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# SMT007 MAGAZINE


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SMT007 MAGAZINE

# Coming to Terms With AI

In this issue we examine the profound effect artificial intelligence and machine learning are having on manufacturing and business processes. We follow technology, innovation, and money as automation becomes the new key indicator of growth in our industry.




# SMT007 MAGAZINE


# Coming to Terms With AI

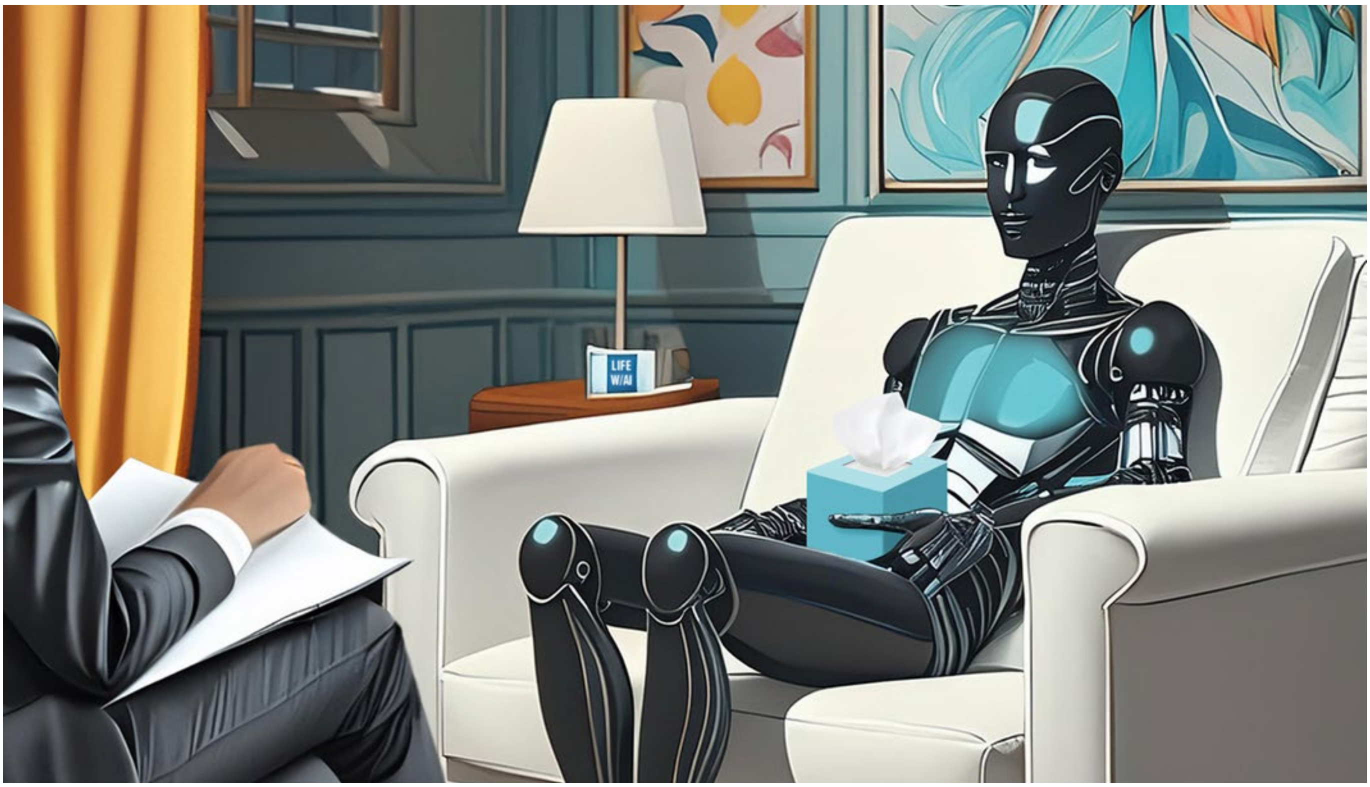
## Nolan's Notes

by Nolan Johnson, I-CONNECT007

How fast do things move in the world of data analytics? Here's an example. We've been planning this issue on artificial intelligence for the past few months, and, in fact, I had already written this column about a month ago. Then I went to IPC APEX EXPO and upended it all. I originally had compared AI to drag racing in that (CPU) horsepower and new (data) vehicles have steadily delivered higher performance competition. That seemed pretty accurate given how generative AI models dominated the popular media with amazing results—and sometimes spectacular crashes.

In all my career, I've never seen a new technology move so fast into adoption as has been the case with AI and machine learning (ML). I'm not exaggerating when I call this the largest inflection point in manufacturing since steam, with undeniably the fastest rate of change, something that, understandably, is a lot to come to terms with.

This was made abundantly clear during my recent week in Anaheim. For me, news and perspective came from two main sources: My conversations at the show with industry experts were followed by a research report



about data and AI recently published by MIT[1]. In our special coverage of the trade show *Real Time With... IPC APEX EXPO 2024 Show and Tell Magazine*, I wrote about the collaboration emerging across the electronics manufacturing equipment market. As a result, we scrambled to gather the very latest AI-related news from the show to include in this issue of *SMT007 Magazine*. Take note: There was a lot to gather.

Serendipitously, after returning home with my head full of digital factory developments, I came across this research from MIT that made clear that the collaboration I saw in our industry is emerging across nearly all levels of business.

Here is a list of key findings published in the Executive Summary of the paper:

- CIOs are doubling down on their investments in data and AI
- Consolidation of data and AI systems is a priority
- Democratization of AI raises the stakes for governance
- Executives expect AI adoption to be transformative in the short term
- As generative AI spreads, flexible approaches are favored
- Lakehouse has become the data architecture of choice for the era of generative AI
- Investment in people will unlock more value from data and AI

The data was collected last summer, and respondents came from eight industry sectors—retail, media, telecom, manufacturing, government, health care, financial, and energy—with each organization earning a minimum of $500 million a year in revenue.

In the conclusion, the report states, "Generative AI will be an inflection point. Experts predict that it will [unleash] a new wave of productivity, potentially adding trillions of dollars of new value across industries."

All this begs the question: How does this change electronics manufacturing? Glad you asked. The new data infrastructures that AI is bringing mean creative new productivity tools—as evidenced by the tools the team at Plato Systems is bringing for human/machine interactions into your data infrastructure for efficiency and quality assessment. New data infrastructures are also driving hardware development in stressful ways. We spoke with IBM's Arvind Kumar on work to push Moore's Law forward, and not surprisingly, he talks at length about chiplet architectures and advanced packaging. We also excerpt a chapter from a new book recently published by I-Connect007 authored by Cogiscan's Julia Cliche-Dubois, *The Printed Circuit Assembler's Guide to...Factory Analytics.* Also included are fresh news on AI developments and collaborations from Arch Systems, Aegis, and Koh Young. Columnist Mike Konrad brings his inside-the-ballpark perspective on the transformation now underway.

Our long-time columnist Dr. Jennie Hwang continues her multi-part series on artificial intelligence. I encourage you to revisit her primer in the April issue.

We may call this AI stuff "intelligence," but AI is to data what the steam engine tractor was to farm work. It didn't replace the farmer, but those farmers who came to terms with the steam engine were able to produce like never before. AI won't replace us. AI will automate the mundane and find hidden patterns in the data. It still takes skilled human insight to make sense of those patterns. **SMT007**

**References**


1. "Laying the foundation for data- and AI-led growth," MIT Technology Review Insights.



**Nolan Johnson** is managing editor of *SMT007 Magazine.* Nolan brings 30 years of career experience focused almost entirely on electronics design and manufacturing. To contact Johnson, click here.

# Using AI to Redefine Productivity

**Feature Interview by Nolan Johnson**
I-CONNECT007

Plato Systems, a machine perception company spun out of Stanford University, employs AI and video data to analyze and optimize the human component in manufacturing. Initially focused on semiconductors, Plato Systems has expanded into EMS manufacturing. Co-founder and CEO Amin Arbabian, along with product advisor Anders Holden and head of growth Luis Vidal, discuss their approach to changeover optimization and its impact on productivity in the industry. They've also included customer Raj Vora in the conversation.

***Nolan Johnson: Amin, I want to discuss AI on the manufacturing floor, and I'm particularly intrigued by Plato's focus on changeover. Why don't we start with an overview of your company?***

*Amin Arbabian:* We're fundamentally a machine perception company. If you look at your current changeover process, ask yourself, "What is the changeover? How do you qualify it?" A changeover is a step in the process where the level of interaction between the operator and the machine is critical. It's also a big piece of your total productivity, especially if you have a significant number of changeovers in your operations. It's where you have multiple steps and sequences that must be done.

Much like a pit stop in a Formula One race, you have to optimize your process. If you want to codify changeovers, start by considering that they're a manifestation of the operator-machine interaction. We're bringing operator and factory behavior to the table through specific AI detection.

Amin Arbabian

If you think about physical industries worldwide, they're about 30–40% of our global GDP in regards to more than manufacturing and logistics. In the U.S., manufacturing is about $2 trillion—about 10–20% and 2–3% of global GDP. We have this huge part of our economy with 12–13 million employees, yet the productivity levels have been stagnant or declining in the past few years, by 2–3% year-over-year in some sectors. Why is that the case?

We've had digital transformation, Industry 4.0, and so forth, but we haven't increased productivity. In parallel, labor trends show there are huge problems with hiring and turnover in the sector. We have about 13 million employees and more than a half-million openings in manufacturing. It's a huge gap; this problem will not go away. We need better leverage.

***How is your company addressing this?***

*Arbabian:* At Plato, our core thesis is that understanding and optimizing factory behavior is still very analog, very manual. We're still analyzing factory behavior like we did 150 years ago when Taylor and Gilbreth started the field of industrial engineering. They did time-and-motion studies by observing with a stopwatch; we're not far removed from that today. Currently, as a solution, we're sitting on the mezzanine and watching the whole floor to gather data. Another solution is through Gemba Walks, where you're on the floor watching what's happening. Without the operator context, it's almost impossible to identify the right levers, let alone optimize, automate, and run it as efficiently as it's supposed to. Consequently, AI applied to manufacturing would be incomplete without this new data set.

AI is a function of your data quality and data sources. For example, you can't have a self-driving car if you have no sensors to see the world. You might have all the internet data and all the big data, but it won't drive in a real environment. We believe that operator behavior unlocks the potential of AI for manufacturers.

We started with semiconductor manufacturing because this segment understands the value of data. Every aspect of the machines and the environment is digitized. It's run with productivity, efficiency, and quality in mind. We think electronics manufacturing sectors adjacent to semiconductor are similar. They have the same bottleneck areas. It's more than building an advanced product; your process of building it is also advanced. That's the idea for starting with a more complex and advanced manufacturing environment and propagating out toward a broader basis.

*Anders Holden:* Getting more specific to PCB and SMT production, there's a sweet spot for our technology where the optimal balance between human and machine is reached. Obviously, the line is automated, and it runs by itself most of the time. But when it stops, you need a specific, well-thought-out response. If a machine goes down in the middle of a run, you need to respond to the machine prompt. Maybe you need to change a reel or call maintenance, but the response and the actions are very tightly choreographed. That means we know what "good" looks like from the outset; there isn't a wide range of different responses. Similarly, a well-executed changeover will look the same every time. There's the same number of minutes in each station, the same sequence of stations. We're experts at codifying that. We've been very lucky that this is an early place to test our technology because it's such a good fit between the technology and the problem space.

***It seems that the human aspect is shifting from what it used to be to something new. How do you approach that trend, especially when it comes to robotics and automation?***

*Holden:* Our goal is to empower the operator. U.S. operators and manufacturers need to continuously raise the bar to remain competitive. We look to other places where they've been raising the bar on human performance. In Formula One, for example, how much time do they spend on fine-tuning the details of a pit stop, which essentially is a changeover? In manufacturing, there haven't been any technological solutions to treat the operator as an athlete. That thinking is just starting to emerge. Our coaching tool can help to empower them.

Let's say we have a crew running an SMT line, and they want to increase uptime by 20%. That's totally doable on most lines, but they need to get into the details. I start here, then I move here after this many seconds; you treat it more like dance choreography. To do this type of analysis, they need tools and support. Our vision is to provide that toolset, be it codifying the changeover or giving you stats about how well you did vs. last time or vs. your best changeover ever. It might even be a benchmark against other companies. We also enable management to systematically observe and rectify discrepancies in productivity or yield across various facilities, production lines, or shifts. We can bring the same level of rigor they have in professional sports to these operators. We can make it fun to become good.

Anders Holden

***The Formula One pit stop analogy is great because many of the companies in EMS—especially if they're Tier 2 or 3—don't run so much like Formula One's three-second pit; they run like NASCAR, where it's more like 35 seconds. Tell me more about the tools you're developing.***

*Arbabian:* First, our philosophy is objective observability with automatic data. That is a critical foundation. The first plateau is the observational piece: You observe a process, and now you want to go and optimize your problem. The first thing you do after you've watched 20 of these things is qualify the steps: These two people need to be here, and this first step lasts one-and-a-half seconds. So, you break that one-and-a-half seconds into pieces. That's the observed piece of our product.

Now that you've observed it, the second plateau is investigating and finding a root cause. With the data, we give you actionable insights into root causes for problems, improving productivity by looking at actions, sorted, ranked by impact, and so forth. It's an all-around pri-

Raj Vora

oritization of "Where do I start? What do I do tomorrow?"

The third phase is to establish the framework for training material on what good behavior is. You need to answer questions like, "How do I qualify it? How do I establish it as a standard process?" All of this is possible by using a foundation of new data.

***I'm very interested in understanding what that digital mezzanine looks like.***

*Raj Vora:* If you were to watch a video, it would tell you objectively everything that happened because I'm learning how everyone's perception of what happened is so different than what actually happened. Having video pinpoints without any sort of opinion.

For instance, there's a clip where I can see that the machine was down. If I ask an operator tomorrow what happened, I'll get their perception. But in a video, I can see what happened at that moment. Once you connect machine real-time data to this, for example, "An event at 2:59 p.m., machine went down for 13 minutes," you can get an objective answer. Maybe they couldn't find a part, a part wasn't counted properly, or someone went to the bathroom. This gives you that capability to actually see what happened.

The true value, though, is adding digital information in the form of scientific data. Not only can you see the behavior, but you get signals from the machines: A machine flagged an alert. What happened next? Who did what, and why didn't a machine get back up and running?

Let's say I want to place 3 million components on that line during every shift, but I'm losing 10% of that, which amounts to 300,000 components not placed. At 7 cents a placement, that's in the range of $150,000. It gets much more interesting when we're talking about big, marginal gains like this. OEMs talk about pennies for parts, but in our business, it's about seconds. I'm charging my customers for the time it takes to place parts. Every second the machine is not running means no revenue.

*Holden:* In one video from Raj's line, they're in the middle of a changeover. We can see the printer and each of the pick-and-place machines in the front. One of the machines is blinking a fault, but nobody's there. Later in the video, someone approaches the printer. In this case, someone is tidying up, but no one is responding to the pick-and-place machine. If you jump to a certain point in the video, you see someone at the pick-and-place machine, and someone else on the printer. You can see this story unfolding. There's a lot going on but it's not obvious what the pattern is.

