since etch rate can greatly influence production rates, it is a major factor when comparing etchants.

Table 1: Reactions for cupric chloride and alkaline etchant.

	Cupric Chloride	Alkaline Etchant
Etch	$\text{Cu}^0 + \text{Cu}^{+2}\text{Cl}_2 \rightarrow 2 \text{Cu}^{+1}\text{Cl}$	$\text{Cu}^0 + \text{Cu}^{+2}(\text{NH}_3)_4\text{Cl}_2 \rightarrow 2 \text{Cu}^{+1}(\text{NH}_3)_2\text{Cl}$
Regeneration	$\text{Cu}^{+1}\text{Cl} + \text{NaClO}_2 + 6 \text{HCl} \rightarrow$ $\text{NaCl} + 3 \text{Cu}^{+2}\text{Cl}_2 + 3 \text{H}_2\text{O}$ <p>Note: This is the most common reaction, but it is not the only one. Regeneration can also be done with hydrogen peroxide or chlorine gas.</p>	$4 \text{Cu}^{+1}(\text{NH}_3)_2\text{Cl} + 4 \text{NH}_3 + 4 \text{NH}_4\text{Cl} + \text{O}_2 \rightarrow$ $\text{Cu}^{+2}(\text{NH}_3)_4\text{Cl}_2 + 2 \text{H}_2\text{O}$

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BY TAIYO



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Etch Rate

Between the two etchants, alkaline etchant dominates in etch rate. Alkaline normally has an etch rate of 2–2.5 mils/min, whereas cupric chloride typically has an etch rate of 1–1.6 mils/min.^{1, 2} This is one of the reasons why alkaline is favored more than cupric chloride. Since etching usually takes a large portion of time in the making of a PCB, having this reduction in etch time can nearly double your production. For you to get the same production level with cupric chloride, you would need to invest in a longer etch section of your processing line, which would mean increasing the number of sequential etch chambers.

Regeneration

As seen in Table 1, both etchants can undergo a regeneration reaction to restore the etchant's quality. Although they both have the capability, cupric chloride has an upper hand because the regeneration reaction is simple. Regeneration for cupric etchant, in most cases, involves simply feeding your reagents into the etcher.

For alkaline etchant, it is more complicated because the regeneration reaction is dependent on oxygen, which it gets from air flowing through the machine. This can be tricky because you need an optimal flow of air

through your machine. For alkaline etchants, it is important to have a sustainable amount of ammonia in your solution (see “chemistry control” below). If air flow through the etching machine is excessive, there will be a rapid loss of ammonia. On the other hand, if you do not have a high enough airflow, your etch rate will drop faster as you etch more panels. There is another form of regeneration for alkaline etchant that is done through liquid-liquid extraction.³ It is an efficient way to regenerate alkaline etchant, but it is not common. This is because of the additional capital cost and the required know-how to make it work properly. Often it is considered easier to send the used alkaline etchant to a company that will regenerate it, with liquid-liquid extraction, for resale.

Etch Factor

Another matter where alkaline etchant is highly favored is etch factor, the ratio of downward etch to sideways etch. Alkaline etchant offers the benefit of a 4-to-1 etch factor (meaning it etches downward four times as much as it etches sideways). Cupric provides a standard 3-to-1 etch factor (Figure 1).

Alkaline etchant's better etch factor opens the opportunity to maintain finer spaces and

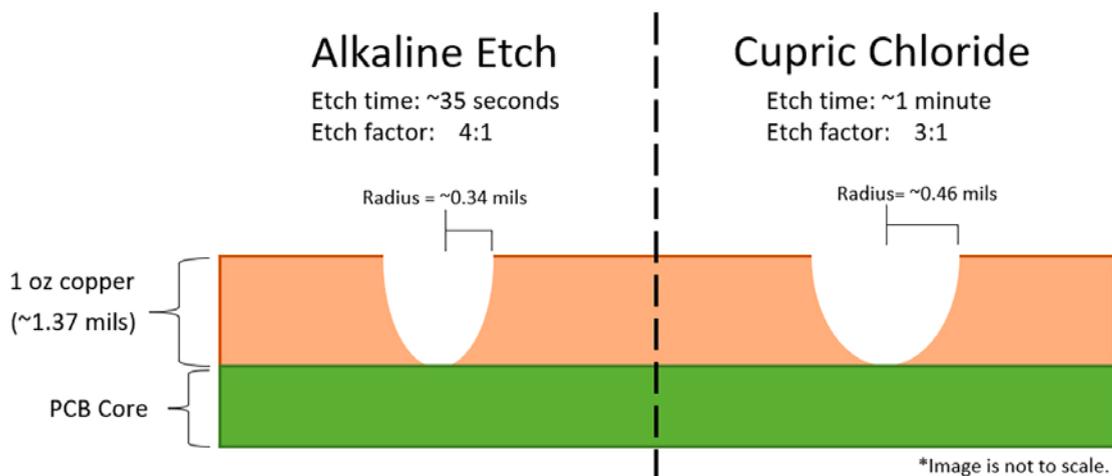


Figure 1: Comparison between alkaline and cupric etchant for the etching of one-ounce copper. Image is for purposes of demonstrating expected values from etching. Alkaline etch values are based on ideal operating conditions.

line widths when you are etching panels with thicker copper layers. Although alkaline can provide a great etch factor, a 4-to-1 ratio can only be obtained if the etchant is kept at its optimal condition, which is easier said than done.

Chemistry Control

Although alkaline etchant has some qualities that can prove to be great for PCB production, it is a challenging etchant to maintain. There are many extra precautions that need to be taken with alkaline etchant that wouldn't be necessary for etching chemistries like cupric or ferric chloride. This is because the chemistry is based on ammonia, a very volatile gas. Once the ammonia content in solution drops too much, there is an irreversible precipitation reaction, known as "sludge-out," that renders your etchant unusable. To avoid this, you must ensure that the etchant is constantly in use and not allowed to sit idly for more than two days. While it is in use, you must maintain a strong handle on your etchant's conditions.

The parameters alkaline needs to be within are often narrow and not so easily controlled.

Cupric chloride provides a stark contrast to this because it is quite easy to handle. It is perhaps the most forgiving of all metal etchants because the parameters you need to keep a consistent etch rate have a relatively large window. If there is some deviation from the parameters, your etch quality will not change much. Additionally, unlike alkaline etchant, intermittent use is allowable; therefore, if you are not etching panels on a daily basis, this is a suitable etchant for your process.

Resist Compatibility

Resist compatibility is important in any chemical etch process. This is because if your resist and etchant are incompatible, the resist will lift or disintegrate off the surface during etching, thus preventing you from obtaining your desired features. Between alkaline and cupric, resist compatibility varies greatly. One matter that is a deal breaker for some PCB fab-

Table 2: Advantages and disadvantages of cupric chloride and alkaline etchant.

	Pros	Cons
Cupric Chloride	<ul style="list-style-type: none"> • Cost of etching is less than alkaline • Easy to control and maintain • Easy treatment of rinse water • Simple regeneration Process • Surface contaminants hardly affect etching 	<ul style="list-style-type: none"> • Incompatible with most metallic resists • Slower etch rate than alkaline • More sideways etch than alkaline • By-products may be expensive to dispose
Alkaline Etchant	<ul style="list-style-type: none"> • Faster etch rate • Better etch factor (less sideways etch) • Compatible with most common metallic resists • Spent solution often taken back by supplier 	<ul style="list-style-type: none"> • Difficult to control for optimal performance • Crystallization can cause equipment problems • Low viscosity promotes chemistry migration • Not sustainable for intermittent use • Ammonia odor • Incompatible with most aqueous dry films • Difficult treatment of rinse water

ricators is that cupric chloride is incompatible with most metallic resists. For this reason, cupric chloride etching is often dedicated to the manufacturing of inner layer PCBs. Alkaline is on the opposite end of the spectrum because it can be used with most metallic resists, but it has a drawback of being incompatible with many alkali strippable photoresists (dry film). Since these etchants cover two completely different ends of this spectrum, most PCB manufacturers will adopt both etchants into their etch shop so they can make both inner and outer layers.

Summary

Each etchant clearly has their own strengths and weaknesses. Table 2 shows a side-by-side comparison of the differences between the two etchants.

From Table 2, it can be concluded that cupric chloride may be the better etchant to go with if you are given the choice. With its simplicity in chemistry and required maintenance, it makes up for any of its shortcomings. Using alkaline

etchant does not seem necessary unless you are a PCB manufacturer who is running production every day, needs tight lines and spaces on your PCBs, and/or needs to use metallic resists. If that does not describe you as a PCB manufacturer and yet you still desire to use alkaline, it is recommended that you get a chemist or process engineer experienced in maintaining the alkaline etch chemistry. **PCB007**

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

Faster Computing Results Without Fear of Errors

Researchers have pioneered a technique that can dramatically accelerate certain types of computer programs automatically, while ensuring program results remain accurate.

