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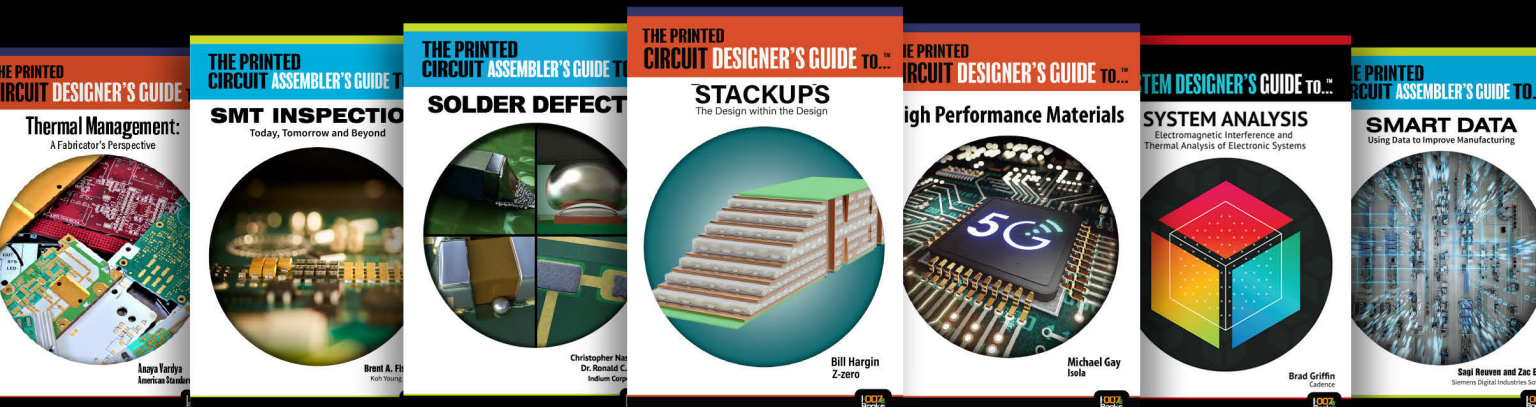
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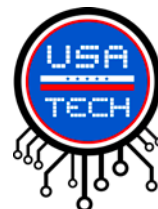
Time to Invest?

After years of being squeezed by supply chain dynamics, printed circuit board manufacturing is once again growing across the globe. This begs the question: Is now a good time to invest in PCB fab? In this issue, we explore both the market and government forces at play.

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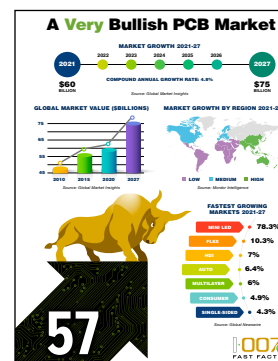


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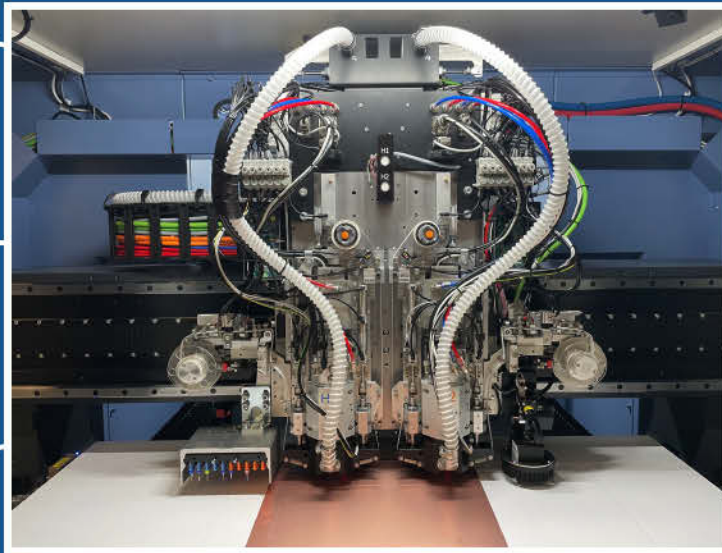
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The Shifting Supply Chain: An Argument for Investment

Nolan's Notes

by Nolan Johnson, I-CONNECT007

The gears of the economy worked like clockwork for quite a long time, at least in North America, Europe, and Asia. Overall, that smooth operation is no longer the case, for several reasons. It's as if the watchmaker has upended the clockworks onto the worktable and is rearranging the mechanism to work differently—to tell a different time, if you will.

In the overall economy, there are bearish signs (9.1% inflation year-over-year in the U.S. in mid-July). But in electronics manufacturing, the market looks quite bullish on the demand side. This month's cover reflects that dynamic—a bullish industry within what seems to be an emerging bearish economy.

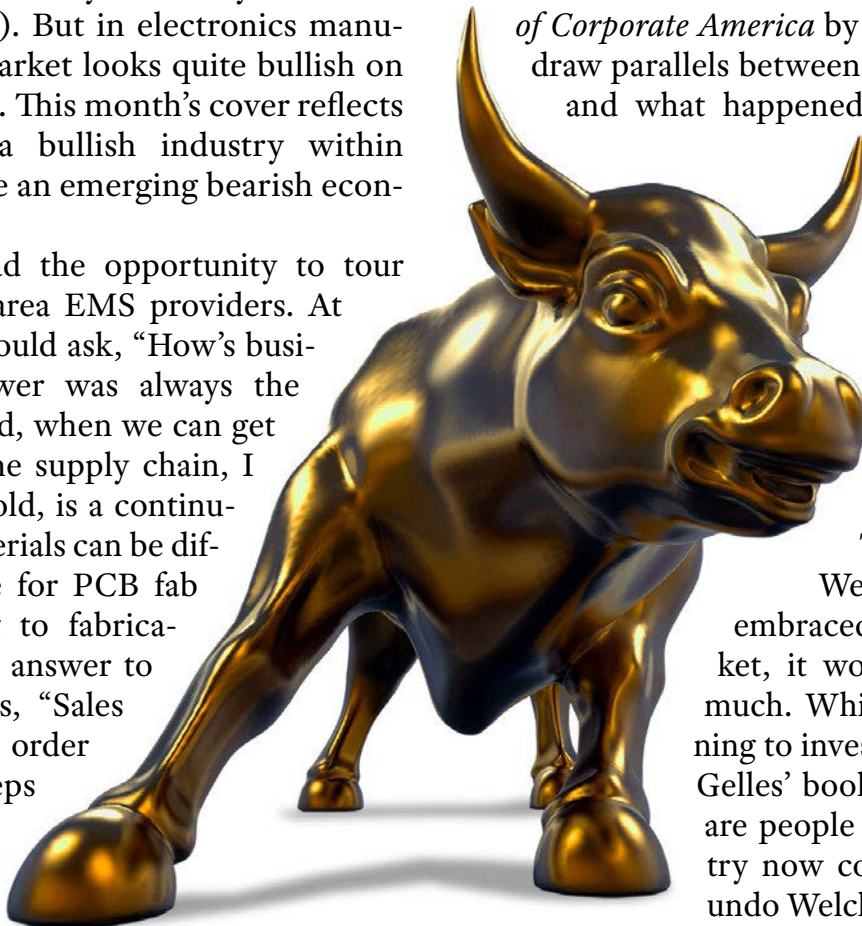
Recently, I had the opportunity to tour seven San Jose-area EMS providers. At each facility, I would ask, "How's business?" The answer was always the same: "Very good, when we can get components." The supply chain, I was frequently told, is a continuing stressor. Materials can be difficult to procure for PCB fab as well. Talking to fabricators, the general answer to my question was, "Sales are good, our order backlog just keeps extending. It's staffing that's throttling us."

In a separate conversation recently, a fabrication industry insider said, "We hire someone, train them, and they jump ship for the grocery store down the street because they're paying \$2/hour more than we can afford. It's hard to keep our people."

More than once as we put this issue together, one source would refer to the book, *The Man Who Broke Capitalism: How Jack Welch Gutted the Heartland and Crushed the Soul of Corporate America* by David Gelles, and draw parallels between Welch's approach and what happened in PCB fab: By

reducing (eliminating?) R&D, and throttling the investment in new processes, the U.S. lost its competitive edge and over-optimized the supply chain.

Twenty years ago, Welch's approach was embraced; in today's market, it would seem, not so much. While I'm just beginning to investigate the ideas in Gelles' book for myself, there are people in the U.S. industry now considering how to undo Welch's legacy.



One might consider the U.S. CHIPS Act, which has been in the global news, an example of taking action to reverse Welch's mark. And right behind the CHIPS Act is HR 7677, the Supporting American Printed Circuit Boards (SAPCB) Act. There's never been a time when PCB fabrication has held such a high profile on the economic stage. Now seems a good time to remind ourselves of the ancient proverb found in multiple cultures, "In chaos, there is opportunity."

For this issue, we asked that in these times of change, whether now is a good time to invest in PCB fabrication. Well, if I'm completely honest, our initial thought was, "If you think it's been bad so far, just wait for Q4!" As we took that question to our expert sources, the response was two-part: Supply chain woes are going to continue; but now is a good time to invest in upgrading fab facilities. At least, that seems to be the news outside Asia.

IPC Chief Economist Shawn Dubravac sat for an interview wherein he looked forward into Q4 2022 from a macro level. See what he had to say in "Q4 Concerns: Hold On to Your Hats." Also at a high level, Pete Starkey reports on the Prismark presentation to the recent EIPC Technical Snapshot, as delivered by Dr. Shiuh-Kao Chiang, managing partner at Prismark Partners. The outlook in Asia, says Dr. Chiang, is going to be challenging. His theme: "The party's over."

To help you better follow the developments of the CHIPS Act and the SAPCB Act, and with the help of the PCBAA, we're proud to bring you an interview with HR 7677 co-sponsor, U.S. Rep. Blake Moore, R-Utah, and PCBAA president Travis Kelly. They detail the bill and their expectations of the effect it will have on PCB fabrication. Originally, the bill brought two levers to move the industry: a pool of funding for PCB manufacturing competitive development, and a 25% tax credit for purchasers of U.S. manufactured printed circuit boards. On July 8, just after we conducted the interview, the tax credit was removed from

the bill through amendment. The original interview has been edited to reflect that recent change.

To continue our examination of legislative activity, we interviewed Christopher Peters of USPAE, another association advocating for support from Capitol Hill. He takes a deeper look at the CHIPS Act and its potential impact on investment. Finally, to round out our coverage on this topic, Dr. John Mitchell, president and CEO of IPC, asks, "Is the U.S. Government Ready to Meet the Test of Technological Leadership?"

To complement our legislative coverage, we spoke with M&A experts inside the industry to gain a sense for how investment might manifest itself in this economic climate. Jeff De Serano of PCB Technologies, and Tom Kastner of GP Ventures, shared valuable insights that we know will help you better understand what everyone is going through.

Of course, we also bring you a whole cadre of columnists this month: Page Fiet, Christopher Bonsell, Matt Stevenson, Happy Holden, and Michael Carano.

Our content is driven by your comments and feedback. We always welcome discussion about the content we publish, and your take on any industry topics you would like to see us cover. Our mission at I-Connect007 is to publish news and information that moves the conversation forward within the industry. It is our hope that the information in this issue will propel the industry's reinvigoration by starting conversations within your company, and within the wider industry. Let us know what you think. **PCB007**



Nolan Johnson is managing editor of *PCB007 Magazine*. Nolan brings 30 years of career experience focused almost entirely on electronics design and manufacturing. To read other "Nolan's Notes" columns, [click here](#).



Q4 Concerns: Hold On to Your **Hats**

Feature Interview by Nolan Johnson

I-CONNECT007

IPC Chief Economist Shawn DuBravac has plenty to share about the state of the U.S. economy and how the electronics manufacturing industry might weather the storms of high inflation, rising interest rates, and low unemployment. It's an interesting situation to find ourselves in as the flurry of opinion on a 2023 recession starts to take shape. Does it make sense to invest in PCB fab now? And how does the rest of the world feel about it? Shawn gets to the bottom line.

Nolan Johnson: Shawn, the economic outlook hasn't been too rosy. I'm hoping our discussion today will provide some perspective for what to expect, especially for manufacturers in Q4.

Shawn DuBravac: I would characterize it as the playing out of dueling narratives. For context, in March 2020, we went into a very steep, quick, deep recession. This was a pronounced, unprecedented recession. Had it continued, it would have been by far the worst economic environment we have ever seen. Companies—and the federal government—responded to that abruptness very quickly. In the auto sector, you saw them cut production significantly, driving it essentially to zero in anticipation of a very deep recession. The government, through both fiscal and monetary policy, brought in unprecedented amounts of support for the economy. With no confirmation about how long it would last, we had several stimulus measures.

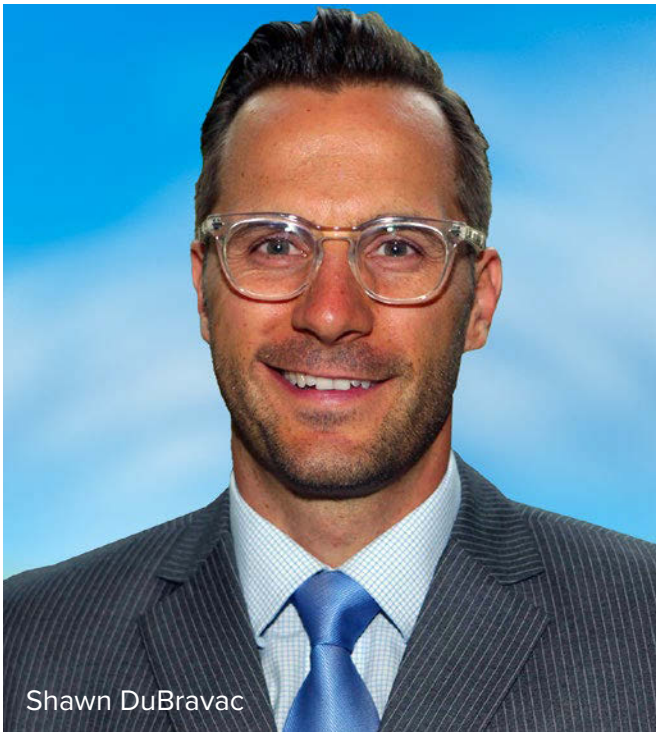


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Shawn DuBravac

That stimulus drove demand, but you also saw shifting demand because people were moving away from services toward durable goods. They moved away from going to the theater. They moved away from the amusement parks. They moved toward products that they could put in their homes. At the same time, every business had to go online, so the demand for cloud storage and hardware shot up. These things were tied together when you started to pull the string.

Where does that leave us today? COVID remains a major concern, but in much of the world, we're operating alongside it. People have gone back to buying and partaking in services. Demand for travel and hospitality has been very strong. And there has been an equally abrupt shift in the purchase of lots of these durable goods that did so well in the first 18 months. If you look at the big retailers, like Target, Walmart, Best Buy, they're all feeling over-inventoried on the consumer side. At the same time, you have unprecedented inflation rates that are impacting consumers. It's a narrative of shifting focus, priorities, and desires among consumers, and the headwinds that they face.

When you look at other parts of the industry, though, demand still looks at least somewhat resilient. There's pent-up demand for what I'll call supply, pent-up demand for production capacity. That produces this residual demand, a backlog that can feed future months. Now, that can change very quickly. But if you look at the industrial side of the economy, the demand is very strong. They have not been able to meet demand. It looks like that strength should continue at least through the fourth quarter of this year and probably into 2023. I've talked to big industrial companies, and I'm sure you have these conversations too. They're saying, "We have backlogs that will take us well into 2023." Thus, there ends up being these two competing narratives. In one narrative, demand is slowing. In the other, demand remains solid because of a strong backlog of orders that are waiting to be fulfilled.

For the consumer narrative, high inflation is what gets the headlines. We have officially ended the bull market and we have started a bear market. Every day there's a crypto platform that implodes and that is keeping the attention. But operating behind that is an economy that thus far looks resilient. Unemployment is obviously very low, and the demand for those areas that our industry supports is holding up quite well—industrial, for one; and clearly defense demand should remain strong. The defense industry has drawn down inventories because of support for Ukraine. At the same time, there's concern about other geopolitical uprisings or other geopolitical dislocations. There is a demand, at least in the U.S., to build up some of that defense industrial capacity, and defense inventory to have ammunitions and equipment available to us should we need it.

Johnson: What I would expect a vice president of sales in the PCB marketplace to respond back with, "Okay, so our production schedule may end up with some holes for our consumer clients, but there is industrial business to fill that space. We're still going to be at capacity."

DuBravac: Yes, at least initially, that's what it looks like. Now, the Catch-22 would be part shortages. If I can't get certain things, if I know that I've got a six-month wait on certain key components, then I may wait on PCB orders. So, I think if you look at our book-to-bill numbers over the last few months, when order flow seems to ebb a little bit, I think some of that is EMS companies saying, "I'm not going to order right now because I can't get these other three things that I need to get. I need all my components to come in." The economics are such that they need it all to come in the back door at the same time. They don't want to be holding inventory. They can't carry it.

Right now, everything is fine with bank lending and lines of credit, but it's an important area to watch. Managing the cash flows is what a lot of businesses are doing. It's almost like the manufacturing is second to making sure you've got cash flow to cover it. My sense is that order flow has been a result of part shortages and longer lead times. Some of that will probably continue. A big risk factor is China's zero COVID policy. Even though Shanghai and other areas were shut down for nearly two months, the ports did okay. There were definite delays, but not as severe as it could have been. It could have been really bad if things were shut down for many months.

Let me address the auto industry, which is significantly under-inventoried. That won't change this year, and the auto sector will be working to get back into what they would consider a healthy inventory position for much of 2023. Obviously, the different segments of the electronics supply chain have unique dynamics at play. For example, when it comes to the auto sector, anything in the electric vehicle supply chain is in high demand. EVs are essentially oversubscribed and sold out everywhere. Even a recession is unlikely to dent that category.

There is pent-up demand because auto manufacturers aren't dedicating as much capacity to EVs as there is demand for that segment.

Johnson: Shawn, do you see this as an opportunity to be investing in capacity?

DuBravac: The great challenge with investing in additional capacity is the amount of uncertainty around future demand. That's what holds companies off from really building out greater capacity. Some companies, like TTM which recently announced a new facility in Malaysia, are making the commitment to build out capacity. Other companies are strategically adding capacity as well, especially where it looks like a very long season of demand—EVs, for example, if you were doing anything in that space, then you have some assurance. There's a lot of momentum suggesting that adding capacity now will just be the start of capacity coming on in this space. For others, though, it's challenging to add capacity when there's uncertainty about future demand.

The great challenge with investing in additional capacity is the amount of uncertainty around future demand.

Johnson: Such as looking at your supply chain. You can add the capacity, but will you be able to get the incoming components you need to make it work, for example?

DuBravac: Definitely. There are a lot of challenges when we think about adding capacity. Adding more physical assets is just a piece of it; labor is another. Labor costs are definitely a constraint on adding capacity. If I need more workers, can I find and retain them? Can I deploy that capital in a very productive way?

Johnson: With everything going on, is now

a good time to add capacity? It's hard to figure out. It's a cloudy crystal ball. There are plenty of reasons to argue that now is a good time to invest in this industry. There is pent-up demand. Electronics are used increasingly in products. We know that there will be a step function in what needs to be produced for automotive alone, let alone other parts of the industry. You see the U.S. government start to understand the need to be strategic with the industry to achieve a healthy domestic manufacturing sector. We've also learned about supply chain resilience. It would seem like this is a reasonable time. You've got private equity firms that seem to be getting involved. As a smaller shop in this space, is this a good time to be seeking out additional investment, capital, or help?

DuBravac: I think it could be a good time to seek outside investment. It remains to be seen how external capital will change and if that will become harder to come by. Monetary policies are tightening, and that will reduce liquidity by design. Presumably, there will be less funding available, so it will become harder. To me, the ideas around resiliency makes a lot of sense. There will be growing demand to produce products and other pieces of the production cycle closer to the market that you are trying to serve. Building strategic capacity makes a lot of sense right now, and private investors are looking for long-term returns.

For example, not just building out capacity in terms of how much you can produce but in areas that have strong demand. Whether that's more sophisticated, more complex electronics, or whether that's some of these areas we've already hit on when we think about the defense, industrial, auto, but especially around some of the more sophisticated and technical

pieces. There are long-run opportunities there. As you pointed out, the demand is growing. To satisfy that demand, we must add capacity over time, and companies that are looking to gain share will be adding capacity broadly; companies that are looking to be more influential in these markets will be adding "strategic capacity" that's focused broadly on some of the complex, highly technical pieces of the supply chain.

Johnson: It's an interesting situation to be in.



We're starting to see the U.S. government and Congress line up and send the message that we need to bring this infrastructure back, both in semiconductors, and PCB, with what's going on there. That level of funding can make a huge difference in our industry. At the same time, we're a free market in the United States. It needs to be compelling for private investment. That's how our economic system runs well. But it's about knowing the right time to invest, because we have not been a desirable place to spend money in the past.

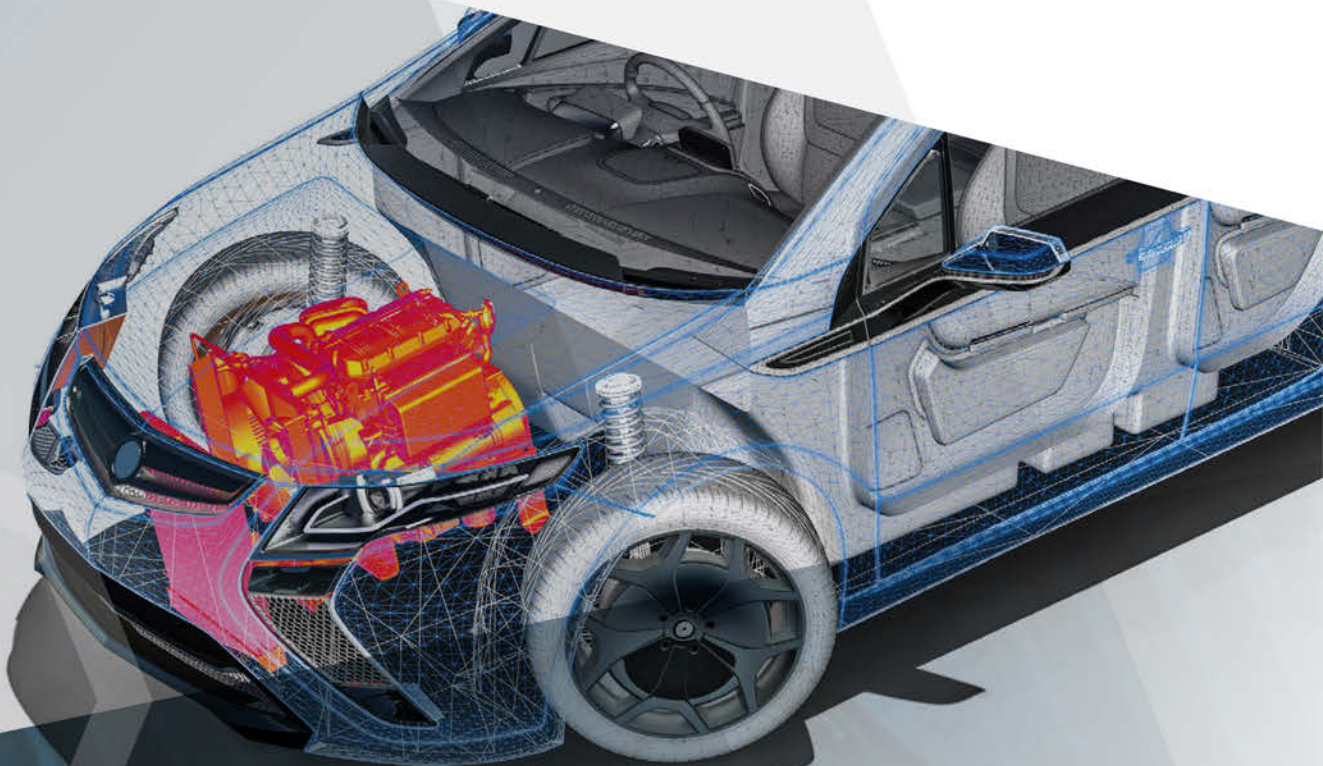
DuBravac: When I've had conversations with the U.S. Commerce Department—and IPC's Vice President of Government Relations Chris Mitchell is obviously in constant conversation with them, so he would be a good source—they're looking at how to incentivize private investment. They recognize that any amount of support that the Commerce Department or the federal government provides would be limited; not just how to move beyond creating subsidies, but to really create long-lasting investment.

What they would like to do is almost match private investment so that it can, in ways,



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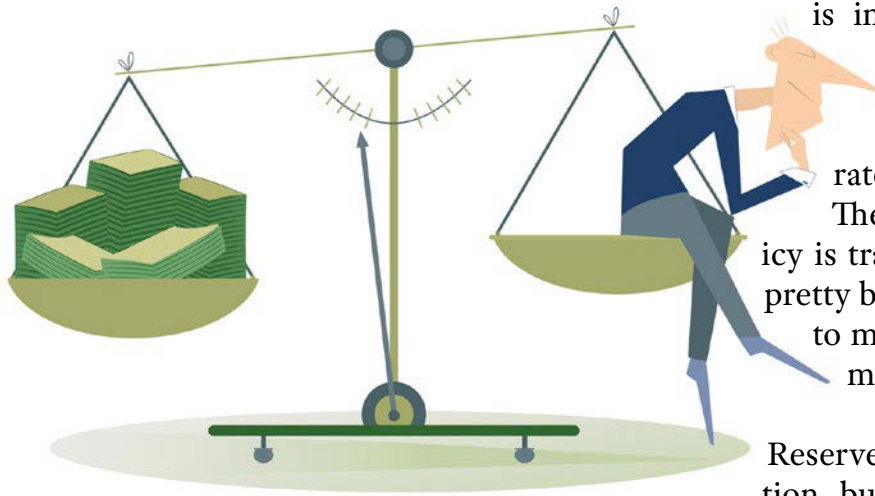


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increase the rate of return for private investors. Then you start to get attractive rates of return that would draw in private equity and others that are historically looking for much higher rates of return, like 30-, 40-, 50%-types of rates of return. It's hard for them to be convinced to move into certain parts of manufacturing where it doesn't look like those rates of return could be realized. But if the investment is matched and essentially subsidized by public finance, by government, then those types of rates of returns become available. Washington is looking at that.

The U.S. Commerce Department is really trying to understand the electronics industry. What's driving decisions within electronics manufacturing from the OEMs all the way up the supply chain. What meaningful levers could we use to make smart decisions that create universal win-win situations for investors, manufacturers, and ultimately, consumers at the other end of the supply chain.

Johnson: Our readers are working on their strategic plans for 2023. What's your advice to them right now?