Imagine you were looking at a well-rehearsed changeover that went according to script. Right before the last board passes through the printer, somebody will be there, and then you will see the sequence bar for the process. As they change each of the pick-and-place machines, you'll see this Gantt Chart below the video moving, and then boom, the changeover is done.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Each of these Gantt chart bars are predictable: the duration of time spent on the printer is within a minute or two every time. For a given transition between two programs, you should see the same thing. That's the data, and now you can start applying logic and rules to it. You can determine things, such as that your changeover was slow because printer time was five minutes above average, or maybe the sequence was out of order. After you've watched a couple of these videos, you should be able to see and tell the story just from watching these events.

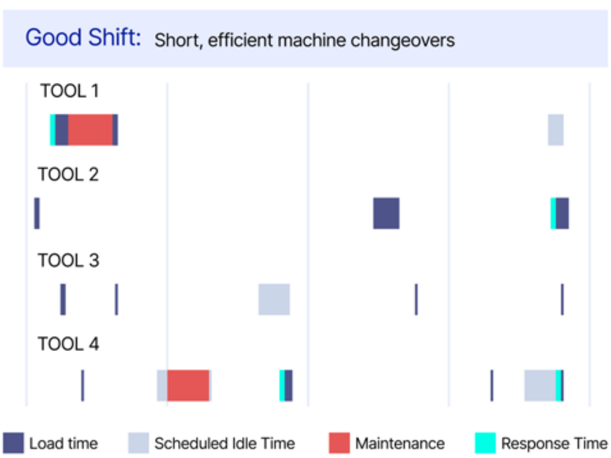
***With enough of these examples, can you start to develop new best practices?***

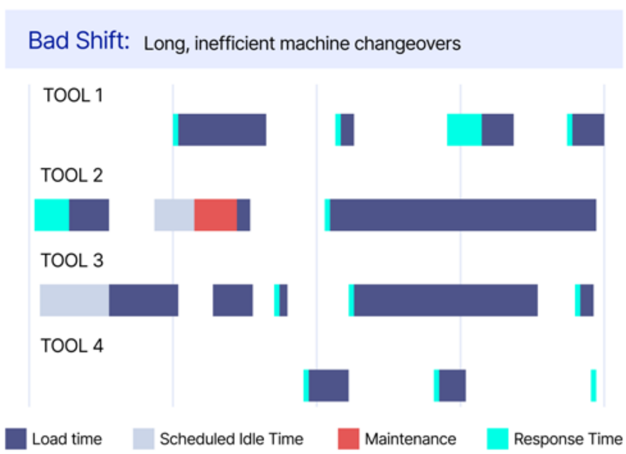
*Holden:* That's a key insight from operations: Good performance means low variability. That's just Operations 101. It's as true for operator data as it is for machine data. A well-running machine doesn't vary, and a well-running operator will do the same thing, the same way, every time. Using that fact, we can codify what "good" looks like. Anything that doesn't look like "good" can be improved. Now we have the opportunity for tangible coaching because there is real video evidence. That radically changes the game for folks like Raj, who are trying to run a business in a difficult environment.

***Raj, how much improvement have you've seen?***


*Vora:* We've only been ramping up for about a month, so it's a little early to tell. We're starting to capture video, review it, and figure out what's going on. We want to videotape good events as well, and we haven't done that yet. I would say we're still early in our process.

*Holden:* We try to get 10–15 percentage points on the line. What we've seen typically depends on how much potential there is. We're working with another line with an operational efficiency (OE) of about 55%. It would be fairly simple to get them to between 65–70% by implementing some straightforward changes, some of which they already knew, some of which they didn't. But you need the evidence to make a move. If you don't have data, you don't have facts, and



Luis Vidal

then it becomes very hard to change people's behavior.

***Specific to changeover, if my facility specializes in small volume, high mix, would that give me more opportunity to realize changeover efficiencies, rather than a facility doing long run, high volume jobs? Are there more opportunities to apply these tools on the floor than just changeover or operator response time to a machine alert?***

*Luis Vidal:* Smaller and midsize players gain a lot when they increase OE from 50 to 65%. In higher volume players, the line revenue might be $20–25 million a year, on average. Even small changes in OE can make a difference from a growth standpoint.

In very large organizations, change can be a challenge. Things are political, and there are many decision-makers. If you want to recommend a change to optimize, you might need to supply 10 examples of why it's not working. Our system gives people the ammunition they need to go into a very complex organizational environment and say, "Hey, this doesn't work. Here's the reason why. Let's go fix this." The data will set you free.

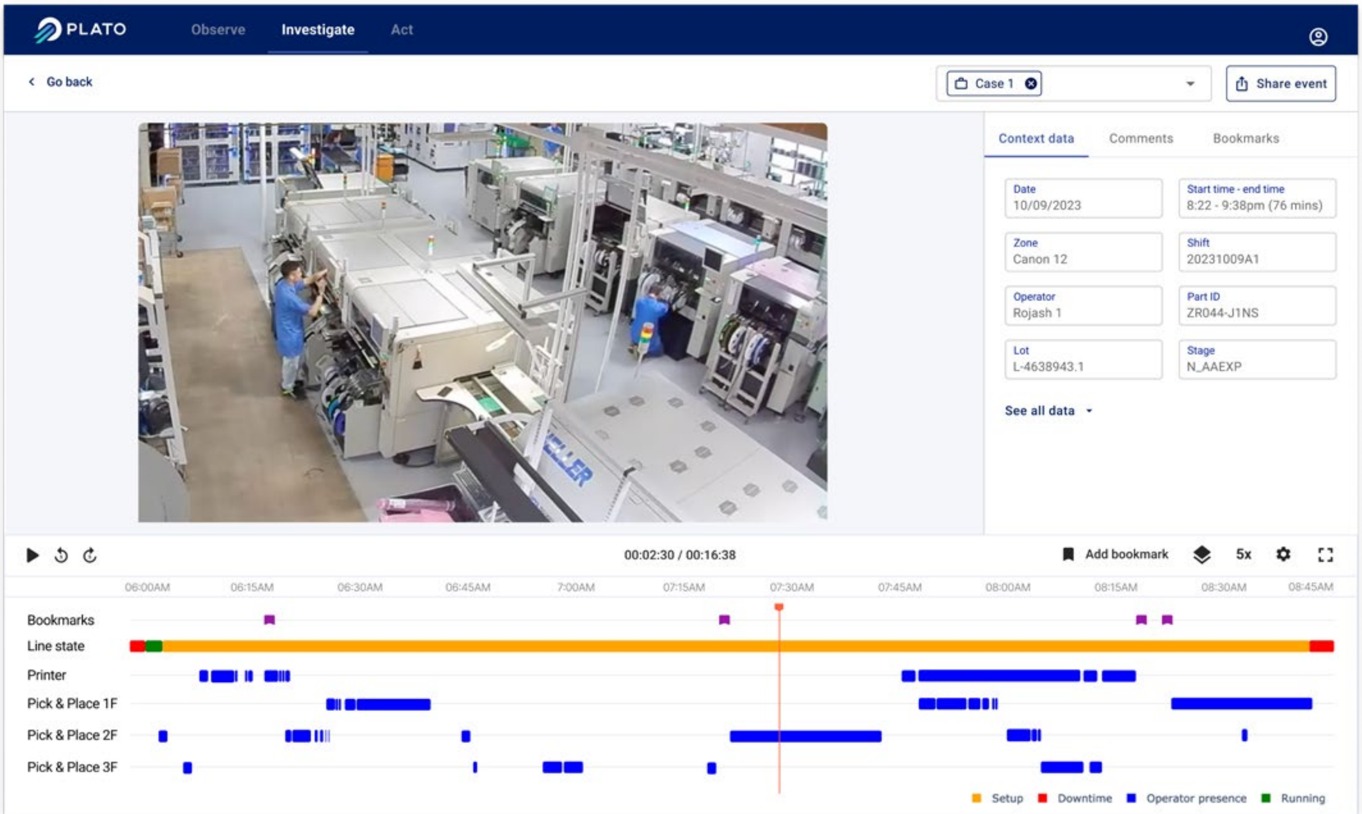
*Vora:* To Luis's point, we sometimes have difficulty convincing our customers to make changes. I might say, "Why is this so expensive? Make this change, and I can reduce your price." But he doesn't until he sees his product on the line. Instead, I can show him a video and show him how long it takes compared to this other board, which was designed correctly. I can show why it moves so much more efficiently through our system. I think there is a case to be made.

*Holden:* The main impact is wherever operator behaviors matter. There are other processes, like material prep. If something is slow, it's usually because the material wasn't ready, or it was prepped the wrong way. It's very rare that it's because something broke somewhere.

There's another video of a downtime event that's just over an hour long. In it, you can see this yellow stock light blinking. There's nobody there; somebody should go check it. Then, you can see when they responded to the light. They're arriving but they don't take any action to respond to the light. If they see it, why are they just waiting? Turns out this operator has run out of material. She's ordered it from the warehouse and is waiting for the warehouse to bring it over. In the video, we see the delivery. Then there's some chatting and now she's doing the change. There was an hour of time spent here.

Because of the video, it only took us five minutes to figure out what happened, and we didn't have to watch the whole hour. We can also see that it wasn't necessarily the operator's fault. The question is really, "Why wasn't it ready?"

***Even in our focused manufacturing space, AI providers are churning. A couple have radically pivoted, and others are gone. Where do you see this going?***




*Holden:* One big differentiator is where you sit in the stack; there's a bullwhip effect. For example, the fabric of jeans doesn't change much, but the way the jeans look changes every month. We're so deep down in providing this foundational technology. That won't change; it's not a fashion thing.

AI adoption will move ahead slower than we would like, but it's marching forward regardless of market conditions and whatever flavor of the month has the investors interested. The basics of aggregating, manipulating, and presenting this data as basic statistics and working with operators will stay fairly stable.

> **AI adoption will move ahead slower than we would like, but it's marching forward...**

We hope to become just part of the platform where other players will come along and use our data, just as they use machine data, to create cool solutions on top of our foundation.

*Arbabian:* One foundational component is access to clean, labeled, proprietary data that differentiates companies. That hasn't changed. The second component is the compute power. The computer and the data are the foundations upon which everything is built. With all the big players in AI, the models are converging. The only divergence is regarding who has a new data source. Google will come up with a new model because they have access to your Gmail data that doesn't exist for anybody else. At Plato, once we brought the spatial data into the mix, applying AI to event detection has been transformative because it's a new data source. You're seeing the whole picture for the first time.

***Fascinating conversation. Thank you all.***

*Arbabian:* Thank you, Nolan. We'll keep you posted as things progress. **SMT007**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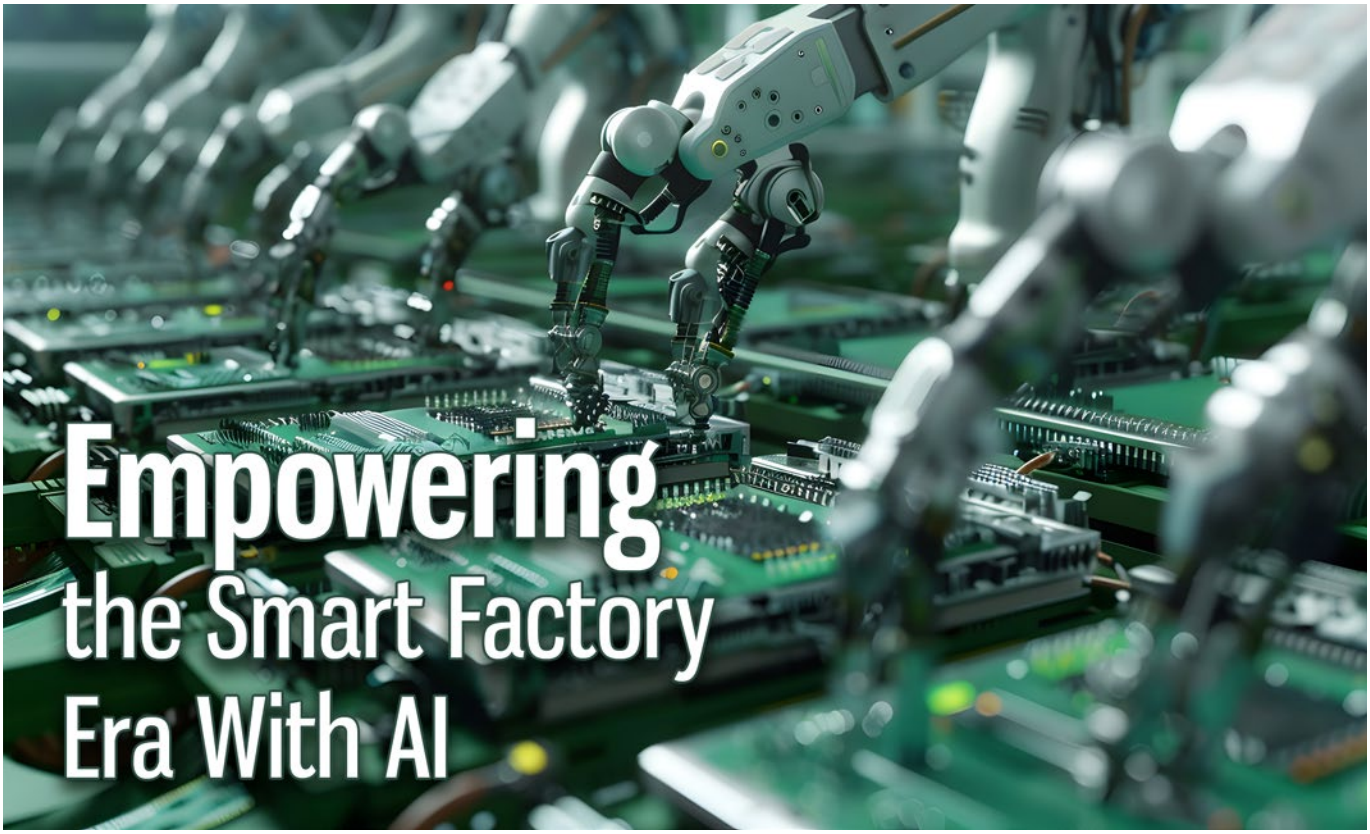



# Empowering the Smart Factory Era With AI

**Feature Article by Joel Scutchfield and Brent Fischthal**
KOH YOUNG INC.

The paradigm of operational excellence has emerged as a key focus area in today's rapidly evolving manufacturing landscape. Realizing this shift, manufacturers are increasingly exploring ways to optimize operations to meet the challenges of the "new normal." The manufacturing sector's challenges, particularly regarding personnel and talent, are not going away. Thus, the conversation has shifted toward addressing these challenges through automation, artificial intelligence (AI), and collaboration with suppliers.

The Smart factory marks a paradigm shift in manufacturing, eliminating inefficient and error-prone practices. Powered by advanced technologies such as IIoT (Industrial Internet of Things), AI, and machine learning (ML), it relies on cooperation between advanced inspection systems and process control tools to ensure quality at every step of production.

There are many moving parts here, but the potential for gain is immense. The overall results can be quite impressive when you start looking at the organization from the top down and finding places where improvements can be made. For example, manufacturers can become much more profitable with their existing headcount by implementing these emerging AI-powered technologies.

For example, previously, the focus was on how to get more out of a supplier by squeezing them as much as possible. However, the paradigm is shifting toward a more collaborative approach. Now, manufacturers are seeking ways to reduce their supplier base and solidify relationships with strong suppliers who share their vision. The conversation then naturally progresses from supplier to partner.