Their system boosts the speeds of programs that run in the Unix shell, a ubiquitous programming environment created 50 years ago that is still widely used today. Their method parallelizes these programs, which means that it splits program com-

ponents into pieces that can be run simultaneously on multiple computer processors.

This enables programs to execute tasks like web indexing, natural language processing, or analyzing data in a fraction of their original runtime.

The system also makes it easy for the programmers who develop tools that data scientists, biologists, engineers, and others use. They don't need to make any special adjustments to their program commands to enable this automatic, error-free parallelization, adds Vasilakis, who chairs a committee of researchers from around the world who have been working on this system for nearly two years.

This new system, known as PaSh, focuses on program, or scripts, that run in the Unix shell. A script is a sequence of commands that instructs a computer to perform a calculation. Correct and automatic parallelization of shell scripts is a thorny problem that researchers have grappled with for decades.

(Source: MIT News)



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Radars, Missiles, and the World's Costliest Computer

Happy's Tech Talk #9

by Happy Holden, I-CONNECT007

Let's have a little fun and walk back nearly 70 years into the history of electronics and computers. What was the world's most costly computer and why? The answer is not today's supercomputers¹, nor computers built during World War II. Instead, it lies in a real-time air defense radar system built during the height of the Cold War of the 1950s that had left the U.S. extremely vulnerable to a Soviet bomber attack.²

Introduction to SAGE

This was the beginning of a North American strategic defense system, eventually known

as the Semi-Automatic Ground Environment System (SAGE). It was conceived in 1954 by the scientists at MIT's Lincoln Laboratory for the air defense of the U.S. and Canada. The idea was that a large network of radars would automatically detect a surprise bomber formation as it approached the U.S. mainland from any direction² (Figure 1). By the time of its full deployment, there were 24 direction centers, three combat centers, and hundreds of radars². These were built to analyze radar data and respond with appropriate actions by directing Air Force and Navy interceptor fighters,

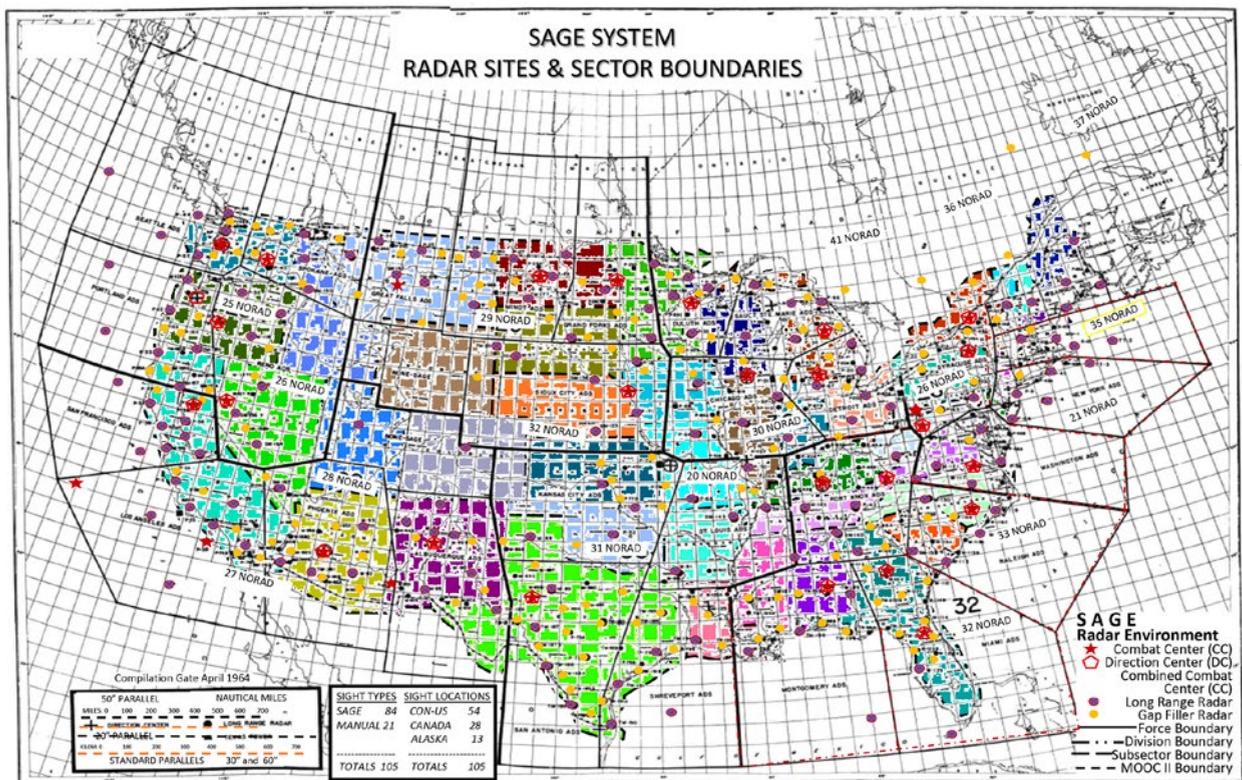
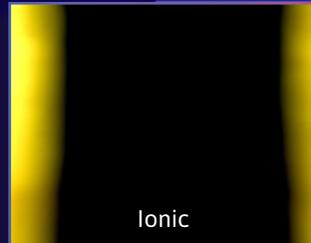
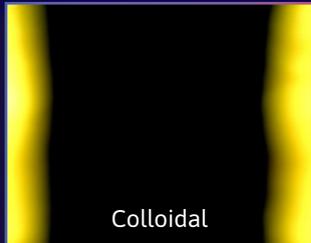


Figure 1: The full extent of the SAGE system covered all of North America with nearly 15 Defense Districts.

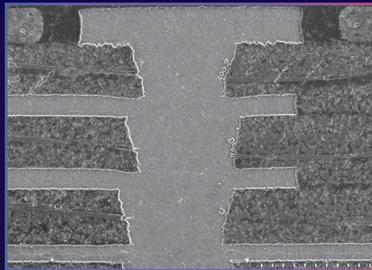
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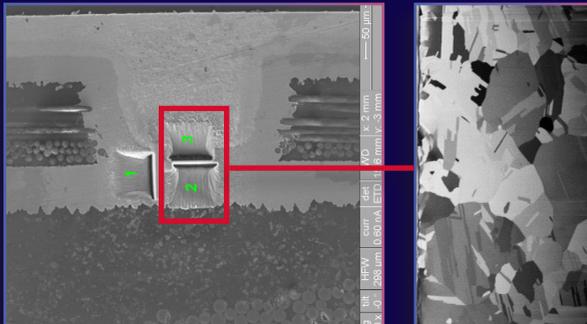
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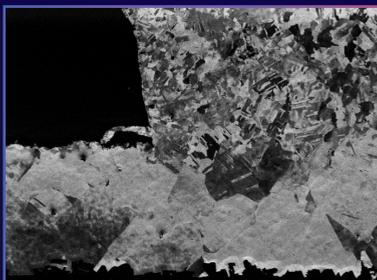
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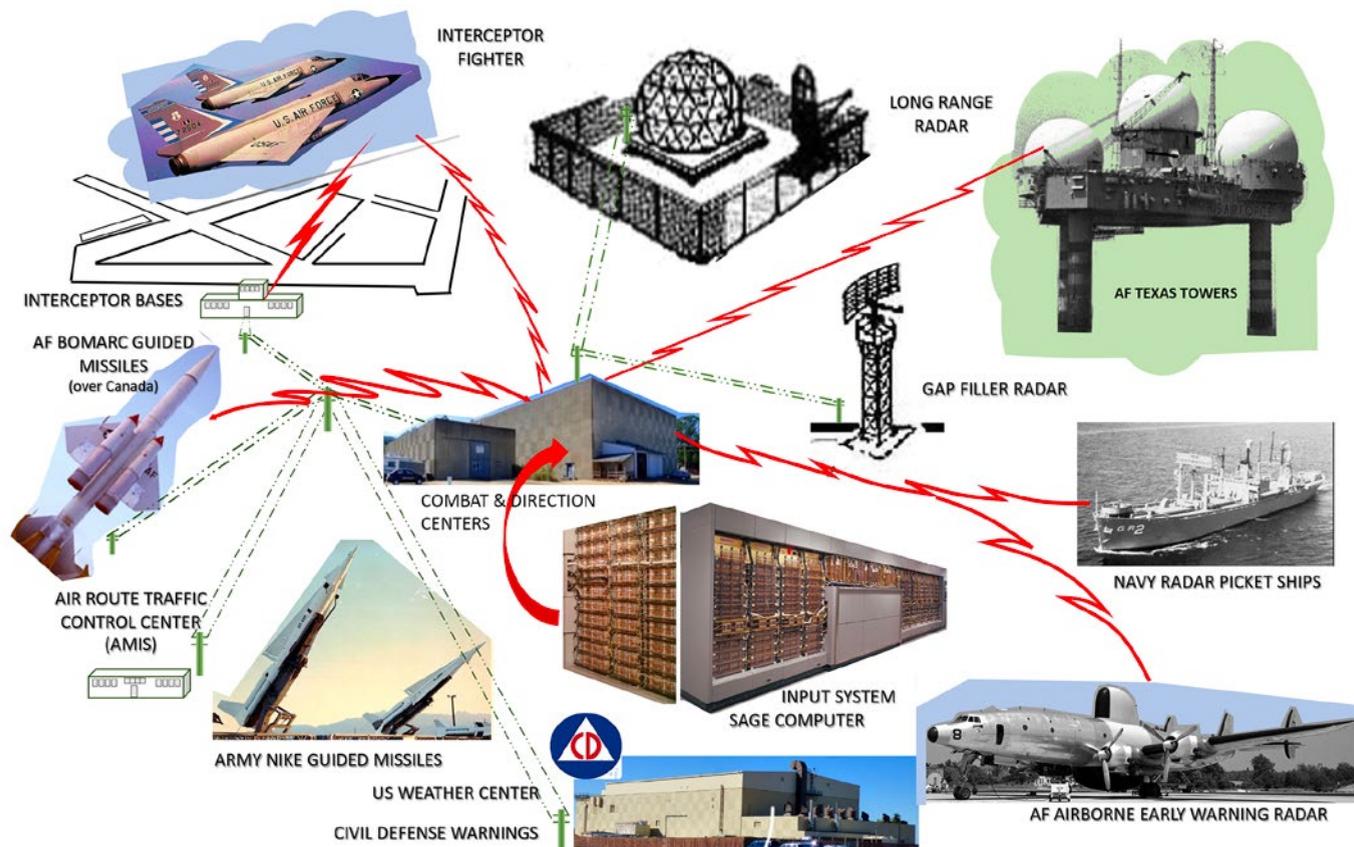