DuBravac: As much as the last 24 months have been a challenging environment, the next 24 months will be equally challenging, but for different reasons. The probability that we end up in a recession is growing. The Federal Reserve

is in a very difficult spot right now, where there is a very strong economy, very high inflation, and very strong motivation to raise interest rates aggressively to lower inflation.

The problem is that monetary policy is transmitted into the economy with a pretty big lag. So, as interest rate hikes tend to materialize, we see the full effects six months or so after they've raised rates.

The challenge for the Federal Reserve is to raise rates to combat inflation, but they'll only know where they are six months from now. The challenge is that they'll be raising rates into a slowing economy, and that they'll ultimately overshoot and tighten too much too quickly. Normally, if inflation rates weren't this high, they could take time. They could raise rates slowly and allow those rate hikes to have full transmission into the economy. But they don't have that luxury now. Companies are making decisions in an economic environment where it looks like the probability of recession is growing. I say there's probably a 50% chance we're in a recession next year. If you look at any of the CEO surveys, they say the probability is higher. From our own sentiment survey that we published for June, almost 80% of executives are concerned about a recession in 2023.

That cloud hangs over investment, capacity, and other decisions that executives are making right now. That's why the underlying industry that companies are in is becoming so important. If you are in the right space, you won't feel the economic downturn quite as significantly. The jury is still out as to the extent of any recession, how strong or muted it might be. If we have a shallow recession in 2023 and we move out of that, then I don't think that's too much to worry about. If we're in an environment where we have high inflation rates and low growth rates, that becomes a problematic environment because you've got workers who are wanting higher salaries, but the underlying growth isn't there to support higher salaries. Going into this

environment, the industry or subsectors that you're in become very important.

Johnson: That becomes an exercise in strategic planning to figure out whether you need to invest, pivot, or exactly what you need to find the right spot for you based on your skill set.

DuBravac: This year, as companies enter that strategic planning period, it is especially important that companies review their portfolio not just from their assets, but where their production capacity is going. What are their portfolios of products and services that they are producing.

Johnson: You mentioned that the Federal Reserve doesn't have the advantage of time to make slow changes and let them play out entirely. They don't have that opportunity this time around. Can you explain?

DuBravac: It goes back to this idea that it takes about six months for interest rates to be fully transmitted into the economy. In a normal environment, if you felt like things were overheating a little bit, you raise interest rates, then wait and see how that plays out. If it has the desired effect where it slows growth, keeps prices well contained without raising unemployment, then you're good. If you find that, after two or three months, it's not really having the full effect that we need, then you can raise interest rates again, and maybe you move another 25 basis points. You have time in which to raise interest rates over a longer time horizon as well as you can do smaller moves. When you're looking at 8% inflation and very low unemployment—the situation we're in—the Fed is betting that the economy can endure pretty high interest rate increases over a short period of time without stalling and without falling into recession.

I know the Fed is looking at job openings. Normally, the Fed is trying to balance these two mandates of low unemployment and low

inflation. In some ways, they compete against each other because you can get low unemployment with low interest rates, but you don't typically get low inflation with low interest rates. It's the opposite. The Fed is betting that they can raise interest rates and it won't stall the economy, but it will cause companies not to be looking for so many jobs. It will moderate the labor market through the job openings. But on the tech side, companies are already announcing hiring freezes. Netflix has done some layoffs. You have some companies that are already into the layoff stage.

The Fed is betting that they can raise interest rates and it won't stall the economy, but it will cause companies not to be looking for so many jobs.

Johnson: Intel just did this recently.

DuBravac: It's surprising news from a company like Intel where you've got strong demand. The struggle for the Fed is it will need to move rates aggressively higher to combat inflation, and they won't know the full impact of those rate hikes for some time. By the time they are fully absorbed in the marketplace, we could be in a meaningful recession, which would then force them to reverse course, if they could, but that will be very difficult to do if inflation is still high. They're going to potentially get stuck in this Catch-22.

Now, the good thing about the U.S. is that we do have strong underlying growth, so the Fed's problem is very different than central banks in other parts of the world. The Fed's problem is high inflation, but in an environment where



there is still strong growth. Europe is looking at high inflation in an environment where there isn't strong growth. They must move much more delicately and be much more tentative than the United States.

We're probably looking at another 50-basis point hike here at the next meeting, but there are definitely talks. I haven't looked at the future's market to see what's priced in, but there are talks of maybe they'll move 75 basis points given the inflation numbers that we got recently. My sense is the Fed feels like they have the luxury of being able to move aggressively because unemployment is low and there are many job openings. The rest of the economy, the rest of the world, doesn't have that luxury. Things are slowing. Asia is not facing quite the inflation rates that we have here, but Europe is definitely slowing at the same time that they have very high inflation rates. That's a very difficult environment to be in.

Johnson: In closing, I wanted to talk about the emergence of some very focused advocacy groups in the United States—USPAE and PCBAA. Obviously, the IPC has been involved in advocacy on a global level, which includes some in the U.S. Do you feel these organizations are having an impact?

DuBravac: Yes. My read on Washington is that they are more receptive than ever, and that you have some people who are really wanting a good outcome, and really wanting to understand our industry. There's a desire to understand the factors that cause it to grow or move, and the forces that will drive investment, to understand the nuances of our industry. I don't know that I've really felt that in the past.

Johnson: Is there anything else you would like our readers to understand about the current economic climate or another topic?

DuBravac: I would point to some of IPC's research. That sentiment content we publish every month gives a good sense of how the industry is feeling. You see the mix of emotions. They report high and rising costs. They report pricing pressure when it comes to materials and components as well as labor. At the same time, they talk about strong pent-up demand in terms of backlog. This last month, we saw that profit margins are coming under pressure. This is a challenging environment for manufacturers—how to price in an environment where your costs are rising is a challenge, and companies haven't been in this environment for a very long time so they're learning. That's a piece that they definitely need to incorporate. Some of the data shows that. Concerns around inflation and recessions from the most recent study were very interesting as well.

Johnson: Great. Thank you, Shawn. **PCB007**

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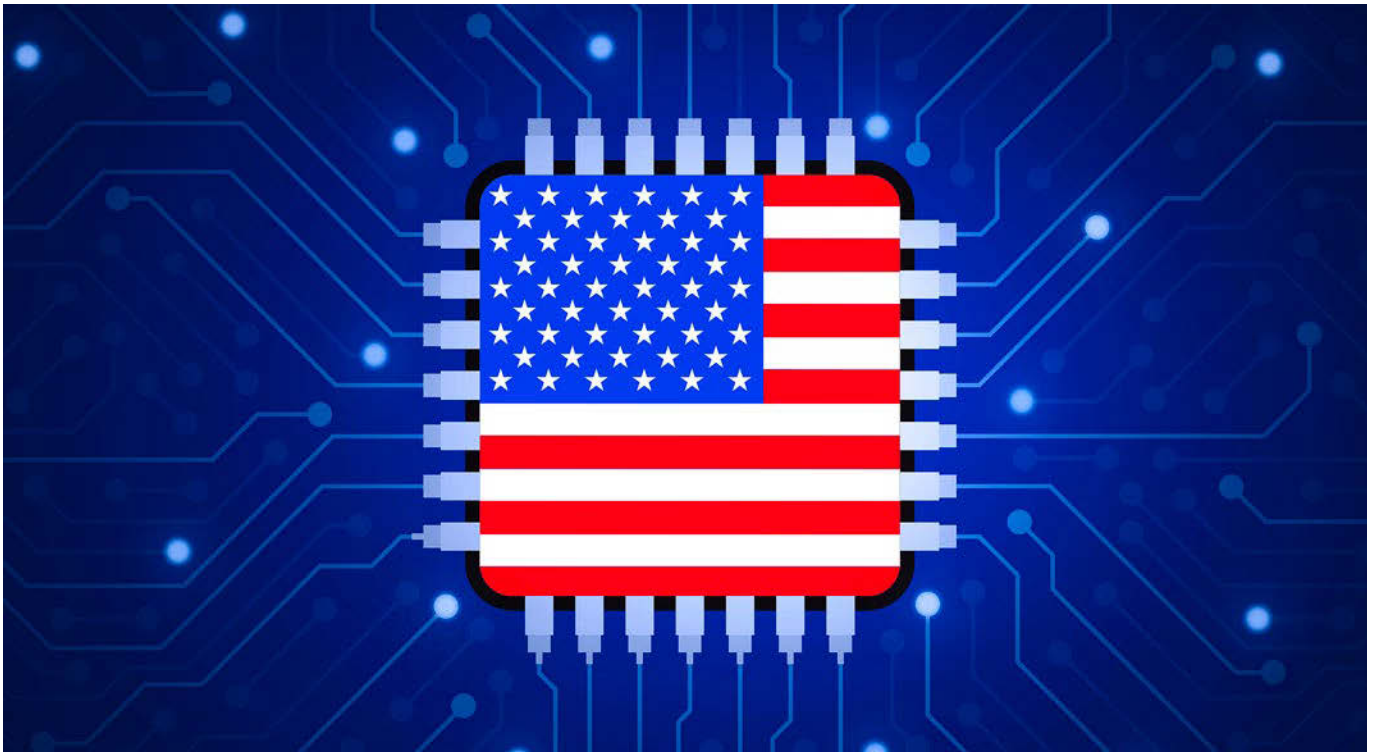
One World, One Industry

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

Supply chain disruptions related to the COVID pandemic, geopolitical tensions, and other factors are forcing companies to rethink their global manufacturing operations and suppliers with an eye toward hedging against risk. For close to a decade, IPC has been encouraging its members to establish a layered approach to supply chain management, one that recognizes that companies must have multiple supply chains that complement one another. The challenge for companies that pursue this lay-

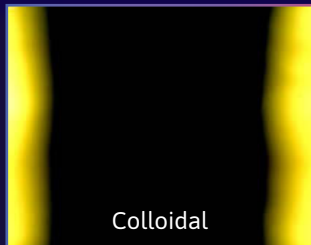
ered approach has always been managing the tension between supply chain risk and optimization. Hedging against risk raises costs, while fully cost-optimized supply chains can expose companies to disastrous risk.

Now these long-standing supply chain considerations are being upended as many governments are expanding investments in semiconductors and potentially in the broader electronics industry. In the United States, Congressional action to approve \$52 billion in CHIPS

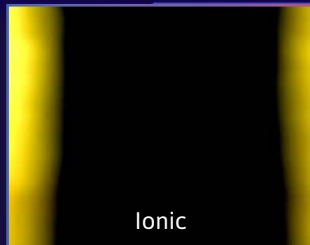


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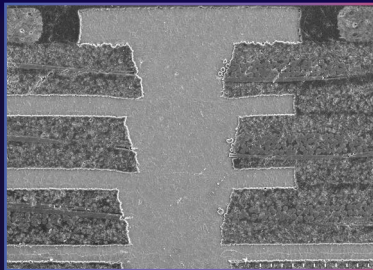
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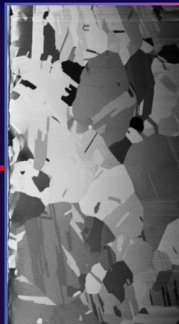
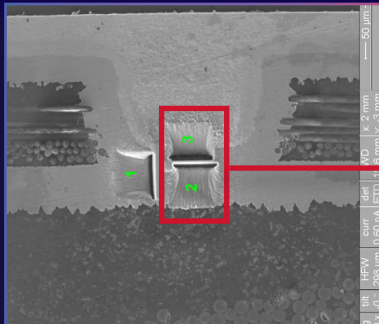
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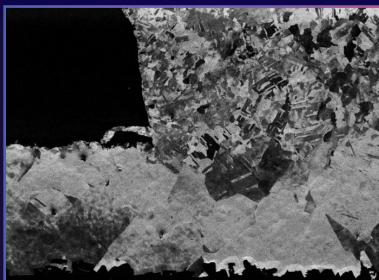
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Act funding, with strong support from President Biden, is creating huge expectations for an unprecedented infusion of funds into our industry. Congress is also considering an overhaul of federal R&D programs, as well as CHIPS Act-like legislation to bolster the U.S. printed circuit board industry.

These are all exciting developments, but the looming and still unanswered question is whether Congress can meet these high expectations. Passage of the Bipartisan Innovation Act, which includes the CHIPS Act funding, will create the framework for government support, but Congress will still need to appropriate the actual funds. The administration, congressional champions, and the tech industry had hoped Congress would approve these funds last summer; then by year-end; then by spring 2022; and now by this summer. The likelihood is dimming, however, as the approach of the midterm election starts to guide the decision. Nothing in recent political history would suggest that Congress can pass a bill of such significance in the months leading up to an election.

And yet, the industry continues to press the case, understanding that progress can occur in surprising ways, and that no one piece of legislation is ever a silver bullet. The industry must walk and chew gum at the same time. Even as we lobby for passage of the CHIPS funding—which incidentally will support IC substrate fabrication—we must also advocate for a half dozen other initiatives that collectively hold the potential for a manufacturing resurgence in the U.S. These other initiatives include the PCB Act, the supply chain resiliency fund in the Bipartisan Innovation Act, and a presiden-

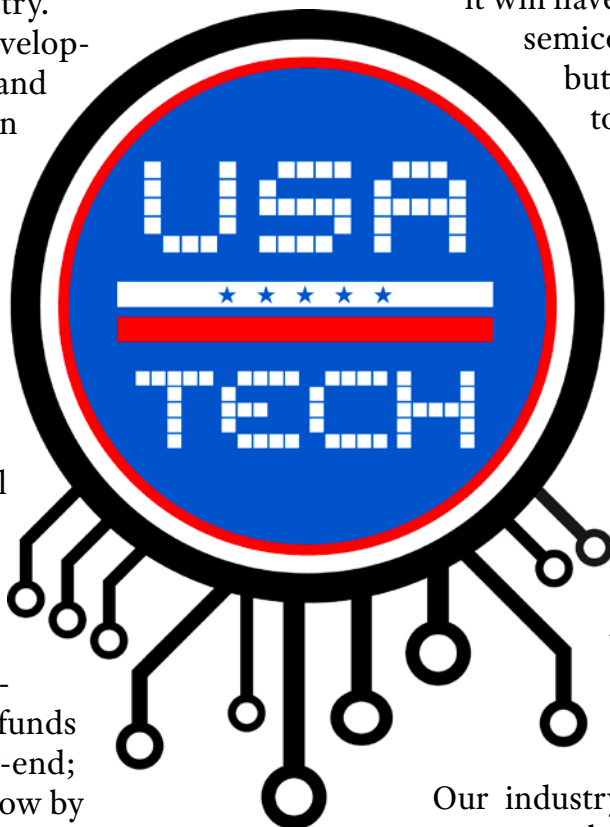
tial national security determination on PCBs and IC substrates.

Again, all these efforts are positive, but proposals don't move the market, and they certainly don't lead to private sector investment in U.S. manufacturing. If Congress fails to act,

it will have dire implications for U.S. semiconductor manufacturing, but it will also send a signal to companies worldwide that the U.S. is not serious about manufacturing. It suggests that the U.S. government has learned nothing about supply chain vulnerabilities from the pandemic, natural disasters, or geopolitical tensions. It suggests that the U.S. does not yet appreciate the connection between manufacturing, on one hand, and innovation, security, and resiliency on the other.

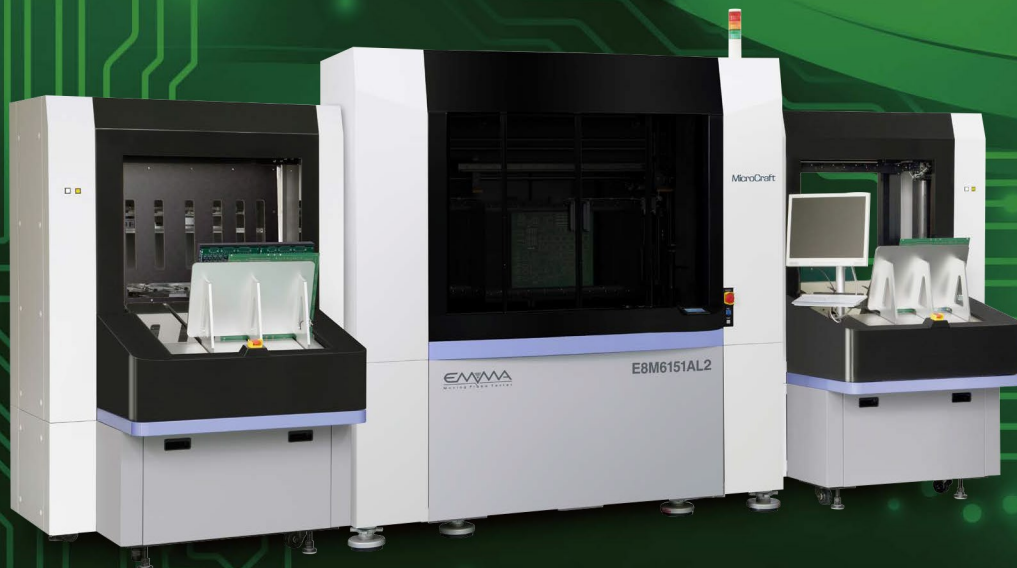
Our industry is now waiting for the government to show up in the way they have promised. The wait is stymying private sector investments, and more and more, companies are deciding to leave the waiting room and take opportunities to nations with governments that are ready to back rhetorical declarations with real support—financial and regulatory.

The U.S. government is being tested right now. Can its leaders come together and position the United States for technological leadership in the years and decades ahead? It's not yet clear they are ready to meet the test. **PCB007**



Dr. John Mitchell is president and CEO of IPC. To read past columns, [click here](#).

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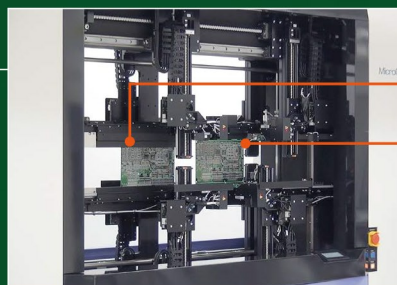
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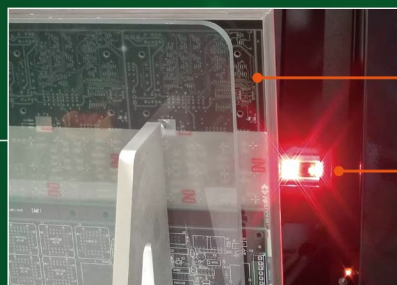
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The Challenges of the 2022 PCB Market: **The Party's Over**



Feature Article by Pete Starkey

I-CONNECT007

With his knowledgeable insight into the business and technology of the printed circuit industry, Dr. Shiuh-Kao Chiang, managing partner at Prismark Partners, has put a global perspective on the challenges of the 2022 PCB market. His presentation at the EIPC Summer Conference in Orebro, Sweden, on June 14 was eagerly awaited by an attentive audience, keen to share his vision. From his comments, it was clear that 2022 will be an interesting year and does not appear particularly friendly for the PCB business.

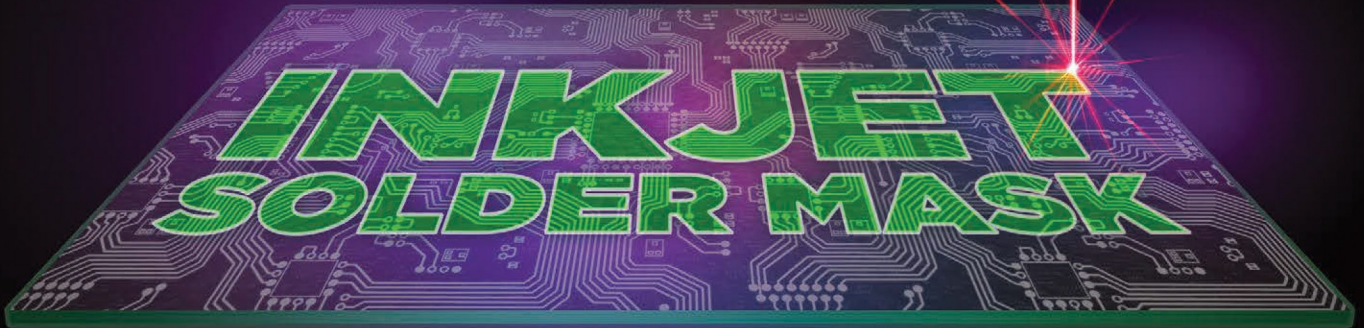
In his presentation for [EIPC's Technical Snapshot webinar](#) in February, Chiang commented that the 2021 PCB market was characterised by surging revenue and profit growth in packaging substrates, although strong demand, high material costs, fractured supply logistics,

increasing inventory, and tightening cash flow squeezed the margins of most PCB companies. Other issues influencing the 2021 market were supply availability and capacity constraints for PCB raw materials, currency exchange rates, long lead times for critical processing tools, and supply shortages for selective semiconductors and other devices.

Now he was able to reflect upon 2022's first quarter results. "The electronics industry is in the late stages of a historic cycle fueled by the COVID-19 pandemic, but cracks are now forming at the edges," he said. "No party lasts forever." The pandemic dividends have been quickly evaporating with the end of synchronous demand cycles for PCs, TVs, and gaming, and the 5G bump for smartphones is waning. The inflated "just-in-case" demand due to

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supply chain uncertainty is disappearing, with the end of double ordering and the digestion of heightened inventories.

The current forecast is for modest growth, with factors like inflation, high interest rates, a strong U.S. dollar, the Ukraine conflict, and China's zero-COVID policy to be considered.

Chiang summarized the main challenges to the electronics industry as:

- High inventory along the supply chain
- Weak demand due to declining purchasing power
- High inflation and high interest rates
- Over-supply of rigid and flexible boards
- Geopolitical conflicts causing high energy costs
- Pandemic lockdowns causing disruptions in supply-side production and logistics
- Labour shortages and material cost volatility

He believes that the strongest segments are those with the longest lead or that are undergoing transition. He listed industrial and medical, automotive, computing and communications infrastructure, and other consumer electronics, particularly wearables.

Looking forward long-term at the PCB market value and product mix, he predicts a compounded average annual growth rate of 4.6% over the period 2021 to 2026, with a forecast total value in 2026 exceeding \$100 billion, of which packaging substrate will constitute 21.1%, with flex at 16.9%.

Who was making a profit in 2021? Sixteen of the top 30 PCB companies achieved operating margins above 10%, and the majority of these were Taiwanese. Who was investing? For the most part, these same companies each had CapEx of over \$200 million.

Reviewing geographical trends over the last two decades, Chiang noted that China has become the dominant manufacturing site for circuit boards, while the Americas, Europe,

and Japan have become niche-product or low-volume suppliers. Taiwan and Korea have concentrated on advanced technologies, and Southeast Asia has become a favourable investment location for Japanese and Korean companies. It remains to be seen whether the trade, political, environmental, and labour-cost issues will change the PCB industry landscape again.

It remains to be seen whether the trade, political, environmental, and labour-cost issues will change the PCB industry landscape again.

Returning to 2022 PCB market opportunities, he observed that the substrate market is experiencing continued growth driven by advanced flexible substrates for BGAs, together with increasing adoption of system-in-package and module substrates. Around 14% growth in value is expected in 2022. More non-consumer applications, such as automotive, high-performance computers, high-speed networking, and satellite communications will require HDI products, although a weak smartphone market could impede HDI growth. Faster data rates for infrastructure will require more advanced low-loss multilayer boards. The automotive market will demand more reliable high-current and high-thermal circuit boards, and there will be a decline in orders for rigid boards for consumer and PC applications.

The first quarter of 2022 was strong as a consequence of carry-over from 2021.

Indications are that the industry will have a relatively weak second quarter, particularly in Asia, for these reasons:

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- The Shanghai lockdown
- Impact on automotive manufacturing
- Impact of the Russia-Ukraine war on manufacturing in Europe
- Rapid fall in the demand for PCs and graphics cards
- Rapid fall in consumer demand and the decline in the handset market

The current consensus for the third quarter is that there will still be some inventory issues to resolve. There will be price erosion due to competition. Will there be over-supply? That is still uncertain. Maybe the rebound will happen in the fourth quarter? In Chiang's opinion, the forward visibility remains unclear, and it is difficult to make accurate projections. In broad terms, the 2022 market will be "flattish or up slightly," although packaging substrates will remain very strong.

So, 2022 does not appear particularly friendly for the PCB market.

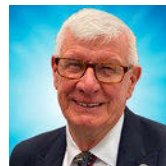
What About Suppliers?

Looking upstream at the equipment and material suppliers supporting the PCB industry, the equipment companies benefited substantially in 2021 from the capital expenditure of the major PCB manufacturers, and a lot of the high-end equipment came from Europe. Chiang had some words of warning for European PCB

manufacturers: "Be cautious about your competition. Your competitors in China are growing. They are expanding their market share and continue to upgrade their technical capability."

Suppliers of materials, especially rigid laminate, had a wonderful year in 2021. All their raw material prices increased, and they successfully passed on the costs to their customers while maintaining their profit margins. But they anticipated price erosion in 2022, and many of the Chinese and Taiwanese producers are seeing their local currencies depreciating against the U.S. dollar which, in addition to any inventory-related issues, will bring their revenues down. And end-customers facing tremendous headwind on their own pricing will pass back pressures to lower prices.

Chiang's closing comments were that 2022 will be an interesting year after the glory days of 2021, with many challenges to be confronted. His suggested approach is to aim to maintain relative stability in managing a business and to work toward finding the best solution to deal with a couple of those challenges at a time. **PCB007**



Pete Starkey is an I-Connect007 technical editor based in the U.K. with over 45 years' experience in the PCB industry. He is also a Fellow and Council Member of the ICT, an Honorary Fellow of the EIPC, and a member of the European Technical Committee of the SMTA.