Matric Group, a world-class EMS provider, clearly embraces this new normal, and Vice

President of Operation Patrick Stimpert is driving this manufacturing revolution. "We don't go into vendor relationships without it being a partnership," Patrick says. "I will not do it. If you're asking me to take a machine and go out on a limb for you, you're going to be right there with me. We're going to fail together, or we're going to succeed together. It's been nice to see Koh Young and Panasonic Connect work together. It's good when I pull both parties into a room and say, 'Hey, this is our next step, and I need you guys onboard,' and for them to say, 'Yes, we're going to do it.'"

In the Smart factory ecosystem, data fuels continuous improvement. Inspection-based process control tools generate valuable data, offering insights into trends, patterns, and potential improvements. Manufacturers can use this data to identify bottlenecks, fine-tune processes, and predict maintenance needs while maintaining the highest quality standards. From automated programming and smart review that help operators to conduct autonomous process optimization for printers and mounters to assist engineers, Koh Young is applying AI to help inspection equipment mitigate talent shortages and improve operational efficiency.

As this evolution continues, it changes the approach to product design and solution offerings and, more importantly, it strengthens the relationship with the manufacturer. One case study comes from Holger Groksch, head of manufacturing in the SMT department at SICK AG. Groksch and his team are focused on performance, and as Holger says, "It's not just controlling quality, it is about making the quality better at the machine level."

He continues, "Koh Young provided very high performance and support to help us install the Koh Young Process Optimizer (KPO) Printer." When SICK first installed the solder paste inspection (SPI) machine, they reduced its failed parts at the end of the line by half. This was a dramatic reduction and process improvement. Now, SICK has installed the KPO Printer, and Holger believes this could once again halve the number of failing parts at the end of the line. These real yield improvements are both significant and achievable using the combination of AI-powered software and hardware solutions.

As we witness this era of evolution and digital transformation, we are enthusiastic about the potential for game-changing operational improvements by:

- Making our equipment and software even more user-friendly, reducing the need for extensive training and the potential for errors, and expediting programming and NPI.
- Enhancing the networking capabilities of our machines, enabling small teams of experts to manage multiple machines remotely if necessary.
- Ensuring that the highly accurate and valuable data collected can be used to enhance processes, going beyond a simple go/no-go decision on a board.
- Extending our focus beyond the machine and driving improvements throughout our entire product portfolio.
- Aggregating all collected data to provide real intelligence with actionable insights that enhance line, factory, and business performance.
- Continuously bringing technological innovations to market.
- Most importantly, we listen to our customers and implement the improvements they require.

The integration of AI in electronics manufacturing emerges as a pivotal solution. By embracing AI, manufacturers can streamline operations, enhance efficiency, and maintain high-quality standards, all while reducing the dependency on a large workforce. AI has proven to be instrumental in mitigating talent shortages through autonomous decision-making.

The application of AI-powered technologies, such as automated programming, smart review, and autonomous process optimization, mitigates talent shortages and significantly improves operational efficiency. By leveraging AI, companies are transforming the industry, paving the way for smarter, more efficient, and more reliable manufacturing processes. As the industry continues to evolve, the integration of AI in electronics manufacturing will play an increasingly critical role, ushering in a new era of innovation and productivity.

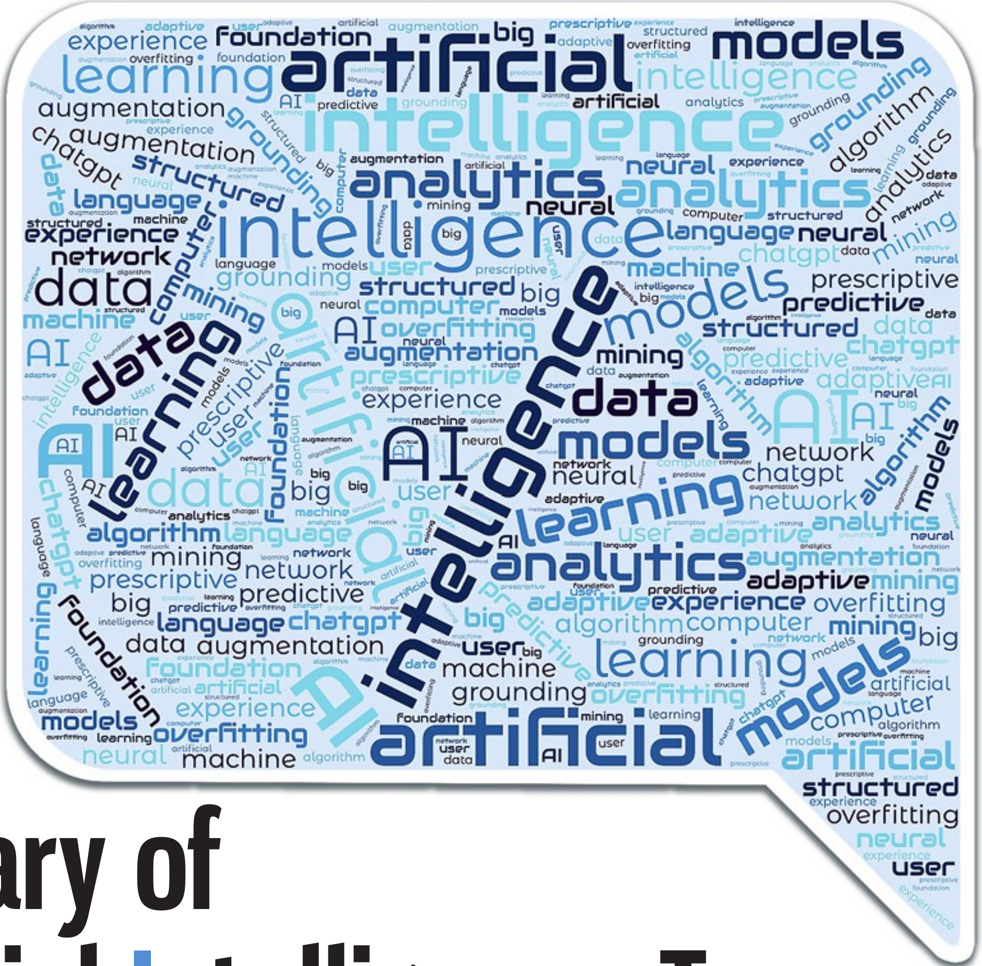
We are excited for things to come as the industry further adopts AI. A transformation from an inspection machine supplier to a smart factory solution partner has been underway for years at Koh Young Technology. It was able to pave the way from equipment supplier to solution provider with measurement-based inspection data collected by its solder paste inspection (SPI) and automated optical inspection (AOI) machines. Many successful implementations have been made to leverage our AI engines and technologies developed at our research labs to improve manufacturing processes. **SMT007**

**Joel Scutchfield** is general manager of SMT business operations and director of sales at Koh Young Inc.

**Brent Fischthal** is head of global marketing at Koh Young Inc.

## Real Time with... IPC APEX EXPO 2024 • Joel Scutchfield, Koh Young


**Operational Excellence and Smart Factory Initiatives:** Koh Young general manager, Joel Scutchfield, defines operational excellence and operational efficiency and touches on automation, AI, and collaboration as solutions to resource limitations.



# Glossary of Artificial Intelligence Terms

Discussing artificial intelligence relies on a number of specific terms and concepts. This glossary, collated from numerous sources, captures some of the terms most likely to appear in AI-related discussions in the EMS sector.

**Artificial intelligence (AI):** AI is a branch of computer science. AI systems use hardware, algorithms, and data to create “intelligence” to do things like make decisions, discover patterns, and perform some sort of action. AI is a general term; more specific terms are also used in the field of AI. The two of the primary ways in which AI systems are built: 1) through the use of rules provided by a human (rule-based systems); or 2) with machine learning algorithms. Many newer AI systems use machine learning (see definition of Machine learning).

**Artificial general intelligence (AGI):** Artificial general intelligence has not yet been realized and would be when an AI system can learn, understand, and solve any problem that a human can.

**Artificial narrow intelligence (ANI):** AI currently can solve narrow problems. For example, a smartphone can use facial recognition to identify photos of an individual in the Photos app, but that same system cannot identify sounds.

**Adaptive learning:** Subject or course material is adjusted based on the performance of the learner. The difficulty of the material, the pacing, the sequence, the type of help given, or other features can be adapted based on the learner’s prior responses.

**Algorithm:** Algorithms are the "brains" of an AI system, and what determines decisions. In other words, algorithms are the rules for what actions a computer takes. The AI system is based on algorithms. Machine learning algorithms can discover their own rules (see Adaptive learning and Machine learning for more) or be rule-based, where human programmers give the rules.

**Big data:** Refers to the large data sets that can be studied to reveal patterns and trends to support business decisions. It's called "big" data because organizations can now gather massive amounts of complex data using data collection tools and systems. Big data can be collected very quickly and stored in a variety of formats.

**Black boxes:** Many machine learning algorithms are "black boxes," meaning that we don't have an understanding of how a system is using features of the data when making decisions (generally, we do know what features are used but not how they are used). There are currently two primary ways to pull back the curtain on the black boxes of AI algorithms: interpretable machine learning and explainable machine learning (see definitions).

**Chat-based generative pre-trained transformer (ChatGPT) models:** A system built with a neural network transformer style of AI model, these systems work well with natural language processing tasks (see definitions for Neural networks and Natural language processing). In this case, the model: 1) can generate responses to questions (Generative); 2) was trained in advance on a large amount of the written material available on the web (Pre-trained); 3) and can process sentences differently than other types of models (Transformer).

**Computer vision:** Computer vision is a set of computational challenges concerned with teaching computers how to understand visual information, including objects, pictures, scenes, and movement (including video). Computer vision (often thought of as an AI problem) uses techniques like machine learning to achieve this goal.

**Data mining:** Data mining is the process of sorting through large data sets to identify patterns that can improve models or solve problems.

**Deep learning:** Deep learning models are a subset of neural networks. With multiple hidden layers, deep learning algorithms are potentially able to recognize more subtle and complex patterns. Like neural networks, deep learning algorithms involve interconnected nodes where weights are adjusted, but as mentioned earlier, there are more layers and more calculations that can make adjustments to the output to determine each decision. The decisions made by deep learning models are often very difficult to interpret as there are many hidden layers doing different calculations that are not easily translatable into English rules (or another human-readable language).

**Explainable machine learning (XML) or explainable AI (XAI):** Researchers have developed a set of processes and methods that allow humans to better understand the results and outputs of machine learning algorithms. This helps developers of AI-mediated tools understand how the systems they design work and can help them ensure that they work correctly and are meeting requirements and regulatory standards.

**Foundation models:** Foundation models represent a large amount of data that can be used as a foundation for developing other models. For example, generative AI systems use large language foundation models. Foundation models can speed up the development of new systems, but there is controversy about issues of trustworthiness and bias in the data.

**Generative AI (GenAI):** A type of machine learning that generates content, currently such as text, images, music, videos, and can create 3D models from 2D input. See ChatGPT

definition; ChatGPT is a specific example of GenAI.

**Grounding:** Grounding is the process of anchoring artificial intelligence (AI) systems in real-world experiences, knowledge, or data. The objective is to improve the AI's understanding of the world so it can effectively interpret and respond to user inputs, queries, and tasks. Grounding helps AI systems become more context-aware, allowing them to provide better, more relatable, and relevant responses or actions.

**Intelligence augmentation (IA):** Augmenting makes it possible to do the same task with less effort. This might include letting a human engineer or operator choose to automate redundant tasks so they can do more things that only a human can do.

**Large language models (LLMs):** Large language models form the foundation for generative AI (GenAI) systems. LLMs are artificial neural networks. At a very basic level, in their training, the LLM detects statistical relationships between how likely a word is to appear following the previous. As they answer questions or write text, LLMs use the model of the likelihood of a word occurring to predict the next word to generate. LLMs are a type of foundation model, which are pre-trained with deep learning techniques on massive data sets of text documents. Examples of GenAI systems currently available include chatbots and tools, such as OpenAI's GPTs, Meta's LLaMA, xAI's Grok, and Google's PaLM and Gemini.

**Machine learning (ML):** Machine learning algorithms will identify rules and patterns in the data without a human specifying those rules and patterns. These algorithms build a model for decision-making as they go through data. Algorithms used in machine learning require massive amounts of data to be trained to make decisions. In most cases the algorithm is learning an association (when X occurs, it usually means Y) from training data that is from the past. Two, since the data is historical, it may contain biases and assumptions that we do not want to perpetuate.

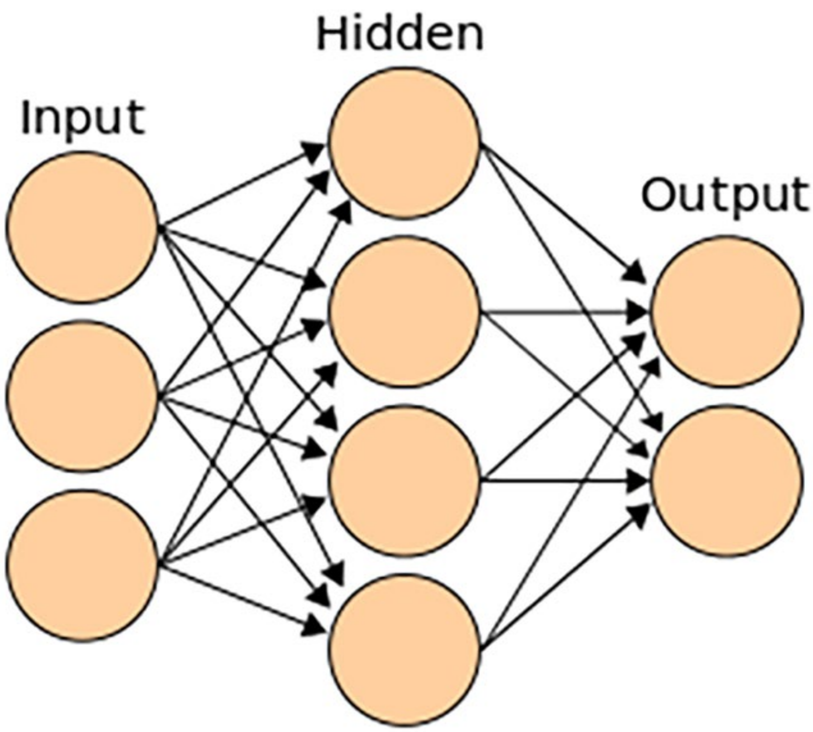



Figure 1: Illustration of the topology of a generic artificial neural network. This file is licensed under the Creative Commons Attribution—ShareAlike 3.0 Unported license.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**Natural language processing (NLP):** NLP uses an understanding of the structure, grammar, and meaning in words to help computers "understand and comprehend" language. NLP requires a large corpus of text (usually half a million words). NLP technologies help in many situations that include scanning texts to turn them into editable text (optical character recognition), speech to text, voice-based computer help systems, grammatical correction (like auto-correct or Grammarly), summarizing texts, and others.

**Neural networks (NN):** Neural networks, also called artificial neural networks (ANN) are a subset of ML algorithms. They were inspired by the interconnections of neurons and synapses in the human brain. In a neural network, after data enter the first layer, the data go through a hidden layer of nodes where calculations that adjust the strength of connections in the nodes are performed and then go to an output layer.

**Overfitting:** Overfitting is a problem that occurs when a model is too complex, performing well on the training data but poorly on unseen data. Example: A model that has memorized the training data instead of learning general patterns and thus performs poorly on new data.

**Predictive analytics:** Predictive analytics is a type of analytics that uses technology to predict what will happen in a specific time frame based on historical data and patterns.