Figure 2: These districts would command and control the radars and defense elements of interceptor fighters and guided missiles.⁵

and Air Force, Army, and Navy guided missiles (Figure 2).

(I actually grew up in Alsea, Oregon not far from Camp Adair, a SAGE command center, where I once got to tour the blockhouse. This station was in operation until the late 1960s—the middle of my college years in Corvallis.)

Many of the missiles along the Canadian border (like the BOMARC) had nuclear-tipped warheads that could explode over Canada. Fortunately, they were never used, although one accidentally blew up in New Jersey and contaminated the area with plutonium³. These were the first supersonic missiles. By 1949, the rockets could reach altitudes of 100,000 to 150,000 feet and had the capability of flying at Mach 6.9⁴. To be effective, the SAGE system would have to direct interceptors and missiles to their target until their own radar acquired

the targets. Smaller missiles were coordinated for city defenses (Nike Ajax/Nike Zeus) and used conventional warheads. Construction was completed in 1962.

SAGE Hardware

To get the project underway, it was decided to use the experimental technology of an MIT-built computer, an IBM-Whirlwind II, the most powerful of its time. Each direction center housed a dual-redundant AN/FSQ-7 computer that consisted of over 500,000 lines of code and executed over 25,000 instructions, by far the largest computer programs ever written at that time². The computers and personnel were all housed in a windowless concrete blockhouse (Figures 3 and 4a). The all-tube computer had an impressive set of components and characteristics⁶:

- 49,000 vacuum tubes
- 13,000 gallium transistors
- 175,000 diodes
- 256 KB of ferrite magnetic core RAM (Figure 3d)
- 12 10.7-inch, 2900 rpm magnetic drum memory of 256 KB (disc drive not invented yet)
- Six IBM-728 tape drives to store the software
- Weighing an impressive 250 tons
- Consuming 3 million watts of power
- Occupying 21,780 square feet

In addition, it was the first computer to be networked, to have a completely redundant hot backup computer on standby, and to use large 20-inch CRTs as operating consoles.

The SAGE System Packaging

The undertaking of this ambitious system was monumental. Every U.S. state and Canada became involved (Figure 1). For the first time, all the independent defense elements were connected to central control systems by underground dedicated telephone lines as well as radar picket ships and “Texas Towers” at sea, and airborne early warning. Also monumental were the hundreds of new long-range radars and unmanned, automated “gap filler radars” constructed across the U.S. and Canada. Burroughs and Western Electric had the

responsibility for these computers and connecting all these elements together.

The SAGE Computer

The SAGE computers (Figures 4b and 5) were constructed on three of the four floors of the CC and DC blockhouses. They were interfaced to 150 operating consoles (Figure 5) that were manned by Air Force personnel on a 24/7 basis,

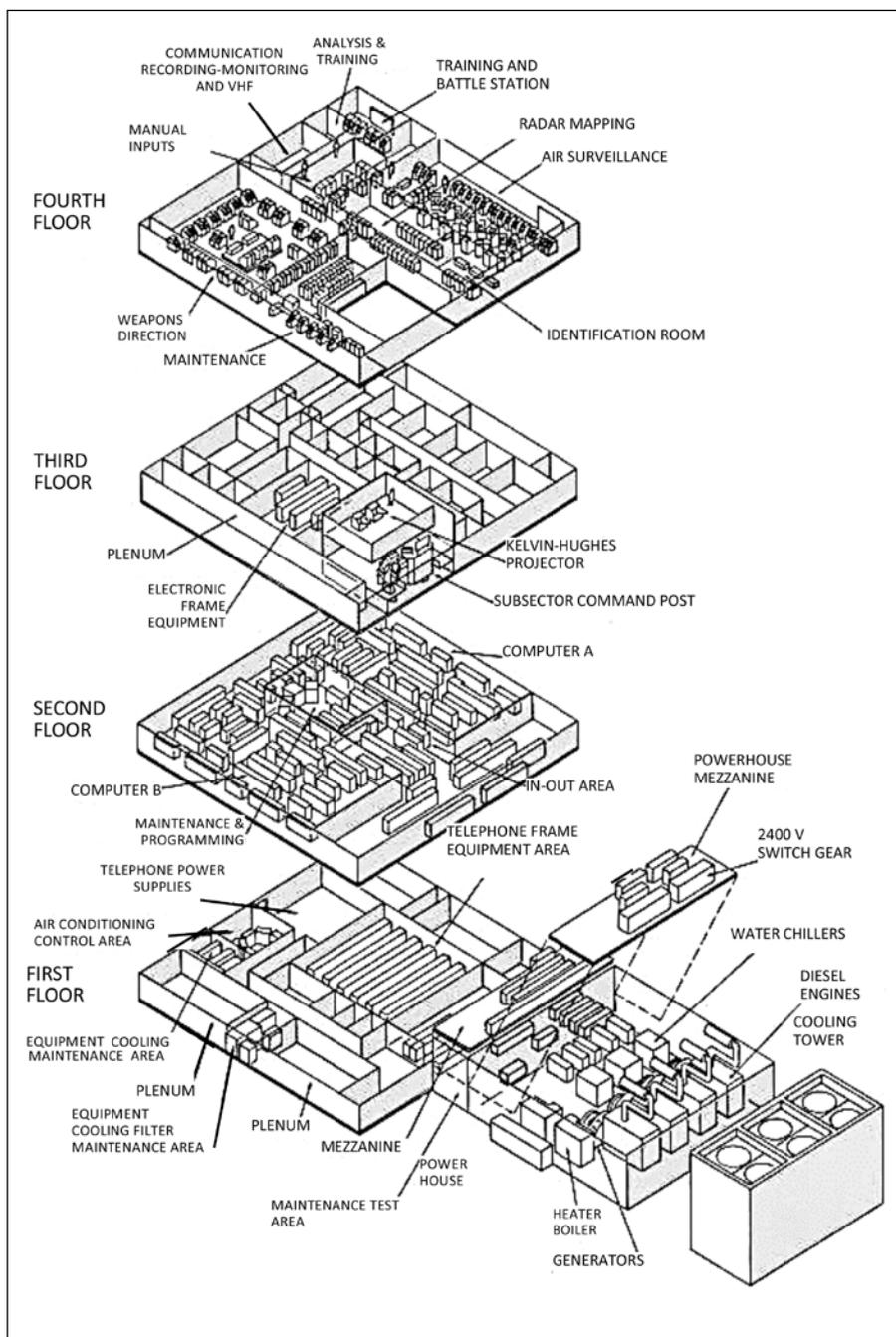


Figure 3: The four-story concrete CC/DC blockhouse housed all computers, power, and maintenance.⁷



Figure 4: A SAGE system: a) CC/DC blockhouse; b) the SAGE tube-based computer; c) The circular CRT display screen; d) the 256 KB core RAM.⁷

all operating at a blistering 75,000 instructions per second (equivalent to an Intel 386).⁷

While some functions of the system were automatic, it still took an operator to spot and

identify an unidentified radar target and decide whether it was friend or foe. The automatic part came because all domestic and military aircraft had filed flight plans that the computer had stored on a magnetic drum and would match to real-time radar data. If the operator decided that the flying object was “foe,” the track was moved to a combat center and the weapons director for actions. If interceptor fighters were scrambled, the computer would guide them to intercept this Identification Friend or Foe (IFF). If a missile was employed, the computer would automatically guide the missile closer so that its own radar could be employed. Then warnings would go out to all civil defense alerts.