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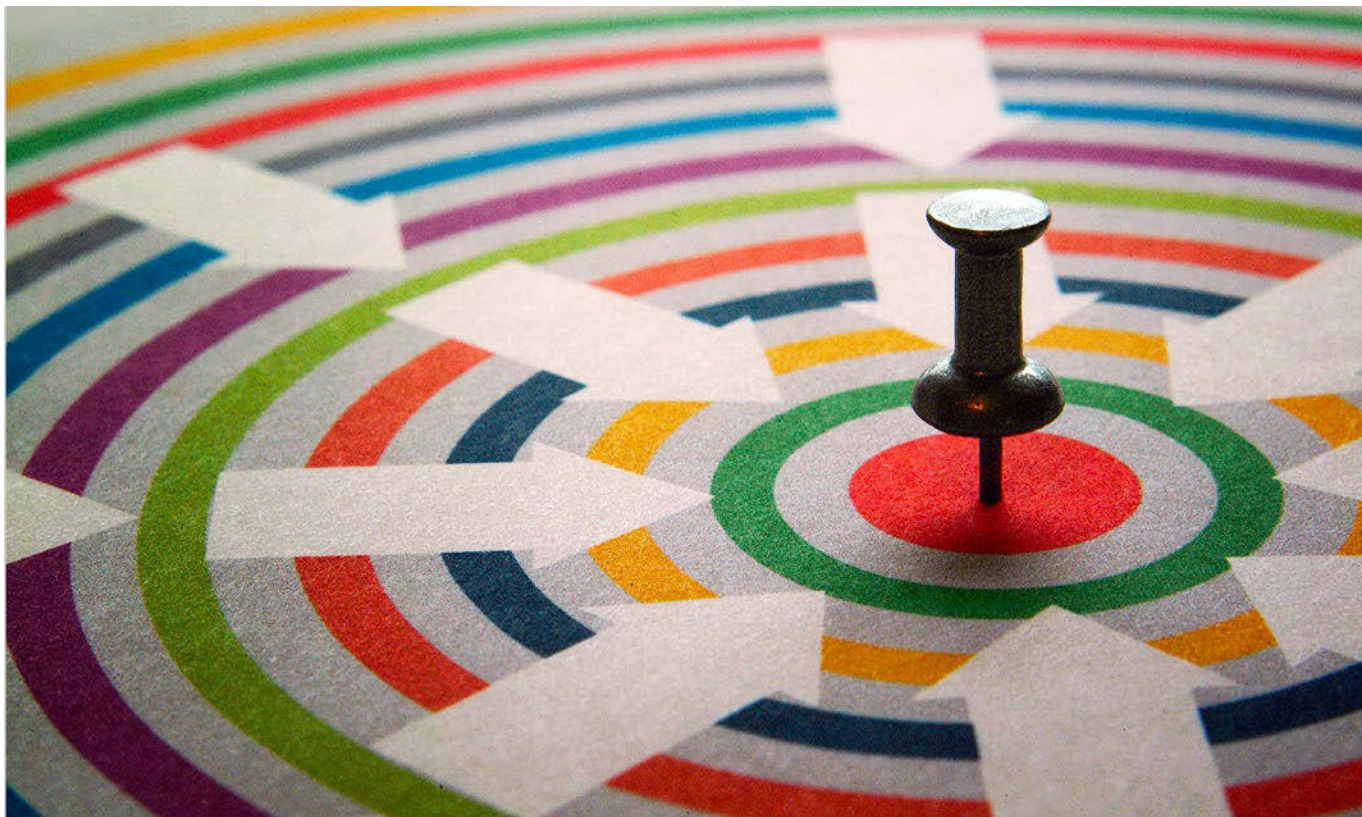
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Today's M&A: Right on Target

Feature Interview by Nolan Johnson

I-CONNECT007

In this enlightening conversation with M&A specialist Tom Kastner, Nolan Johnson learns that it's a buyer's market—and a seller's market too. This sets up an interesting dynamic no matter which side you might be on. What trends are in play that have led to this situation and how can you make the most of it? Tom shares valuable insights that will get you thinking and planning your own strategies.

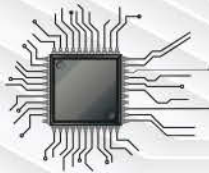
Nolan Johnson: Tom, if PCB fabs are actively planning to expand their business in response to the current market, and if they're looking for investment money, where is that money? Is this a good time to invest, and why?

Tom Kastner: I'm very bullish on the PC board industry and the EMS industry, but then

I'm very bullish on the entire U.S. electronics industry. Coincidentally, I think it's both a good time to sell and a good time to buy.

Johnson: Why is it both a good time to sell and a good time to buy?

Kastner: Recently, we represented a fabricator and an EMS company in their sale to a strategic buyer in the industry. For sellers, especially for companies that are doing well, it's a good market. For companies that are not doing so well, whether they're smaller or just not as profitable, there's still a lot of liquidity for all types of companies. Whether they're growing and very profitable, or maybe not growing so much and not so profitable, there's still a lot of liquidity for both.

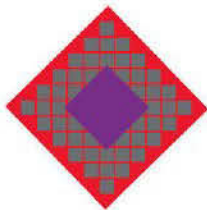


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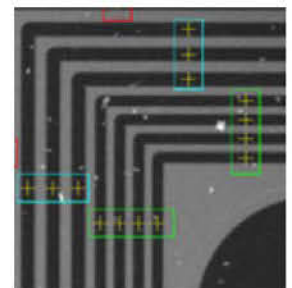
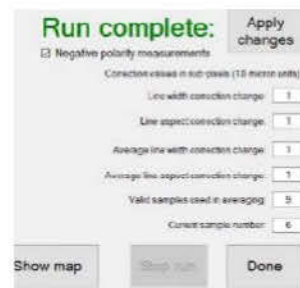
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Now, why is it a good time to invest in the industry? I think it's because we're talking about advocacy: a quick increase in expectancy requests in the U.S. supply chain; increased awareness of what should be made in the U.S., according to ITAR rules, or for supply chain security purposes. Those are all great tailwinds for the industry. I certainly do not think that all the business is coming back to the U.S. That's just not going to happen. But if a small portion of the overall market comes back, that's a huge benefit to the industry.

Johnson: What's your opinion on how the PCB industry in North America should be retooling to maximize this opportunity?

Kastner: The larger companies like Summit, TTM, and so on have the capital to invest in themselves and the companies that they acquire. A lot of the companies that are smaller just really have not invested. Many have, but many have not.

There's a huge investment deficit. Many of those smaller companies that have not invested are very good acquisition targets, and some buyers are looking for that type of target. The companies that have kept up with investments are great acquisition targets for Summit and others that are looking to acquire larger PC board shops.

Johnson: Some of the larger shops—Summit, TTM—come to mind, of course. It seems like there's some private equity activity as well.

Kastner: Yes, there is quite a bit of private equity interest in the sector. In general, the private equity firms are interested because they have an interest in re-shoring and investing in the U.S., and the trickle-down business that will come with the emphasis on investment in semiconductors and the supply chain in the U.S. The private equity guys are pretty smart cookies. They know what they're doing. TTM is a bit of a mixed picture, but certainly FTG

has done a couple of acquisitions and Summit has done several. Fralock is an assembly company that acquired both Lenthor and Career. Fralock is private equity-backed, and really, the private equity-backed companies have been doing more acquisitions in the space than the public companies.

There's a lot happening in the EMS sector as well. But I think they're mostly going after that trend to re-shore and shore up the semiconductor supply chain.

Johnson: So far, we've talked about buying and selling. What about just raising capital? We were mentioning that the smaller mom and pop shops may not have been keeping up on the investment end; they may not necessarily have had the capital or the cash flow to grow their business, keep it on the leading edge, and make that sort of investment. Is there a strategy for them or is that a good investment for someone else?

Kastner: You really don't see much venture capital or early-stage capital in PC boards or in PC board-related technology. Interest rates have recently increased, but even now, interest rates are relatively low. There's still a lot of credit, so it's pretty easy to get financing for either new or used equipment. But a lot of the smaller shops are asking, "Okay, where do we start?"

Many of them start with direct imaging, which is probably the right place. Next, it's test equipment, new drilling machines, or a new wet processing line. But where you see them jump forward is when they get into direct imaging and new high-speed drills. I'm guessing it's because they put it off for 10 years, and finally got to the modern age. There's plenty of money for equipment financing or to improve facilities, but frankly, a lot of owners have been milking the cash cow.

For the milkers, I don't know how much longer they can survive. I visit some shops, and I'm just amazed that they can stay in business.

I don't mean to put them down. I very much admire them for being able to survive and do what they do, but I'm not sure how much longer they can do it that way. It makes it hard for them to grow the business. There's either bank financing, or private equity financing is available.

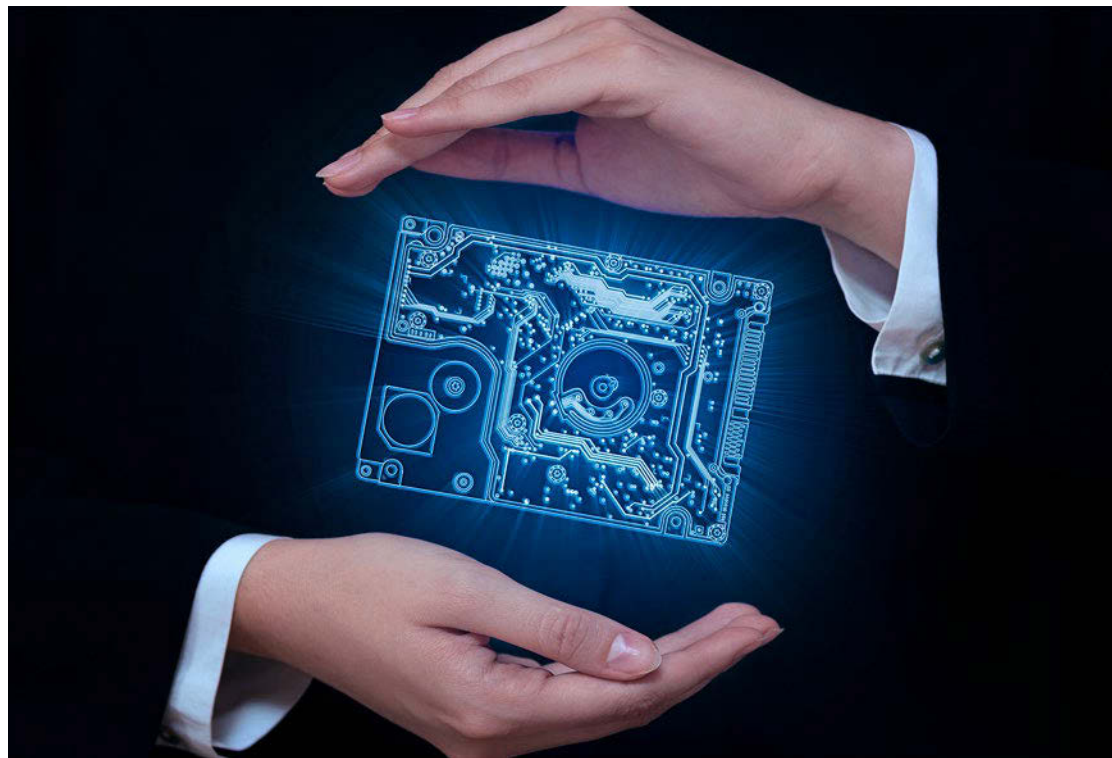
Johnson: How much influence has the recent U.S. government legislation—the CHIPS act, the PCB

Act of 2022—had on the current M&A environment? Is government involvement helping to change the investment perspective?

Kastner: Yes, particularly among the private equity world and other investors, and for banks as well. Every little bit helps. Every private equity deal that's done, every acquisition that's announced, is just further evidence that this is a good sector to be involved in.

There are also the other market dynamics that are helping. There's the trend to move away from manufacturing in China for IP security reasons. There have always been logistics and communications reasons, and now add IP security to that list. I'm hearing more and more that the end customer would like to move production to North America, because they're concerned about IP security for medical equipment, communications, or other things where there's a fairly high margin.

Johnson: You just ran through some key areas where a fab might invest to upgrade their manufacturing floor. But simultaneously the



U.S. electronics industry is increasingly protecting the IP. We have the emergence of the CMMC (Cybersecurity Maturity Model Certification), for example, creating a certification process that runs through the supply chain. There will be companies which, I suspect, receive notice that they need to go through CMMC compliance because something that they build is specified for a system that requires it. Going forward, it looks to become a key part of the industry just to do business and, in many ways, a place to invest as well, regarding cybersecurity, data management, and basic hygiene.

Kastner: Everyone will need to pay attention to that bill sooner or later. Companies typically do not announce that they were hit by ransomware, but I know it has affected everybody. But in tandem with protection against ransomware or other cybersecurity issues, you must ensure you're compliant. Those concerns are only going to increase as the compliance requirements come online, but it's also good business practices. If you haven't been hit yet, you're just lucky.

Johnson: Right. Elsewhere in our recent coverage, Divyash Patel refers to it as “basic hygiene.” You think of it like brushing your teeth and combing your hair. It just needs to be done.

Kastner: If you don’t have ISO or UL, it’s pretty tough to be in business anymore. It will be the same with cybersecurity: you must maintain a certain level. Again, it’s tougher for the smaller mom and pop shops to keep up with that. It’s just another headache. Whereas the larger shops could spread that investment over a wider base and it’s easier for them to do. I think it’s another thing that will lead to more consolidation in the industry.

Johnson: It seems like the trend is further consolidation into fewer, larger, more capable companies. Tom, does that still leave a place in the market for a boutique company?

Kastner: Absolutely. One thing you don’t see too much of are greenfield investments, but I think it would be a fair number of niche companies that are really good at one or two smaller markets. Typically, those niche markets are very profitable, so those companies can invest in equipment and other things, like cybersecurity.

Johnson: Is this a good time for an OEM to consider a captive shop? There are pros and cons to that approach. Certainly, keeping your IP all on your own campus is one advantage. Is now a time to follow the lead of Whelen Engineering or Schweitzer Engineering Laboratories in Idaho?

Kastner: Yes. There’s Schweitzer and some other small ones, right? It would be interesting to consider doing that. The problem is, of course, finding the right people to hire.

Certainly, the talent pool is getting older. It’s definitely an older industry. I wonder, between the permitting, the talent, and the amount of investment that’s required, if the return on

investment is strong enough vs. just focusing on your own products. Without knowing the calculations, it’s hard to decide. Obviously, those two companies did their calculations and decided it makes a lot of sense. So, if it makes sense for them, it must make sense for others.

At the same time, just being able to buy from the domestic market has its advantages. Everybody in the U.S. is having trouble finding any talent, from sweeping the floors all the way up to the CEO suite. These companies must decide whether they want to invest their time and money in finding talent for part of those supply chains, or if it’s better invested in another part of the business.

Johnson: I think that’s something that is emerging in our conversations for this issue. There’s money to invest. Investment is necessary to move forward, but it includes equipment, talent, and security. You’ll have to respond pretty much to all three, but in your own order.

Kastner: That’s right.

Johnson: Tom, thanks so much for this conversation; it sheds much light.

Kastner: You’re welcome. I enjoyed the conversation. **PCB007**



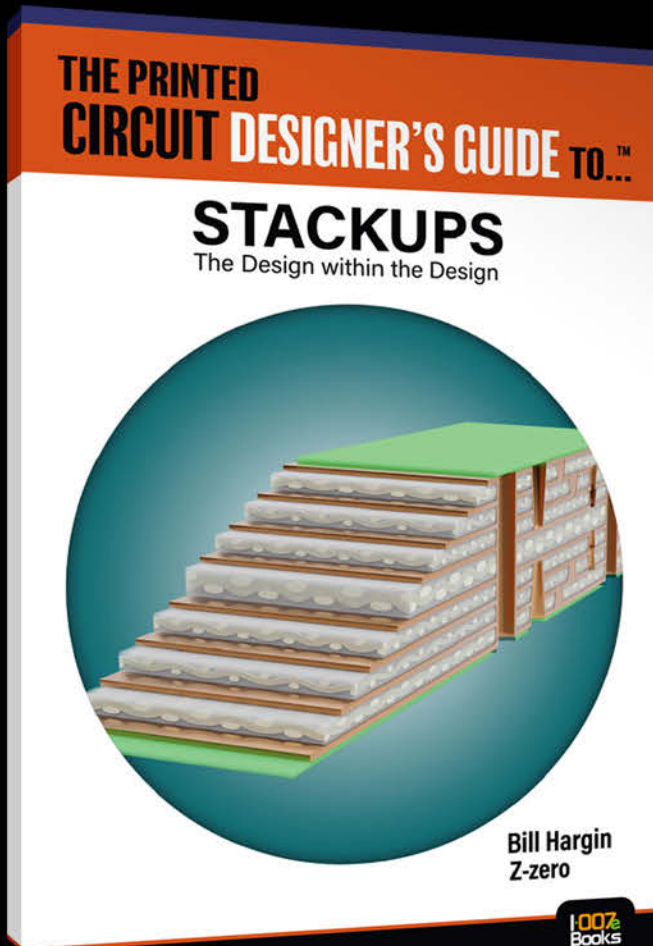
Tom Kastner is the president of GP Ventures Ltd (www.gp-ventures.com), an Investment Banking firm focused on sell-side and buy-side transactions in the tech and electronics industries. GP Ventures

has offices in Chicago and Tokyo. Tom Kastner is a registered representative of and securities transactions are conducted through StillPoint Capital, LLC—a Tampa, Florida member of FINRA and SIPC. StillPoint Capital is not affiliated with GP Ventures.

Curious about the basics of the M&A process?
[Read an additional interview with Tom Kastner on page 58.](#)

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The European Semiconductor Industry Association (ESIA) reports on the release of the new semiconductor market forecast generated in May 2022 by the World Semiconductor Trade Statistics (WSTS).

Hitachi Power Semiconductor Device Develops High-Voltage Motor Driver IC Products ▶

Hitachi Power Semiconductor Device, Ltd. has developed two high-voltage motor driver ICs, primarily for room air-conditioners. The single-chip IC products are able to tolerate large variation of supply voltage.

Off-season Offsets Wafer Pricing Increase, 1Q22 Foundry Output Value Up 8.2% QoQ ▶

According to TrendForce research, although demand for consumer electronics remains weak, structural growth demand in the semiconductor industry—including for servers, high-performance computing, automotive, and industrial equipment—has not flagged, becoming a key driver for medium- and long-term foundry growth.

Hitachi High-Tech Launches Dark Field Wafer Defect Inspection System DI2800 ▶

Hitachi High-Tech Corporation announced the launch of the Hitachi Dark Field Wafer Defect Inspection System DI2800, a critical component in any semiconductor manufacturer's metrology capabilities.

Cadence Design IP Portfolio in TSMC's N5 Process Gains Broad Adoption Among Leading Semiconductor, System Companies ▶

Cadence Design Systems, Inc. announced a wide range of leading semiconductor and system customers have successfully adopted the comprehensive line-up of Cadence® Design IP in TSMC's industry-leading 5nm process technology.

Lattice, AMI Expand Partnership to Secure Next-Gen Server and Datacenter Platforms ▶

Lattice Semiconductor, a low-power programmable leader, announced it has expanded its long-running partnership with AMI.

Siemens Extends Support of Multiple IC Design Solutions for TSMC's Latest Processes ▶

At the TSMC 2022 Technology Symposium, Siemens Digital Industries Software announced that its ongoing collaboration with longtime foundry partner TSMC has resulted in new product certifications for several of Siemens' most advanced toolsets.

Cisco, Ford CEOs to Discuss the Role of Technology in Transforming the Automotive Industry ▶

"If I had asked people what they wanted, they would have said faster horses." Famously credited to auto pioneer Henry Ford, these words imply that in times of massive change, predicting what's next is close to impossible.

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My Time on the IPC Board of Directors: Standing on the Shoulders of Giants

The New Chapter

by Paige Fiet, TTM-LOGAN

At Joe O’Neil’s Hall of Fame ceremony in January, he talked about his first IPC APEX EXPO. He said he felt he was sitting at a table with the “giants of industry.” That analogy perfectly describes how I felt during my tenure on IPC’s Board of Directors. Each time we met, I had the distinct feeling that I was conversing with today’s giants.

A few years ago, IPC began several initiatives to engage young engineers. One result was the IPC Education Foundation. In its early days, the focus of IPCEF was primarily to develop student chapters at colleges and universities. In 2019, Michigan Tech, where I was attending school, became one of the first 10 universities to start a chapter. As IPCEF grew, so did its ambitions and plans. At the same time, IPC’s Board of Directors approached the Foundation with a new idea: have a student director

join the board for a one-year term.

In 2020, IPC made the announcement to each student chapter about its intentions for a student director to join the Board. One of my professors (and an advisor for my IPC Student Chapter) said he wanted to recommend me for the position. To say I was nervous is an understatement! I had one previous internship under my belt working in electronics assembly and had just accepted an internship at Calumet Electronics. However, I felt there were other students more qualified for the position. My professor insisted I apply, and he wrote my letter of recommendation. About a month later, the Board announced its top seven finalists—and my name was on the list.

The board then provided a short bio about each candidate and invited all student chapters to vote. I didn’t have to wait long this time. In fact, it was during the first week of COVID-19 lockdowns, and I was back in my hometown, when I received the email that changed both my career trajectory and my life. Shane White-side and John Mitchell announced that I would be the first student director on the IPC Board of Directors.

I was both honored and surprised to have



Paige Fiet (center) at a board meeting in Napa Valley.
Paige brought her mom, standing to Paige’s left.

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Paige Fiet (fifth from left) at a football game outing with some members of the Board of Directors.

been chosen as the student director. I was not expecting that at all. But after my initial surprise, I started thinking about what was to come. I became very excited and anxious to start my work with the Board.

Because of the lockdowns in 2020, most of my work with the Board was through virtual meetings. Some meetings were two to three hours, while others exceeded eight hours. Yes, those were long days. What I found most appealing about each board member was the passion and enthusiasm for what they do. They spoke with such intensity in matters they cared about the most. Once I was able to meet them in person at a quarterly meeting, I saw the love and friendship they had for each other. Over breakfast they would discuss improvements to processes, ask about family members and friends, and laugh about “the good ol’ days.” Although most industries would classify them as competitors, they saw themselves as allies: a unified team with a drive to improve and nurture the industry. At one event, I invited my father to come as my plus one. He later shared his observation that everyone seemed very relaxed, and he was awestruck with their passion for their jobs.

During the meetings, I was able to provide insight into the wants and needs of budding engineers like myself. I pushed the Board to provide more funding for the student chapters and focused heavily on developing education

programs. The board members taught me about corporate economics and their plans for growth. Outside the meetings, they mentored me in career development.

But the best thing the board members gave me was a desire to stand on their shoulders and keep improving the industry into the next several decades. The enthusiasm I saw at each meeting was contagious and exhilarating. I left

each one hungry for more. This encouraged me to learn more about the industry. The best way to learn is to be more engaged, so I quickly joined committees for assembly, fabrication, and technology solutions. I found myself as an Emerging Engineer to increase my activity. As I learned and grew my professional network, I found subject matter experts and invited them to give presentation at my student chapter or host classes at other student chapters.

At the 2022 IPC APEX EXPO, my time on IPC’s Board of Directors came to an end. Even though it’s a one-year position, I served two years because of the lockdowns. I know the Board is left in good hands with Hannah Nelson, a student at Valparaiso University who is now serving her term as a student director. Hannah brings so much joy and a unique outlook into what students want to see. She has already started engaging in committee meetings and is participating in the Emerging Engineer program for students. Going forward, I am excited to see the benefits she will bring to the industry. **PCB007**



Paige Fiet is a process engineer at TTM-Logan, a former student director on the IPC Board of Directors, and an IPC Emerging Engineer. To read past columns, [click here](#).

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Printed Circuit Boards: Past the **Lobby** and Onto the **Floor**



Feature Interview by the I-Connect007 Editorial Team

Editor's note: This interview was conducted on July 6, 2022. At the time of our discussion with U.S. Rep. Blake Moore (R-Utah), House Resolution 7677 (HR 7677) had been introduced to Congress, comprised of an investment program and a tax credit for purchasers of printed circuit boards. In our interview, we discussed details about both key sections. On July 7, an amendment to HR 7677 was published, in which the tax credit portion of the bill had been removed. This interview has been edited to remove the tax credit-specific sections of the conversation.

There has not been a time in recent memory when the U.S. legislative body is putting as much focus on the microelectronics indus-

tries. One bill, the CHIPS Act, was signed into law last year. A new bill introduced this year seeks to allocate funding for printed circuit board fabrication. In this exclusive interview, our team spoke with Travis Kelly, CEO of Isola Group and president of the Printed Circuit Board Association, and U.S. Rep. Blake Moore (R-Utah), who has co-sponsored the bill now before the House. Travis and Blake both express optimism about onshoring domestic production, but the realities of the legislative calendar may pose some risks.

If you would like your voice to be heard, reach out to your U.S. legislators, or visit one of the associations mentioned in this interview: PCBAA, IPC, or USPAE. Each is lobbying on your behalf.

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Nolan Johnson: Thank you, Travis and Rep. Moore, for joining this conversation regarding the Supporting American Printed Circuit Boards (SAPCB) Act of 2022. Our readership is the electronics manufacturing sector that designs, manufactures, and assembles those printed circuit boards, so this legislation is near and dear to their hearts and wallets. We're delighted to have you here. Would you provide some background on the genesis of this proposed legislation?

Travis Kelly: As you know, the printed circuit board industry in the United States has gone from roughly 2,000 companies down to 145, which is very draconian in terms of the overall resiliency of that domestic supply base. We are constantly looking at the different levels of competition within the industry; ultimately, we need to level the playing field. In some cases, the U.S. printed circuit board fabricators and assemblers are actually competing against countries, not companies. This means competing against foreign subsidies in terms of some of the competition that arises. We want to level the playing field so that the U.S. domestic industry, as it relates to microelectronics, is not only resilient and sustainable but also secure. HR 7677, supporting American-made PCBs, is important to the overall health of the domestic industry.

Rep. Blake Moore: As I work throughout my district, I haven't seen anything more consistent. In my role, I'll interact with leaders from car dealerships to manufacturing operations. I was just at a meeting this morning where the topic was the dire need for chips. They told me they're having to pay more than what they had built their cost models on, and they are desperately in need of product. I've never seen something so ubiquitous across our economy that needs this big family of semiconductor capability. We need to shore up our supply chain; it's tied directly to national security and my distrust of Chinese-made products. I believe



Rep. Blake Moore

legislation like this will help onshore production and will address the supply chain issues regarding national security.

Passing this legislation will show industries that we know they're working hard but it's virtually impossible to do the job that they need to do at scale. I'm in contact with a company right now that manufactures sensors for weather-related issues and builds predictive models for numerous government agencies. They can't do their job because they can't even get access to this material. This is where we can step in and help. We shape the legislation, as Travis mentioned.

Johnson: Is it fair to say that the primary objective of this legislation is to both level the playing field and increase availability in the supply chain?

Moore: For me, the primary objective is about what's important long term. We know we have ceded so much of our manufacturing capability to adversarial nations. Looking at the big picture means pulling that back and using



Travis Kelly

those opportunities of scale to build back that network in the U.S. better. I want to bolster domestic printed circuit board production, while strengthening supply chains. We must complement semiconductor incentives by encouraging domestic PCB manufacturing and addressing the acute need to reduce supply chain disruptions.

Let's make sure to bolster our capability, our workforce, and the network. While our first foray into this topic was defense related, we know it naturally broadens out to more commercial use. Defense is a good place to start because we know we cannot trust some adversarial nations. Let's build from there and use increased defense production to scale up. Ten years down the road, we will be up and running, and have a lot more capability than we had before. We will need to have the workforce to take on that need. Utah, for example, has a really strong manufacturing capability.

Workforce issues are tough, but we have the capability. The best thing for our economy is to have a strong manufacturing base with a

diverse workforce and production-based capability because it gets you through the economic downturns. You're not just wholly reliant on a consumer-based economy. It's important to think long term.