**Prescriptive analytics:** Prescriptive analytics is a type of analytics that uses technology to analyze data for factors such as possible situations and scenarios, past and present performance, and other resources to help organizations make better strategic decisions.

**Structured data:** Structured data is data that is defined and searchable. This includes data like phone numbers, dates, and product SKUs.

**Training data:** This is the data used to train the algorithm or machine learning model. This data has been generated by humans in their work (or other contexts) in the past. While it sounds simple, training data selection is important because the wrong data can perpetuate systemic biases. If you are training a system to help with hiring people, and you use data from existing companies, you will be training that system to hire the kind of people who are already there. Algorithms take on the biases that are already inside the data.

**Transformer models:** Used in GenAI (the T in GPT stands for Transformer), transformer models are a type of language model. They are neural networks and are also classified as deep learning models. They allow AI systems to determine and focus on important parts of the input and output using a self-attention mechanism to help.

**Unstructured data:** Unstructured data is data that is undefined and difficult to search. This includes audio, photo, and video content. Most of the data in the world is unstructured.

**User experience design/user interface design (UX/UI):** User-experience/user-interface design refers to users' overall experience with a product. These approaches are not limited to AI work. Product designers implement UX/UI approaches to design and understand the experiences their users have with their technologies. **SMT007**

**Resources**


- *Glossary of Artificial Intelligence Terms for Educators*, by Pati Ruiz and Judi Fusco, CIRCLS.
- "Artificial Intelligence (AI) Terms: A to Z Glossary," Coursera.org.
- "AI Terms Explained," Moveworks.com.




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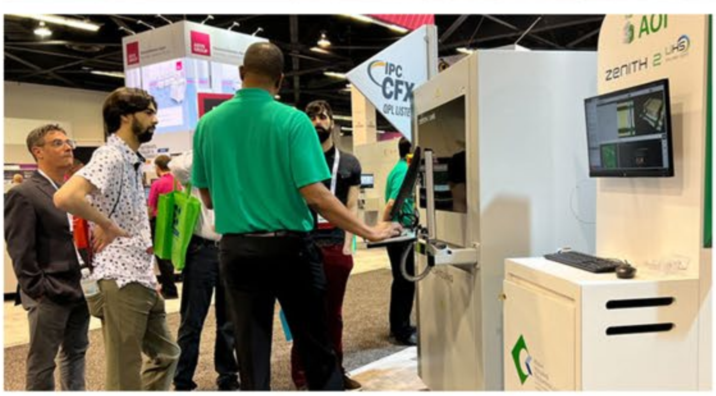



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Enterprise Systems
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Performance Analytics Platform
Designed by Data Experts
We are DÜRR
iTAC


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Reinigung
Čištění
Очистка
清洗
Vệ sinh
KYZEN
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3D X-Ray Microscopy
Xradia Versa


# Chiplet Architecture for AI Will Create New Demands for Assembly

Interview by Nolan Johnson
I-CONNECT007

As we examine the entire AI ecosystem more closely, it becomes clear that AI algorithms are intensely hungry for compute power. This demand is accelerating beyond the customary rate predicted by Moore's Law, just as traditional semiconductor fabrication methods are failing to maintain Moore's Law. It's a real dilemma.

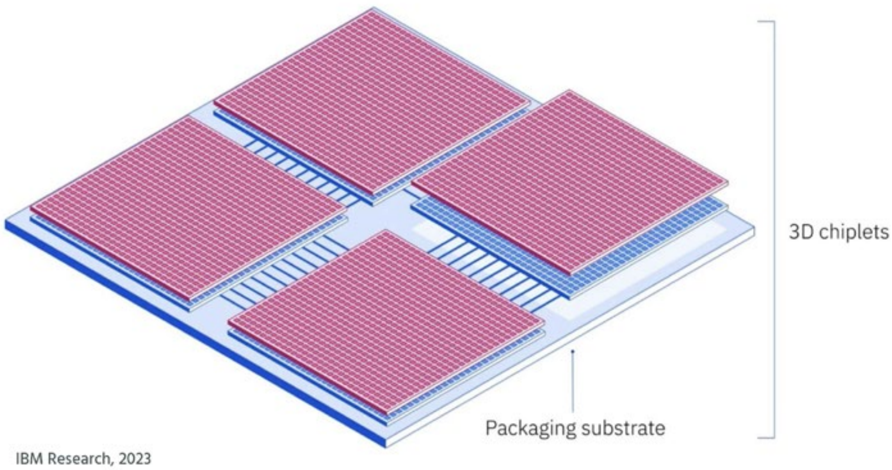
Those watching AI say that advanced packaging techniques, which have been in R&D development for some time, see AI as their killer app. AI is needed to propel these cutting-edge packages into the mainstream.

At a 2022 symposium on advanced packaging in Washington, D.C., I met Dale McHerron, a researcher on AI compute hardware. As we discussed IBM's work in this area, Dale introduced me to Arvind Kumar, a principal research scientist and manager in AI hardware and chiplet architectures.

I reached out to Arvind to discuss his keynote presentation at the recent IMAPS conference where he discussed the AI hardware ecosystem and role of advanced packaging. Those in the assembly services industry know that any new packages will require accurate and reliable placement on the EMS manufacturing floor. Arvind shares his perspective and some predictions based on his research. It is also clear there is still much coordination and communication needed to make this work.

***Nolan Johnson: What is chiplet architecture and why does it matter? How is advanced packaging moving forward?***

*Arvind Kumar:* Chiplet architectures, which allow the partitioning of complex designs into tightly co-packaged sub-elements, are influencing the way we think about packaging. We




***Chiplets allow cutting-edge manufacturing techniques to be used only for the pieces that really matter, as opposed to the entire monolithic chip.***

That's right. In fact, that is another very strong motivation for the chiplet paradigm. It allows the leading-edge nodes to focus on the logic and the compute parts, for example. Many of the other parts of a system-on-chip (SoC) don't scale in the same way, so there's no real incentive to tape out those portions in the leading node; they may actually perform better at an older node. In general, we call this breakup of a monolithic chip into chiplet components "disaggregation."

would like to put more chips into a single package and have them talk to each other with high bandwidth, low latency, and low-energy interconnects. That goal is driving emerging packaging technologies to higher interconnect densities, more routing layers, and larger body sizes.

***Ever since semiconductors were developed, we've used the thought pattern of making bigger monolithic chips. Why the change?***

For a long time, the fundamental idea was that we could get more performance out of larger dies at the most advanced technology node. Fabricating all parts of a chip at the most advanced node is getting very expensive and has major yield challenges, so this drives us toward smaller die sizes. Additionally, we can partition the chip such that some parts that don't scale well can remain in an older technology node. That's a very natural fit for chiplet architecture.

***Aren't we starting to use a building block approach?***

Yes, and that's another great advantage in a few different ways. Starting from one product, we can use this building block approach to make different part numbers and define the right-sized chip for a particular application. It also opens the gateway to creating heterogeneous chiplet architectures for targeted applications for which creating an ASIC would be simply too expensive.

***One example might be that you need to include a USB I/O interface; that subsystem can be added through a standard chiplet part using an older fab capability.***

Exactly. We're currently looking at how we can optimize this disaggregation, or "chiplet factoring," for an AI chip application. We're working on questions like, "How would we break up the fundamental components of an SoC into chiplets, and what is the optimal technology node for each of these pieces?"

***Your recent presentation at the IMAPS conference makes the point that AI and ML are driving this rapid pace of hardware development. Tell me more about that.***

On the one hand, the compute and memory demands of AI are growing exponentially as AI has become a pervasive workload. On the other hand, we've encountered the stalling of traditional scaling; we can't get as much compute power growth through scaling as we could count on in the past. Chiplets are a way to meet these very high demands.

To be very specific, we looked at a few different ways in which AI systems could benefit from chiplet architectures. One example is in the high-performance AI space—one that IBM is going after for its traditional enterprise computing customers. How can we get more compute power and memory into a smaller volume through chiplet architectures? Another example is in the edge space to see whether we could use these types of chiplet architectures to realize new applications.

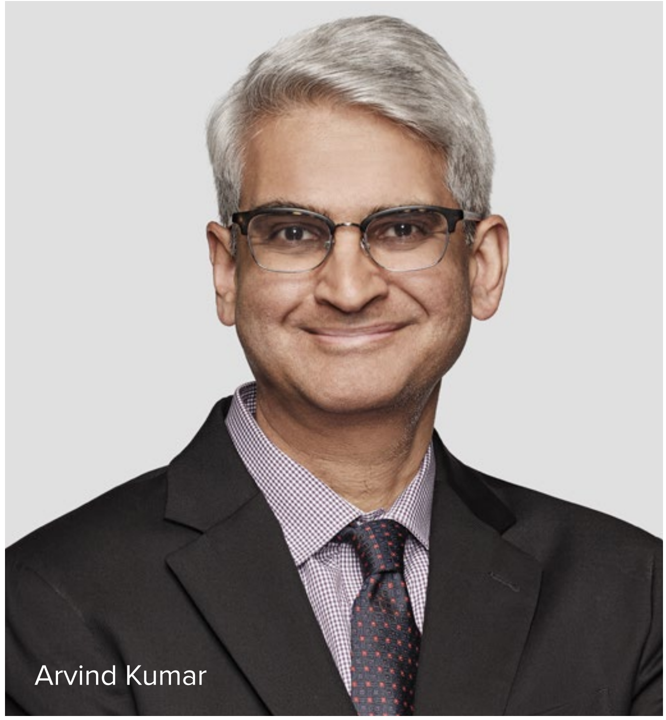
***What kinds of new applications are you anticipating?***

In my presentation, I gave an example of an application in the millimeter wave space that leverages the AI chiplets we are developing, combined with other potential chiplets. This approach could be used to fully realize the promise of millimeter wave systems for commercial and DoD communications and sensing applications. The automotive space is also ripe for using chiplets to create modular systems, and that could really benefit from the addition of AI acceleration chiplets.

***Semiconductors have embraced Industry 4.0 for some time now, and PCBA houses seem to be following the lead of semiconductors in embracing this technology. Will this sort of capability advance their ability to implement a meaningful factory of the future on their manufacturing floor?***

Fabrication processes have become so complex that having a lot more metrology capability at each step in the factory would be a very high value-add. AI adds a powerful tool for real-time monitoring of defects on the factory floor.

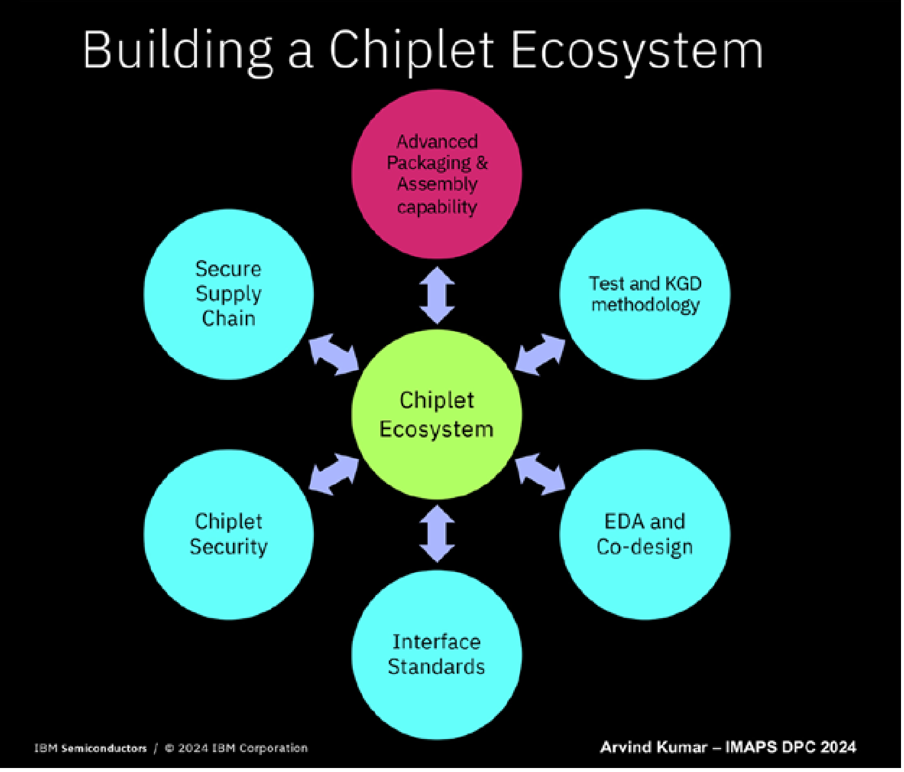
***Likewise for assembly, of course. One of the changes underway, thanks to advanced packaging, is that the physical packaging industry is rapidly changing to handle the growing amount of IO and compute power that's involved there. One example is that passive components are driving down sizes into the very small realm, while, simultaneously, active computing components in advanced packages are migrating toward 10,000-plus ball grids and more on a package that measures 100 millimeters on a side.***


Arvind Kumar

***Meanwhile, the assembly houses have to handle both of those trends with 100% accuracy. What's in the future for the larger packages?***

Packages will get larger when we look at these types of chiplet architectures because, from a design point of view, it is very fruitful if we can put more chiplets into a single package. Naturally, that significantly affects many of these constraints, particularly those tied to mechanical and warpage issues, and certainly that must be accounted for.

Regarding actives and passives, it is becoming more helpful to integrate passives closer to the active elements for voltage regulation closer to the point-of-load. Second, the merging of components at the package and board levels is reducing the number of layers in the hierarchy.




complex system. It involves a lot of unique challenges that are not present when designing a monolithic chip with a single chip module. So, these various stakeholders must work together to form a unified flow to realize these kinds of chiplet architectures.

***At the assembly step, when they're building up the finished product, is that where all those decisions come together?***

That's right. A number of standards and test procedures would need to be in place at that level to ensure a good final product.

***Are you suggesting that passives could be included inside the advanced package along with the chiplet architecture?***

Absolutely. This is already happening, and it's a big benefit for the high-power demands, like voltage regulation and controlling droop. Integrating passives in these advanced packages offers a significant benefit.

***There's a historical push-and-pull cycle in printed circuit boards: You get all this complexity on the boards from cutting-edge chipsets, then those chipsets move on to a single chip, and the board simplifies.***

That's right. It's all related to becoming more compact and getting more components into a smaller volume.

***Five years from now, how will the overall supply chain—your ecosystem—look different in response to these new chiplet architectures?***

The chiplet ecosystem will evolve and mature. That means these elements will be better interconnected. Right now, there are a lot of very independent players. But as chiplet architectures gain momentum, these layers will become more integrated. It's important to understand that a chiplet architecture is a very

***Are you involved in the standards definition processes for this area?***

I'm personally tracking it, while others in IBM and our broader team are heavily involved.