Figure 6 shows a close-up of the SAGE computer computing module.

The entire module was hand soldered. Considering the 7,000 modules per computer, and two computers in each of the 27 installations, 378,000 modules had to be manufactured by

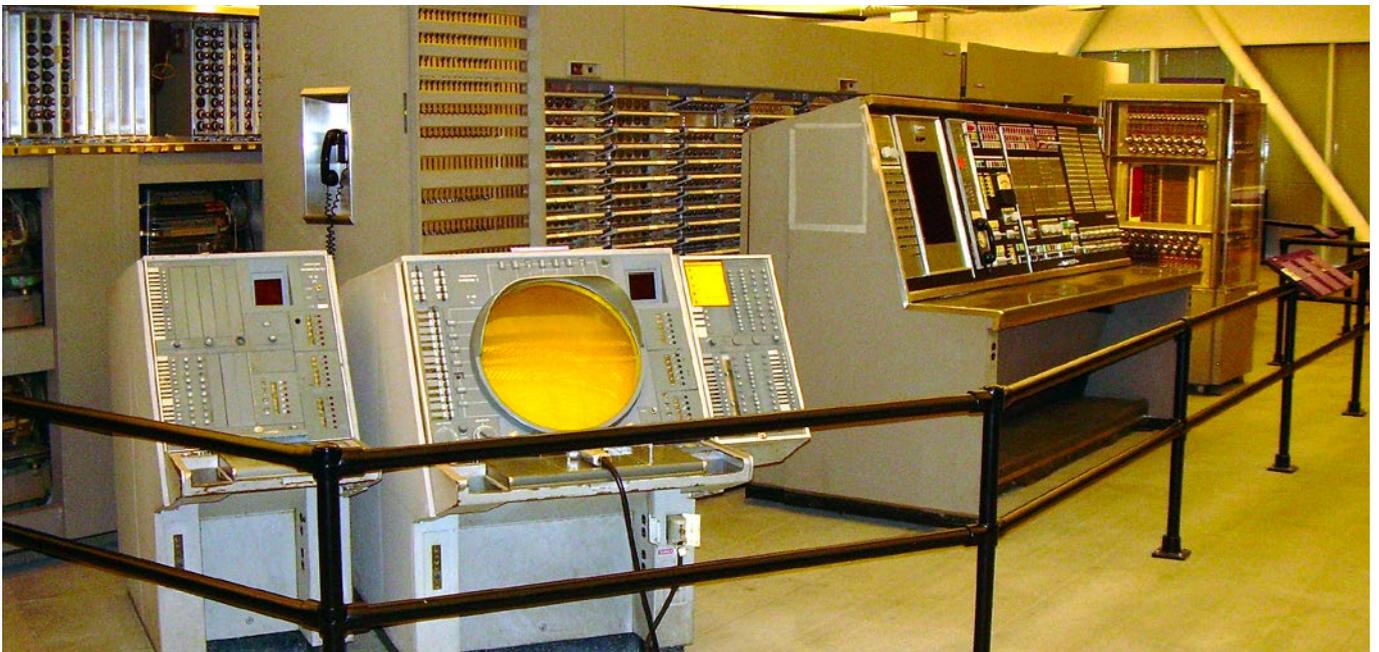
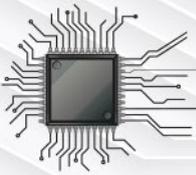


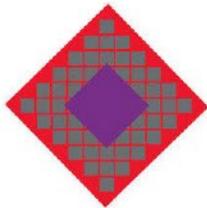
Figure 5: All the elements of a SAGE computer system and consoles. The 20-inch OA-1008 Situation Display (SD) shown in the forefront was equipped with a light gun for a user interface. As Air Force personnel would man the console in eight-hour shifts around the clock, perhaps that is why the console was equipped with a cigarette lighter and ash tray! (Image: Steve Jurvetson, Wikimedia Commons)



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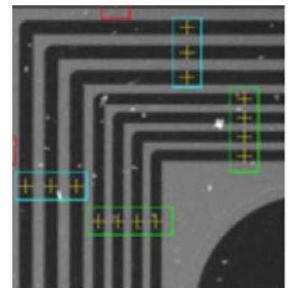
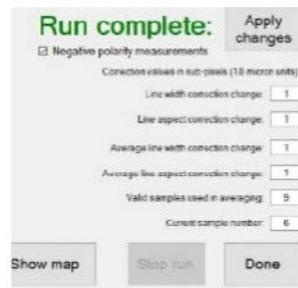
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IBM, not counting spares. But availability was 99.97%.⁷

The Operating System

The software was written by the RAND Corporation with the help of IBM and System Development Corp. (SDC). The 250,000 lines of code, at the peak, employed 20% of the world's programmers. The one million words of code were written in assembly language and JOVIEL. Forty-four manuals of schematics and specifications, including S/W coding, are available from IBM⁸.

The Final Outcome

By 1983, the system was finally shut down as ICBMs made it obsolete. Over the horizon, radars like the Distant Early Warning Line (DEW Line) and orbiting satellites were replacing it. It was not completely dismantled as many of the radars were upgraded and a newer SAGEII computer from Hughes was available to use the software; it was turned over to the FAA for domestic flight control.

The success of the system came at an enormous cost. While neither IBM nor the government have ever released production costs on the secretive (and now decommissioned) project, civilian estimates put the total development cost at \$8–\$12 billion (\$65–\$97 billion when adjusted for inflation). This would be three times the cost of the Manhattan Project.

While source opinions vary on the effectiveness of this project, John F. Jacobs, associate head of Lincoln's Division 6, stated:

“One of the outstanding things... was the esprit de corps—the spirit that pervaded the operation. Everyone had a sense of purpose—a sense of doing something important. People felt the pressure and had the desire to solve the air defense problem, although there was often disagreement as to how to achieve that end. Energy was directed more toward solving individual problems, such as making a workable high-speed memory or a

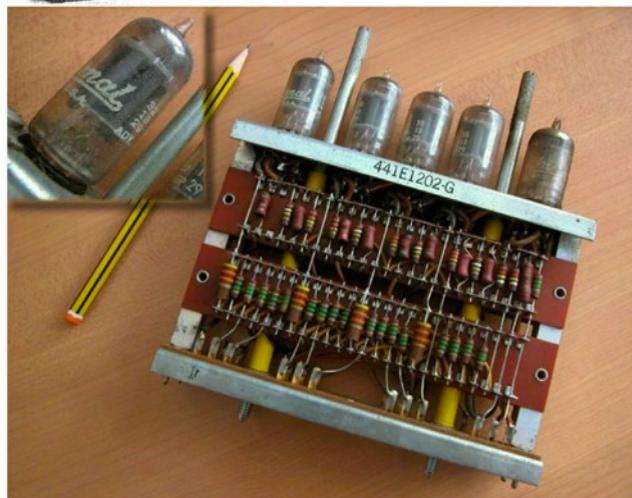
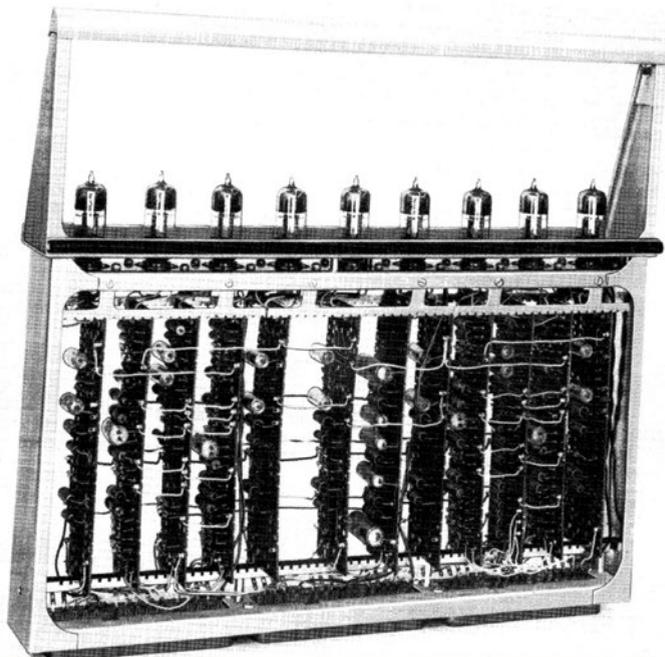


Figure 6: No circuit boards; a close-up view of two of 7,000 tube circuit modules, all hand-wired.⁵

useable data link, than it was toward solving the problem of the value of the finished product. It was an engineer's dream.”⁹

What I found was that the system pioneered many firsts:

- Real-time computer architectures
- Core memory
- Magnetic drum memory
- Networking of sensors, computers, autonomous elements, and humans
- Simple CRT operator interfaces—light pen

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The irony of the SAGE computer is that in its last few years of operations, replacement vacuum tubes had to be purchased from the Soviet Union, as they were no longer manufactured in the West. **PCB007**

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Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa Westwood, Merix, Foxconn, and Gentex. He is currently a contributing technical editor with I-Connect007, and the

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

AI Helps Autonomous Vehicles Avoid Idling at Red Lights

In a new study, MIT researchers demonstrate a machine-learning approach that can learn to control a fleet of autonomous vehicles as they approach and travel through a signalized intersection in a way that keeps traffic flowing smoothly.