Kelly: Rep. Moore is spot on. The question does need to be bifurcated between short-term and long-term goals. HR 7677 will provide that initial investment in the domestic industry. There's roughly \$3 billion earmarked for an expansion and modernization of facilities and equipment as well as workforce development. That's the adrenaline that the microelectronics ecosystem needs as it relates to printed circuit boards. If you look at overall defense spend, you're really looking at roughly 3% of the overall market, which is not sufficient to create a sustainable domestic industry.

We need to look at the different critical end-uses. If we all agree that defense is a critical end-use infrastructure—like 5G, 6G, medical, commercial, aerospace, or banking—to support that we need a trusted and resilient supply. Then you have an aggregated demand of roughly 26% of the global market that I think would be sustainable. We're not myopic; we know we need to be protected both economically, and to Blake's point, for national security. That's where we need to get our voice around this, and that's why HR 7677 supporting American-made PCBs is so important.

Barry Matties: Do you see the number of shops increasing in the long term as well? What projections are you making?

Kelly: I get that question a lot: What is the right number? I will often respond by saying that 4% global market share being manufactured in the U.S. is definitely not the right number and 100% being manufactured in the U.S. is also not the right number. Similarly, you might see consolidation with several companies, so does 145 become 120? Maybe. Do you see new companies starting? I don't think so. I

think we'll see consolidation efforts and some investment in expanding current PCB fabricator and assembler footprints—similar to what Isola Group did. We invested \$40 million into Arizona to expand our footprint and automate our facilities. I expect to see very similar activity elsewhere in the United States. I don't see too many new entrants coming in.

Moore: This goes back to the adage, "Success breeds success." With the tumult that exists in the South China Sea, moving forward I strongly feel this is an area where we can grow and start to pull production back to the United States and partner countries. We've done it well in the past. I love the push and pull concept there. You see where the incentives are. What can we do to incentivize that and get more capability back here?

Matties: Will we see more captive facilities? Will this incentive drive captive OEMs to set up their own PCB fabrication?

Kelly: Both Barry and I know there are some OEMs that are doing the vertical acquisitions, even though it's greenfield, they say it's vertical acquisition and doing the captive approach. Many OEMs are concerned about the resiliency of the supply chain. Once again, COVID taught many lessons on numerous fronts and one happens to be that the global supply chain, although it can be effective, can wreak havoc if you over-index, especially at the end use. I think you'll see a nice hybrid approach: some captive, some consolidation. You may even see some, I'll say Asian, competitors start building brick and mortar in the U.S. Typically, economies will evolve when they're forced into innovation and into creating new strategies to go to market.

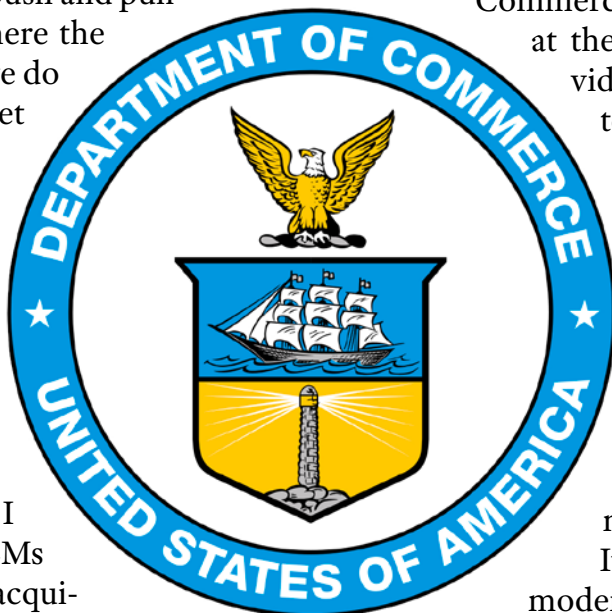
Johnson: Travis, we've already discussed a potential consolidation, but also new capabilities and capacity build-out in existing companies. We touched on whether new companies might start up to fill into this space, and we've just mentioned captive sites. We've already identified four different ways the industry might create more resiliency in printed circuit board fabrication. How does HR 7677 enable these approaches? How do we expect to see the funding used?

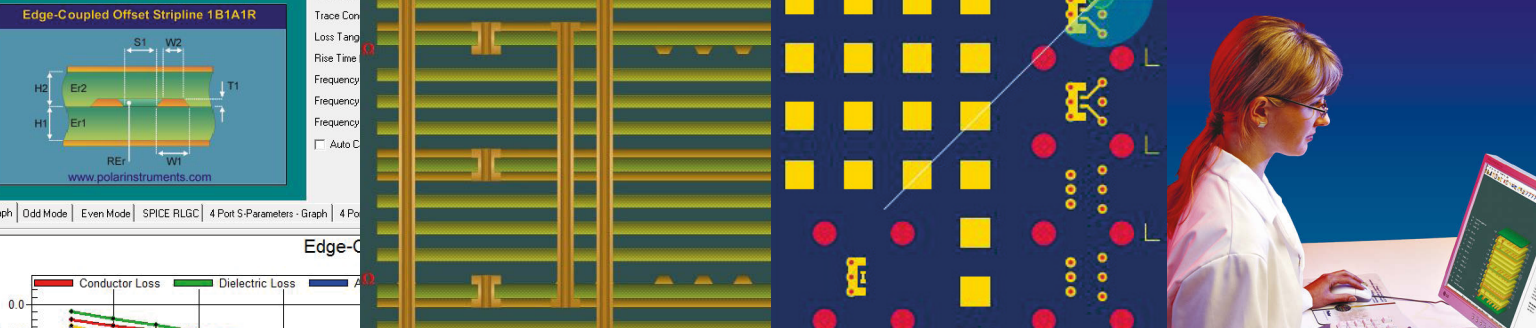
Kelly: We will focus on the \$3 billion investment from the government. From an investment standpoint, the U.S. Department of Commerce is always going to look at the companies that are providing that best-in-class technology, that can provide the great workforce opportunities, especially in underserved areas of the country, and that will be successful from a competitive global economic standpoint. There will be certain criteria relative to how that money gets spent.

It will be spent on modernization, expansion, and workforce development to scale up.

We need to have enough brick and mortar, the right workforce, and the R&D to stay on top of that technology curve to ensure the supply is both trusted and resilient. That's why this bill is so important for the domestic industry, because that \$3 billion original investment is the catalyst behind beefing up the industry, ensuring that the infrastructure and workforce development exist, and it's a really nice adrenaline shot to do what we say we can do.

Johnson: How do HR 7677 and the CHIPS Act work in sync? How does that happen?



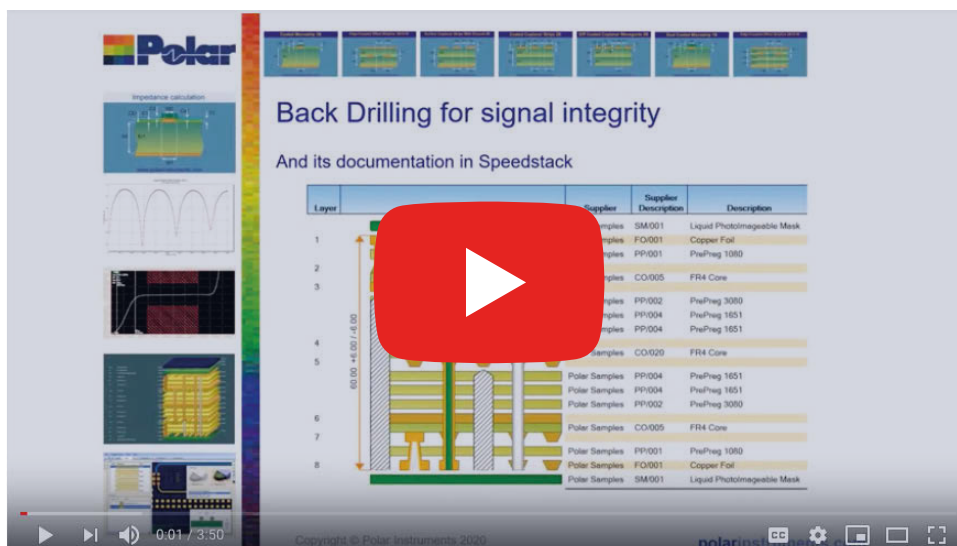


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Moore: They complement each other. This PCB-focused effort is similar to the effort to reassure manufacturing for semiconductors. They're both trying to accomplish a similar objective and the general product family is similar. This is about a DoD call for domestic investment and it provides for the proper incentives necessary to meet this growing challenge. I'm working on it as a conferee with both the House and the Senate China bills. Not everybody is even comfortable with the Senate's USICA legislation, but then House Speaker Nancy Pelosi complicated the process by adding a lot of her unrelated priorities into the COMPETES Act. It extended the China legislation far beyond where people were comfortable supporting it.

Now in trying to reconcile those two, we know we need to get the CHIPS Act going, and it is broadly supported. The hope is that even if the wider China legislation simmers and fizzles out throughout this tumultuous campaign season, there's a potential the CHIPS Act could

I'm not sure that printed circuit boards have ever made their way to an active discussion on the floor of Congress, and how the two bills align. They're mutually exclusive. One was introduced with the CHIPS Act. This one, HR 7677, was introduced a couple months ago. I like these discussions because it's beginning to resonate, meaning it's not just semiconductors and it's not just printed circuit boards. It is a very complex microelectronics ecosystem where the chip is the brain, and the PCB is the body. Neither one can work without the other. Printed circuit boards are more than just boards. There's all the componentry as well. One doesn't work without the other.

For the first time in a long time, legislators see that this needs to be a holistic approach. The discussion is much broader than one or the other. To fix the root cause of problems you can't just go after the symptoms. That's why this legislation is so important.

If you really want to have a microelectronics ecosystem that is trusted, resilient, and sus-



get pulled out and passed separately, but it's the main negotiating piece motivating the entire conference process for many Republicans. I can't stand this process. I don't think it's the right approach for the American people, the manufacturers, and the people working and paying their taxes who are frustrated that our government can't come up with reasonable solutions. I want to be a reasonable voice, and I've come in on bipartisan legislation, in particular this PCB legislation. We must move the ball forward and not get hung up on politicizing the process of passing key legislation.

Kelly: I want to thank Reps. Moore and (Anna) Eshoo, D-Calif., for co-sponsoring this bill.

tainable, then you must look at all the different aspects and activities that it takes to ensure that supply chain is resilient. It's a lot more than just semiconductors. That's why we always say chips don't float; they must be embedded into a board to function. This is how I see the conversations aligning with the CHIPS Act and HR 7677.

Johnson: As we're recording this interview, it's the July 4 congressional break. Congressman Moore, where is HR 7677 in the process?

Moore: It has been introduced and it's on the front end of the process. We are closely watching what's going on with the China legisla-



you have more visibility into that than we do. From a private industry standpoint, the Printed Circuit Board Association of America will continue to educate, advocate, and legislate as much as we can on behalf of the printed circuit board industry. The best thing we can do is to get more visibility and make people more conversant on what the issues are. We must keep driving home the idea that we need a trusted and resilient supply chain.

tion. To give you a sense of where things are right now, there are three more weeks in July and then you have the August recess period. We meet for three weeks in September, then we recess in October. It's not the schedule I would choose, but that's the way an election year works.

I hate to be the bearer of bad news, but it's going to take quite a bit in that short timeframe before the election season comes to get anything done outside of what's already in the pipeline. You might see something late breaking as we approach the end of the year, but if the House flips, Democrats are going to offload all the appropriations responsibilities back onto the Republican side.

In the meantime, last year's NDAA (National Defense Authorization Act) succeeded in including language on printed circuit boards and that was enacted into law. So, we have seen more traction on the NDAA, but this particular bill, HR 7677, is still on the front end.

Kelly: Blake, that's a consistent message that we're hearing from everyone: With midterm election distractions, it's a long putt to think this bill gets approved this year. But obviously

Moore: Travis, I think the lead-in can be what gets done on the China legislation. That can give us a sense for the appetite that exists, given that CHIPS and SAPCB are similar and working in concert. There's at least an indicator that will tell us what might come of this.

Matties: Travis, what can the fabricators do to help support and move this along?

Kelly: PCBAA, as well as our colleagues IPC and USPAE, are sending a letter to the representatives of Congress signed by CEOs of domestic operations. As part of PCBAA, I have joined Will Marsh (VP, TTM Technologies) on Capitol Hill numerous times, meeting with Rep. Moore and other representatives, trying to get co-sponsors and further sponsors.

The key is to continue advocating for the microelectronics domestic industry. It's important and a needed resource that we provide. Rep. Moore said it right: It's national and economic security. We need to continue to drive those points home.

Johnson: Closing thoughts and remarks?

Kelly: From the Printed Circuit Board Association of America and all its members, we very much appreciate the work that Blake Moore

and Anna Eshoo have put into this bill. It's fantastic that the printed circuit board industry is getting visibility on the importance it plays in microelectronics. Thank you very much, Blake, and thank you, Anna, for co-sponsoring.

Moore: I want to thank our respective teams for all their effort. Will Marsh has been a valuable resource working with my chief of staff, legislative team, and my defense team.

This situation affects everybody. It is ubiquitous, and something that we never really grappled with before last year. We all know what circuit boards are, but I never got into the weeds until this role in Congress. Now I see how this touches every industry. When you can look closely at the national security side, it's worth putting in the time and effort.

Shoring up our national security supply chains is what our job in Congress is designed to do. The number of jobs and manufacturing plants just in Utah's 1st Congressional District is overwhelming. We must also ensure we have strong supply of rare earth and critical minerals, and we need to keep costs in check. In addition, we have amazing people running the companies that are relying on PCBs, and they're trying to provide government contracts, defense work, and just general commercial applicability. When something like this touches so many facets of our lives, we must find some reasonable solutions. I am very confident that the work that we've done is that right direction.

Matties: Thank you for putting so much energy into this. Congressman Moore, when you became aware of the situation, how surprised were you that we were so vulnerable?

Moore: It's my first term in Congress and I'm excited to talk about how I am trying to build a productive way forward, because it becomes such a blaring issue. I was very surprised to see how close this is to every industry. For example, as general consumers, we

all buy cars. It's a typical purchase that has occurred seamlessly for decades in our nation. Now we have vehicles waiting on the lot for technology components that we know how to build, but we are just facing a major disruption. That's very concerning. The pandemic highlighted some areas of our national economic armor that are vulnerable, so I was thrilled to put some elbow grease behind this.

Matties: Thank you for bringing it up to a high level of priority. Travis, thanks to you and the PCBAA for being such a strong voice for the PCB industry. Your results are already evident.

Kelly: Great. Thank you very much. **PCB007**

FOR YOUR INFORMATION

CHIPS for America Act: The Creating Helpful Incentives to Produce Semiconductors for America Act incentivizes investment in the U.S. semiconductor industry. While it was passed in January 2021, a funding package has not been approved by Congress.

HR 7677: Introduced in House, the Supporting American Printed Circuit Boards Act of 2022 is intended to provide incentives for the domestic production of printed circuit boards, and for other purposes.

USICA: United States Innovation and Competition Act of 2021 addresses U.S. technology and communications, foreign relations and national security, domestic manufacturing, education, trade, and other matters. The text of this bill substituted the text of the America COMPETES Act of 2022. The amended bill was passed by the Senate and sent back to the House.

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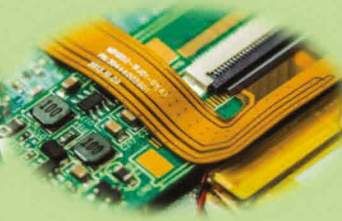
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Feature Interview by Nolan Johnson

I-CONNECT007

Jeff De Serrano, president of PCB Technologies U.S. Operations, takes us through some of the struggles of the PCB industry over the past 30 years, how U.S. legislation seeks to level the playing field, and whether a “monopoly” of fabricators is healthy for our industry. In his chat with Nolan Johnson, Jeff gets out his investment playbook and talks strategy. Don’t miss this one.

Nolan Johnson: Jeff, you have an interest in getting involved with advocacy groups. What’s your motivation? As a fabricator, what value do you see in them?

Jeff De Serrano: We hope people understand that we’re not just a commodity in the United States. When PCB production went over to China, it became a commodity. When I started in this business, it was a unique industry. We built some of the craziest stuff to make the world go around; being an engineer, an EE, I thought it was great.

Then it switched to a commodity. After 2008, finance took over most of the purchasing activities for OEMs, and they’d say, “We’re not paying for that. You can buy it over there and it’s cheaper.”

In the United States, we all suffered for a while. With these advocacy groups, I’m hoping everyone will realize and understand that it’s not a green thing and it’s not a commodity. When you’re 4,000 units a year or 10,000 units a year, it’s not a commodity. When you’re buying a million a month, that’s a commodity. We don’t make bread; we make customized specialty items for military warheads, the communications network infrastructure, 5G, and other strategic applications.

The U.S. manufacturing industry is up against a challenge: To make money, you need to be in the advanced technology market, and the equipment investment is very expensive. It’s not just a commodity anymore. That’s the main thing for me.

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Johnson: You're an industry insider, but right now, you're also an advocacy group outsider. What's your assessment of how they've performed over the past couple of years? I'm thinking of PCBAA, USPAE, and IPC. Each has a slightly different focus and mission statement.

De Serrano: I have not joined the PCBAA. They're tightly focused on the DoD market. They're making headway, but anything in the government takes a very long time. We're only "this big" in a pot that's much bigger, but I do think they are making progress.

At least it's a path forward and we can speak to the DoD folks. They understand that in the truest sense in America, their supply chain is almost gone. You've got major players acquiring everybody and all these other mom-and-pop shops that can't keep up with the cost to invest in the latest technology.

Johnson: We've got the CHIPS Act, as well as the Supporting American Printed Circuit Board Act of 2022, which is basically the PCB fabrication and assembly equivalent of the CHIPS Act. Both bills are on the Hill right now, going through the process to become law. This seems like a major accomplishment. How do you view that legislation as far as helping the industry?

De Serrano: I know about the CHIPS Act and it is awesome. If you look at the scope of things, in the 1990s we made most of our semiconductors here; overseas was 10% or 12%. Now it's maybe 8% here and Taiwan is making 85%.

We all learned a lesson with the effects of the pandemic that relying on low-cost regions to make America great, really didn't make us



Jeff De Serrano

great. Things are cost efficient for a certain amount of time, but sooner or later it catches up with you—and now it has caught up with us. The government needs to be more involved on the printed circuit board side. It needs to invest money back into some smaller businesses that have been around for 30 years, to help them modernize. Now, I'm not sure those older shops are going to be there by the time that legislation goes through, but I think the

government must make a significant strategic investment to ensure we're all safe.

The CHIPS Act is good legislation. But Congress has yet to agree on a bill that would appropriate resources for its various programs, so there's still work to be done. One thing about legislation is you get all this money, but does it go to the right place? Now that we have the advocacy groups fighting for us, the hope is they will help drive the traffic to the right place. We won't know until get there.

Johnson: How does this play out? For example, as a fabricator and an owner, you are working to grow your business. When you consider supply chain resiliency concerns—in all industries, as well as our own—and this upcoming legislation, is now a good time to be investing in PCB fabrication?

De Serrano: 100%. Now, the PCBA is a different story because they can't get specific components and their lead times are 12 to 13 months sometimes. But the PCB business right now is the highest I've ever seen in 30 years. It's almost like the early '90s or late '90s when we were practically printing money.

The manufacturing space is in dire need because now everything has a circuit board in

it. It used to be that a car had something like three circuit boards. Now, they have 103, right? We're walking around with circuit boards in our pockets, on our bodies every day, whether it's your watch, your phone, or your earbud. Sometimes you have all three at once. Twenty years ago, you had zero. You had a bag phone in the car. That's why all these private equity money guys are trying to get in this space right now.

Johnson: Is that where the money's coming from? Private equity?

De Serrano: Yes.

Johnson: What about venture capital?

De Serrano: PE guys. They want to get in now, turn it in three to five years, and sell it. They'll buy two or three.

Johnson: It seems that the strategy is to gather up the small mom-and-pop shops into a larger operation under private equity money. That consolidates the market. Will this be good for us?

De Serrano: In the long run, yes, if it doesn't become a monopoly. For example, the DoD used to have quite a few vendors, but many of those vendors were acquired and now the DoD has that one big supplier, us, and a couple others; but they don't have a lot. If suddenly there were only 10 fabricators in the United States but they're all U.S. owned, that wouldn't be too bad, because you would still have competitiveness.

The problem is with the mom and pops that are doing \$4 million. You buy them for \$5 or \$8 million, then you have to invest \$10 or \$12 million more, just to get it up to where I can build a three-lam job with a 0.5 mil pitch BGA, stacked microvias, or rigid-flex.

Sooner or later, it will probably boil down to having maybe 15 or 20 companies in the United States that build circuit boards for the whole country. Each one of them might own

three or four shops. Numbers vary depending on who's counting, but there are about 150 left. Some additional acquisitions haven't been announced. I know because we were trying to buy one when it got sold to another company. We're probably down to 140-something now. Out of the 140, my data shows us that about 90 of them are \$10 million or less in revenue. There are about 25-30 shops that are \$10 million to \$21 million in revenue. Then you have maybe 10 or 15 left that are above that. That's about all there is.

Sooner or later, it will probably boil down to having maybe 15 or 20 companies in the United States that build circuit boards for the whole country.

I don't think anybody will catch up to the two major companies because they continually look at making investments. If they consolidate the market too much, then it would be terrible for the whole United States. It would be like the cellphone networks. We used to have 20 companies doing cellphone networks. Now you have Sprint and T-Mobile together, AT&T, and Verizon. There are three. I don't think three suppliers would be good for our industry.

Johnson: Is there hope for the small boutique shops?

De Serrano: If the PE guys come in and acquire them, there's hope. When I'm analyzing these companies, I find that some have very large buildings—maybe 40,000 square feet—but their revenues are more like \$15 million. If you have a building that large and you do things

right, you should run between \$2.8 million and \$3.7 million a month out of that square footage. Quite a few are running \$3, \$4, or \$5 million a year in revenue, and most without a sales organization to push them to the next level. In this space, you're either a sales company that manufactures circuit boards or you're a manufacturing company that sells circuit boards. You must decide which one you want to be.

Most of those small shops are manufacturing companies that sell circuit boards. That means the sales guys push the hard stuff to their manufacturing team and they say it is too hard to build. When you are a sales driven company

from the top down, manufacturing will find a way to get it done. This is what makes us better; your average sale price goes up. The can-do attitude of "figure out how to build it." Whereas manufacturing looks at it and says, "We're not touching it." You must decide what you want to be.

I'm a proponent that sales drives companies to succeed to the next level. The mom and pops must struggle with that.

Johnson: Excellent. Thank you.

De Serrano: My pleasure. PCB007

BOOK EXCERPT

The Printed Circuit Designer's Guide to... High Performance Materials

Chapter4: Copper Foil

Copper foil is the standard conductive layer used for metal-clad laminates, although other options are available. There are two main types of copper foil used for PCB boards today: electrodeposited (ED) foil and rolled annealed (RA) foil. ED copper foil is produced by a continuous process which yields a well-controlled product in mass volume and low cost as compared to RA copper foil. ED copper foil has a wide range of thicknesses, from 5 micron to 400 micron, for PCB applications. IC substrate application requires an ultra-thin foil which is supplied on an 18–72-micron copper carrier and range in thicknesses from 1.5 micron to 5 micron.

Rolled annealed foil yields a very smooth surface where the process deforms the copper crystalline structure to achieve thickness. Unfortunately, the foil is only available in a 25" wide format. This makes use of the foil difficult in the large batch processes



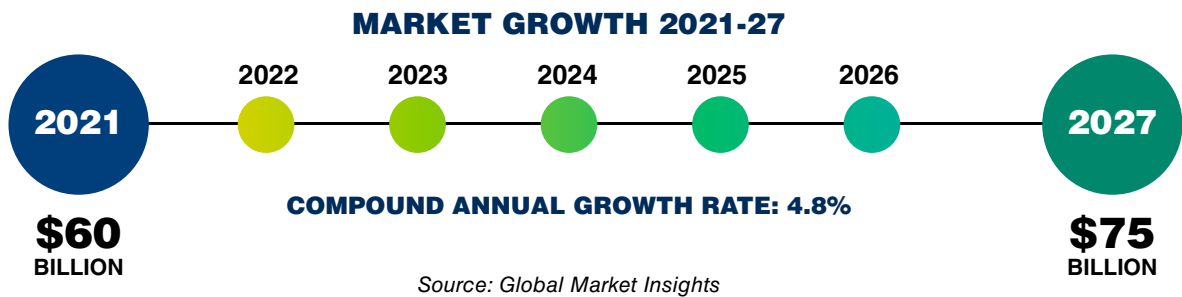
used by laminators to manufacture laminates. Most processes are designed around a 50-inch-wide machine direction of the glass using large hydraulic presses with platen sizes to accommodate the 50-inch glass width. Use of the RA foil reduces productivity and results in higher cost. With the development of newer smooth ED foils that are as smooth as RA foil, the need for RA foil and the associated cost has been largely mitigated.

ED copper foil that is commonly used for radio frequency and microwave and HSD designs—where high frequency boards require very low roughness—is required

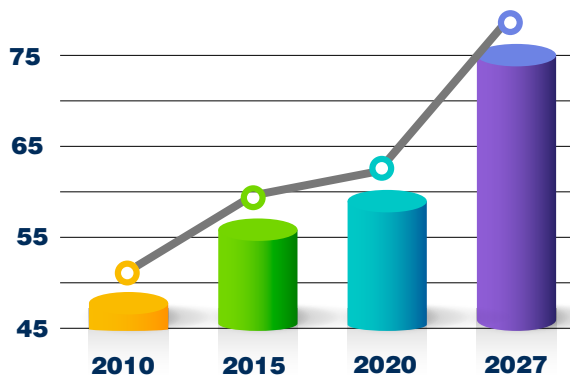
to reduce the conductor losses. Roughness is one of the key factors for high frequency applications where conductor loss is the secondary contributor to overall loss after dielectric losses at frequencies over about ~10 GHz.