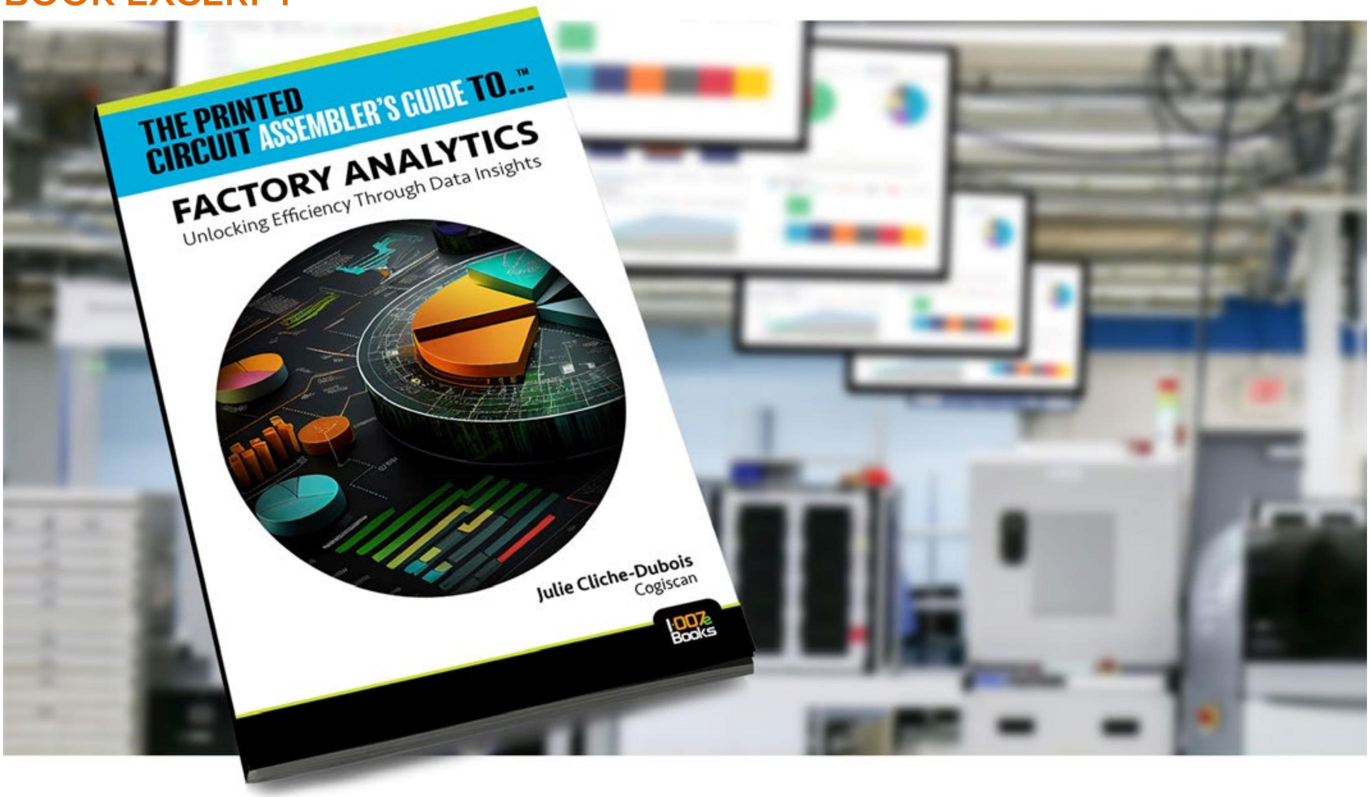
***Where are the standards being developed that you're watching?***

There are a number of different and disparate organizations right now. Interface standards are being driven by consortia, such as the UCIe (Universal Chiplet Interconnect Express); packaging standards are being discussed in different forums. Security is a very ripe area, but those standards are only beginning because chiplets from heterogeneous sources present new security and supply chain challenges. Known good die and test methodologies require standards; IEEE has significant activity in this area. The EDA vendors often have tools, but they aren't interoperable; that's another area where standards could be beneficial to enable the best tool from a particular vendor to be combined with other tools that do a different function.

***Arvind, thank you so much.***

Thank you. **SMT007**

BOOK EXCERPT




# Chapter 5: Measuring and Monitoring Global Factory Health

Editor's Note: The following is an excerpt from *The Printed Circuit Assembler's Guide to...™ Factory Analytics—Unlocking Efficiency Through Data Insights*

Previous chapters were mainly focused on analytics at the operational level for the different roles that are deeply involved in the day-to-day manufacturing process. While these detailed analytics are highly important to understand in-depth what is happening on the factory floor, they do not provide a quick and holistic overview of factory productivity. This snapshot of floor health is essential in terms of flagging investigation and for planning purposes. We will look at important analytics that provide a real outlook on factory performance.

Electronics manufacturers today are eager to incorporate analytics into their operation because these tools are intentionally designed to drive continuous improvements and thus leverage a better ROI. Offering a panoramic view of assembly and manufacturing data, line and factory level analytics transcend individual instances, allowing insights to be gleaned from a holistic perspective to drive both decisions and action. This collective wisdom can be translated across a spectrum of product types, fostering overall enhancement rather than addressing instances in isolation. In this way, analytics are a catalyst for manufacturers looking to continuously improve.

## Overall Equipment Effectiveness (OEE)

Important analytics that provide a realistic outlook on "in the now" factory health can be distilled down as OEE. The OEE score is the industry standard that represents the ratio of fully productive time to planned production time. It takes into account the following three factors:

OEE = Availability x Performance x Quality

While the absolute value of OEE is important, the focus should be on improving that

value. Looking at trends over time and having a target defined as a main objective is a good start. Generally speaking, an OEE of 85% would be the ideal, but before setting a target, the current value should be both measured and known. Setting unrealistic targets is totally demotivating and will not help drive tangible improvements.

When talking about OEE at the line level, there are three options:

## 1. The line as "one unit":

- OEE is measured for each machine and calculated as an average.
- The advantage here is that every machine is represented and will thus have an impact on the OEE. It's then easier to assess the efficiency of each machine and to see when and where improvement is needed.
- If the data is already collected and normalized, it's no extra effort to include it in the calculation.
- Since all machines do not have the same impact on the production line, this approach can certainly diffuse important information. As an example, if one or two machines are overperforming on the line, it can give a false impression that the entire line is performing efficiently.

## 2. The bottleneck machine as the "line reference":

- Typically, one machine on the line is slower than all the others, making it the bottleneck. As the limiting factor in overall line efficiency, it's easier to target improvement efforts on the bottleneck machine only.
- Unplanned downtime at the already bottlenecked machine will have a significant impact on all downstream operations on the line. However, by focusing only on the bottleneck, it is possible that other machine constraints will be missed entirely.
- Over-optimizing the bottleneck machine can have consequences on downstream processes.

## 3. The fastest machine as the "line reference":

- This method is definitely used as a motivator for improvement as it provides a framework for performance evaluation.
- But it can also be demotivating when the benchmark is not applicable to all other machines. Since all machines have different capabilities and functions, the expectations for improvement need to be properly balanced. For example, if the focus is solely put on speed improvements, other important factors would be neglected, such as quality. Prioritizing speed over quality can result in an increase in defects—increasing the overall scrap rate and wasting both materials and time.

While improving a single machine's performance (like the bottleneck machine) can be a quick band-aid to inflating metrics, it's smarter to take a wider perspective on the entire process. That's why including every machine on the production line in OEE calculations is the way to go, as it will provide realistic insights and data-driven actions. SMT007

Continue reading...

# MilAero007 Highlights

## Real Time with... IPC APEX EXPO 2024: IPC Government Relations Holds Lawmakers Accountable ▶

The IPC Government Relations team is constantly educating Congress and the executive branch about the importance of a robust domestic electronics manufacturing industry. As Richard Cappetto explains, the GR team is focused on proactive strategies, workforce policies, and sustainability, as well as the significance of apprenticeship programs, President Biden's executive order, and employer incentives.

## NASA Selects First Lunar Instruments for Artemis Astronaut Deployment ▶

NASA has chosen the first science instruments designed for astronauts to deploy on the surface of the Moon during Artemis III. Once installed near the lunar South Pole, the three instruments will collect valuable scientific data about the lunar environment, the lunar interior, and how to sustain a long-duration human presence on the Moon, which will help prepare NASA to send astronauts to Mars.

## Northrop Grumman, EpiSci to Collaborate on Advanced Autonomy Capabilities ▶

Northrop Grumman Corporation is collaborating with EpiSci to further develop advanced, trusted autonomous tactical solutions for the United States and its allies.

## NASA, Japan Advance Space Cooperation, Sign Agreement for Lunar Rover ▶

Japan will design, develop, and operate a pressurized rover for crewed and uncrewed exploration on the Moon. NASA will provide the launch and delivery of the rover to the Moon as well as two opportunities for Japanese astronauts to travel to the lunar surface.

## UK Space Agency Awards Space Reactor Development Project to BWXT and Rolls-Royce ▶

The contract further strengthens UK and U.S. collaboration on first-of-a-kind space technology innovation as detailed under the Atlantic Declaration commitment. In an announcement made by UK Prime Minister Rishi Sunak and U.S. President Joe Biden on June 8, 2023, both countries pledged to study "opportunities for co-operation on space nuclear power and propulsion."

## Airbus to Acquire INFODAS and Strengthen its Cybersecurity Portfolio ▶

Airbus Defence and Space has entered into an agreement to acquire INFODAS, a Cologne-based, German company that provides cybersecurity and IT solutions in the public sector including for defence and critical infrastructures. The transaction is subject to the customary regulatory approvals and is expected to be finalised before the end of 2024.

## The Impact of U.S. Defense Production Act on PCB Industry ▶

This interview with David Schild, executive director of PCBAA, covers the recent passage of the Defense Production Act and its impact on the printed circuit board industry. It highlights the importance of funding, domestic production, and government support for the industry's growth.

# DESIGN TIPS #124:

## ETCH COMPENSATION

What is minimum space and trace? The answer depends on the starting copper weight.

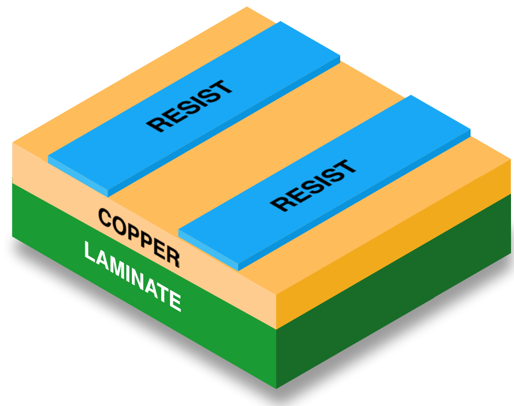
This is because we must do an etch comp on the traces in CAM to compensate for known etch loss. The space between traces after compensation will play a role in whether a board can be manufactured.

The lower the spacing width, the higher the cost. Designers don't always account for the proper starting copper weight after edge compensation.

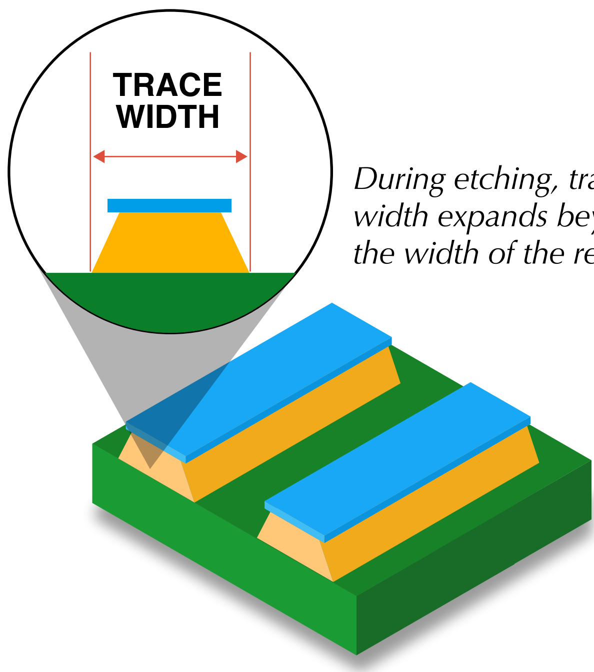
### Design tips:

- For accurate starting copper weight, **add a half mil (.0005″) to all copper features**.
- **Start with 3/8 or 1/4 oz. foil**, reducing etch comp and less likely to cause a spacing issue.
- **Boards that call for full body electrolytic gold are not comped** to avoid gold slivers occurring during the etching process.

**Before etching**




**After etching**




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

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# The Rise of Collaborative Intelligence in Manufacturing

**Feature Article by Jennifer Davis**
ARCH SYSTEMS

Every modern manufacturer grapples with a common challenge: extracting actionable insights from the ever-growing sea of operational data. The challenge of the data deluge isn't just overwhelming; it coincides with a broader shift in automation needs. While traditional forms of automation, such as robots, remain vital, the focus is expanding to encompass automating the very intelligence needed to run a factory efficiently. As a result, a new generation of tools and technologies, including artificial intelligence (AI) is beginning to transform the way factories operate.

Designed to unlock the true potential of data, AI algorithms can analyze vast amounts of data, identify hidden patterns, predict potential issues, and empower manufacturers to make data-driven decisions and optimize production processes in real-time.

However, AI's effectiveness hinges on high-quality, readily utilizable data. Manufacturers increasingly demand solutions that not only leverage AI but also seamlessly integrate with existing data infrastructure. Because of this, we're seeing an exciting trend emerge: solution providers are increasingly forging partnerships to bridge data silos and unlock the full potential of AI for their clients. This collaborative ecosystem holds the key to accelerating the path toward manufacturing excellence.

While collaboration is crucial to accelerating that path, manufacturers must first have a digi-

talization plan, one that includes a specialized approach to data as well as alignment and commitment from internal teams to the successful application of it.

## From Data to Actionable Insights: The Power of Analytics

Modern factories generate a wealth of data from machines, sensors, and software systems. But the true power lies in transforming the data into actionable insights to drive tangible improvements. This requires a seamless information flow, from rich machine data to insightful dashboards and, ultimately, actionable steps on the shop floor.

Here's a breakdown of the ideal data-to-action cycle:

1. **Rich machine data:** Capture comprehensive data from all aspects of production.
2. **Standardization and brokering:** Ensure data standardization through a central broker, allowing for seamless integration across different systems.
3. **Cloud analytics:** Leverage the power of cloud computing for advanced analytics and AI model training.
4. **Insightful dashboards:** Present insights and key performance indicators (KPIs) in a user-friendly and visually appealing manner. This allows potential bottlenecks, equipment failures, quality issues, etc., to be identified in real-time.
5. **Intelligent actions:** Bring corrective actions to the surface, complete with AI-guided playbook recommendations, and enable annotation by factory experts—allowing excellence anywhere in the organization to become excellence everywhere.

> "...AI can predict potential equipment failures before they occur."

This approach to data unlocks exceptional opportunities both immediately and in the longer run. Genealogy and rich machine data can be harnessed to automatically provide valuable insights for operational decisions in the manufacturing process. With the help of advanced algorithms and machine learning techniques, this data can be analyzed in real-time to identify trends, detect anomalies, and predict potential issues before they occur.

Examples of how advanced data techniques are unlocking proactive problem-solving:

- **Automated root cause analysis:** Traditionally, identifying the root cause of a quality issue can be a time-consuming and laborious process. AI can analyze data from various sources, including machine sensors, inspection systems, and process data, to automatically identify and diagnose problems on the factory floor. This not only reduces resolution times but also empowers manufacturers to prevent similar issues from recurring in the future.
- **Predictive maintenance:** By analyzing sensor data from machines, AI can predict potential equipment failures before they occur. This proactive approach to maintenance allows manufacturers to schedule repairs during downtime, minimizing production disruptions and maximizing equipment lifespan.