Using simulations, they found that their approach reduces fuel consumption and emissions while improving average vehicle speed. The technique gets the best results if all cars on the road are autonomous, but even if only 25 percent use their control

algorithm, it still leads to substantial fuel and emissions benefits.

Typical approaches for tackling intersection control problems use mathematical models to solve one simple, ideal intersection. That looks good on paper, but likely won't hold up in the real world, where traffic patterns are often about as messy as they come.

While humans may drive past a green light without giving it much thought, intersections can present

billions of different scenarios depending on the number of lanes, how the signals operate, the number of vehicles and their speeds, the presence of pedestrians and cyclists, etc.

Researchers approached the problem using a model-free technique known as deep reinforcement learning, a trial-and-error method where the control algorithm learns to make a sequence of decisions. It is rewarded when it finds a good sequence. With deep reinforcement learning, the algorithm leverages assumptions learned by a neural network to find shortcuts to good sequences, even if there are billions of possibilities.

(Source: MIT News)



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¹IPC. (2017). Findings on the Skills Gap in U.S. Electronics Manufacturing.

Opening New Opportunities in Mexico

One World, One Industry

by Guest Columnist David Hernandez, IPC

IPC and WHMA have long supported the electronics assembly and wire harness manufacturing industries in Mexico, but recent regional growth coupled with supply chain disruptions necessitated a closer relationship. Lorena Villanueva, the new director of IPC Mexico, will be based in Mexico City and her presence will help IPC provide better support, training, and engagement with Mexico-based companies and personnel.

Lorena has more than 15 years of experience in client relationship management, strategic planning, and project management for companies such as Genpact, GMAC, American Express, GE, and Lucent Technologies. She is a certified Six Sigma Black Belt and holds a master's degree in economics.

Lorena and I have reviewed each of the 130+ IPC and WHMA members operating 315 manufacturing facilities in Mexico. More than 4,000 IPC certifications have been earned by workers in Mexico, facilitated through our partner certification centers in 12 locations throughout Mexico. The National Statistical Directory of Economic Units (DENUE) in Mexico estimates there are 481 electronics manufacturing sites in Mexico and IPC strives to play a role in each one, including the facilities not yet built.



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The impact of global events on supply chains has opened more opportunities in Mexico. OEMs are expanding the number of suppliers they use, and Mexico has proven it can produce assemblies for verticals like automotive, medical devices, aerospace, and communication equipment.

As shifting supply chains move to Mexico, the industry needs more trained workers. IPC has always offered IPC standards and certification exams in Spanish, but in 2021 we launched two operator training courses in Spanish to help meet this need. Lorena and I discussed IPC's commitment to supporting and growing our Spanish-speaking membership. When she accepted the position, she told me that IPC creating education courses in Spanish was a deciding factor.

Another exciting event is scheduled for September 27–29. IPC and WHMA are producing the M-EXPO Wire Processing Technology show in Ciudad Juarez just across the border from El Paso, Texas. Leading companies in the wire and cable harness assembly industry are exhibiting and we are working to build a series of educational workshops like those at our upcoming Electrical Wire Processing

Technology Expo (EWPTE) show in Milwaukee, Wisconsin. IPC/WHMA is also providing an instructor-led training session for wire harness operators to help local facilities train effectively. IPC and WHMA are proud to produce M-EXPO and believe it is important for the industry to hold these shows in the regions where the work takes place.

The executive teams at IPC and WHMA are thrilled to have Lorena join our team. Her commitment to excellence has been illustrated throughout her career and we cannot wait to see her success with IPC/WHMA. If you have operations in Mexico or anywhere in Latin America, feel free to reach out directly to LorenaVillanueva@ipc.org and start the conversation in English or Spanish. **PCB007**

For additional information, visit mexico.ipc.org, or email us at mexico@ipc.org.



Guest Columnist, **David Hernandez**, is vice president, IPC Education. To read past *One World, One Industry* columns by John Mitchell, [click here](#).

A large graphic featuring the number '1007e' in a 3D, blocky font. The '1' is white, the '007' are orange, and the 'e' is green. Below the logo, the tagline 'Get smarter here.' is written in a white, sans-serif font. The entire graphic is set against a black background with a subtle reflection effect.



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ein Electronics Industry News and Market Highlights



Dell Technologies World 2022 ▶

Liquid, a leading software company delivering data center composability, announced the company is collaborating with Samsung, the world's largest provider of memory technologies, and Tanzanite Silicon Solutions, the leader in memory pooling technology, to demonstrate composable memory via the Compute Express Link (CXL) 2.0 protocol at Dell Technologies World 2022.

Semiconductor R&D Spending to Rise 9% After Hitting Record in 2021 ▶

New update shows Intel continues to lead research and development ranking, the top 10 raised spending 18% last year, and 21 companies invested \$1 billion or more on R&D in 2021.

Dell Solar Community Hubs Bring Technology, Healthcare, Workforce Skills to Remote Communities ▶

Dell Technologies, in partnership with Computer Aid, Intel, and Microsoft, announced its Solar Community Hubs strategy, marking an evolution in its established Solar Learning Labs program.

Silicon Creations, Achronix Semiconductor Partner to Drive More Performance, Flexibility into High-Speed Trading ▶

Silicon Creations, a leading supplier of high-performance analog and mixed-signal intellectual property (IP), has partnered with Achronix Semiconductor Corporation, a leader in high-performance FPGAs and embedded FPGA (eFPGA) IP.

Renesas to Invest, Restart Operation of Kofu Factory; Boosting Power Semiconductor Production Capacity ▶

Renesas Electronics Corporation, a premier supplier of advanced semiconductor solutions, announced that it will conduct a 90-billion-yen worth investment in its Kofu Factory, located in Kai City, Yamanashi Prefecture, Japan.

A New Age of 2.5D Materials ▶

Scientists are exploring new ways to artificially stack two-dimensional (2D) materials, introducing so-called 2.5D materials with unique physical properties.

Qualcomm Introduces Automated Frequency Coordination Solution for Enhanced Wi-Fi Performance in 6 GHz Spectrum ▶

Qualcomm Technologies, Inc. announced its Qualcomm AFC Solution, immediately available for integration into customer products, built to deliver enhanced 6 GHz operation in a turnkey, cost-effective, and scalable implementation with access point (AP) agent and cloud systems with end-to-end validation and certification.

Self-driving Microscopes Discover Shortcuts to New Materials ▶

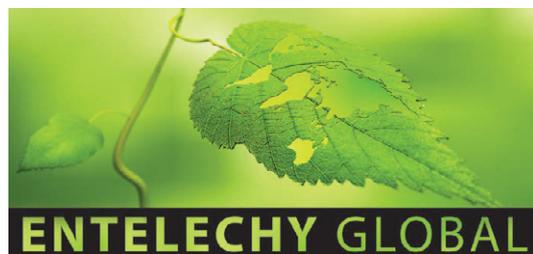
Researchers at the Department of Energy's Oak Ridge National Laboratory are teaching microscopes to drive discoveries with an intuitive algorithm, developed at the lab's Center for Nanophase Materials Sciences, that could guide breakthroughs in new materials for energy technologies, sensing, and computing.