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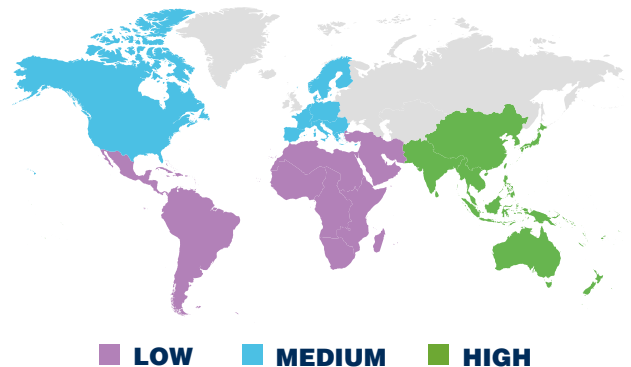
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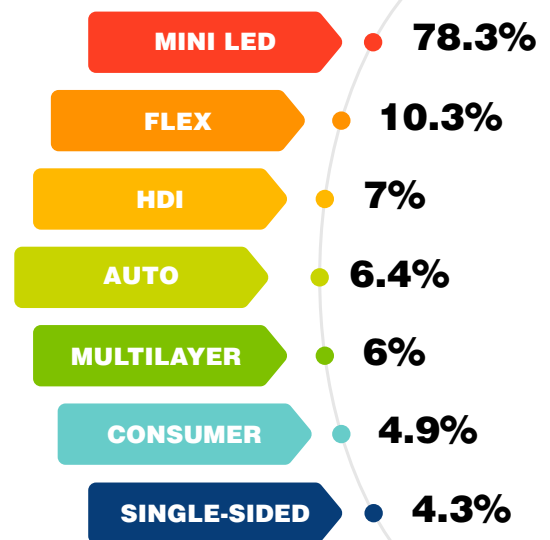
GLOBAL MARKET VALUE (\$BILLIONS)

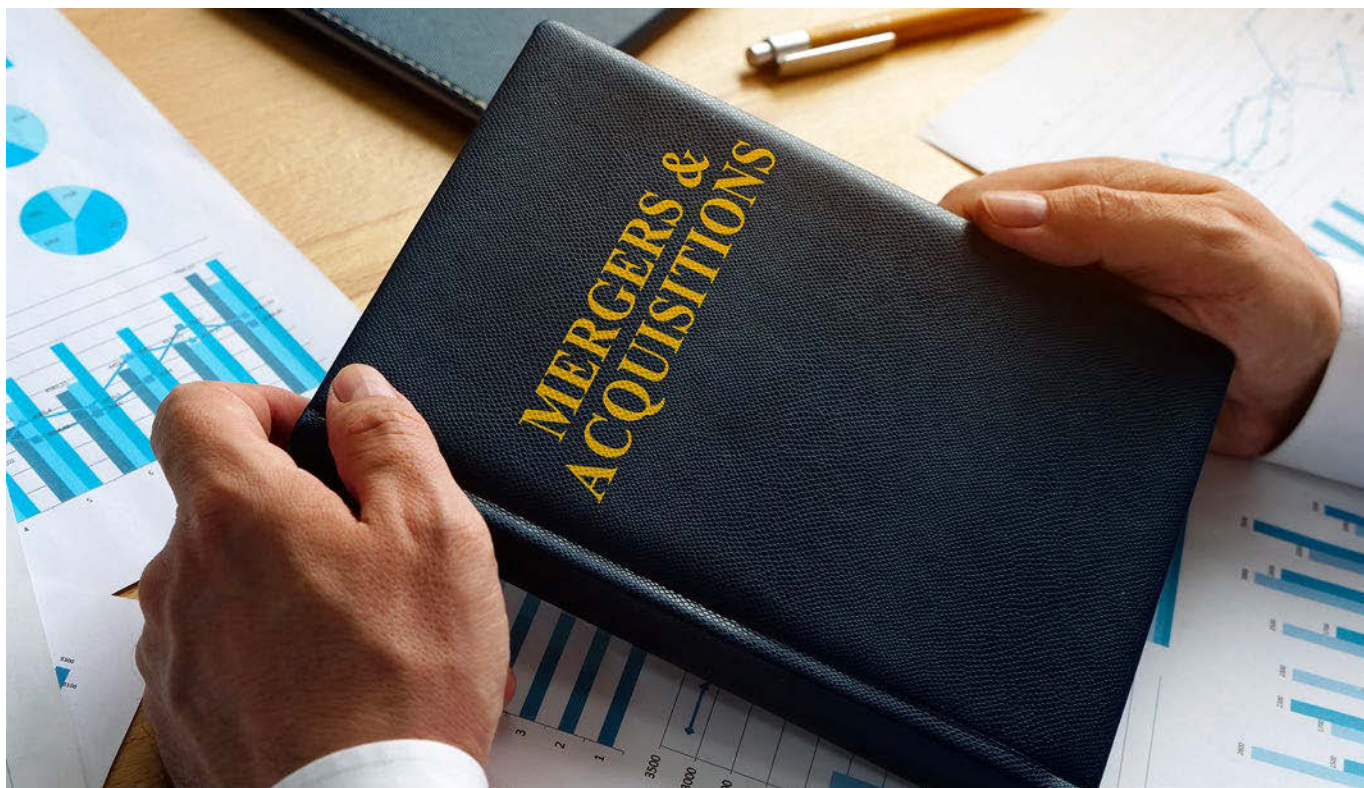


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A Primer on M&A

Feature Interview by Dan Beaulieu

D. B. MANAGEMENT GROUP

Tom Kastner of GP Ventures is a busy man these days. He's been involved in several M&A deals, including a recent acquisition by Summit Interconnect. Tom spent some time with Dan Beaulieu, who often consults with PCB and PCBA companies, about what it looks like when a company is thinking of buying or selling—and how a consultant like Tom helps negotiate the best deal.

Dan Beaulieu: Tom, thanks for talking with me. I know you are very busy with your focus on PCB and PCBA-related companies. How did you get involved in this area of your business?

Tom Kastner: I started in the industry with Hakuto, a Japanese company which makes cut-sheet laminators for PCB manufacturing.

They also distribute components and semiconductor equipment. I started with connectors, followed by RF/microwave components, then I got into corporate investments and PCB equipment. I've been in M&A since 1996.

Beaulieu: You have completed several company sales in the past. Please share some of your recent examples of your successes.

Kastner: The most recent was Royal Circuits and Advanced Assembly to Summit Interconnect. Overall, I have been involved in more than 20 deals in the PCB and EMS sectors.

Beaulieu: Tom, if someone wants to sell a business and they want to hire you, what does that look like?

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Kastner: First, we talk about the owner's goals and expectations. If they are looking to sell soon, we focus on the process of selling. If they are looking to get ready to sell in three to five years, we can talk more about long-term preparations.

Beaulieu: I assume all your dealings are in the strictest confidence?

Kastner: Yes, my business is dealing with very sensitive subjects, so confidentiality is key for me and my clients.

Beaulieu: Tell me about the process.

Kastner: In the beginning, I'll talk with the owner about the potential value of the company and the possible terms such as cash at closing, earnouts, etc. I'll also visit the company and get to know them better. Once we are signed up, we put together a professional executive summary and confidential presentation. We reach out to potential buyers which are screened in advance by the client. We'll answer questions and, after a certain period, ask for initial offers (IOIs). The top bidders get invited to Zoom calls and in-person meetings, then we ask for letters of intent (LOIs). We sign one LOI, then go into due diligence. Once due diligence is completed and we negotiate the purchase agreement and other closing documents, we close the deal.

Beaulieu: Tom, let's get a little more specific about your fees. I know that you customarily charge a monthly retainer. What is that for?

Kastner: With my team, we spend an incredible amount of time on each deal, so we feel we should be compensated in part for our time.



Tom Kastner

Usually, 90–95% of the total fee is based upon success, so the retainer is a small part of the deal.

Beaulieu: That makes a lot of sense. Now let's talk about what your team provides with that retainer.

Kastner: It includes all the services described earlier, from developing the materials to closing the deal.

Beaulieu: How do you find the right buyers for the company you are selling?

Kastner: We reach out to as many buyers as possible. Sometimes, the most obvious buyer closes the deal. Sometimes, it's a buyer we never thought would be interested or that we had never heard of before. Buyers know that we'll be reaching out to a wide range of buyers, so there will be competition. Also, by engaging our firm, the seller is sending a strong signal that they are serious.

Beaulieu: How is the price of a company developed? How do you set the price?

Kastner: Before getting started, we talk with the owner about the probable valuation range of the company. We do not go to market with an asking price, however, we let buyers compete to set the market valuation.

Beaulieu: Is it possible to sell a company that is not making any money?

Kastner: Yes, but it's not easy. Typically, if a company is not making money, we'll look to represent a buyer who is looking for that type of deal. Most likely, the valuation will be related to the value of the assets.

Beaulieu: What is the most important piece of advice you would give to someone selling a company?

Kastner: Prepare as much as possible, get educated about the process, and assemble a good team of advisors.

Beaulieu: How long does this all take?

Kastner: For a seller, we usually estimate between six to nine months from the time that we are engaged. It's possible to sell more quickly if a pre-emptive buyer emerges. If something happens during the process, such as the company's results drop or the economy falters, it can take longer.

Beaulieu: What are some of the challenges of selling a company?

Kastner: The biggest issue that occurs is that the company's results start to drop. Sometimes, the timing is not right in terms of the overall economy, the electronics sector, or global events. Buyers have issues that come up from time to time.

Beaulieu: What is an LOI, what does it mean in the process, and what are the steps after the LOI?

Kastner: A letter of intent is a document that spells out the valuation, terms, and conditions of a deal. It is typically non-binding except for an exclusivity clause and any break-up fee. Once an LOI is signed, we move into due diligence.

Beaulieu: What is due diligence? What does that encompass?



Dan Beaulieu

Kastner: Due diligence is an intense examination of the seller's information. Buyers investigate all aspects of a company. It starts with accounting, but it includes legal documents, customers, suppliers, employees, IT, facilities, etc. Even the most prepared sellers will learn something about the company during the due diligence process.

Beaulieu: How long does it take from LOI to actual

completed sale?

Kastner: For prepared sellers and motivated buyers, it usually takes 45–60 days. If a seller is not very prepared, the due diligence process can be much longer. Also, if major items come up that need to be resolved, it can be much, much longer. By preparing in advance, we can help cut down the due diligence time. Also, if the buyer knows that other buyers are waiting outside the window, that can motivate them to move faster.

Beaulieu: Then you get a success fee on the sale. What does that consist of?

Kastner: We receive a percentage of the value of the transaction, plus a bonus if we really hit it out of the park.

Beaulieu: Is the retainer taken out of the final success fees?

Kastner: No, we work hard, and we earn both the retainer and the success fees.

Beaulieu: Now let's talk about buy-side agreements. How does that work?

Kastner: When we work with buyers, we will reach out to a pool of sellers to find the right fit for our client's criteria. We gather information, set up calls and meetings, help negotiate with the seller, and generally assist the buyer through to closing.

Beaulieu: How do you find qualified buyers and how do you know they are qualified?

Kastner: Our buy-side clients are usually private equity-backed and/or have experience with acquisitions. I might sound like Yogi Berra or something, but I try to work with buyers who have money, because it takes money to buy companies. Buyers can also use debt as well as earnouts and other types of deferred payments to make acquisitions.

Beaulieu: What is the most important piece of

advice you would give someone buying a company?

Kastner: Be patient and do not just fall in love with the first owner who wants to talk. Be ready to hit the eject button if the deal stops making sense.

Beaulieu: Tom, thanks for talking to me today.

Kastner: My pleasure. **PCB007**

Tom Kastner is the president of GP Ventures, an investment banking firm focused on sell-side and buy-side transactions in the tech and electronics industries, and an I-Connect007 columnist. To read past columns, [click here](#).

Dan Beaulieu is president of D.B. Management group and an I-Connect007 columnist. To read past columns, [click here](#).

SIA Applauds Renewal of WTO Tariff Moratorium, Urges WTO to Make it Permanent

The Semiconductor Industry Association (SIA) released the following statement from President and CEO John Neuffer in support of the outcomes produced by the World Trade Organization's (WTO's) 12th Ministerial Conference (MC12). Among the critical results achieved during the ministerial was a renewal of the WTO Moratorium on Customs Duties on Electronic Transmissions, an agreement that has served as a foundation for global digital trade for the last quarter-century.

"After a rocky start, MC12 produced important outcomes for global trade in semiconductors and a range of other essential technologies, services, and industrial products. We greatly appreciate the strong leadership of Director-General Ngozi Okonjo-Iweala and the tireless work of the U.S. negotiating team and all Ministers to deliver positive results, including the agree-

ment to extend the WTO Moratorium on Customs Duties on Electronic Transmissions until the next Ministerial. For nearly 25 years, the Moratorium has supported the explosive growth of global trade for big and small companies across all sectors, including Internet-related services, entertainment, semiconductors, and consumer and industrial electronics.



John Neuffer

"Ultimately, the WTO needs to make the Moratorium permanent, so we can put behind us the highly unpredictable renewal process that exposes the global economy and America's industries and workers to damaging uncertainty. SIA stands ready to make this case forcefully while demonstrating to developed and developing countries alike the benefits of keeping digital goods and services free of import duties across all sectors."

(Source: SIA)



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Supplier Highlights



Atotech Partners with QSolid in the Endeavor to Develop Germany's First Quantum Computer ▶

Atotech, a global market leader for specialty chemicals, equipment, software, and services, is one of the technology companies involved in developing Germany's first error-improved quantum computer.

It's Only Common Sense: Our Time to Shine ▶

This is our time. Some domestic PCB fab houses feel they got the short end of the stick for the past 30 plus years, believe their customers have sold them out to the cheap labor companies (and took their technology with them), their time has come.

Ventec Meets Demand for Taiyo LPI Solder Mask Products in Europe ▶

Following Ventec's announcement of its exclusive distribution agreement with Taiyo, customers in mainland Europe and the UK are now guaranteed reliable, immediate, and flexible access to the full color range of Taiyo Liquid Photoimageable (LPI) Solder Mask inks.

KLA Announces \$1.5 Billion Sustainability-Linked Revolving Credit Facility ▶

KLA Corporation announced the successful closing of an inaugural \$1.5 billion sustainability-linked revolving credit facility. The new five-year facility reinforces the company's commitment to its environmental, social, and governance (ESG) programs and goals.

ILFA GmbH Announces System Partnership with Atotech ▶

For its expansion plans, the Hanover-based PCB producer ILFA relies on the expertise of the respective industry leaders. In the field of wet chemistry and electroplating, the specialist Atotech has now been acquired.

Ucamco Adds In-house Production of Large and Extra Large 'Bird of Prey' Photoplotters ▶

Ucamco has added the in-house production, from scratch, of new large and extra-large format laser photoplotters to its capabilities.

High Density Packaging User Group Announces Grace Electron Membership ▶

High Density Packaging (HDP) User Group is pleased to announce that Grace Electron Technology Co., LTD. has become a member.

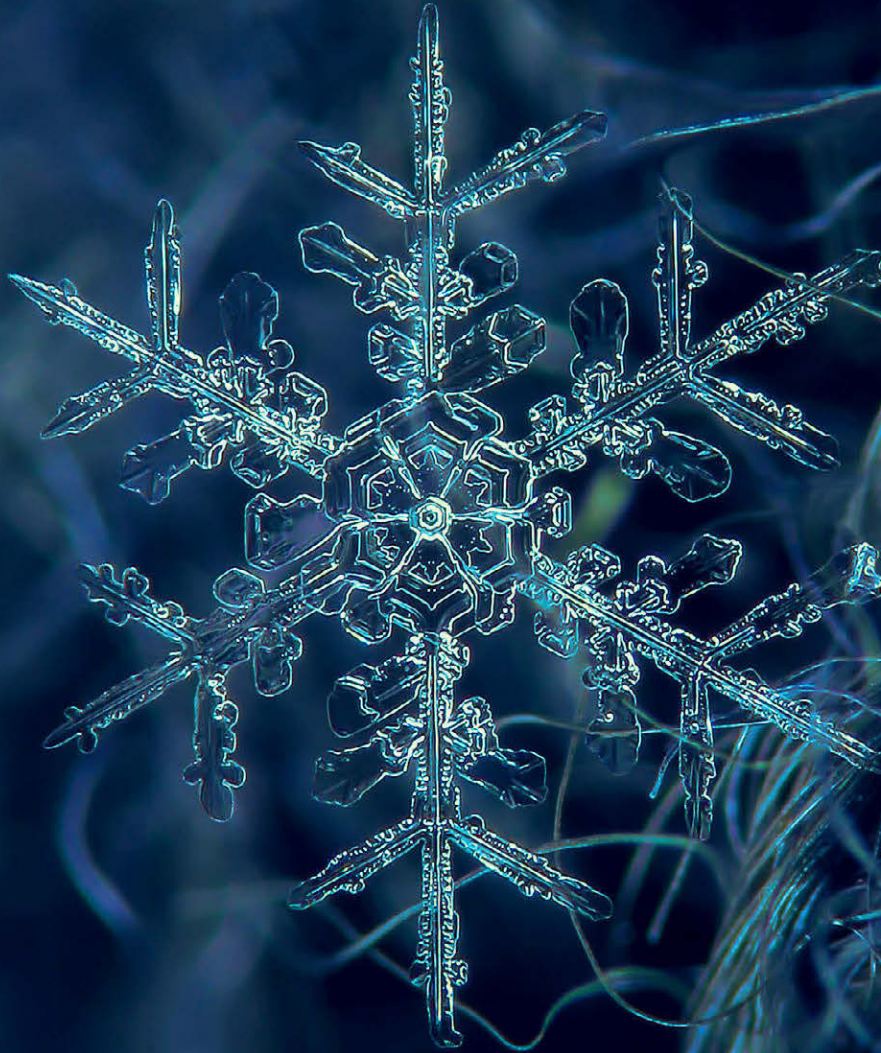
Matrix USA Promotes Sunil Shah to VP, New Product Development ▶

Sunil has been the major contributor to the Company's growth in the High Tg FR-4 market, focusing on the Kingboard Product Group for the past 10 years.

Atotech Expands Product Offering with Digital Factory Suite ▶

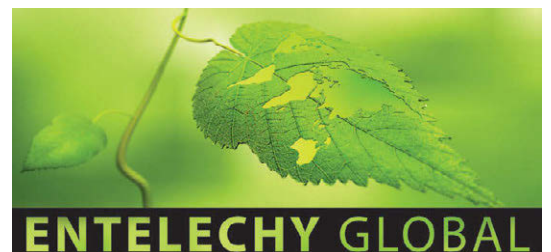
As a leading specialty-chemicals technology company, and market leader in advanced electroplating solutions, Atotech announced that it has expanded its product offering with the Digital Factory Suite.

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Don't Sludge-Out: A Guide for Alkaline Etching

The Chemical Connection

by Christopher Bonsell, CHEMCUT

In my last column, “Etchants of the Industry: Cupric vs. Alkaline,” I compared cupric chloride and alkaline cupric chloride. In that column, I mentioned that alkaline etchant is the most used etchant for PCB fabrication. It is used because it provides a high etch rate, improved etch factor, and compatibility with metallic resists. Although it has some great benefits, it has the drawback of being difficult to control. The etching chemistry requires a delicate balance, and the parameters it needs to stay within are relatively tight. Not only are the margins for error small but falling outside these parameters may have consequences. If you are not careful enough, you could hit the point of “sludge-out”—a point where your etchant will undergo an irreversible precipitation reaction. Sludge-out can dramatically reduce the effectiveness of your etchant, and it can cause severe damage to your products and etching equipment. To prevent sludge-out from happening to you,

Etch Reaction
$\text{Cu}^0 + \text{Cu}^{+2}(\text{NH}_3)_4\text{Cl}_2 \rightarrow 2 \text{Cu}^{+1}(\text{NH}_3)_2\text{Cl}$
Regeneration Reaction
$4 \text{Cu}^{+1}(\text{NH}_3)_2\text{Cl} + 4 \text{NH}_3 + 4 \text{NH}_4\text{Cl} + \text{O}_2 \rightarrow \text{Cu}^{+2}(\text{NH}_3)_4\text{Cl}_2 + 2 \text{H}_2\text{O}$

Table 1: Etch and regeneration reactions for alkaline cupric chloride.

here is a short guide to understanding the chemistry control for alkaline etchant.

Understand the Chemistry

Utilizing alkaline etchant requires a thorough understanding of the chemistry taking place inside the etching machine. Inside the etch chamber, two reactions are the focus: the etch reaction and the regeneration reaction. Those reactions are shown in Table 1. How the reactants are incorporated into the reactions are shown in Figure 1.

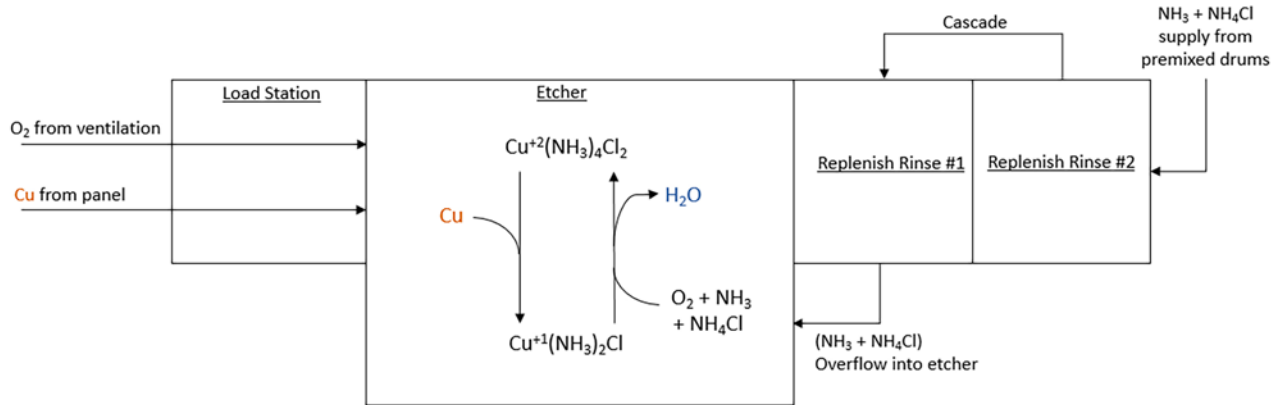


Figure 1: Process flow for an average alkaline etch machine. Sources of ammonia (NH₃) and oxygen (O₂) can vary, but the methods shown in the diagram are the most common.

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From the table, the first reaction is the simple etch reaction where the etchant ($\text{Cu}^{+2}(\text{NH}_3)_4\text{Cl}_2$) reacts with copper (Cu^0) to provide the spent form of alkaline etchant ($\text{Cu}^{+1}(\text{NH}_3)_2\text{Cl}$). The etch reaction is relatively simple, unlike the regeneration reaction. The regeneration reaction tends to be the primary cause for concern because it is complex yet essential to your process. The regeneration reaction is important because it allows you to etch your panels and not see a decline in PCB quality or production rate. In the regen-

The regeneration reaction tends to be the primary cause for concern because it is complex yet essential to your process.

eration reaction, the spent form of the etchant reacts with ammonia (NH_3), ammonium chloride (NH_4Cl), and oxygen (O_2) to convert the etchant back to its original form. Water (H_2O) is a by-product of this reaction. All the reaction components (ammonia, ammonium chloride, oxygen, and water) play a vital role in maintaining the etchant. Ammonia plays a critical role in pH control, ammonium chloride contributes to chloride content, oxygen acts as the limiting reagent in regeneration, and water helps with specific gravity control (copper concentration control). These components to the reaction help you stay within the parameters alkaline etchant needs to function. The main factors you will need to watch out for are pH, chloride levels, and air flow. These should be the focus of your efforts because these tend to be the most high-risk or difficult things to control.

pH Control

Holding a steady pH value in alkaline etchant is the biggest challenge. One of the main rea-

sons it is difficult to manage is because pH is not a value that is easily measured. Alkaline etchant can easily damage pH probes and cause inaccurate readings. Since pH dropping can cause sludge-out, having inaccurate pH readings cannot be acceptable. To monitor pH, it is recommended to use pH probes along with routine titrations. The pH should be kept within the range of 8.1-8.2 (may vary slightly depending on chemical supplier).¹ If you start to notice the formation of dark blue crystals in your etchant, that is also a sign that your pH is too low.

Another reason pH is difficult to control is because it can fall out of range easily. This is because pH is maintained with ammonia gas, and sufficient pH levels rely on having ammonia dissolved in the etchant. With ammonia being highly volatile, keeping it dissolved in your etchant can be difficult. There are many variables that can affect how ammonia remains in the etchant. Temperature, spray pressure, and ventilation are the main parameters that affect whether ammonia escapes or stays in the etchant.

Even if you are not using the etchant at a given time, you still need to worry about maintaining pH. If alkaline etchant is allowed to sit for a long time in an unsealed environment, the ammonia will bleed out of the etchant, drop the pH, and sludge-out will occur. To prevent this, it is best to pump it out of the etching machine and place it in drums if you don't plan to use it within three days. By placing the etchant in drums, you are sealing it and preventing the ammonia from escaping.

Chloride Control

It is also necessary to sustain chloride levels to prevent sludge-out. Like pH control, it is a good practice to perform routine titrations to check chloride levels. Thankfully, maintaining your chloride level is easier than maintaining pH. This is because the only way to lose your chloride content is by dilution or insufficient input to keep up with the regeneration reac-

tion. The most common cause of chloride loss involves people utilizing only ammonia instead of the typical ammonia-ammonium chloride blend in the “replenish rinse” section. Using only ammonia effectively dilutes the chloride content and causes the concentration to fall out of the desired range. Chloride content should remain within the range of 160-165 g/L. If your chloride levels drop too much, that will result in the formation of light-blue crystals. To bring chloride levels back up, you can simply dissolve ammonium chloride crystals into your etchant.

Optimized Air Flow

To have a steady etch process, it is important to maintain the regeneration reaction. Maintaining a steady regeneration reaction relies on having a sufficient supply of the limiting reagent, oxygen, to keep up with production. Since oxygen must be pulled into the etch chamber through the ventilation system, some additional challenges come into play. This is because the air flow needs to be optimized. With too little air flow, you may not have enough oxygen to sustain your etch rate. Too much air flow will cause your ammonia to leave the etchant and cause the pH to drop—potentially leading to sludge-out.

In cases of large-scale PCB production, sometimes ventilation is not enough. In these cases, additional air sparging in the etcher

sump is needed. Air sparging is a method to feed oxygen into an etchant by bubbling compressed air through the bottom of the etch bath. It has some of the same challenges as the normal ventilation approach. Too much sparging can drive excessive ammonia out of the etchant, but too little may not be sufficient to keep production steady. Finding the optimal air flow can be a trial-and-error process, but with a careful watch on pH and etch quality, you can find the optimal amount.

Conclusion

Chemistry control for alkaline etchant has always been a challenge. Most of that difficulty comes from not having the proper understanding of how alkaline etchant works, and what it needs to stay stable. Now that we have covered the main troublesome areas, you are better equipped to maintain and get the most out of your alkaline etchant. **PCB007**

References

1. “Process Guidelines for Alkaline Etching,” Chemcut.net, October 2001.



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

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BUILD ELECTRONICS BETTER

OPPORTUNITIES FOR SMALL AND MEDIUM-SIZED PCB FABRICATORS TO COMPETE ON THE WORLD STAGE

By Mike Carano

CHAIRMAN, IPC THOUGHT LEADERS PROGRAM

Electronics are a global driver for the world's economy. They are omnipresent in everything from life-saving medical equipment to safety and security systems, telecommunications, and automobiles. Electronics manufacturing involves significant job creation within the industry itself as well as in other industries through improved productivity and constant innovation. Applications such as wearables, augmented and virtual reality, and high-end graphics and video are just a few of the electronics-based innovations coming our way.