These kinds of insights allow businesses to optimize their operations, increase efficiency, and reduce downtime. Furthermore, these insights can support strategic decision-making, enabling continuous improvement and innovation in the manufacturing process. For example, with the rich data from all machines along the route, defects found in the testing process can be automatically linked back to placement machines, specific components, recipe instructions, manufacturing equipment, etc., and identified with remarkable accuracy.

With this framework in place and intelligent actions now flowing, manufacturers can sit back and enjoy the spoils of their labors, right? Not quite.

While getting to this point is a monumental accomplishment for manufacturers, the power of the data can still be extended. Collaboration between systems enhances this framework exponentially for manufacturers.

However, implementing a seamless experience for the end user means they must first overcome a few existing challenges.

## The Challenge: Integrating with Existing Systems

Modern factories rely on a complex ecosystem of data sources to function efficiently. These include SCADA, MES, ERP, PLCs, machine data, sensor data, and QMS systems, to name a few. These systems play a critical role in managing and controlling production floors for compliance and efficiency.

Even so, integrating these systems with new AI solutions presents some unique challenges:

- **Data silos:** Legacy systems often operate in silos, limiting communication channels between them. Dismantling these silos is crucial for AI solutions to access comprehensive data.
- **Standardization issues:** Data formats and communication protocols can vary significantly, creating compatibility hurdles during AI solution integration.
- **Change management:** Replacing or significantly altering established systems poses a change management challenge. Factory personnel accustomed to existing workflows require training and adaptation to embrace new AI-powered solutions.
- **Organizational readiness:** Beyond financial resources, successful AI adoption requires a commitment to change. Cultivating a data-driven culture and ensuring the right internal expertise exists within the organization is crucial.

While MES and QMS are common examples, it should be noted that the integration challenge extends to other established systems from machine vendors, software providers, etc. For these reasons and many others, comprehensive AI solutions need to seamlessly connect with this broader ecosystem for optimal effectiveness.

## The Ecosystem Advantage: Collaboration for Amplified Impact

Fortunately, a new wave of collaboration is emerging, and solution providers (including software vendors, machine vendors, and other data providers) are increasingly finding ways to partner, recognizing that doing so bridges the gap between different data points and functionalities, delivering faster and greater value to their mutual customers.

This ecosystem approach offers several advantages, some of which include:

- **Enhanced functionality:** By combining expertise, partners can create AI solutions that address a wider range of manufacturing challenges.
- **Streamlined integration:** Partnerships can lead to pre-built integrations with existing systems, minimizing implementation time and resources required.
- **Improved user experience:** A unified platform with combined functionalities delivers a more holistic view of operations for manufacturers.
- **Accelerated improvement:** With complementary systems committed to assessing the effectiveness of actions taken, operational improvements are validated, repeated, and extended more quickly.

The benefits of collaborative solutions are numerous. Let's highlight just a few use cases where electronics manufacturers can already benefit:

- **Predictive quality:** Automated data analysis and insights can reveal that a specific manufacturing process, product revision, or even a product design is showing a high defects per million opportunities (DPMO). AI-powered analytics identify the root cause and recommend actions to be implemented on the factory floor. Continuous monitoring and comparison against benchmarks assess and confirm the effectiveness of the recommended actions.
  - For example, contextualizing the rich machine data with the materials used in production allows manufacturers to isolate material-related problems, such as date codes, and enact line stops automatically, preventing further quality defects.
- **Predictive utilization:** AI empowers manufacturers with foresight into potential production shortfalls. This allows for proactive measures to minimize delays and disruptions. By analyzing various data sources like production targets, routes, schedules, and machine data, AI can identify areas for improvement and suggest targeted interventions on the shop floor. These insights lead to continuous improvement in process efficiency and cost savings from reduced downtime and resource waste.
  - For example, planned run times can be validated against genealogical and historical data. This allows manufacturers to identify golden run times, enable more accurate planning, ensure continuous product flow, and for under-utilized equipment to be transferred to alternate lines.
- **AI-driven supply chain optimization:** AI can analyze historical demand patterns, production data, and real-time market fluctuations to optimize supply chains. This can help electronics manufacturers ensure just-in-time delivery of components and prevent stock shortages, ultimately leading to smoother production processes and reduced costs.
  - For example, when a component runs out, manufacturers can contextualize attrition levels against lead times from supply chain information, enabling them to set specified attrition thresholds to reduce material shortage downtimes.

These are just a few examples, and the possibilities are constantly expanding. As technologies evolve and partnerships within the ecosystem strengthen, we can expect even more innovative AI applications to rapidly emerge.

By fostering collaboration within the manufacturing ecosystem, solution providers can empower electronics manufacturers to unlock the full potential of this transformative technology.

## The Human Element and The Road Ahead

While AI automates certain tasks, human expertise remains critical. AI excels at data analysis and pattern recognition, but human judgment and problem-solving are irreplaceable. However, AI can and should augment human workflows, freeing workers to focus on higher-level decision-making and continuous improvement initiatives specific to their organizations.

The powerful combination of human and machine intelligence is the key to achieving true manufacturing excellence.

AI systems now constantly analyze data to automatically identify and diagnose problems on the factory floor, including those previously noted for automated root cause analysis and predictive utilization, and support guided playbooks with corrective actions.


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When this proactive approach to problem-solving is combined with the understanding and expertise of factory experts and placed alongside the ability to automate actions directly in the manufacturing loop, the path to manufacturing excellence is significantly accelerated.

## Collaboration: The Key to Accelerated Manufacturing Excellence

The goal of effectively harnessing and utilizing manufacturing data for its full impact on operational improvement once seemed elusive. Now, it's a landscape of vast opportunity as data practices have evolved to unparalleled levels of sophistication and ease-of-use.

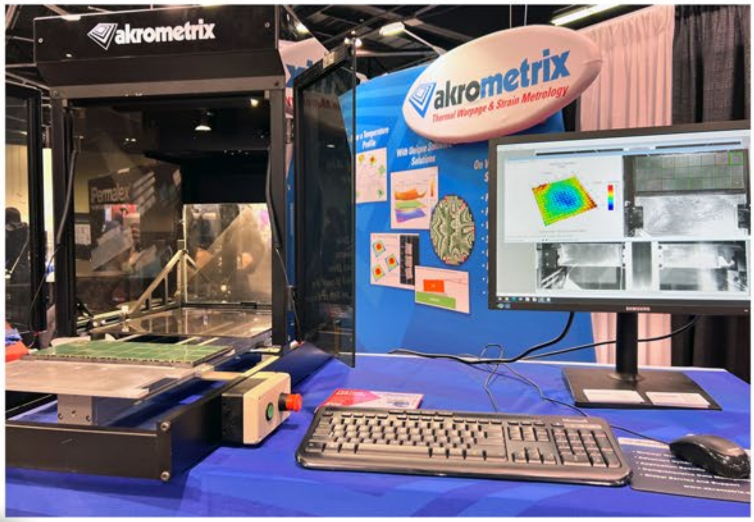
It's also increasingly important that manufacturers have the proper data frameworks in place now because the next wave, fueled by AI capabilities, is already at our door. Without an adequate data foundation, AI will be fundamentally frustrated, and organizations will fall further behind.

For those already on a strong data journey, it's an exciting time as the accelerated path to manufacturing excellence lies not just in adopting AI, but in harnessing the power of collaboration within the manufacturing ecosystem. By working together, solution providers and manufacturers are now unlocking a future of collaborative intelligence, one marked by unprecedented innovation, efficiency, and productivity. **SMT007**

**Jennifer Davis** is VP of communications and marketing at Arch Systems.

## Real Time with... IPC APEX EXPO 2024 • Tim Burke, Arch Systems


**Progress Update and Future Vision of Arch Systems:** Recently, Arch Systems announced a significant collaborative partnership with Aegis, which reflects Arch Systems' shifting focus from merely collecting data to providing actionable insights.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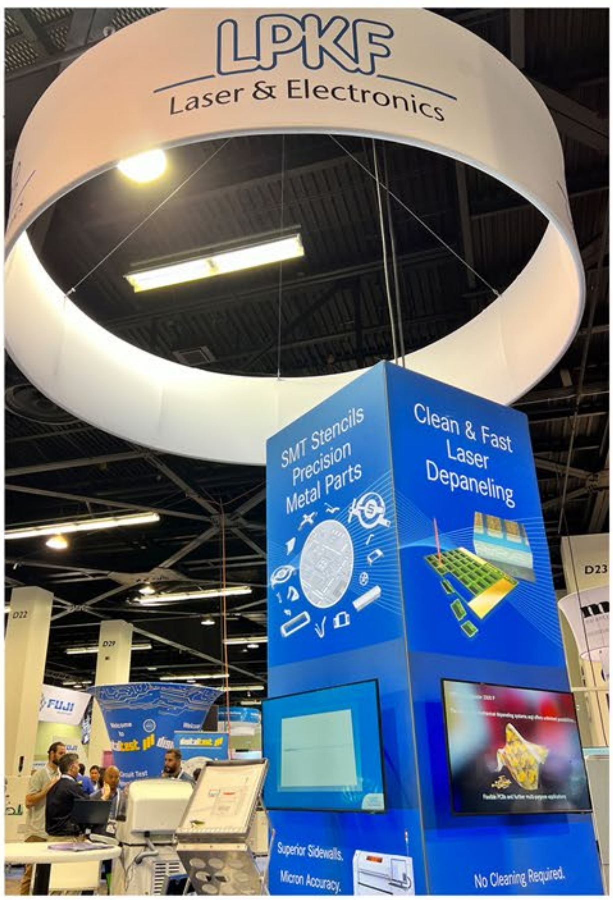
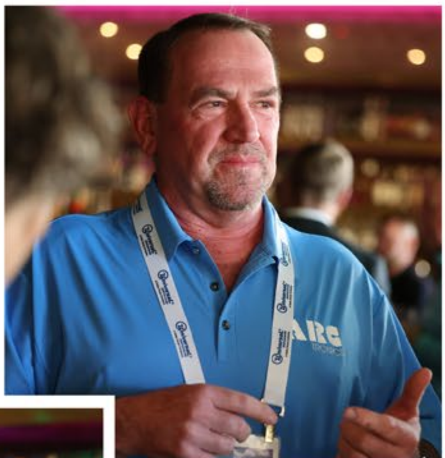




ARC

# The Transformative Role of AI and ML

## The Knowledge Base

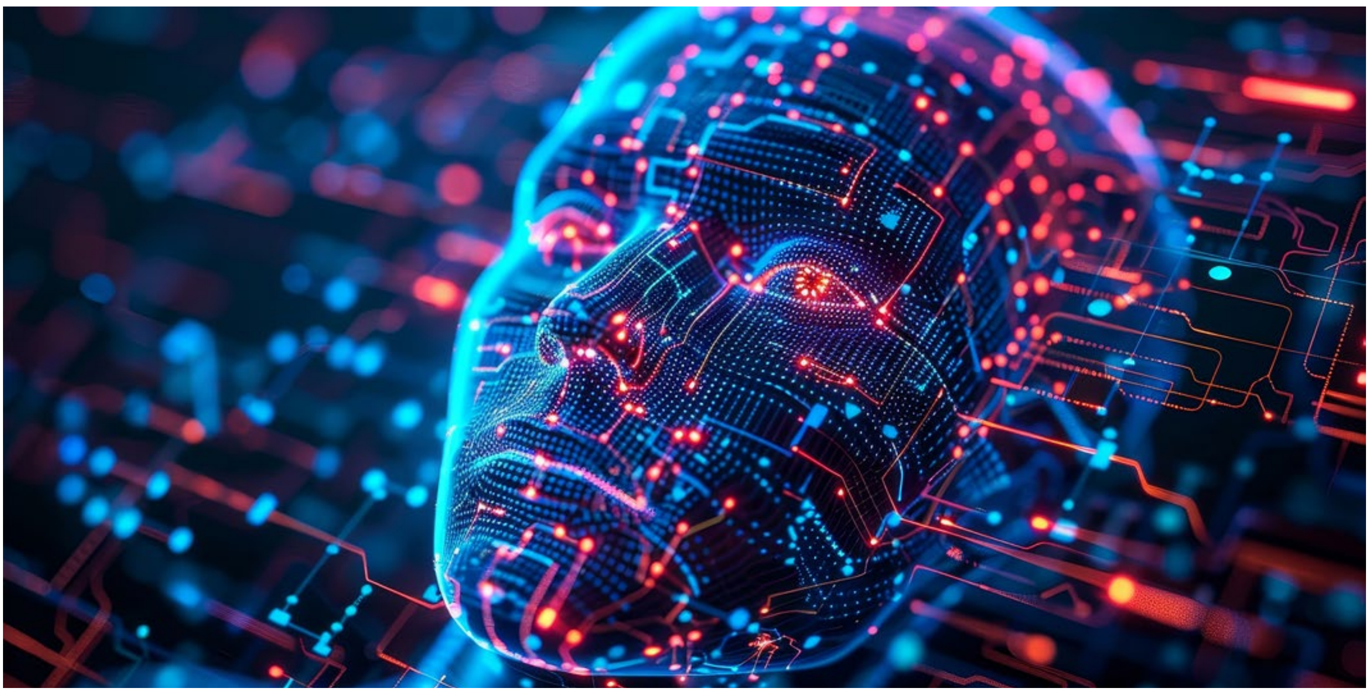
Feature Column by Mike Konrad, SMTA

Artificial intelligence (AI) and machine learning (ML) are at the vanguard of a technological revolution, redefining the parameters of manufacturing and business processes. Perhaps their most notable impact is within the electronics assembly industry, where they drive unprecedented levels of automation, enhancing efficiency and contributing to significant financial outcomes. This exploration delves into the transformative role of AI and ML, shedding light on the mechanisms of automation enhancement and the resultant financial implications.

### The Catalysts of Industry 4.0

The integration of AI and ML within the manufacturing sector marks a pivotal shift toward Industry 4.0, an era characterized by Smart manufacturing techniques that leverage digital technology for improved productivity and efficiency. These technologies are not merely tools but catalysts that initiate a profound transformation in manufacturing paradigms.

AI and ML algorithms stand out for their ability to process and analyze vast datasets, identify patterns, and make informed decisions, at best, with minimal human intervention. Their application spans various domains within manufacturing, including predictive maintenance, quality control, supply chain management, and optimized production planning, thereby enhancing operational efficiency and reducing costs.



## Automation in Electronics Assembly: A Closer Look

In the world of electronics assembly, where precision and efficiency are non-negotiable, AI-driven automation technologies are making significant inroads. Incorporating such technologies not only streamlines operations but also ensures high-quality outcomes.

**Robotic process automation (RPA):** RPA leverages AI to automate repetitive and labor-intensive tasks, such as soldering, component placement, and testing. Guided by AI, robots execute these tasks with unparalleled precision and consistency, significantly boosting productivity while minimizing the likelihood of errors.

> RPA leverages AI to automate repetitive and labor-intensive tasks...

**Automated optical inspection (AOI) systems:** These systems employ AI to enhance quality control processes, enabling the rapid and accurate inspection of components and assemblies. Their ability to detect minute defects ensures superior product quality, significantly reducing waste and the costs associated with rework.

**Predictive maintenance:** Utilizing AI to anticipate equipment malfunctions before they occur, predictive maintenance minimizes downtime and extends the equipment's operational lifespan, which translates into considerable cost savings.

**The financial implications of automation:** The adoption of AI-driven automation within the electronics assembly industry yields substantial financial benefits, including cost savings, increased revenue, and strengthened market competitiveness.