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ET and the DoD

Testing Todd

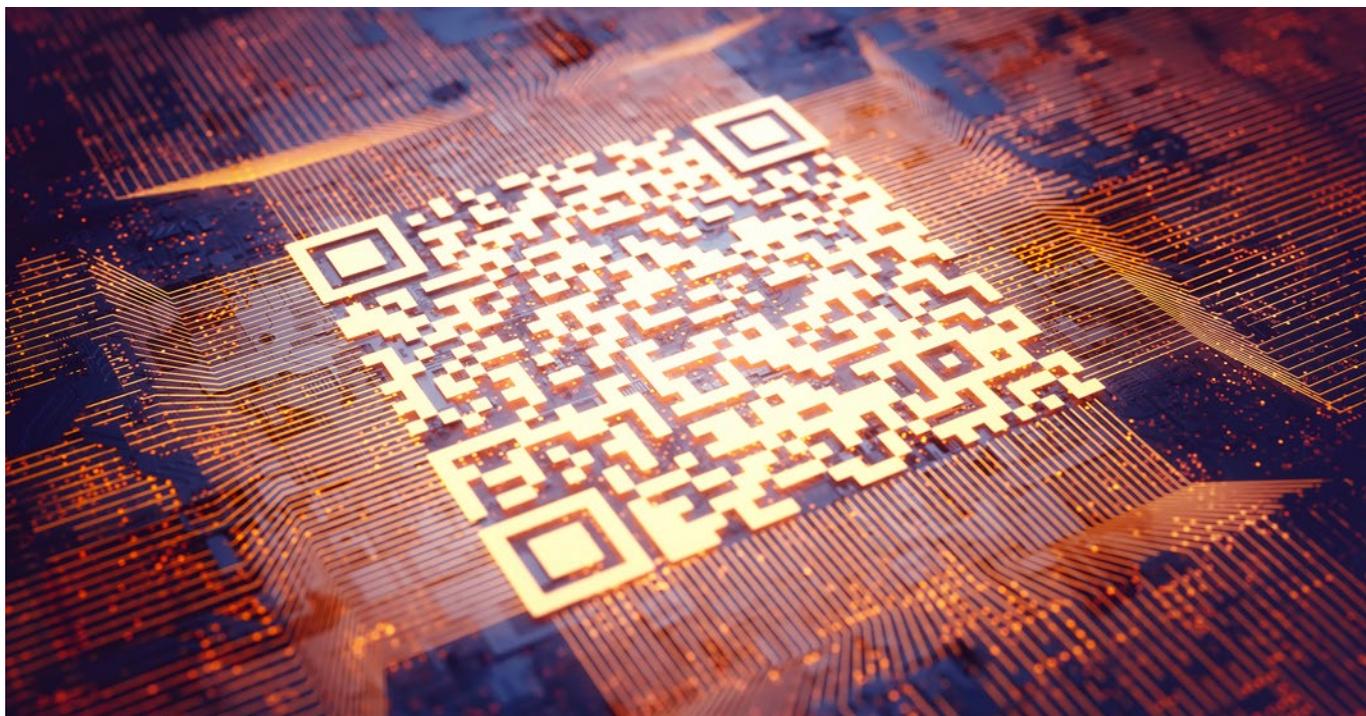
by Todd Kolmodin, GARDIEN SERVICES USA

Building printed circuits can be a tricky business. There are many attributes that go into the production process. Initially, there is the sales interface with the customer, the receipt of the data for the initial quotation. Then there is the procurement process for raw materials, which must be done to the customer specifications. It could be the base materials, plating, mask, or screen, and that is just for the physical build part of the process. They may have special requirements for acceptance, dimensional tolerances, hole tolerances, and the like. That is all just the customer documentation. They may stipulate the industry standard(s) that are to be used for the general manufacturing process—IPC 6012, 6013, etc., and the electrical acceptance standards, for instance, IPC 9252.

Now, if that isn't enough, throw in Department of Defense (DoD) or aerospace specifications.

This month let's dive into the DoD and how this affects electrical test (ET). The current build specification for the Department of Defense for rigid product is MIL-PRF-31032. However, we still see specification calls for MIL-PRF-55110 and MIL-PRF-50884 (flex). We periodically see IPC-ET-652 called out, but new builds should use IPC-9252.

For the ET arena, the call to the older specifications, 55110 and 50884, are not usually an issue if the revision level is specified. It isn't safe to assume "latest rev" when you see this called out. The Defense Logistics Agency (DLA) requires these specifics to be called out for traceability. So, make sure when these speci-





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LIVE WEBINAR

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Our webinar on thermal management with IMS will review popular applications, provide top tips and best practices on IMS material selection and the options that are available to help designers overcome thermal-management challenges and achieve the thermal performance needed to achieve a given target.



Presented by
Robert Art
Ventec International Group

Date: June 23, 2022
Time: 15:00 (CET) / 09:00 (EST)

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fications are called (55110 and 50884) that the appropriate revision and amendment (if applicable) are specified. The reason for this is that older revisions did not allow certain types of test methodology available today to be used as they were not available when the older revision was created. For example, the use of indirect test by signature comparison, sometimes stated as discharge test on a flying probe, was not allowed in earlier revisions of the specifications. It has only been in recent years that this practice is allowed and only in certain revisions of the specifications.

Now, when talking about MIL-PRF-31032 and electrical test, it's a new ballgame. Just stating, "Test to MIL-PRF-31032," will not work. You see, with MIL-PRF-31032, you also have the build supplements, usually referred to as "slash sheets." There are slash sheets one to eight. They specifically address the type of product manufactured and requirements above the standard 31032 specification. If that isn't enough, the slash sheets all have a revision level and likely an amendment. So, when your customers request builds compliant to MIL-PRF-31032 you need to push for the slash sheet, revision, and amendment to be used. As of June 2022, the specification sheet is MIL-PRF-31032/1D with Amendment 3.

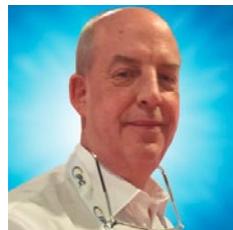
If this is documented on the production traveler or document, it will remove all confusion at the time of electrical test. This document contains all relevant information as to what test methodologies are allowed and what

documentation is required for traceability. If the "slash," revision, and amendment are not given, there is a chance that the product could be tested outside the requirements the customer intended.

Working with the DLA over the years, this is one of the most common audit nonconformances I've found regarding electrical test service centers and in-house ET departments. These specifics need to be on the Certificate of Compliance (CoC) for all military products.

If you receive product calling out MIL-PRF-31032 that does not specify the specific revision, slash sheet/revision, and amendment, the appropriate action is to stop and query your customer or sales team to gather this information before proceeding. Failure to do so may result in an audit nonconformance and incorrect traceability of the product tested.

We all know it is taxing enough to go through these periodic audits so having these ducks in a row will stop an almost sure nonconformance and corrective action. Plus, it will make the electrical test department or service center confident they are providing the service(s) the customer intended. **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 promotional banner for a training video series. On the left, there is a logo for "1-007e WORKSHOP" in orange and white, with "American Standard Circuits" below it. In the center is a portrait of Joe Fjelstad, a man with short grey hair, smiling, wearing a dark leather jacket over a red shirt. On the right, the text reads "On Demand: Free Training Video Series" in white, followed by "FLEXIBLE CIRCUIT TECHNOLOGY" in large, bold, white letters. Below that, it says "with Expert Joe Fjelstad" in white. At the bottom right is a green button with the text "WATCH NOW" in white.

Why Choose Fein-Line?

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Fein-Line Associates is a consulting group serving the global interconnect and EMS industries, as well as those needing contact with and/or information regarding the manufacture and assembly of PCBs. Dan (Baer) Feinberg is a 50+ year veteran of the printed circuit and electronic materials industries. Dan is a member of the IPC Hall of Fame; has authored over 150 columns, articles, interviews, and features that have appeared in a variety of magazines; and has spoken at numerous industry events. As a technical editor for I-Connect007, Dan covers major events, trade shows, and technology introductions and trends.

Fein-Line Associates specializes in:

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- New product market entry
- Merger and acquisition due diligence
- Market information and market research
- Expert witness assistance and seminars regarding all aspects of printed circuits
- Electronic assembly manufacturing and marketing

Fein-Line Associates
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San Clemente, CA 92673

Telephone: (949) 498-7866
Email: baer@feinline.com



Dan (Baer) Feinberg



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PCB Technologies' iNPACK to Focus on Miniaturization, Packaging

PCB Technologies' Jeff De Serrano, Yaniv Maydar, and Alon Menache discuss their new venture, iNPACK. They explain their plans to focus on advanced packaging, miniaturization, and other high-end technology, with much faster time to market, and they offer a view of the global market as well.



Jeff De Serrano

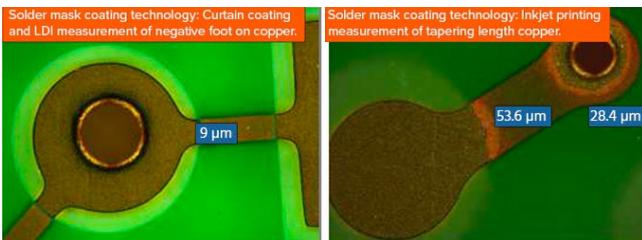


Yaniv Maydar



Alon Menache

Additive Reality: Let's Drop a Line About PCB Cross Section



My recent column, "Additive Manufacturing Requires Additive Design Techniques," presented several cross sections of solder mask coated with an inkjet technology. However, the choice of the cut's location is slightly different from the usual dam or copper edge coverage.