In many respects, the technological advancements that make these electronics possible are nothing short of amazing. And the heart of the electronic system is the printed circuit board.

Without the printed circuit board, there is nowhere for semiconductor chips and other components to go. As the saying goes, "Chips don't float," meaning the printed circuit board is the interconnection of the entire electronics system.

Trusted manufacturers of these complex interconnection substrates are needed to support mission critical applications. And yet the manufacturing landscape for printed circuit boards has largely shifted to Asia; and domestic expertise has shrunk along with the industry's footprint in North America.

Significant investments in printed circuit board technology and manufacturing are critical to the continued strength of the strategi-

cally vital U.S. electronics manufacturing sector, and they would be remarkably less costly than investments in the “golden child”—the semiconductor industry.

What Led to This Situation?

Prior to the Asian Shift of 2000-2001, just over \$11 billion worth of printed circuit boards (PCBs) were produced in the United States. Along with Japan, the U.S. enjoyed a leadership position in this very critical and enabling technology.

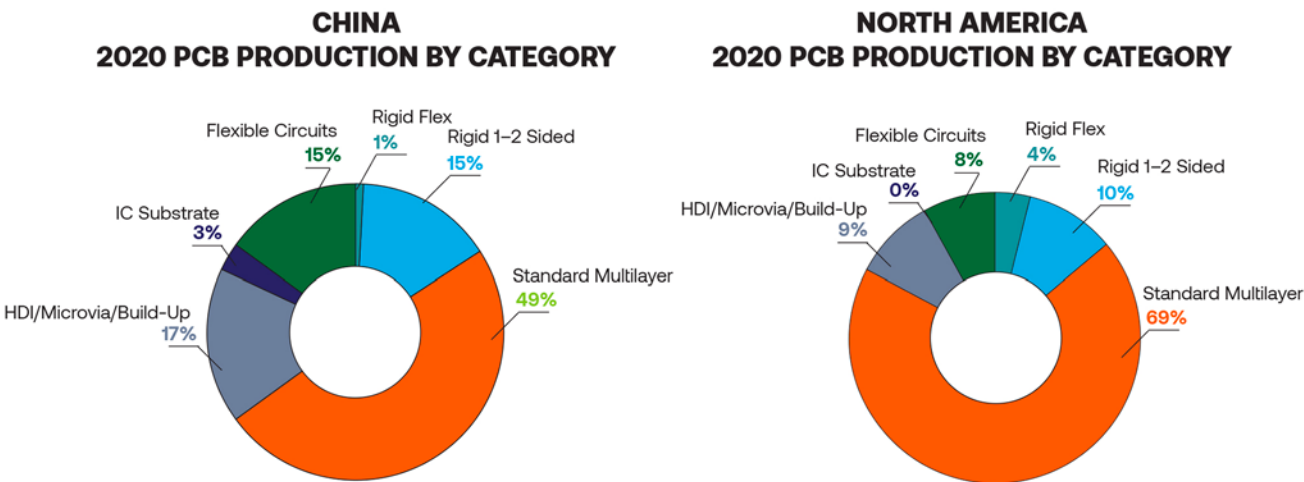
Today, just over \$3.5 billion worth of PCBs are produced in the United States. The decline was due in part to the original equipment manufacturers (OEM), which as recently as the mid-1990s produced their own captive interconnects to support their hardware. However, as technology advanced, many OEMs decided to shutter their PCB fabrication facilities and switch to merchant fabricators. These fabricators were primarily overseas, and over the last two decades, China has risen to become the dominant force in the PCB industry.

The loss of OEM in-house fabrication led to a loss in technological leadership. Large OEMs had been staffed with engineering and manufacturing talent that disappeared with the transition to overseas merchant fabrication. In addition,

the OEM captive facilities had possessed everything needed to lead and take advantage of advancements in R&D, materials, and processing. However, once the outsourcing decision was made, the U.S. lost those technological capabilities as well, including in the areas of high-density interconnect (HDI) and automation.

Today, there are fewer than 200 PCB fabricators in North America, down from approximately 1,500 in the 1990s. Many of these individual manufacturing sites were under the umbrella of a handful of companies. Beyond this core group of 10 to 12 large firms, the U.S. printed circuit board manufacturing is now concentrated in many small, single-site facilities with less than \$15 million in annual revenue. The high-volume production has found its way to China and other countries in Asia.

In addition, Figure 1 shows how China has positioned itself in the areas of HDI/microvia/build-up technology as well as flexible circuits. HDI/microvia/build-up technologies are critical for miniaturization, enabling next-generation telecom, high-performance computing, and IC substrate/semiconductor packaging. Flexible circuits, especially high-volume reel-to-reel production, serve multiple end markets including automotive, medical and computer/laptops.



Source: World Electronic Circuits Council, WECC Global PCB Production for 2020, August 2021.

Figure 1: China and North America PCB production by category.

While the Asian Shift may mean a dimmer future for the PCB industry in North America, there are some opportunities. Figure 1 indicates the importance of high-layer-count PCBs, flexible circuits, rigid-flex, and high-density (HDI) technologies in North America. Fabricators have some of the capabilities to support these technologies currently. Thus, there is a footprint that needs to be expanded further.

End Markets for PCBs

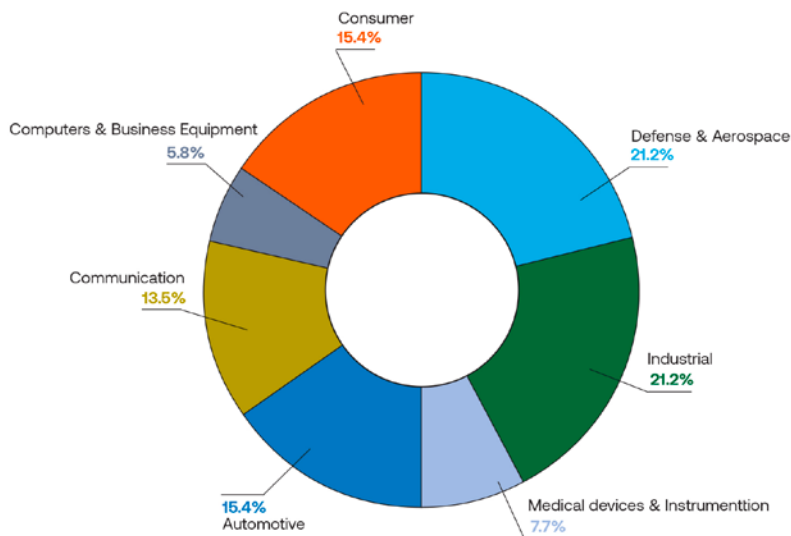
While the consumer and low-end computer and office equipment segments may not offer growth opportunities for the U.S. PCB fabrication base, there are opportunities in telecommunications and internet infrastructure; aerospace and defense (A&D); industrial automation (think Smart Factory and CFX); and other “protected” industries and applications including data transfer, cybersecurity, and servers/data storage.

Technology Trends

By most estimates, the top 100 electronics companies in the world produced more than \$2.4 trillion worth of electronic equipment in 2020. This is significant for several reasons:

- The top 100 firms drive the technology for everything else
- Most of these firms are headquartered in the United States
- Most PCBs are manufactured elsewhere.

Today, the most advanced technologies related to high-end PCB fabrication are no longer being developed in North America. When the leading OEMs decided they would shutter their PCB fabs in favor of buying on the outside, much of the R&D capability went along with it. For example, HDI technology was invented in the United States. It is a great



Source: IPC, PCB Technology Trends Survey 2018, February 2019.

Figure 2: Primary PCB end markets served by OEMs.

enabler because it allows faster signal speeds, smaller form factors, and lower overall system costs. Yet, the majority of HDI production—as well as of the interconnect (IC) substrates that HDI depends on—resides in Asia. This is a major concern because the technology hubs follow the production footprint. This includes specialized equipment, materials, chemistry, and of course, PCB assembly. Further compounding this situation is the now well-publicized computer chip shortage.

Embedding components into IC substrates was invented in the 1950s and ‘60s in North America. It was a laboratory exercise at the time. Today it is another multi-billion-dollar technology. But it’s not about the dollars. It’s about the technology. HDI and embedded components are enabling technologies. They are the building blocks for the next generations of hardware. And we have lost the ability to build such products in North America.

Worse, many procurement managers would like to commoditize the PCB, with the expressed goal of driving down price. Fortunately, thanks to the U.S. International Traffic in Arms Regulations (ITAR), and the U.S. Department of Defense’s PCB requirements, several protected market segments, e.g., aero-

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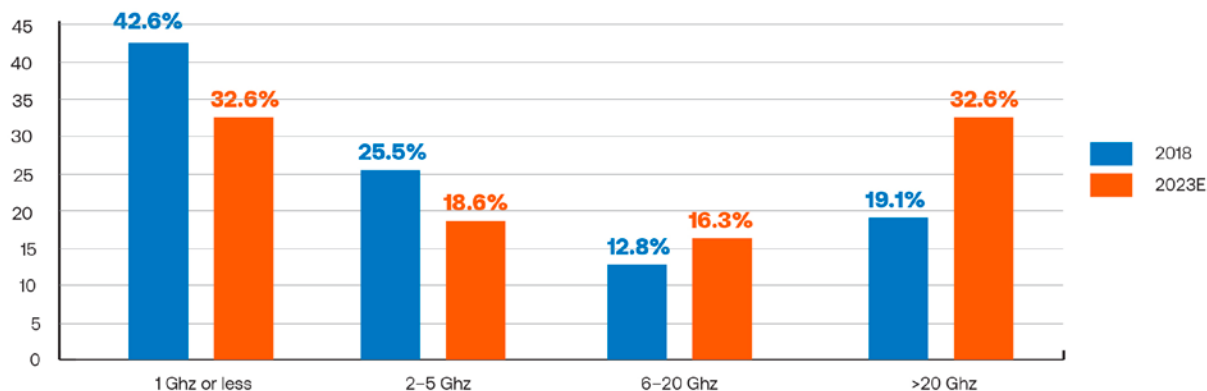


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Source: IPC, PCB Technology Trends Survey 2018, February 2019

Figure 3: Average maximum frequency, five year expectation.

space and defense, internet of things, and high-performance computing must be manufactured in the U.S. and North America through the Trusted Suppliers Network.

And the opportunities do not end there. The trend toward evolving and enabling technologies including artificial intelligence (AI), wearables, additive manufacturing, and Factory of the Future, offers North American PCB firms with ample means to expand their business. However, this requires these firms to step up their game in terms of technology capabilities.

Areas of Opportunity

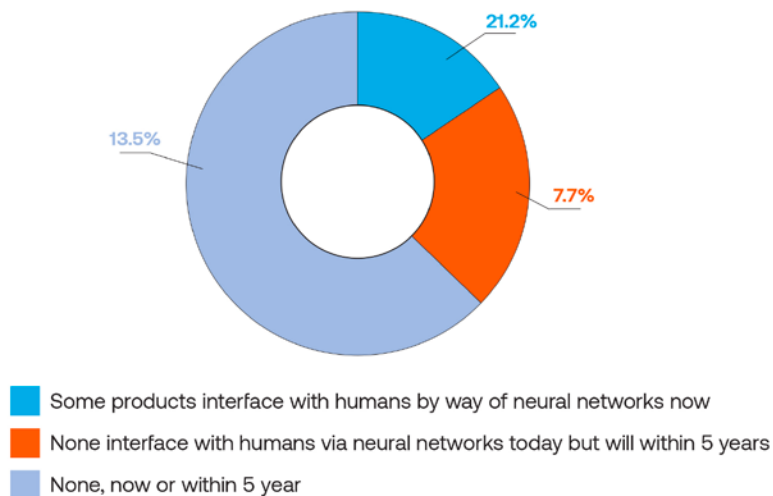
As the famous philosopher Yogi Berra once said, “It ain’t over until it’s over.” Among the many major changes taking place in the electronic interconnect industry are opportunities for small and medium sized companies to step up their technology game.

First, for these firms to even hope to be successful, they must constantly be asking what is happening in their own industry and in other industries that can affect their business. For example, how does artificial intelligence (AI) affect the electronics industry? With products being developed for very high-frequency applications, what will that mean to materials and electron-

ics fabrication? Fabricators need to ensure that processes and materials are coming together to support advanced manufacturing.

The maximum frequency at which OEMs’ products operate is expected to increase over the next five years (Figure 3). Major OEMs in the telecom space anticipate going to 77 GHZ and beyond. They also expect increases in maximum product life expectancy of more than 25 years. This is particularly crucial for PCBs because it will drive reliability requirements even higher.

Figures 4 and 5 indicate additional areas of opportunity.



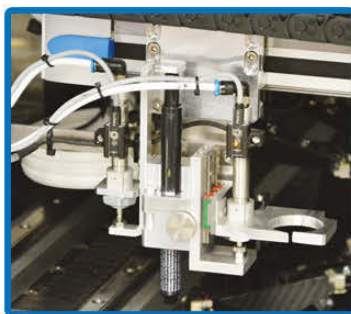
Source: IPC, PCB Technology Trends Survey 2018, February 2019

Figure 4: OEM trends, neural networks.

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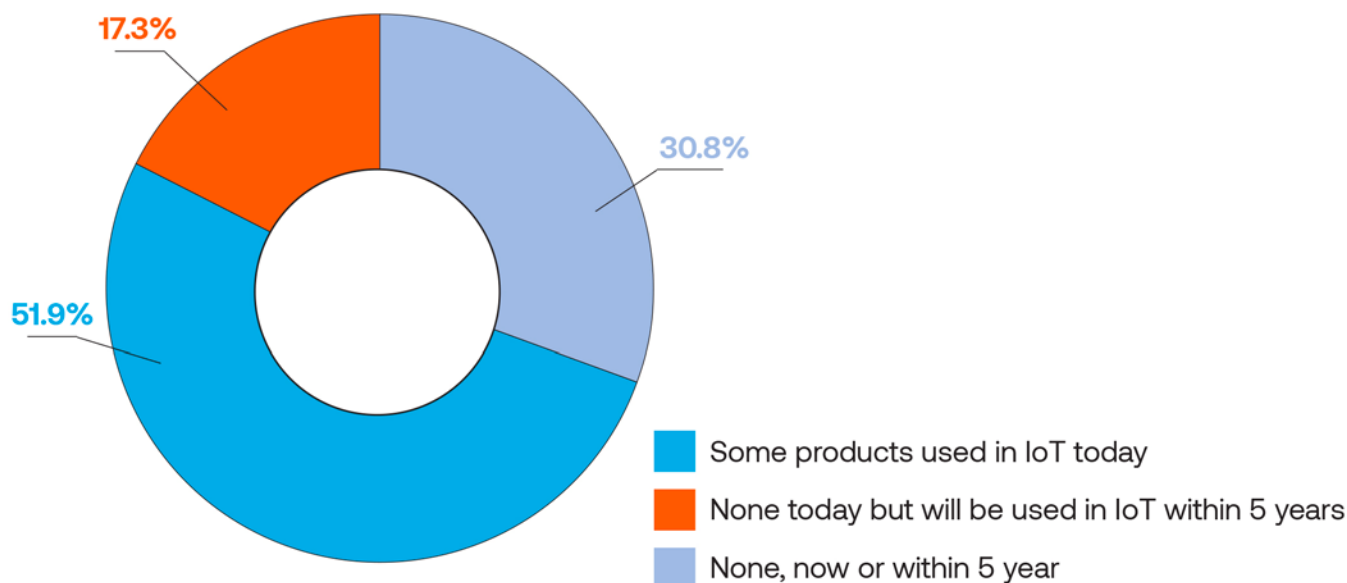
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Source: IPC, PCB Technology Trends Survey 2018, February 2019.

Figure 5: More than half of the OEMs surveyed make products for the IoT.

However, while these tech trends are driving opportunities for the PCB fabricator, they also present significant challenges. When this author interviewed nine board fabricators, the following concerns were cited most:

- Higher layer counts/more HDI/thicker boards
- Finer lines and spacing—sub 2 mil L/S
- Finer pitch
- Ultra HDI
- Small components and micro BGAs
- Higher aspect ratios
- Stacked blind vias and reliability issues
- Thinner dielectrics
- High-speed materials-processing
- Copper via filling capability

In addition, with profit margins already being squeezed by increases in the cost of raw materials and transportation, these firms will continue to have difficulty in attracting and retaining skilled workers. Workforce development and retention have been impediments to growth for years. What can be done?

A Path Forward

A change in mindset will be needed for most North American-based PCB fabricators to move into higher-end advanced technology and manufacturing. One cannot enhance quality and jump up the technology curve without making strategic investments. They will need to upgrade and develop the workforce, and not only engineers but also manufacturing personnel who need to understand the critical aspects of workflow, quality, and time-to-delivery. They will also need to increase manufacturing capacity. And yes, there is a cost to that. However, a loss of market share, excessive reliance on overseas fabrication, and dwindling technological advances are the unacceptable alternatives.

Currently, industry and government actors are planning investments of at least \$50 billion into state-of-the-art semiconductor chip making facilities in the United States. Even so, these facilities, when up and running, will provide only a portion of U.S. chip needs.

And this begs another question: Where will these chips go? Electronic systems require

not only chips but also organic substrates, advanced multilayer boards, as well as assembly and test (OSAT). If we are serious about the future of the tech industry in North America, it is time to recognize that without circuit boards and IC substrates, there is no semiconductor industry.

For the United States to jump the technology curve and enhance the competitive positioning of the PCB fabrication base, we must embrace HDI and Ultra HDI as the standard design set for advanced electronics manufacturing. But it is not a simple technology to master. It will require significant investment in capital equipment, workforce training, and development and adoption of new processing technologies including semi-additive and alternatives to conventional metallization. Fabricators must master key technologies and processing if they wish to be a credible supplier of this growing technology, including:

- Tooling and materials selection
- Small hole drilling and micro-drilling
- Laser via formation
- De-smear, metallization, and hole plugging
- Fine-line and tight-registration, image transfer, and etching
- Blind-via plating (super fill copper)
- Quality control and qualifications (test vehicles, reliability verification)

All that said, the scope of investments necessary to jump start the U.S. PCB industry is significantly lower than those needed for semiconductor facilities. Based on primary research conducted by this author over the past several months, the key lies in increasing both manufactur-

ing capacity and advanced technical capabilities for the top 100 PCB fabrication entities in the U.S. For each facility, the advanced capabilities necessary to increase yields and technical capabilities can be purchased for \$10 million to \$12 million. This includes state-of-the-art laser drilling equipment, laser direct imaging, the latest technology for registration and subtractive processes, and complete upgrades for via filling, metallization, and in-house quality control. The suggested investments and relative costs are shown in Table 1.

The estimates shown in Table 1 add up to approximately \$10 million. Granted this is a snapshot of the capital expenditures required to increase one facility’s capacity and advanced manufacturing capabilities; however, it represents a critical starting point. It does not include investments in increasing the manufacturing footprint through buildouts or leasehold improvements.

How would a small- to mid-sized PCB fabricator that already has reasonable capabilities

Equipment/Technology	Cost (per facility estimate)
Combo UV/CO2 laser via drilling systems (x2)	\$1,350,000
Laser Direct Imaging (x2)	\$1,500,000
Copper via fill plating	\$150,000
High Speed Mechanical drills (x2)	\$900,000
Lamination presses (state of the art) X2	\$1,200,000
Etching/Developer upgrades	\$400,000
Registration systems	\$250,000
Direct Metallization (horizontal)	\$375,000
Flying Probe Tester (X2)	\$400,000
Horizontal processing (Develop, etch, Strip-oxide)	\$1,200,000
Via fill (paste fill) and planarizer	\$600,000
Electroplating line upgrades	\$400,000
Plasma systems	\$500,000
Engineering/IT systems upgrades	\$450,000
In-house reliability testing (IST, CITS)	\$350,000
TOTAL	\$10,025,000

Source: Author’s research

Table 1: Investments needed to position PCB Fabs for future success.

in-house be able to make this investment? One idea would be to subsidize the top 100 firms identified by key OEMs and mil-aero-qualified fabricators with tax incentives and low- to no-interest loans. Assuming the investments identified in Table 1 are made by the 100 firms, the grand total is still just \$1 billion—significantly less than the cost of a single \$10 billion chip-making facility.

Another possible strategy is for firms to apply for R&D tax credits and, if possible, take advantage of accelerated depreciation on the new investments.

Policymakers would be wise to impose a few more requirements on firms that receive such funds and incentives, including paying their workers a livable wage and providing medical and dental benefits; providing a safe working environment; and increasing its workforce commensurate with the added investment.

The near-term objective would be to double the manufacturing capacity for high-reliability complex printed circuit boards and IC substrates in the United States over the next

three years, followed by another 50% increase in capacity by the year 2027.

Summary

While these capacity-expansion goals may seem overly optimistic, given the existing PCB interconnect fabrication footprint already existing in the United States, it is quite feasible. The initiative would involve leveraging the existing, installed base to increase capacity and further advance its manufacturing technology.

If the federal government as well as the major chip manufacturers are serious about semiconductor fabrication in the U.S., then they will need to drive significant investment in printed circuit board manufacturing and the workforce as well. **PCB007**



Mike Carano is chairman of the [IPC Thought Leaders Program](#), and an I-Connect007 columnist. To read Mike's column, [Trouble in Your Tank](#), [click here](#).

The U.S. Economy Needs the Bipartisan Innovation Act and the PCB Act

By Ken Schramko, IPC

After more than two decades of outsourcing, the United States still designs cutting-edge electronics but manufactures only a small fraction of the global supply, creating serious risks to U.S. economic and national security. Now there is a pair of bills in the U.S. Congress that would directly address these concerns, and IPC is leading the charge for them.

The Bipartisan Innovation Act—also known as the U.S. Innovation and Competition Act (USICA) in the Senate and the America COMPETES Act in the House—would provide \$52 billion to boost U.S. semiconductor chip manufacturing and billions more for research and development of other advanced technologies.

Meanwhile, the bipartisan Supporting American Printed Circuit Boards Act (the PCB Act) is a new proposal to invest in the domestic electronics supply chain by incentivizing purchases of domestically produced PCBs and investments in factories, equip-

ment, workforce training, and R&D.

In a new IPC video interview, IPC Vice President of Global Government Relations Chris Mitchell explains why Congress must enact these bills as part of a holistic approach to rebuild the domestic electronics manufacturing ecosystem. He also urges IPC members to get involved and make their voices heard on this business-critical issue.

To learn more and take action, visit [IPC.org](#) and look on the Advocacy page; then visit the Action Alert Center to send a message to your members of Congress with just a few clicks. You may also contact IPC's Ken Schramko if you'd like to add your company's name to our roster of support for these bills.

Please use [this easy link](#) that will identify your U.S. representative and allow you to quickly send them a message of support. There are also options for posting on social media or making a quick phone call.

(Source: IPC)

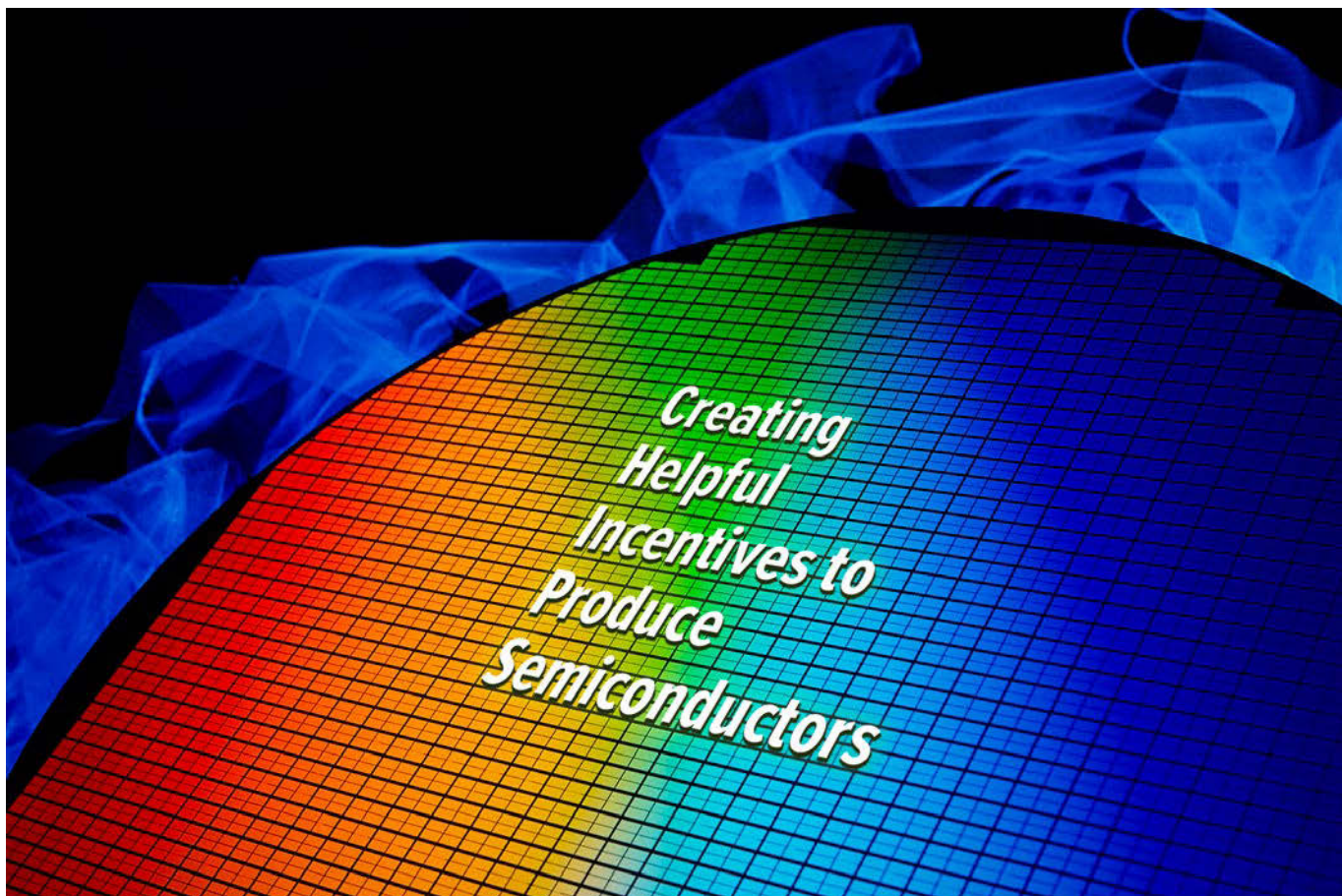
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A Deeper Look at the CHIPS Act Investment

Feature Interview by Nolan Johnson

I-CONNECT007

In this interview with Chris Peters at U.S. Partnership for Assured Electronics (USPAE), Nolan Johnson seeks for better understanding regarding the implications of funding the CHIPS Act. Frankly, where and how will the \$52 billion be spent? Who will decide how the funds are allocated? And surprisingly, who will benefit the most from this boost into the microelectronics industry?