**Cost reduction:** Automation diminishes the need for manual labor, reducing the volume of human-caused mistakes, leading to significant labor cost savings. Although initial investments in AI technologies can be substantial, the long-term savings on labor and reduced errors and waste significantly outweigh these costs.

**Revenue growth:** By enhancing production capacity without compromising on quality, automation enables companies to meet increased demand more efficiently. The agility afforded by automation also allows companies to swiftly adapt to market changes, capturing new opportunities and driving revenue growth.

**Competitive advantage:** In the competitive landscape of electronics assembly, the efficiency, quality, and speed facilitated by AI-driven automation provide companies with a distinct advantage. This edge enables them to deliver superior products more swiftly and cost-effectively than competitors relying on traditional manufacturing methods.

**Navigating the challenges:** Despite the evident benefits, the integration of AI and ML into manufacturing has challenges. The high cost of initial implementation, the necessity for skilled personnel to manage and maintain AI systems, and concerns surrounding data privacy and security represent significant obstacles. Moreover, there are societal implications, such as the potential displacement of jobs due to increased automation.

To overcome these challenges, companies must commit to training programs that equip their workforce with the necessary skills to collaborate effectively with AI technologies. Additionally, adopting a strategic approach to the implementation of AI can help manage costs and maximize return on investment.

## Dispelling Misconceptions of AI and ML

As AI and ML continue to shape the future of manufacturing and electronic assembly, it's

essential to address and dispel common misconceptions surrounding these technologies. Misunderstandings can lead to unrealistic expectations, fear, and resistance to adoption, hindering progress and innovation.

### *Misconception 1: AI and ML will lead to massive job losses*

One of the most prevalent fears is that AI-driven automation will result in widespread unemployment. While it's true that certain tasks may become automated, history shows that technological advancements often lead to the creation of new jobs and industries. Rather than eliminating jobs outright, AI and ML are shifting the nature of work. Repetitive and hazardous tasks can be delegated to machines, allowing human workers to focus on more complex, creative, and strategic activities that add greater value.

### *Misconception 2: AI can fully replace human decision-making*

Another common misconception is the belief that AI and ML can completely take over human decision-making processes. While these technologies can process and analyze data at speeds unattainable by humans, they lack the ability to understand context in the way humans can. Human oversight is crucial, especially in making decisions that involve ethical considerations, nuanced judgments, and an understanding of social dynamics.

**"Human oversight is crucial, especially in making decisions that involve ethical considerations..."**

### *Misconception 3: AI and ML are only for large corporations*

Many small- to medium-sized enterprises (SMEs) assume that AI and ML technologies are beyond their reach and are reserved for large corporations with substantial resources. However, the democratization of technology has made AI and ML tools more accessible than ever. Cloud-based services and AI platforms offer scalable solutions that SMEs can leverage to improve efficiency, enhance product quality, and compete more effectively in the market.

### *Misconception 4: Implementing AI and ML is overwhelmingly complex*

The thought of integrating AI and ML into existing processes can seem daunting. The journey toward AI adoption is a gradual process that can be managed with careful planning and execution. Starting with small-scale projects, leveraging expertise, and utilizing user-friendly AI tools can simplify the transition. Education and training also play a crucial role in demystifying AI and ML, empowering teams to embrace these technologies confidently.

### *Misconception 5: AI and ML guarantee instant results and instant ROI*

Expecting immediate and significant returns upon implementing AI and ML technologies is unrealistic. Like any strategic investment, the benefits of AI and ML unfold over time. Initial challenges and learning curves are to be expected. However, with continuous refinement and integration into business processes, AI and ML can deliver substantial long-term value, driving innovation, efficiency, and competitiveness.

Addressing these misconceptions is vital for fostering a realistic and informed perspective on AI and ML in manufacturing and beyond. By understanding what AI and ML can and cannot do, companies are better positioned to leverage these technologies effectively. Embracing AI and ML with a clear vision and strategic approach can lead to transformative outcomes, ensuring businesses not only survive but thrive in the digital age.

## The Road Ahead

The future landscape of manufacturing, particularly in the electronics assembly industry, will be profoundly influenced by AI and ML. Ongoing advancements in technology, coupled with decreasing costs, will make these innovations accessible to a wider array of companies. This accessibility is expected to lead to the development of more sophisticated AI applications, including fully autonomous production lines and AI-driven product design and customization.

Integrating AI with other emerging technologies, such as the Internet of Things (IoT) and blockchain, promises to revolutionize manufacturing processes further. For instance, AI-powered analytics of IoT data could enable real-time supply chain optimization, while blockchain technology offers a secure and transparent mechanism for tracking materials and products.

## Conclusion

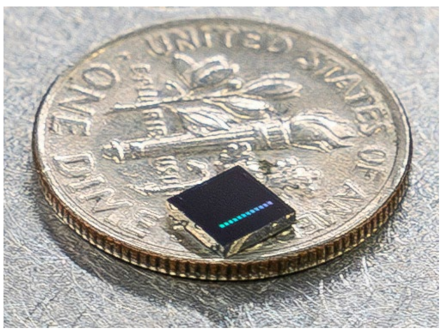
The influence of AI and ML on the manufacturing sector, with a particular emphasis on the electronics assembly industry, cannot be overstated. These technologies are redefining traditional manufacturing approaches, driving efficiency, enhancing product quality, and ensuring cost-effectiveness. While the path to integrating AI and ML into manufacturing processes presents challenges, the potential benefits are undeniable. As we advance deeper into the era of Industry 4.0, the adoption of AI and ML will transition from a competitive advantage to an essential strategy for companies aiming to remain at the forefront of the global market. This paradigm shift not only underscores the transformative potential of AI and ML but also heralds a new era of manufacturing excellence. SMT007

**Mike Konrad** is founder and CEO of Aqueous Technologies, and vice president of communications for SMTA. To read past columns, click here.

# Rice Research Shows Promise for Advancing Quantum Networks

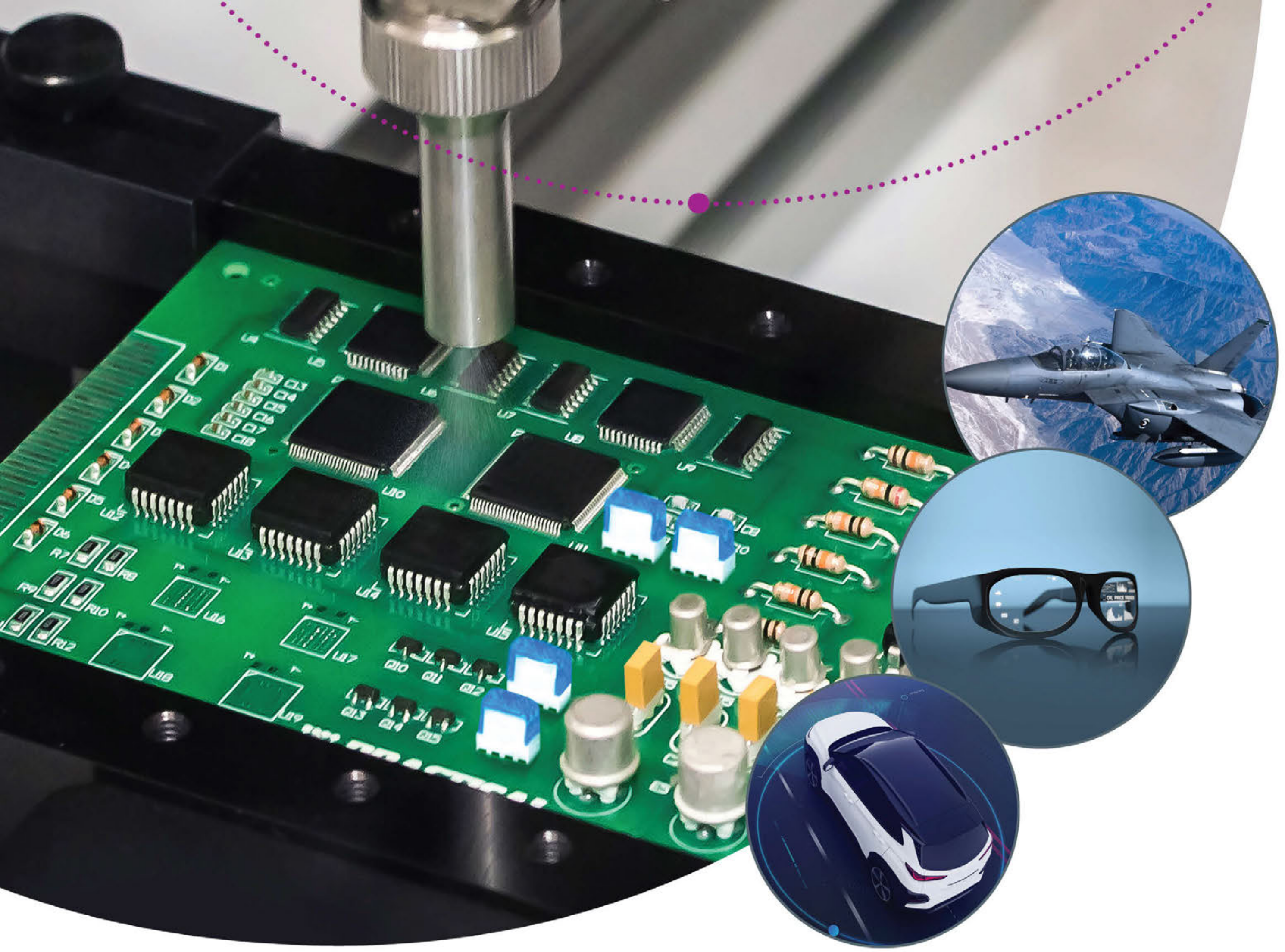
Rice University engineers have demonstrated a way to control the optical properties of atomic imperfections in silicon material known as T centers, paving the way toward leveraging these point defects for building quantum nodes for large-scale quantum networks.

"T centers are a type of atomic defect in the regular lattice of silicon," said Songtao Chen, assistant professor of electrical and computer engineering. "T centers have been generating a lot of interest recently because they show potential as qubit building blocks for quantum networking. They emit single photons at an advantageous wavelength for telecommunication applications, but they suffer from a low photon emission rate."

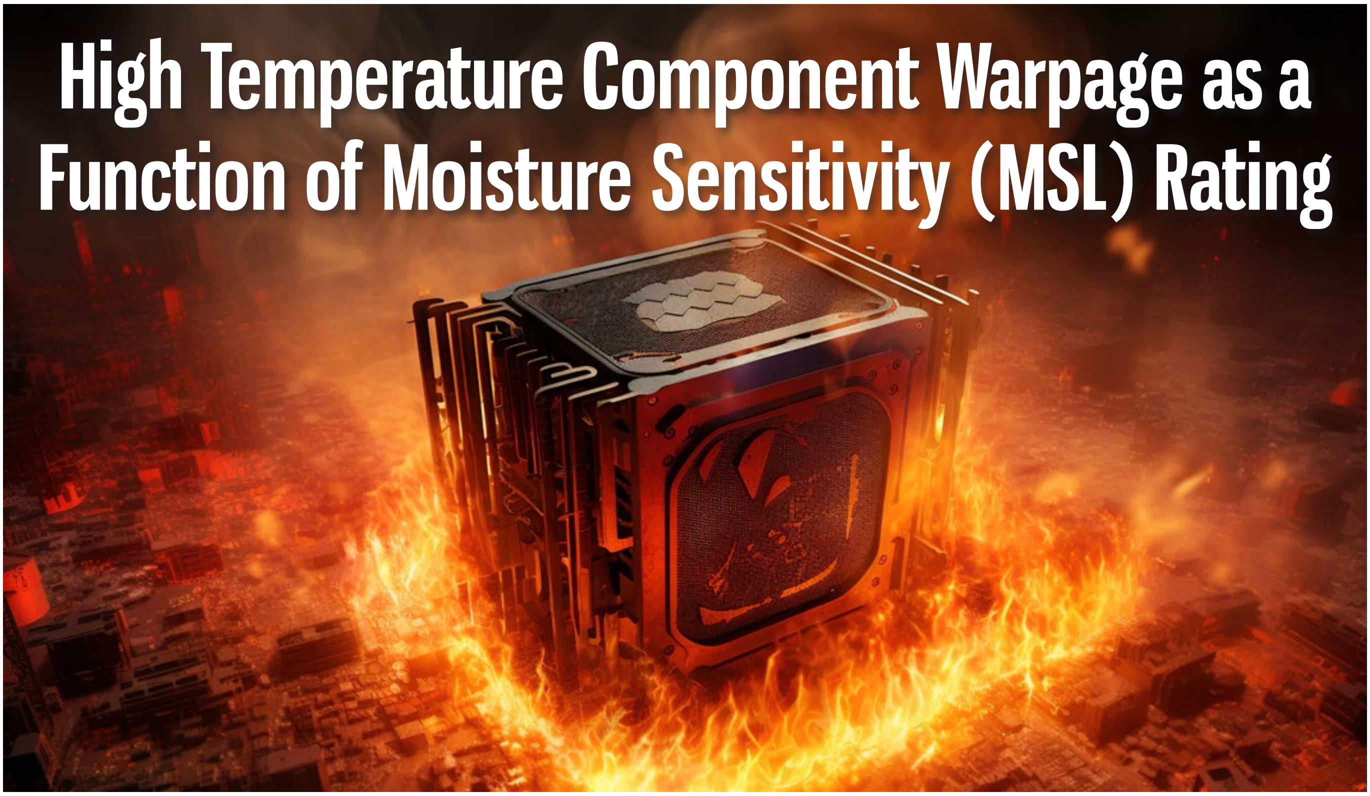


Spontaneous emission—the phenomenon behind the familiar glow of a firefly or other glow-in-the-dark effects—describes the process by which a quantum mechanical system, like a molecule, atom or subatomic particle, transitions to a lower-energy state by releasing some of its energy in the form of a photon. Enhancing the rate of spontaneous emission in T centers is one of the hurdles that scientists need to overcome in order to make T center-based qubits viable.

By embedding a T center in a photonic integrated circuit, Songtao and his team increased the collection efficiency for T center single photon emission by two orders of magnitude compared with typical confocal-type experiments. The team demonstrated that coupling with a photonic crystal cavity enhances a T center's photon emission rate by a factor of seven, exploiting a phenomenon known as the Purcell effect. (Source: Rice University)



# High Temperature Component Warpage as a Function of Moisture Sensitivity (MSL) Rating



**Article by Neil Hubble**
AKROMETRIX

*Editor's Note: This paper was originally published in the Proceedings of SMTA International, Rosemont, IL, Sept. 22–26, 2019.*

## Background

Moisture sensitivity requirements for nonhermetic surface mount devices are defined in the joint IPC/JEDEC standard J-STD-020E, "Joint IPC/JEDEC Standard for Moisture/Reflow Sensitivity Classification for Nonhermetic Surface-Mount Devices," last updated in December 2014[1]. This standard allows customers and suppliers to place electronics devices into specific categories, defined into 8 different moisture sensitivity levels (MSL). Test method criteria are defined within this standard to define MSL levels for different packages. A subsection of MSLs are shown in Figure 1 below, showing the MSL 3 and 4 used in this study.