EIPC Technical Snapshot: Supporting Autonomous Driving

EIPC's 17th recent Technical Snapshot webinar focused on developments in automotive electronics, particularly on advances in the technologies required to support the evolution of autonomous driving.



The Big Picture: Robust Cybersecurity System Means Greater Investment Opportunity

When we make a mistake in business, it's natural for people to notice. One such type of mistake being made by businesses around the world is being victimized by cybercrime.

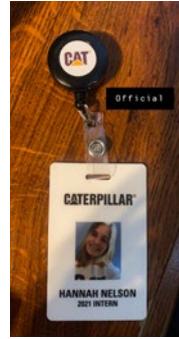
Testing Todd: Optimize Your Training Time

Today's training has become an essential part of any operation, especially because most Quality Management Systems (QMS) require this. To be compliant with ISO9001 you must maintain a competence and training system. However, there are a few things to keep in mind when taking on the competence and training mission.

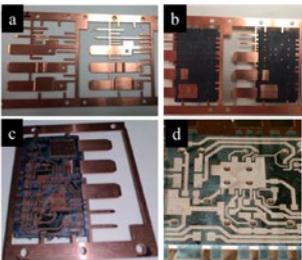


Prepping for an Internship? Three Tips to Shore Up Your Skills

I had just accepted the role of corporate intern at Caterpillar Inc., where I would be working on the product service development team. As I started my internship, I felt like I didn't know anything—and I mostly didn't.



Happy's Tech Talk #7: Next Generation Application Specific Modules



In 1965, Gordon Moore predicted that the number of transistors that could be packaged into a square inch of space would double every year for the near future. Although his projection was later revised, Moore's Law has withstood the test of time for five decades.

The Chemical Connection: The Case for Preventive Maintenance

Preventive maintenance is a routine maintenance performed to ensure equipment runs efficiently and won't experience problems anytime soon. This routine maintenance can become highly important when you are running a business that relies heavily on equipment for production.



A Game Plan for Upskilling Your Fab Workforce

There's been a lot of talk among PCB manufacturers about the need to upskill their workforce. But where do you start—do you set up your own program or send staff to third-party training centers? We asked David Hernandez, IPC vice president of education, to weigh in on this topic.



Technica Heats Up ROI Discussion

The I-Connect007 Editorial Team speaks with Technica's Frank Medina, Ed Carrigan, and Jason Perry about trending hotspots that provide the PCB fabricator a high return on investment (ROI). A common theme: traditional methods for calculating ROI are being replaced by models that include more qualitative factors.

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Career Opportunities



Global Account Manager, e-Mobility & Infrastructure

**Location:
AZ, CA, TX (remote)**

Job Summary:

The Global Account Manager, e-Mobility & Infrastructure is a key position for the sales organization, serving as Indium Corporation's lead sales contact responsible for developing targeted accounts in the e-Mobility and related infrastructure space.

Responsibilities will include:

- sourcing for new global business opportunities
- implementing effective sales strategies
- interfacing with customers' senior management
- execution of action plans through the regional teams
- interaction with internal customers (R&D; Inside Sales; Technical Support; Logistics; Product Management; Operations; Engineering; Quality; etc.) resulting in evaluation, qualification, specification, and maximum customer share for designated customers
- providing risk assessment of the business to senior management

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Electrical Engineer/PCB/CAD Design, BOM/Component & Quality Support

Flexible Circuit Technologies (FCT) is a premier global provider of flex, rigid flex, flex heaters, EMS assembly and product box builds.

Responsibilities:

- Learn the properties, applications, advantages/disadvantages of flex circuits
- Learn the intricacies of flex circuit layout best practices
- Learn IPC guidelines: flex circuits/assemblies
- Create flexible printed circuit board designs/files to meet customer requirements
- Review customer prints and Gerber files to ensure they meet manufacturing and IPC requirements
- Review mechanical designs, circuit requirements, assembly requirements, BOM/component needs/and help to identify alternates, if needed
- Prepare and document changes to customer prints/files. Work with application engineers, customers, and manufacturing engineers to finalize and optimize designs for manufacturing
- Work with quality manager to learn quality systems, requirements, and support manager with assistance

Qualifications:

- Electrical Engineering Degree with 2+ years of CAD/PCB design experience
- IPC CID or CID+ certification or desire to obtain
- Knowledge of flexible PCB materials, properties, or willingness to learn
- Experience with CAD software: Altium, or other
- Knowledge of IPC standards for PCB industry, or willingness to learn
- Microsoft Office products

FCT offers competitive salary, bonus program, benefits package, and an outstanding long-term opportunity. Location: Minneapolis, Minn., area.

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Career Opportunities



Technical Support Applications Engineer

Full-Time — Duluth, GA

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

Responsibilities

- Provide timely, complete helpdesk support for Koh Young users
- Train users on proper operation, maintenance, programming, and best practices
- Recommend and oversee operational, process, or other performance improvements
- Effectively troubleshoot and resolve machine, system, and process issues

Skills and Qualifications

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

Benefits

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

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Sales Technical Engineer

ALTIX, a French company, designs, manufactures, markets and services exposure equipment for the printed circuit board, flexible circuit, metal etching, touch panel and other industries. The U.S. subsidiary, focused on the sale and service of Altix equipment in North America, is looking for a sales technical engineer to support their growth.

Responsibilities

- Promote Altix's products by visiting customers
- Serve as a technical lead & product expert to provide technical recommendations to customers
- Gather on-the-ground market intelligence through customer contact
- Ensure sustainable growth in sales, profits, and market presence
- Develop new business and achieve targets for market penetration, sales and profit
- Manage sales partners

Skills & Qualifications

- Minimum 2 to 5 years' experience in sales for capital equipment in the PCB market or related industries
- Business development and marketing background preferred
- 5+ years' North American business leadership experience in related field
- Strong leadership, decision-making and communication skills.
- Proficiency in standard computer software applications such as Microsoft Office
- Excellent written and oral communication skills
- Willingness to travel within the US, Canada and to France for training

Email contact: sylvain.dromaint@altix.us

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Career Opportunities



Director of Operations State College, PA

Chemcut Corp., a world leader in wet processing equipment for the manufacture of printed circuit boards and chemical etching of various metals, is seeking a Director of Operations.

Objectives of the Role:

- Collaborate with the CEO in setting and driving organizational vision, operational strategy, and hiring needs.
- Oversee manufacturing operations and employee productivity, building a highly inclusive culture ensuring team members thrive and organizational outcomes are met.
- Directly oversee manufacturing operations, production planning, purchasing, maintenance & customer service (product support) and partner with the CEO and controller on sales management to budget for sufficient investment capital to achieve growth targets.
- Aggressively manage capital investment and expenses to ensure the company achieves investor targets relative to growth and profitability.

Qualifications:

- Bachelor's degree in mechanical, electrical, or related fields
- 5+ years' experience in leadership positions
- Leadership skills, with steadfast resolve and personal integrity
- Understanding of advanced business planning and regulatory issues
- A solid grasp of data analysis and performance metrics
- Ability to diagnose problems quickly and have foresight into potential issues

Preferred Qualifications:

- Master's degree in business or related field
- International business experience

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

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Are You Our Next Superstar?!

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

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

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Career Opportunities



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European Product Manager Taiyo Inks, Germany

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

Duties include:

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

Skills and abilities required:

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

What's on offer:

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

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

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R&D Scientist III Orange, CT

Job Description: The scientist will be a leader in technology for plating chemistry development, electrolytes, and additives. The position is hands-on, where the ideal candidate will enjoy creating and testing new aqueous plating processes and materials to meet the most demanding semiconductor applications related to Wafer-Level Packaging and Damascene. The qualified candidate will work as part of the R&D team while interacting with scientists, product management, and application engineers to commercialize new products for the advanced electronic solution business.

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Technical Marketing Specialist Waterbury, CT

This position provides information from the product team to the marketing communications team. It is a multifunctional role that requires some experience within electronics manufacturing supply chain or knowledge of how electronic devices are manufactured, specifically PCBs, semiconductors, and the chemical processes utilized therein. The primary function of this role is to help in the generation of product marketing collateral, but also includes assisting in tradeshow content development, advertising, and launches.

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Career Opportunities



Regional Manager Midwest Region

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

DETAILS OF FUNCTION:

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

QUALIFICATIONS:

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

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

fernando_rueda@kyzen.com

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Field Service Engineer Location: West Coast, Midwest

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

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

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

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

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

Must be able to travel extensively.

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Career Opportunities



American Standard Circuits

Creative Innovations In Flex, Digital & Microwave Circuits

Wet Process Engineer

ASC, the largest independent PCB manufacturer in the Midwest, is looking to expand our manufacturing controls and capabilities within our Process Engineering department. The person selected will be responsible for the process design, setup, operating parameters, and maintenance of three key areas—imaging, plating, etching—within the facility. This is an engineering function. No management of personnel required.