Nolan Johnson: As executive director at USPAE, what is your take on industry investment? There seems to be a lot of belief, whether it's entirely true or not, that much of the IC and PCB legislative funding is meant to help us become more stable in the DoD.

Chris Peters: Let's just talk about the CHIPS Act, where Congress has proposed \$52 billion in funding. Most of it will be funneled through the Department of Commerce, with just several billion targeted to the DoD and a focus on advanced packaging.

Johnson: What does this mean for the manufacturers? How will their competitive marketplace change?

Peters: It will be interesting, because much of the money will be for developing new capabilities, where we need substrate capabilities and more advanced packaging in the United States. It looks like the money will likely be geared

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Chris Peters

toward R&D. Many companies are hoping to receive grants to build facilities, but I don't think that's the way most of the money will flow.

There are some aspects where, if they flow through the Defense Production Act (DPA) Title III program, awards can be given. But I believe DPA is more inclined to invest in technologies or capabilities that help an entire industry, not just something that helps one or two companies build a new plant or a new line. Thinking about the bigger picture, for example, one of the challenges we have in PCBs is finer traces. If you could invest in an infrastructure or R&D that would help bring finer traces to the entire U.S. industry, that's more likely for an award because you're investing in one technology that helps raise the entire industry.

Johnson: This indicates to me that the money more likely will be awarded to material or capital equipment suppliers for development of new capabilities, and that the fabs may be winning. Advanced packaging and substrate tech-

nologies must be at the forefront. It seems the assembly houses won't really benefit from this because, other than buying equipment using these funds, the assembly houses themselves don't have a lot to benefit from here.

Peters: I'm not sure, and I don't know that I would reach that conclusion yet, because we still don't know so much about this. If you think about all these things that are coming down with the substrates, we're talking about putting smaller pitches on smaller pads. The EMS companies must keep pace with that. We can't just do all these things over here and then hand it off to the EMS companies when they're not in a situation to do that. They need to be a part of this equation.

This gets back to what you've been hearing from IPC, PCBAA, and USPAE. It's this idea of looking at the whole ecosystem; you can't focus on just one element. We must bring along the whole ecosystem for this to work. I come from the mechanical side rather than electronics, so I'm looking at this from a higher level of policy and procedure and what we get done. From a technical perspective, I look to industry people for that.

Johnson: The EMS companies would certainly benefit from this, but part of their benefit is going out to invest in the new equipment, to get the new capabilities, to keep up with the new challenges. I don't see a lot of R&D opportunity at the EMS companies. They will benefit from the R&D, but it will be done in other companies upstream from them.

Peters: That may be a good point, but it seems that the EMS companies should be involved to help ensure the innovations can be more quickly incorporated and know what additional training may be needed.

Johnson: I have been told that there is a clause for a 25% tax credit for purchases within the U.S. From your perspective, how do you see

that changing the dynamic? Does that help equalize pricing and value?

Peters: I haven't had conversations with companies to really figure out how that's going to impact them, so I'm not sure. Part of what we—meaning IPC, PCBA, USP—have been talking to the government about is that we need a bit of a stick and bit of a carrot. The stick could be the regulations, like Section 841 of the National Defense Authorization Act, that in summary, says, “You must buy so much U.S. content or domestic content.” The carrot is things like the tax incentives.

I don't know what that's based on. I would hope before they chose 25%, they had done some research, and companies said a 25% research credit would make companies more inclined to buy domestically because it does things like offsets their costs and lowers their risk.

Johnson: All these dynamics are circling each other like a wheel. I want to help our readers understand what the hub is.

Peters: When I think about that, I realize it's all about reliability—that I can acquire or build a part in a reasonable time. That means I need capabilities, capacity, materials, and especially workforce. Then I must rely on them working together correctly, which is a quality issue. Everything feeds into this.

Even innovation feeds into this need for reliability. To me, that's the center. Can I get the part, can I make the part, and can I field it? Logistics is a part of that. Can I repair and replace it? Everything circles around that. That is the problem right now. We don't have reliability; we are facing supply chain issues—lack of materials, workforce, and capability here in the U.S. This all ties back to reliability.

Johnson: It sounds like you are saying the EMS company is the hub. Much of this is being

done so that when you get to that point of contact, where the chips are going on the boards, they've benefited from all the packaging issues, the new supply, the reliability, and the resiliency. It's coming into their facility reliably, and on schedule. They're getting new materials that gives new capabilities. All that R&D starts to show up there at the EMS company, where it all gets put together and shipped out as a functioning sub-assembly, or a complete box.

Peters: If you're thinking about hub from the supply chain perspective, and where in the supply chain everything comes together, absolutely. I've always said the EMS companies have the hardest job, and they've got the most information of any of us. They're the ones that know the most about what is going into that assembly.

**I've always said the
EMS companies have
the hardest job, and
they've got the
most information
of any of us.**

Too often, neither the DoD nor the prime contractors know the full details of what's going in their materials. The company that knows the most about the assembly is the EMS company. From my standpoint, the EMS companies have an incredible amount of information, which is power.

Johnson: Chris, thank you.

Peters: My pleasure, Nolan. PCB007



MilAero007 Highlights



Zentech Appoints Rich Fitzgerald, Experienced EMS Leader, as Chairman of the Board ▶

Zentech Manufacturing is pleased to announce that Rich Fitzgerald has joined the business as Chairman of the Board. Rich has 26 years of executive management experience in electronics manufacturing and distribution.

NCAB Group Acquires Kestrel in the UK ▶

NCAB has acquired 100% of the shares in Kestrel International Circuits Ltd. from the Merlin PCB Group Ltd.

Sypris Wins Award for Electronic Warfare System Upgrade ▶

Sypris Electronics, LLC, a subsidiary of Sypris Solutions, Inc., announced that it has recently received a multi-year, follow-on award from a U.S. DoD contractor to produce and test multiple power supply modules for the upgrade of the electronic warfare suite of an important U.S. fighter aircraft program.

TSF Provides Critical Satellite Connectivity Despite Impact of COVID-19 ▶

In 2021, the tireless work of Inmarsat-sponsored Télécoms Sans Frontières (TSF) continued regardless of the ongoing difficulties related to COVID-19.

American Standard Circuits Installs New Plasma Etching System ▶

American Standard Circuits has recently installed a new Model MK II Plasma Etching System from Plasma Etch.

Inmarsat, Honeywell Launch SwiftJet to Enhance Government Aviation Capabilities ▶

Inmarsat and Honeywell are setting a new benchmark in satellite communications with the launch of SwiftJet, the latest connectivity service for business and government airborne users.

Cobham Mission Systems Purchases Hentec/RPS Photon Steam Aging System ▶

Hentec Industries/RPS Automation, a leading manufacturer of selective soldering, lead thinning, and solderability test equipment, is pleased to announce that Cobham Mission Systems has purchased a Photon steam aging system.

Lockheed Martin Delivers First Five Sentinel A4 Air & Missile Defense Radars to U.S. Army ▶

On May 26, 2022, the STARE Project Office, U.S. Army Sentinel Product Office received the first five radars of its initial contract with Lockheed Martin.

BAE Systems' Airborne Anti-Jam GPS Receiver Boast Greater Compatibility ▶

BAE Systems has expanded the capabilities of its Digital GPS Anti-Jam Receiver (DIGAR) by enabling beamforming with Trimble receivers in addition to its own receivers. DIGAR's beamforming capabilities increase the level of GPS jamming protection for aircraft by a million-fold—helping pilots execute their missions in contested environments.



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Caution—Yield Ahead

Connect the Dots

by Matt Stevenson, SUNSTONE CIRCUITS

Manufacturing yield is a key measure of quality in PCB manufacturing. Measured as a percentage of good parts relative to the total produced, achieving 100% yield rates is extremely challenging for anything but the simplest PCB designs. Most PCB manufacturers produce less than a 95% yield, eating the cost of discards and re-designs. PCB manufacturers can take steps to improve yield rates. It is possible to achieve more than a 98% yield rate by addressing common manufacturing errors, improving safety and quality in tandem, and integrating a Lean approach to all processes.

Addressing Common Errors

Many errors go unnoticed in fabrication and even assembly. Looking out for these during prototyping can catch low yield culprits before production. While testing increases cost and

turnaround during prototype iteration, gains in yield rate will offset this in high-volume production.

Keeping these guidelines in mind can accelerate the process:

- Always double-check that your bill of materials components fits your layout footprint. Replacing a component that doesn't fit its location or size on a board can be costly, if not impossible. Mismatched boards are often unusable.
- Ensure that board materials can withstand the electrical and mechanical demands of your design. Inadequate material can cause failure from thermal or physical stress.
- Don't try to cut corners when it comes to spacing and clearance. Many PCB layout errors are the result of clearance viola-



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tions, e.g., inadequate board edge or drill hole clearance. Damaged components are often the result of solder bridging from solder joints being too close together. Look out for additional PCB layout errors like oxidized copper from missing a solder mask or bowing due to copper imbalance.

- Make sure that the flexibility of your boards fits their function. Properly support your flex boards with stiffeners or fixtures to meet their structural requirements and ensure durability. All that said, these practices are only one part of the puzzle.

Using Technology to Improve Accuracy

Holistically addressing manufacturing speed and accuracy is essential to processing a job at very high yields. Using statistical process control (SPC) software, manufacturers can monitor efficiency and pinpoint errors to ensure greater accuracy. Automated engineering further consistent precision while also increasing

production. This leaves time for highly skilled manufacturers and operators to focus on high-level tasks that utilize their expertise as well as real-time quality control, all of which contributes to competitively high yield production.

Focusing on Quality and Safety

A commitment to quality at every level of organization translates to quality products and is central to successful yield increases. A quality product cannot be sustained without valuing the product's safety from prototype to customer application. Safety supports quality, and quality ensures safety.

At the risk of sounding obvious, use of high-quality materials ensures a high-quality product and increases yield. Avoid the temptation presented by lower cost materials or design shortcuts as these can produce costly errors. In addition to defective boards, errors can cause worker injuries and reduce your labor force lowering both product quality and yield.



Keeping employees safe is also fundamental to high quality, high yield production. Employees who feel assured of their welfare can focus their attention on top-quality work. Providing employees with places to take breaks to recharge and rest and sustaining robust safety measures promotes employee well-being and investment in their work. Regular equipment maintenance also substantially factors into worker safety and ensures that processes flow smoothly. Working in a safe and low stress environment increases employee loyalty—helping to sustain a stable, expert team motivated to produce quality products.

Implementing a QMS and Adopting Lean Principles

Well-defined operating procedures provide another key component to high yield production. Establishing a quality management system (QMS) and achieving International Organization for Standardization (ISO) 9001 certification signal a high value of quality that stands out in the marketplace. While the cost of time and resources may appear daunting, investing in this process can facilitate a standard of continuous quality improvement. Guaranteeing that your organization adheres to ISO's certification requirements, specifications, and guidelines translates to consistency and quality for both process and product.

Improved data, generated through a QMS's consistent documentation, lays the groundwork for evidence-based decision making, providing an informed approach to achievable goals. It can help identify valuable areas for continuous and up-to-date technician training that will enhance skill and renew employee dedication to the task at hand. It also allows for accurate, regular review of processes to remove waste and maintain Lean manufacturing.



Integrating the strategies described here aligns with a Lean manufacturing (Lean) philosophy focused on eliminating any production component that does not deliver value to the customer. This approach requires comprehensive and ongoing process improvement.

Starting from the customer's need for timely, cost-effective PCBs, a Lean approach to improvement works backward from end product to the beginning of the manufacturing process. It assesses each aspect of the process, seizing opportunities to increase efficiency and getting rid of waste along the way. It requires looking beyond the production floor to make innovative process improvements and committed leadership that sets appropriate expectations at every level. This comprehensive system provides the way forward to accomplish high yield rates that keep up with the increasing complexity of modern technology.

Don't settle for sub-95% yields. We believe better is possible, and manufacturers who adopt these principles and processes can improve production yield rates. **PCB007**



Matt Stevenson is the VP of sales and marketing at Sunstone Circuits. To read past columns, [click here](#).

Optical Alignment/Coupon Welding for Stackups

Happy's Tech Talk #10

by Happy Holden, I-CONNECT007

In this month's column, I will discuss optical alignment for pinless lamination stackup, a topic that complements the induction lamination in my [November 2021 column](#). Examples of this type of equipment are seen in Figure 1.

Pin tooling plates have been used for lamination since it first started sometime in the 1960s. I first encountered multilayer stackup when I was assigned to increase capacity for our multilayer output in 1972. This was to accommodate the growth of our computer business. Unfortunately, the explosive growth of our calculator orders in 1973 required that we look for numerous vendors to produce the six-layer logic board in the HP-35 calculator.

Hewlett-Packard evolved from using four small holes in our pin lamination to using a four-slot center-line pin with post-etch punch in 1974. Registration experiments on this transition were highlighted by a DOE in Chapter 3, Figure 4 of my book, *24 Essential Skills for Engineers*¹.

Pin Lamination

Although many schemes have been used, the most popular is the four-pin center-line slot approach. Here a high-precision tooling template with mechanical pins is used for the lay-up and registration. The inner layers must first be prepared with the corresponding registration holes. These holes are generally drilled or punched post etch. The prepreg must also have holes for the pins. These holes do not have to be precise, and they can be 1 or 2 mm larger than those of the inner layers. Stainless steel shims and release film are employed between groups of stackups (called books). For the conventional vacuum-heated hydraulic multilayer press, numerous tolerances lead to misregistration of the various inner layers. Figure 2 illustrates six such tolerances from an excellent paper by Anthony Faraci.²

Pinless Stacking

Around 1999, Faraci, who had been working with multilayer tooling for nearly 15



Figure 1: Three suppliers of multilayer stackup alignment and induction bonding of the stackup: a) DIS Technologies; b) InduBond; c) CEDAL. (Source: Product brochures)

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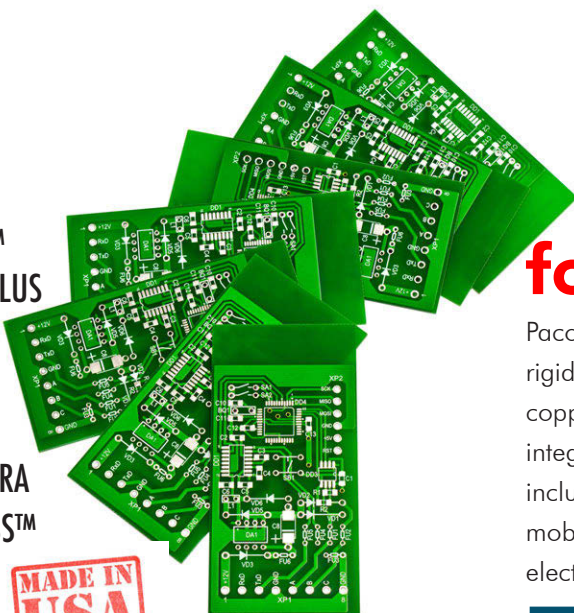


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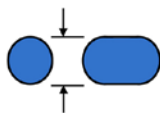
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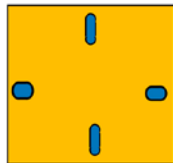
**Punch hole size variation
due to thickness of laminate
on inner layers:**

+/- 25 micron (+/- 0.001 inch)



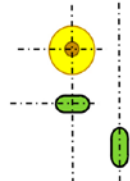
Location tolerance of slot-to-slot on inner layer:

+/- 13 micron (+/- 0.0005 inch)



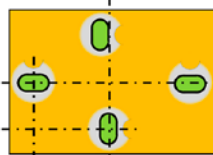
**Location tolerance of
image to punched slot on
inner layers:**

+/- 25 micron (+/- 0.001 inch)



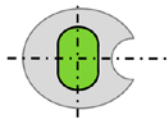
**Location tolerance of
bushing in lamination
plate:**

+/- 25 micron (+/- 0.001 inch)



**Location tolerance of slot
to center of bushing:**

+/- 8 micron (+/- 0.003 inch)



Lamination pin size:

+/- 8 micron (+/- 0.003 inch)

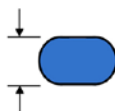


Figure 2: Tolerances associated with pinning systems².

faster, with checks to ensure material order and orientation. The process is shown below:

1. Place the lower lamination plate in position on the layup table and begin layup as usual up to the first separator plate.
2. After placing the first separator plate in location, place the untooled copper foil (this foil will be outside layer n).
3. Next place the untooled prepreg (this is all the prepreg between layers $n-2$ and $n-1$).
4. Place the prepreg along the two perpendicular laser layup lines (Figure 3).
5. Continue placing material up to layer (core) 1 and 2 then activate the welding head.
6. Place the welded package along the two perpendicular laser lines. The welded package consists of layers 2 to $n-1$ with all the associated prepreg welded in place between all the layers.
7. Place the untooled prepreg (this is all the prepreg between layers 1 and 2).
8. Place the untooled copper foil (this foil will be layer 1).
9. Place the next separator plate and repeat the process for the entire book.

The inner layers must first be prepared with the corresponding fiducial targets on top and bottom side for the optical alignment (Figure 3). The prepreg has no need for any hole/punch. The inner layers must have weld coupons etched in the reserve zones on both top and bottom sides (Figure 3), and can be placed anywhere along the edges of the lamination plate or inside the image area.

The use of fiducial targets etched in the layers to align through image processing via CCD cameras is the critical alignment step. This process results in lower manufacturing and maintenance cost due to the elimination of the pins, bushings, and tooled separator plates on the lamination process.

In today's best fit on pin lamination technology guarantees around 75 μm for layer-to-

years, started working on optical alignment. He needed a method to hold layers together, so he looked at eyelets (rivets), hot heads, ultrasonic, and induction. After months of development, he settled on induction and came up with a scheme to "weld" the many inner layers together rather than use the common rivets or plate pins. This has evolved to where welds can be located to interior spots on the I/L core. The pinless systems, with inner layer welding are also available for traditional pin layup.

Process of Operation

The process of using optical alignment is similar to manual layup, only more accurate and

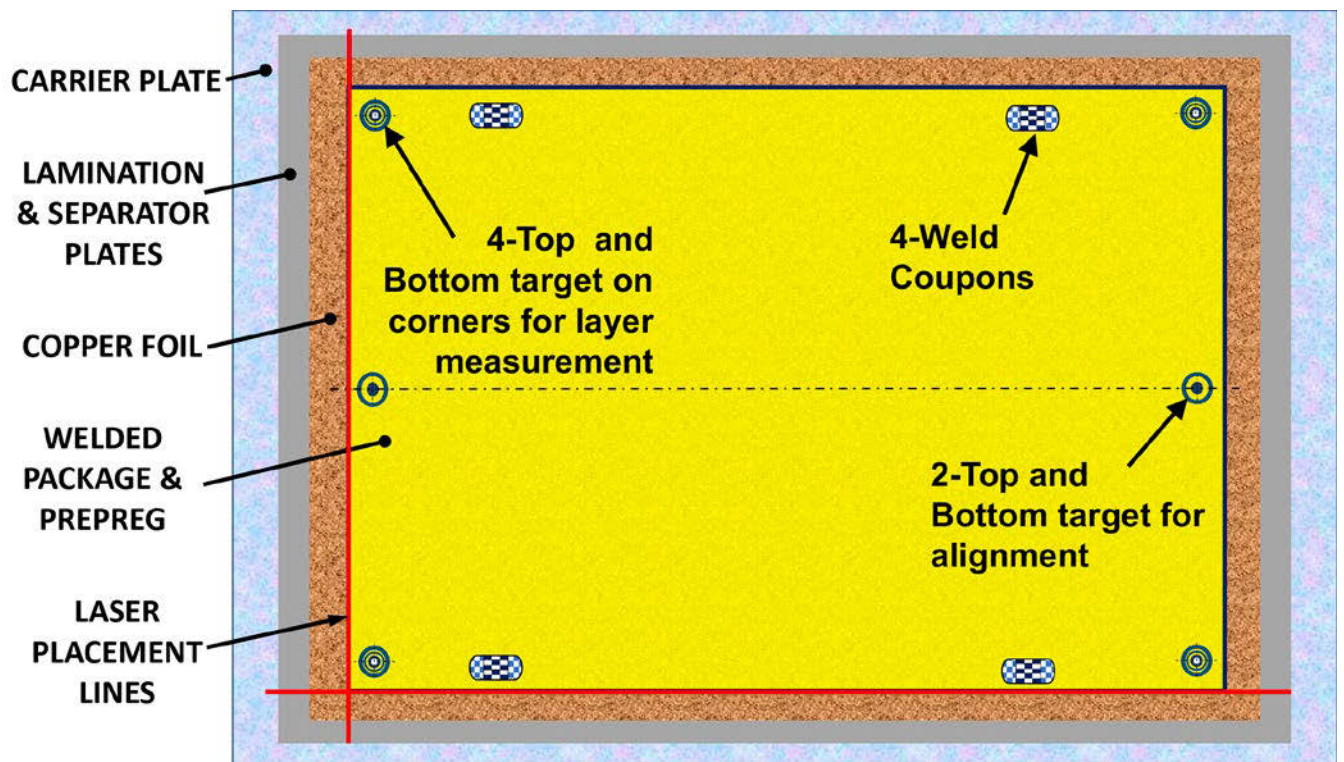


Figure 3: Stackup plates with welded panel, foil, and laser lines used as a guide.

layer registration, while optical registration measures each layer to get the front to back image registration as well the geometry shape of each core and can align inner layers with a tolerance of $\pm 15 \mu\text{m}$ (using direct digital imaging). This is possible because each core is individually inspected and can be rejected as quality control according to a tolerance specification. This new generation of the induction bonders provides a capability to place multiple numbers of bonding points in any location of the multilayer stack for best registration.

Those bonding spots work as virtual pins to help the scale constrain, similar to multiple tooling pins around a single PCB. The bonding points can be placed anywhere in the CAD design, the machine is capable to read and decode the CAD file jobs, and automatically know the coordinates for each bonding location of the panel.

Four bonding heads with independent movement in X and Y axes allow the movement of each head to any location and pro-

vide fast speed for complex panels that require many bonding locations for best registration and multilayer handling. With cores being as thin as 25-50 μm , and sub-laminations common, the welding process can accommodate these variations as well as coppers from one-third to three ounces. Optionally, the registered and bonded multilayer panel could be automatically unloaded at a rear unloading station that could be equipped with a trolley. Also, one plastic protection sheet can be automatically inserted between each panel. The welded coupon bonding process is seen in Figure 4. The welded book can withstand the dilations and shrinkage of the hot press cycles, thereby providing the best possible linear movement of all layers in a multilayer stackup, reducing the internal stress that causes warping and deformations, and moreover reducing the distortions and misalignments between inner layers.

The welded stackup multilayer can be X-rayed to check before and after lamination for compensation adjustments.

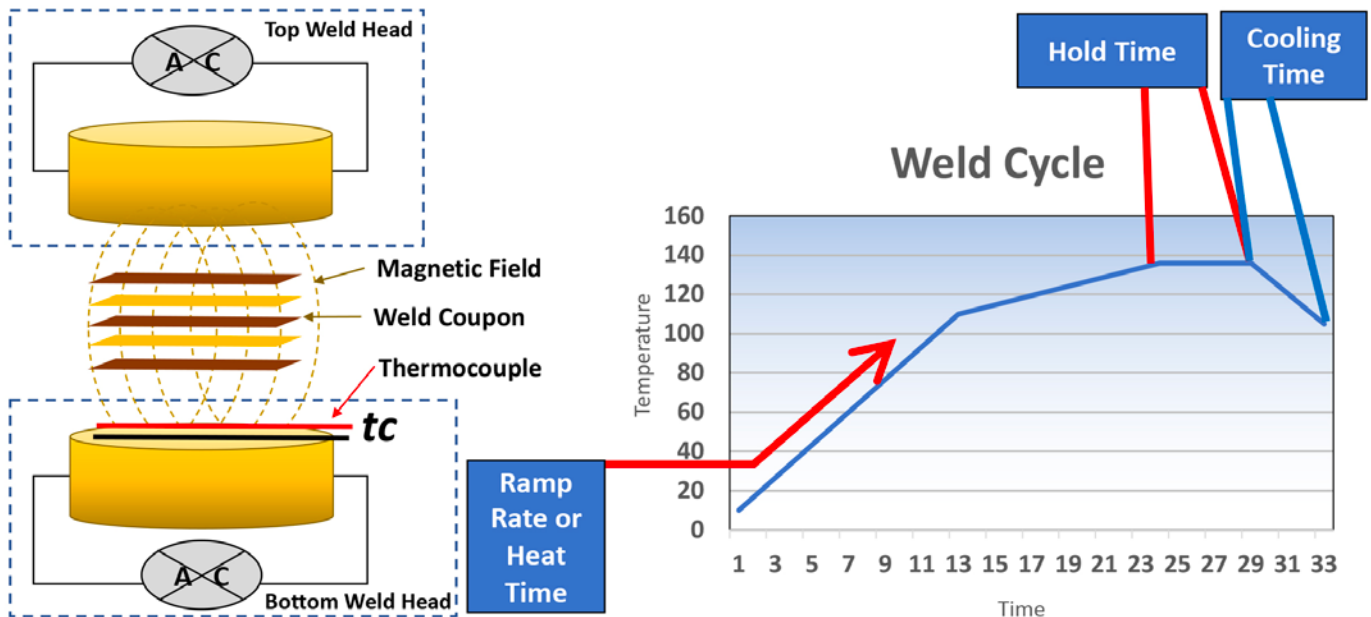


Figure 4: The induction welding process (coupled induction weld heads) and the resulting temperature profile on weld coupons. (Source: DIS Technologies²)

Technical Requirements

The key component to this imaginative process is the induction welding heads. Figure 5 shows three different designs for such induction heating systems. The ability to change the energy and pressure on the coupons is important as materials and constructions change. As multilayers of rigid, flex, and rigid-flex change

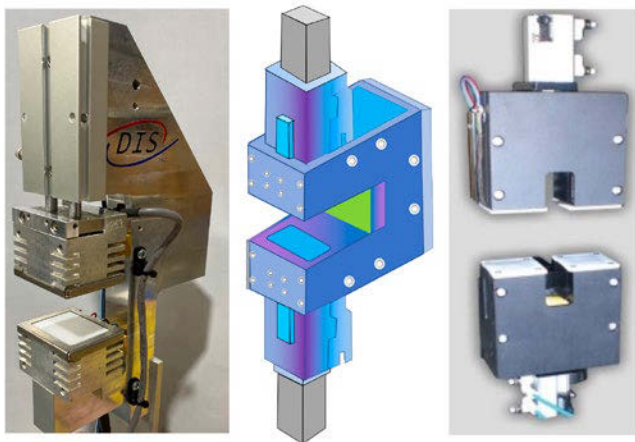


Figure 5: Various induction welding heads. (Source: DIS, InduBond, and CEDAL product brochures)

and become more complex, these welding heads also will probably change.