Essential Responsibilities

Qualified candidates must be able to organize their own functions to match the goals of the company.

Responsible for:

- panel preparation, dry film lamination, exposure, development and the processes, equipment setup and maintenance programs
- automated (PAL line) electrolytic copper plating process and the equipment setup and maintenance programs
- both the cupric (acid) etching and the ammoniacal (alkaline) etching processes and the equipment setups and maintenance programs

Ability to:

- perform basic lab analysis and troubleshooting as required
- use measurement and analytical equipment as necessary
- work alongside managers, department supervisors and operators to cooperatively resolve issues
- effectively problem-solve
- manage multiple projects concurrently
- read and speak English
- communicate effectively/interface at every level of the organization

Organizational Relationships

Reports to the Technical Director.

Qualifications

Degree in Engineering (BChE or I.E. preferred). Equivalent work experience considered. High school diploma required. Literate and functional with most common business software systems MS Office, Excel, Word, PowerPoint are required. Microsoft Access and basics of statistics and SPC a plus.

Physical Demands

Exertion of up to 50 lbs. of force occasionally may be required. Good manual dexterity for the use of common office equipment and hand tools.

- Ability to stand for long periods.

Work Environment

This position is in a manufacturing setting with exposure to noise, dirt, and chemicals.

Click on 'apply now' button below to send in your application.

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Career Opportunities



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

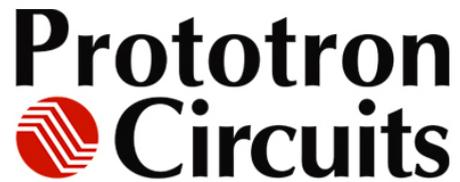
Requirements and Qualifications:

- 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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Sales Representatives

Prototron Circuits, a market-leading, quick-turn PCB shop, is looking for sales representatives for all territories.

Reasons you should work with Prototron:

- Serving the PCB industry for over 30 years
- Solid reputation for on-time delivery (99% on-time)
- Excellent quality
- Production quality quick-turn services in as little as 24 hours
- AS9100
- MIL-PRF- 31032
- ITAR
- Global sourcing
- Engineering consultation
- Completely customer focused team

Interested? Let's have a talk.

Call Dan Beaulieu at

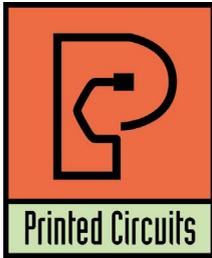
207-649-0879

or email to

danbbeaulieu@aol.com

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Career Opportunities



Printed Circuits, a fast-growing printed circuit board fabricator, offers:

- Excellent opportunities for advancement and growth
- Dynamic manufacturing environment
- Excellent health, dental and other benefits
- Annual profit-sharing plan
- Signing bonus
- Additional incentives at the leadership level
- Clean facility with state-of-the-art manufacturing equipment
- Highly collaborative corporate and manufacturing culture that values employee contributions

Laminator Technician

Nature of Duties/Responsibilities

- Layup cover lay
- Layup rigid flex
- Layup multilayer/CU core boards
- Oxide treat/cobra treatment of all layers/CU cores
- Shear flex layer edges
- Rout of machine panel edges and buff
- Remove oxide/cobra treatment (strip panels)
- Serialize panels
- Pre-tac Kapton windows on flex layers (bikini process)
- Layup Kapton bonds
- Prep materials: B-stage, Kapton, release sheet
- Breakdown: flex layers, and caps
- Power scrub: boards, layers, and caps
- Laminate insulators, stiffeners, and heatsinks
- Plasma cleans and dry flex layers B-stage (Dry)
- Booking layers and materials, ready for lamination process
- Other duties as deemed necessary by supervisor

Education/Experience

- High school diploma or GED
- Must be a team player
- Must demonstrate the ability to read and write English and complete simple mathematical equations
- Must be able to follow strict policy and OSHA guidelines
- Must be able to lift 50 lbs
- Must have attention to detail

Wet Process/Plating Technician

Position is 3rd shift (11:00PM to 7:30AM, Sunday through Friday)

Purpose

To carry out departmental activities which result in producing quality product that conforms to customer requirements. To operate and maintain a safe working environment.

Nature of Duties/Responsibilities

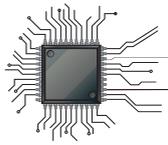
- Load and unload electroplating equipment
- Fasten circuit boards to racks and cathode bars
- Immerse work pieces in series of cleaning, plating and rinsing tanks, following timed cycles manually or using hoists
- Carry work pieces between departments through electroplating processes
- Set temperature and maintains proper liquid levels in the plating tanks
- Remove work pieces from racks, and examine work pieces for plating defects, such as nodules, thin plating or burned plating
- Place work pieces on racks to be moved to next operation
- Check completed boards
- Drain solutions from and clean and refill tanks; fill anode baskets as needed
- Remove buildup of plating metal from racks using chemical bath

Education and Experience

- High school diploma or GED required
- Good organizational skills and the ability to follow instructions
- Ability to maintain a regular and reliable attendance record
- Must be able to work independently and learn quickly
- Organized, self-motivated, and action-oriented, with the ability to adapt quickly to new challenges/opportunities
- Prior plating experience a plus

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Career Opportunities



MivaTek

Global

Field Service Technician

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

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

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

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

More About Us

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

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eptac

TRAIN. WORK SMARTER. SUCCEED.

Become a Certified IPC Master Instructor

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

Qualifications and skills

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

Benefits

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

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Career Opportunities



Rewarding Careers

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

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

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

Associate Electronics Technician/Engineer (ATE-MD)

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

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

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Test Engineer (TE-MD)

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

- Candidates must have at least three years of experience with in-circuit test equipment. A candidate would develop and debug our test systems and install in-circuit test sets remotely online or at customer's manufactur-

ing locations nationwide.

- Candidates would also help support production testing and implement Engineering Change Orders and program enhancements, library model generation, perform testing and failure analysis of assembled boards, and other related tasks.
- Some travel required and these positions are available in the Hunt Valley, Md., office.

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Sr. Test Engineer (STE-MD)

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

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

We proudly serve customers nationwide and around the world.

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

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Career Opportunities

SIEMENS

Siemens EDA Sr. Applications Engineer

Support consultative sales efforts at world's leading semiconductor and electronic equipment manufacturers. You will be responsible for securing EM Analysis & Simulation technical wins with the industry-leading HyperLynx Analysis product family as part of the Xpedition Enterprise design flow.

Will deliver technical presentations, conduct product demonstrations and benchmarks, and participate in the development of account sales strategies leading to market share gains.

- PCB design competency required
- BEE, MSEE preferred
- Prior experience with Signal Integrity, Power Integrity, EM & SPICE circuit analysis tools
- Experience with HyperLynx, Ansys, Keysight and/or Sigrity
- A minimum of 5 years' hands-on experience with EM Analysis & Simulation, printed circuit board design, engineering technology or similar field
- Moderate domestic travel required
- Possess passion to learn and perform at the cutting edge of technology
- Desire to broaden exposure to the business aspects of the technical design world
- Possess a demonstrated ability to build strong rapport and credibility with customer organizations while maintaining an internal network of contacts
- Enjoy contributing to the success of a phenomenal team

***Qualified applicants will not require employer-sponsored work authorization now or in the future for employment in the United States. Qualified Applicants must be legally authorized for employment in the United States.*

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ARLON

ELECTRONIC MATERIALS

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

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

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

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

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

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

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Career Opportunities



U.S. CIRCUIT

Plating Supervisor

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

Competitive benefits package.
Pay will be commensurate
with experience.

Mail to:
mfariba@uscircuit.com

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APCT
Passion | Commitment | Trust

APCT, Printed Circuit Board Solutions: Opportunities Await

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

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

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

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

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Career Opportunities



BLACKFOX

Premier Training & Certification

IPC Instructor

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

*Independent contractor,
possible full-time employment*

Job Description

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

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

Qualifications

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

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

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

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

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American Standard Circuits

Creative Innovations In Flex, Digital & Microwave Circuits

CAD/CAM Engineer

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

ESSENTIAL DUTIES AND RESPONSIBILITIES

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

ORGANIZATIONAL RELATIONSHIP

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

QUALIFICATIONS

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

PHYSICAL DEMANDS

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

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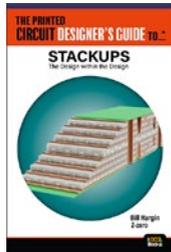
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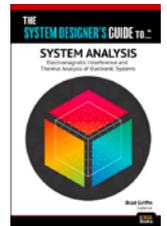
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by Anaya Vardya and David Lackey, American Standard Circuits

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.

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