Weld Coupons

The weld coupons on the perimeter of the inner layer cores replace the old punched or drilled holes. The coupons are varied, but in the range of six to 10 mm wide by 15 to 40 mm long copper and recommended copper clearance. All have solid copper decals as seen in Figure 6.

Each equipment supplier has much more detail available from the many years they have been supplying systems.

Conclusion

As Figure 7 illustrates (a complex 32-layer multilayer), the optical alignment process with the welding of all the cores together improves the registration in multilayer lamination. Coupled with the time savings for layup and the cleanup of epoxy around pin plates, pinless lamination can be a great productivity and quality improvement. This is shown

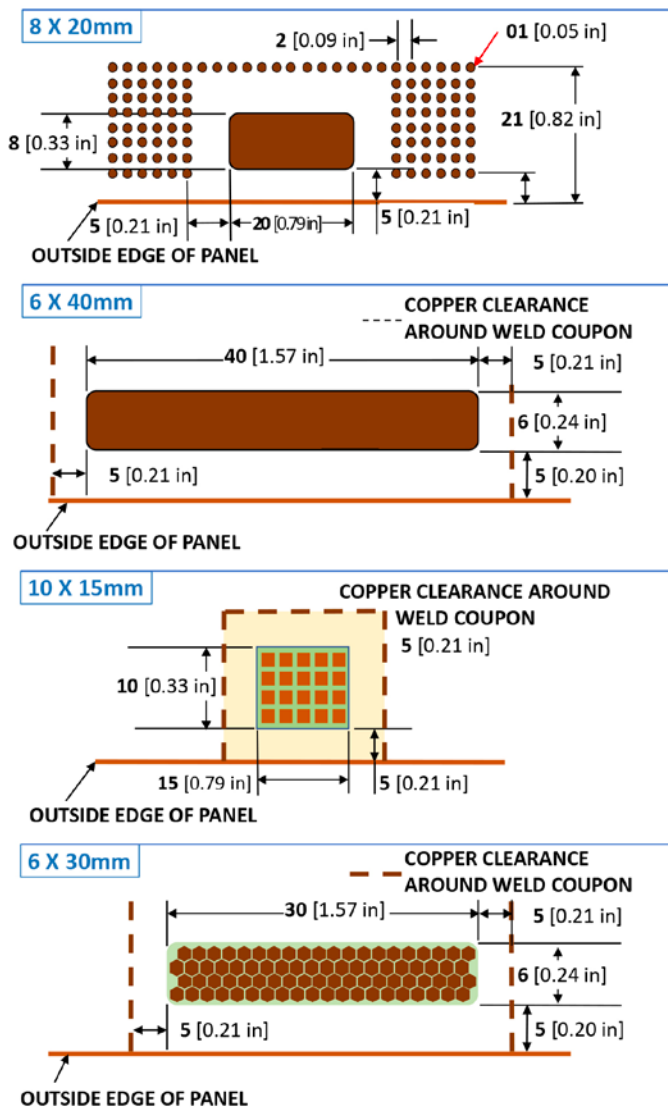


Figure 6: Various weld coupons. (Source: DIS, InduBond, and CEDAL product brochure)

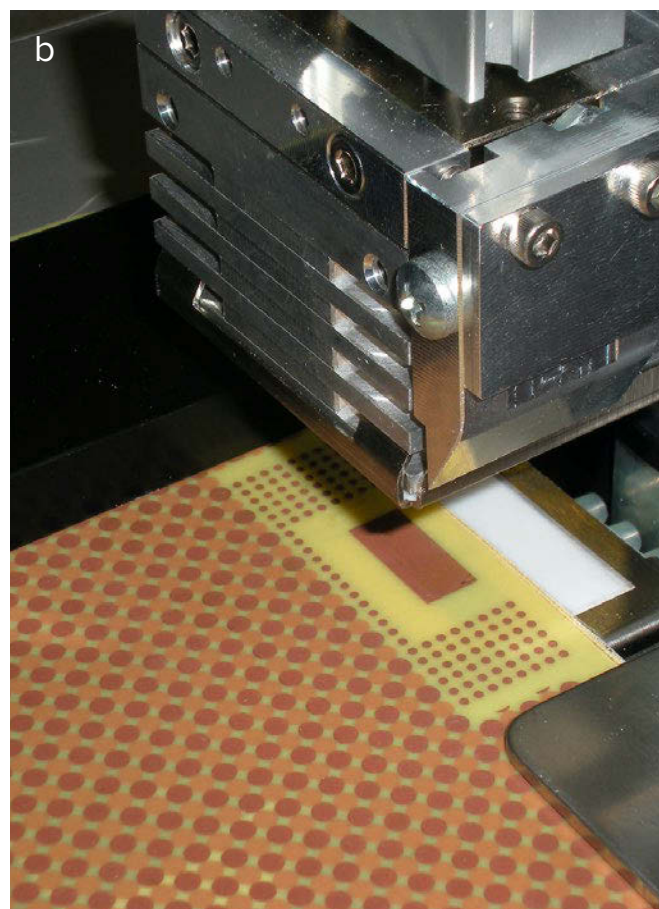
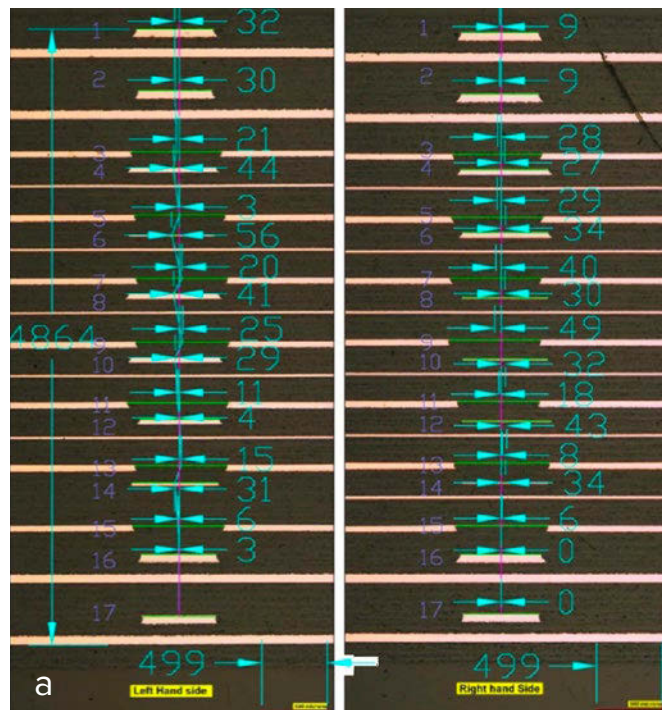


Figure 7: a) Cross-section of a complex 32-layer multilayer with different copper weights, core thicknesses, and sub-laminations; b) Close-up of bonding head and inner layer core weld coupon².

by the more than 250 systems being sold since 2000. The optical and pin alignment systems with their induction core welding have also been adapted for flex and rigid-flex layups. The advantages of pinless:

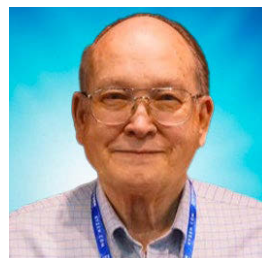
- Increased layer-to-layer registration accuracy
- Increased process predictability and registration data
- Ability to characterize lamination press process
- Ability to register thin cores accurately and consistently
- Flexibility utilizing lamination plates

- Plates do not need tooling holes; this allows the plates to be used for multiple panel sizes, and thus fewer sets of lamination plates are needed
- Separator plates also do not need tooling holes; this allows the plates to be used for multiple panel sizes, thus fewer sets of separator plates are needed
- Cleaner operation; cleaning plates are easier to clean; there are no resin filled tooling holes
- Copper foil does not need clearances for tooling pins, as foil is easily damaged when trying to lay up on pins
- Prepreg does not need clearances for tooling pins which minimizes prepreg dust
- There will be more flexibility in panel sizes without the restrictions of the pins

- The lamination pins and bushings are eliminated, thus eliminating a consumable
- Depinning is not necessary **PCB007**

References

1. *24 Essential Skills for Engineers*, by Happy Holden.
2. "Optical layer-to-layer Alignment," by Anthony Faraci, *The PCB Magazine*, June 2012, pp.40-47.



Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa/Westwood, Mentor Graphics, Merix, Foxconn, and Gentex. To read past columns, [click here](#).

Commission Presents New European Innovation Agenda to Spearhead Innovation Wave

The European Commission has adopted a new European Innovation Agenda to position Europe at the forefront of the new wave of deep tech innovation and start-ups. It will help Europe to develop new technologies to address the most pressing societal challenges, and to bring them on the market. The New European Innovation Agenda is designed to position Europe as a leading player on the global innovation scene. Europe wants to be the place where the best talent work hand in hand with the best companies and where deep tech innovation thrives and creates breakthrough innovative solutions across the continent that will inspire the world.

By leading on innovation, in particular on the new wave of deep-tech innovation requiring breakthrough R&D and large capital investment, Europe will reinforce its central role in shaping the green and digital transitions. Deep tech innovation will reinforce Europe's technological leadership and generate innovative solutions to pressing societal challenges, such as climate change and cyberthreats. Such innovations are likely to irrigate and benefit all sectors from renewable energy to agri-tech, from construction to mobility and health, thereby tackling food security, reducing energy dependency, improving people's health, and making our econo-

mies more competitive. The severe consequences of Russia's war of aggression has given these issues even greater urgency and prompted strategic policy changes to ensure the EU's prosperity and security.

The New Innovation Agenda will in particular:

- Improve access to finance for European start-ups and scale-ups, for example, by mobilising untapped sources of private capital and simplifying listing rules
- Improve the conditions to allow innovators to experiment with new ideas through regulatory sandboxes
- Help create "regional innovation valleys" that will strengthen and better connect innovation players through Europe, including in regions lagging behind
- Attract and retain talent in Europe, for example by training 1 million deep tech talents, increasing support for women innovators and innovating with start-up employees' stock options
- Improve the policy framework through clearer terminology, indicators and data sets, as well as policy support to Member States.

(Source: European Commission)

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Electrodeposition of Copper, Part 2

Trouble in Your Tank

by Michael Carano, RBP CHEMICAL TECHNOLOGY

Introduction

If one thought that electroless copper and other metallization systems were complex and the deep dark secrets of these systems shrouded in black magic, the discussions on electroplating will seem like brain surgery.

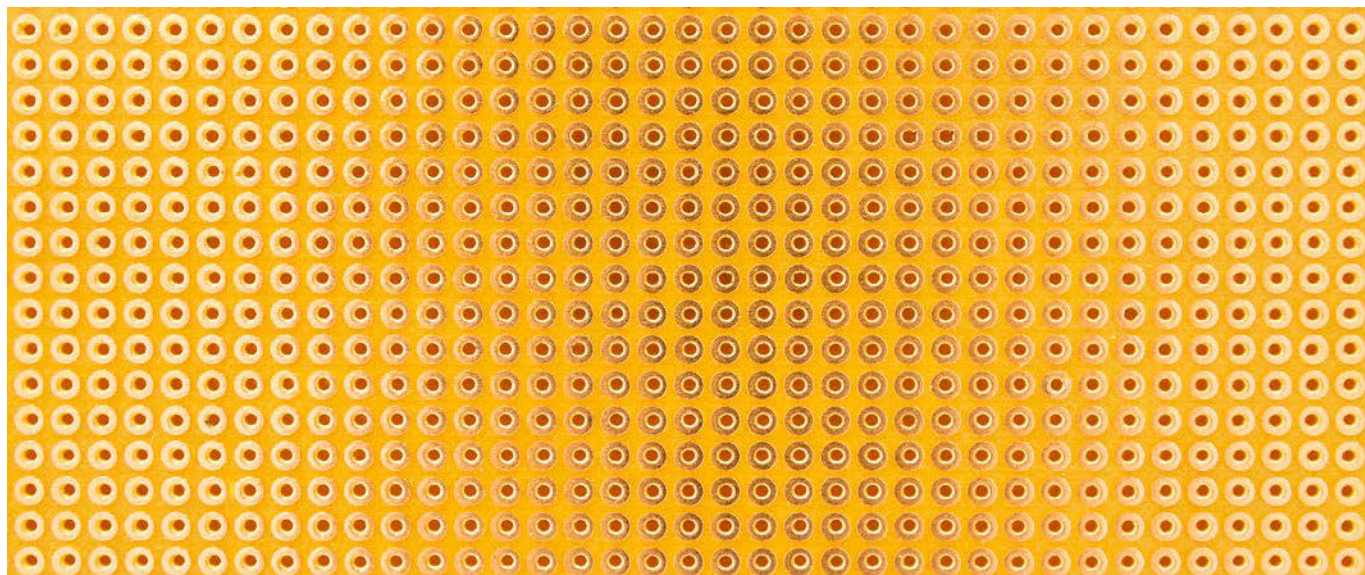
In this next series of columns, the intricacies of electrodeposition technology and its function of building up the thickness of copper in the holes and on the surface will be presented in detail. Function of the active ingredients in the copper plating solutions will be presented. Process control limits for the various plating solution components and the effects on deposit integrity will be discussed.

Electrodeposition

In contrast to the classic initial through-hole metallization with electroless copper, the

buildup of the conductive layer in the through-hole to the desired thickness is being achieved by the electrodeposition of copper. It is understood that these technologies overlap, i.e., some initial metallization processes use direct electroplating and, conversely, fully additive processes build up copper solely with the electroless process.

The historic preference for building up the copper deposit by electroplating has to do with the lower cost, faster deposition rate, and in general, better metallurgical properties of the electroplated copper. Improvements concentrated on the “throwing copper” of the electrolytes, i.e., their ability to deposit a relatively uniform deposit of copper on the board surface and in the through-holes. A shift to higher acid and lower copper concentrations, as well as improved organic additives systems (brighten-





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ers, carriers, levelers), gave improved throwing power. And let's not underestimate the influence that plating cell design, cabling connections from the power supply to the buss bars, and solution movement have on plating distribution and the overall quality of the deposit.

Additional challenges and complications have been introduced due to the changes in circuit board design technology. Shifts in circuit designs toward higher density and ultra-high density have ushered in a new wave of improvements in process technology.

Several other electroplating processes are used in the fabrication of the printed wiring boards. Tin/lead or tin is electroplated, occasionally also electroless plated, to serve as a metal etch resist. Other electroplated metals include nickel/gold and palladium (also deposited from immersion baths or electroless baths) to form suitable surface finishes for insertion connectors or component attachment, e.g., wire bonding. An overview of these processes will be presented in a future column.

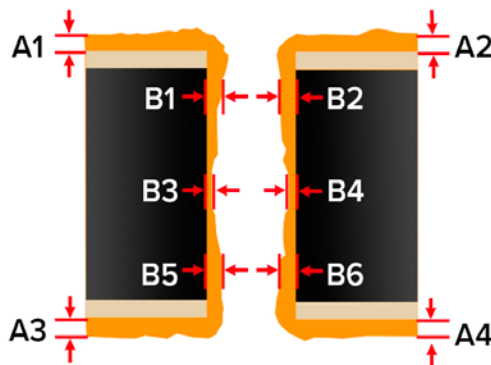
Focusing on the acid copper electroplating process, one would start with the pre-plate cleaning sequence of acid soak cleaner,

micro-etch, and acid predip. The acid predip is optional and if rinsing after micro-etching is sufficient, can be omitted. However, this only applies to using peroxide/sulfuric acid micro-etchants. Use of persulfate-based etchants indicates an acidic pre-dip. Critical acid cleaner variables are chemical composition, concentration, time, and temperature. Regarding the micro-etch, etch depth is the critical parameter, which in turn, is influenced by the chemical composition, concentration, time, and temperature. The acid predip, typically of the same acid and concentration as is used in the plating bath, protects the plating solution from undesirable drag-in, which might adversely affect the composition or concentration of the bath. Thus, chemical composition of the predip and its level of contaminants are critical.

Critical parameters of the acid copper bath include electrical, mechanical, physical, and chemical variables. Starting with the electrical parameters, current density and primary current density distributions affect plating rate, thickness distribution, and the metallurgical properties, e.g., ductility, roughness, and color

What is Throwing Power (T/P)?

The micro T/P is the copper thickness distribution of the hole interior.



$$T/P \text{ (min.)} = \frac{(B3+B4) / 2}{(A1+A2+A3+A4) / 4}$$

$$T/P \text{ (IPC)} = \frac{(B1+B2+B3+B4+B5+B6) / 6}{(A1+A2+A3+A4) / 4}$$

Figure 1: Throwing power is defined in this graphic.

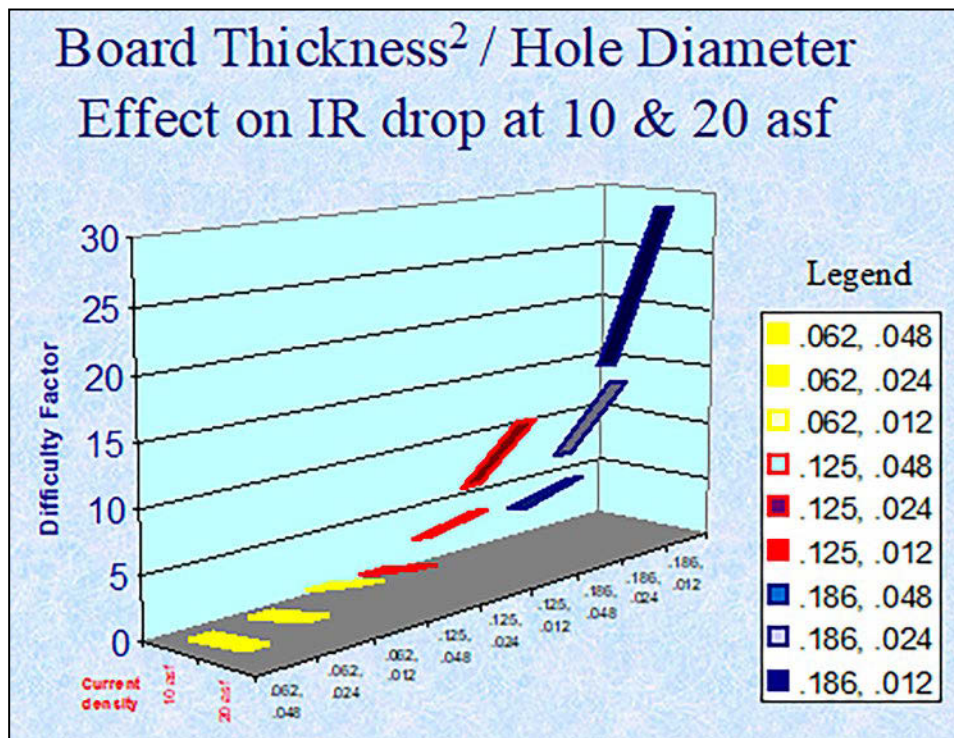


Figure 2: Left hand column represents board thickness, and right-hand column represents hole diameter.

of the deposit. Current density across the plating surface depends on the rectifier capacity, related anode and cathode sizes and spacing, shielding, cell efficiency, and solution conductivity. Current density distribution across the plating surface depends on some of the before-mentioned parameters and, in pattern plating, also on the circuit pattern.

Current density in the through-hole depends on the following additional variables:

- Through-hole diameter and aspect ratio
- Replenishment efficiency (in the holes) of plating solution (agitation)
- Throwing power of the bath, which is largely determined by the acid/copper ratio, the organic plating additives, and the level of impurities (leachants) that interfere with the organic plating additives.

In Figure 1, throwing power is defined for purposes of this and subsequent columns. The actual mechanics of the electrodeposition process and the influence of process parameters will be discussed in future columns.

The degree of difficulty for plating through-holes depends on board thickness as well as hole diameter. For example, given a choice of two holes, both 10:1 in aspect ratio, one prefers a design with a 100-mil thick panel and a via with a 10-mil diameter, vs. a 200-mil thick panel with 20-mil diameter holes. Both designs are of the same aspect ratio.

Figure 2 underscores the difficulty in maintaining throwing power as the aspect ratio and board thickness increase. It illustrates that the IR drop (or the electrical resistance through the via) increases as a squared factor, while via diameter only affects the resistance (or throwing power) in a linear fashion.

In my next column, I will continue to explore the electrodeposition process and the science behind the technology. **PCB007**



Michael Carano is VP of quality at Averatek. To read past columns, [click here](#).

PCB Plating Still Comes Down to Physics

We asked columnist Michael Carano 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 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.



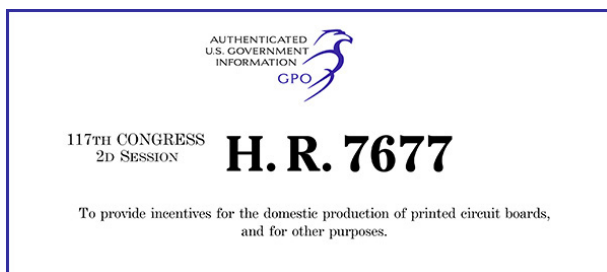
Review: Institute of Circuit Technology 2022 Annual Symposium



The British Motor Museum in Warwickshire, housing the world's largest collection of historic British cars, was the venue for the 2022 Annual Symposium of the Institute of Circuit Technology on June 8, which attracted a substantial gathering of manufacturers and suppliers from the UK printed circuit industry.

IPC-1402, Standard for Green Cleaners Used in Electronics Manufacturing Now Open for Public Review

IPC's draft version of IPC-1402, Standard for Green Cleaners Used in Electronics Manufacturing, is now open for public review.



Industry Groups Urge U.S. Congress to Fix Weaknesses in Electronics Supply Chain

Three top industry organizations have recently urged U.S. Congress to support legislation that would address challenges confronting the U.S. electronics supply chain.



Testing Todd: What's in the Electrical Test Crystal Ball?

We live in an everchanging environment of evolution. From analog, carburetion-driven automobiles and tube televisions to the fully electronic fly-by-wire automobiles and UHD televisions of today. We had to evolve. Today you can speak to your car, speak to your home, and even execute commands by just your voice.

Catching up With Author Ed Chambliss: Fixing a 'Broken' Business Model

I love books, especially good business books. I read three or four a week which I believe makes me a discerning critic. *A One-Legged Stool: How Shareholder Primacy Has Broken Business (And What We Can Do About It)* by Ed Chambliss is one that can help us in both business and life.

Fein-Lines: Virtual Reality is About to Get a Lot More Real—and Fun



While two very interesting technology shows in the past month each had their own focus, I came away from both with the feeling that not only will these industries collide, but we are on the precipice of an explosion in extended reality.

Candor Nails the ROI With InduBond



Nolan Johnson follows up on his original interview with Sunny Patel, engineering manager at Candor Industries, about the economics of this new InduBond X-Press 360 lamination press.

Ventec's Book on Thermal Management: The Summer Sequel You've Been Waiting For

I-Connect007 is excited to announce the release of the second title in Ventec's series on thermal management, *The Printed Circuit Designer's Guide to... Thermal Management with Insulated Metal Substrates, Volume 2*.

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IPC: Higher Costs Continue to Dominate Electronics Industry Narrative

Per IPC's June Global Sentiment of the Electronics Supply Chain report, nine in 10 electronics manufacturers surveyed are currently experiencing rising material costs, while 86% of electronics manufacturers are concerned about inflation.

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- 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.

[apply now](#)

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

[apply now](#)



ventec
INTERNATIONAL GROUP
騰輝電子

European Product Manager Taiyo Inks, Germany

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

Duties include:

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

Skills and abilities required:

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

What's on offer:

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

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

[apply now](#)

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

[apply now](#)



Are You Our Next Superstar?!

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

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

[apply now](#)

Career Opportunities



Sales Representatives

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

Reasons you should work with Prototron:

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

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

[apply now](#)



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.

[apply now](#)

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.

[apply now](#)

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

[apply now](#)



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.

[apply now](#)

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.

[apply now](#)

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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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

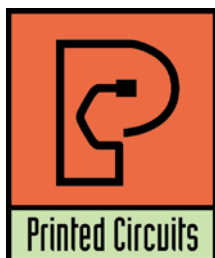
- A love of teaching and enthusiasm to help others learn
- Background in electronics manufacturing
- Soldering and/or electronics/cable assembly experience
- IPC certification a plus, but will certify the right candidate

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



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

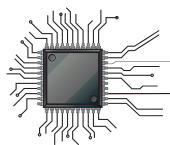
- Load and unload electroplating equipment
- Fasten circuit boards to racks and cathode bars
- Immerse work pieces in series of cleaning, plating and rinsing tanks, following timed cycles manually or using hoists
- Carry work pieces between departments through electroplating processes
- Set temperature 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

apply now

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.

[apply now](#)



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



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.

[apply now](#)

Sr. Test Engineer (STE-MD)

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



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.

[apply now](#)



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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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.

[apply now](#)

BUILD A BETTER WORKFORCE

- Electronics Assembly for Engineers
- Electronics Assembly for Operators
 - IPC-A-610 for Operators
 - IPC-J-STD-001 for Operators
- Wire Harness Assembly for Operators



2/3 of electronic
industry companies
have difficulty finding
production workers.¹

vs



Upskill Your
Employees with
IPC Electronics
Workforce Training

IPC Electronics Workforce Training delivers the fundamental electronics and wire harness manufacturing knowledge critical to the success of engineers and operators. Scale consistent training across your organization.

See our current course listing on training.ipc.org.

Courses can be offered directly to employees or integrated into your training programs.

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

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



NEW! Thermal Management with Insulated Metal Substrates, Vol. 2

by Didier Mauve and Robert Art, Ventec International Group

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



High Performance Materials

by Michael Gay, Isola

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



Stackups: The Design within the Design

by Bill Hargin, Z-zero

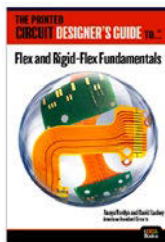
Finally, a book about stackups! From material selection and understanding laminate data-sheets, to impedance planning, glass weave skew and rigid-flex materials, topic expert Bill Hargin has written a unique book on PCB stackups. [Get yours now!](#)



Thermal Management: A Fabricator's Perspective

by Anaya Vardya, American Standard Circuits

Beat the heat in your designs through thermal management design processes. This book serves as a desk reference on the most current techniques and methods from a PCB fabricator's perspective.



Flex and Rigid-Flex Fundamentals

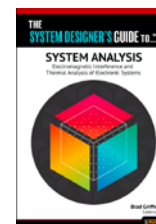
by Anaya Vardya and David Lackey, American Standard Circuits

Flexible circuits are rapidly becoming a preferred interconnection technology for electronic products. By their intrinsic nature, FPCBs require a good deal more understanding and planning than their rigid PCB counterparts to be assured of first-pass success.

The Systems Designer's Guide to... System Analysis

by Brad Griffin, Cadence

In this book, the author, Brad Griffin of Cadence, focuses on EM and thermal analysis in the context of data center electronics systems. Be sure to also [download the companion guide](#) for end-to-end solutions to today's design challenges.



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MAGAZINE

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