The absorption of moisture inside a package can cause vapor pressure within the package. In some cases, this vapor pressure can cause internal delamination of the internal components of the package, and in more extreme cases a "popcorning" effect on the sample surface. The popcorn effect would be seen by warpage analysis, but it isn't clear whether lesser cases of

| | | | [SOAK REQUIREMENTS] | |
|---|---|---|---|---|
| | FLOOR LIFE[4] | | STANDARD | |
| LEVEL | TIME | CONDITION | TIME (hours) | CONDITION |
| 1 | Unlimited | [redacted] | | |
| 2 | [redacted] | | | |
| 2a | [redacted] | | | |
| 3 | 168 hours | ≤30 °C/60% RH | 192[2] +5/-0 | 30 °C/60% RH |
| 4 | 72 hours | ≤30 °C/60% RH | 96[2] +2/-0 | 30 °C/60% RH |
| 5 | [redacted] | | | |
| 5a | [redacted] | | | |
| 6 | Time on Label (TOL) | [redacted] | | |

Figure 1: MSL table from J-STD-020E (partial redaction)[1] multiple joint industry standards and test methods are further defined by JEDEC and other in standards such as J-STD- 033D[2] and JESD22-A120[3].

internal delamination will play a role in warpage levels over reflow. Package warpage is generally accepted to be mainly driven by CTE mismatch between package materials, thus an additional force, such as vapor pressure, is expected to have some level of impact. However, the impact of vapor may not be statistically relevant and may be within the noise of measurement resolution and/or test variation.

One common method for identifying internal package delamination is scanning acoustic microscopy (SAM)[4]. This method can look inside a package for delamination. SAM, or C-SAM, is performed in water and is not used for behavior of a package through reflow temperatures.

A previous iNEMI study "Recent Trends of Package Warpage Characteristic," also asked the question of relations between moisture exposure and warpage[5]. However, this study was unable to find any statistically relevant relation between moisture exposure and warpage. Further studies related to MSL levels have also found that the length of a reflow profile can play a role in the effects of moisture exposure on reliability[6].

Component warpage is a well-established reliability and yield concern for electronics packaging. Multiple industry standards define allowable warpage levels and component testing best practices, including JEDEC JESD22-B112B[7], JEITA ED-7306[8], and IPC-7095D9. These standards are used for testing approaches within this study, as well as data analysis.

Additionally, numerous published studies show the relationship between component thermal warpage and surface mount defects. These studies include such titles as, "Reflow Warpage Induced Interconnect Gaps between Package/PCB and PoP Top/Bottom Packages"[10] and "Effect of Package Warpage and Composite CTE on Failure Modes in Board-Level Thermal Cycling"[11], to name a few.

## METHODOLOGY:

### Moisture Exposure

All samples were subjected to a 24hr 125°C prebake to establish a starting "dry" moisture condition. After this point, samples were tested in four different tracks: control, MSL3, MSL3 "reset track" (samples are baked 24 hours at 125°C after moisture exposure), MSL4. Samples were always tested within six hours of each exposure condition end. The moisture exposure and preheat path of each track is summarized in Figure 2 below.

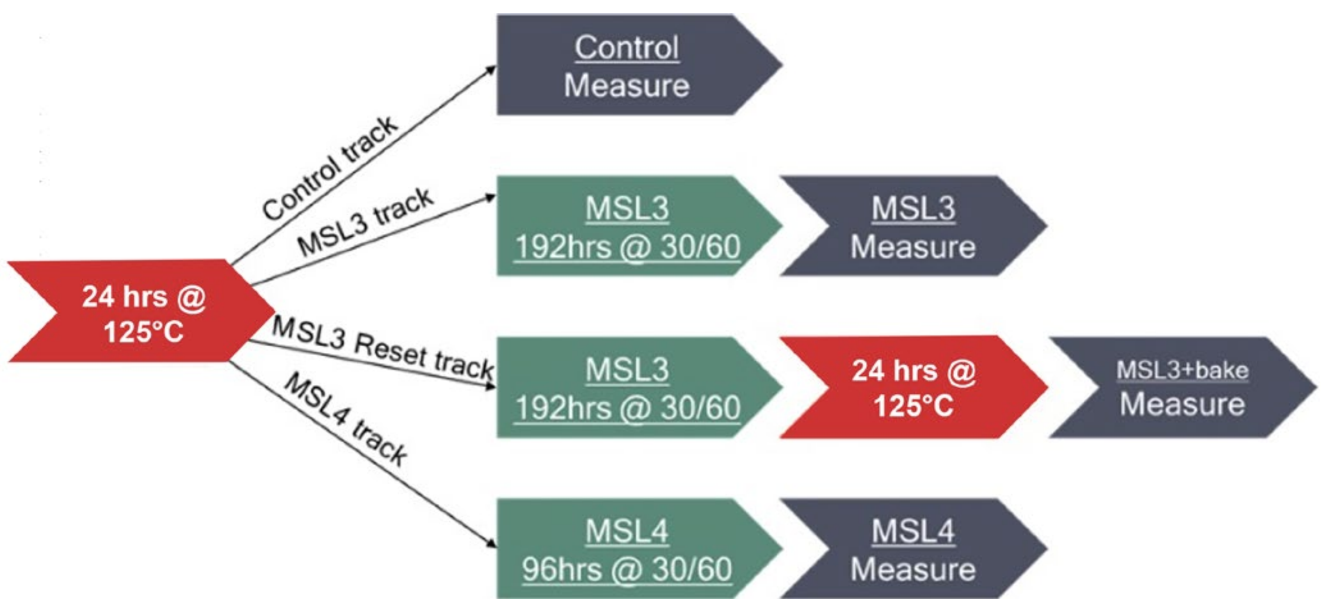



Figure 2: Moisture exposure tracks test samples.

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Table 1: Test samples

| Package | | Sample Quantity per Test | | | |
|---|---|---|---|---|---|
| Type | Size | Contr | MSL3 | MSL3 Reset | MSL4 |
| Molded CSP | 14 x 14 mm | 4 | 4 | 4 | 4 |
| Molded CSP | 11 x 12 mm | 4 | 4 | 4 | 4 |
| Molded CSP | 10 x 11mm | 4 | 4 | 4 | 4 |
| Bare Die FCBGA | 20 x 15 mm | 3 | 3 | 0 | 3 |
| Molded BGA | 27 x 27 mm | 4 | 4 | 4 | 4 |
| Molded PBGA | 40 x 40 mm | 4 | 4 | 4 | 4 |

Six different sample types were tested in this study. Three to four samples per test condition were tested depending on sample availability. Package type and size descriptions were kept generic to protect the component manufacturer. For the same reason, some of the sample sizes are approximate and not exact. A range of different sample types were chosen to represent a reasonable combination of different surface mount package types. Package type, size, and tested quantities are summarized in Table 1.

## Reflow Profile and Measurement Technique

A typical lead-free reflow profile with peak at 250°C was used in this study. An example thermal output from a thermal warpage run is shown in Figure 3. For all tests an extra sample was used purely for capturing temperature within the system. The actual temperature is defined by the red line, Process 1. Other oven commands, including warpage acquisitions are shown on the graphical output in Figure 3. All samples were subjected to a comparable profile.

Surface warpage measurements over temperature are taken using the shadow moiré (SM) technique with samples placed in an IR oven, in a metrology tool used for measuring surface shape over reflow temperatures. The SM technique measures surface height by shining a line light through a grating glass. An interference pattern between the lines and shadow cast by the same lines creates a contour map used for measurement. The SM technique utilizes a phase stepping method, applied for increased resolution. Camera images are captured with different distances between the grating and

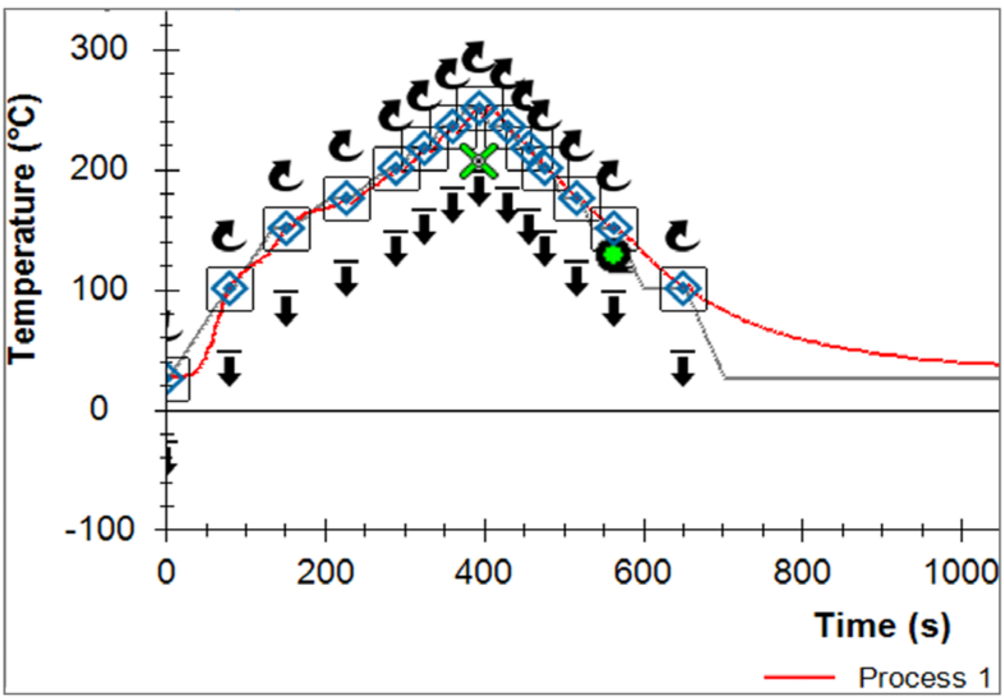

Figure 3: Example reflow profile output.


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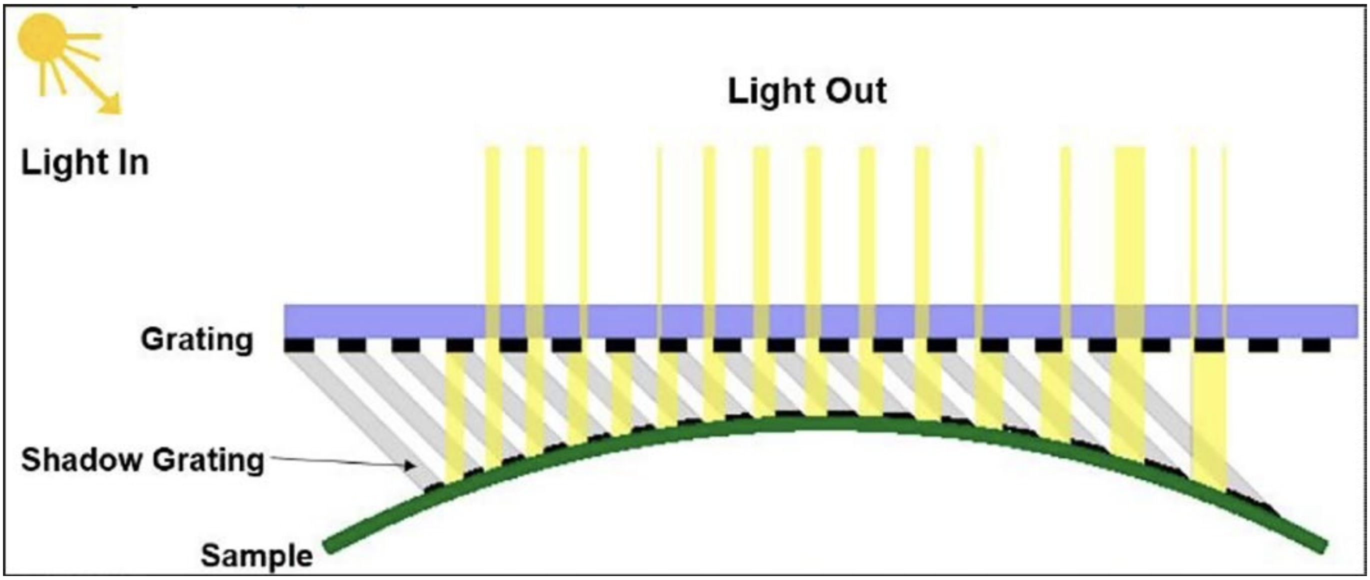


Figure 4: Shadow moiré visual concept.

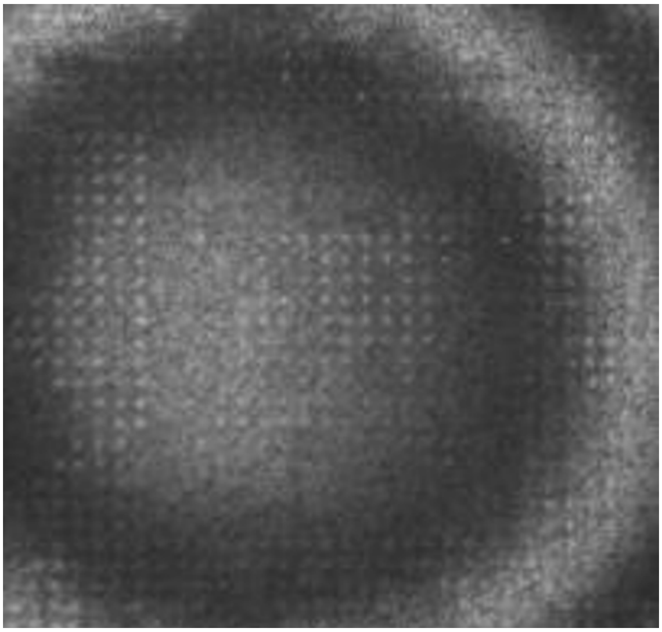


Figure 5: Shadow moiré pattern.

sample. Figure 4 shows a conceptual image of the behavior of light in SM, and Figure 5 shows a contour pattern created by SM on one of the samples under test.

## Controls

The following parameters were kept as controls during all phases of each test:

- SM grating pitch: 200 lines per inch
- Sample coating: White high temperature paint (for increased resolution)
- Temperature profile: See Figure 3
- Sample support: Dark red high temperature glass
- Sample region of interest: Sample edges tracked during heating via automatic edge recognition technology, with an inset to the center of the outer solder ball row
- Working distance from grating: 1.25 mm during acquisition, 3.75 mm during heating and cooling
- Temperature uniformity: Top and bottom heating and multi-zone oven used to minimize temperature variation from sample to sample and within individual samples.

## Variables

Independent variables:

- Moisture exposure
- Sample type dependent variables:
- Coplanarity gauge (highest point to lowest point)
- 3S warpage gauge (coplanarity + sign designation to indicate direction of curvature, including a "transition" category between positive and negative curvature)
- Shape name gauge (samples placed into 1 of 9 defined shape categories)

3S warpage and shape names are further defined in the white paper, "Surface Mount

Signed Warpage Case Study; New Methods for Characterizing 3D Shapes Through Reflow Temperatures."[12]

Additionally, sample shapes are considered from the perspective of both absolute shape at each given temperature as well as a relative shape change from a starting room temperature shape. As starting shape can often be a significant source of sample to sample variation, relative change of the surface over temperature can be an effective method to understand sample warpage. In these cases, the same gauges are used for analysis.

## Results

No "popcorning" was seen on any samples, so no extreme cases of delamination occurred. This suggests the moisture was well controlled and the samples do not easily show these extreme levels of delamination. Longer moisture exposure or faster and higher heating profiles could change this case. Some example 3D surface renderings of the samples are shown in Figures 6 to 9. To give some understanding of surface shapes the most warped and least warped sample is shown from the smallest and the largest sample. The out-of-plane scale is consistent to the part type. Note that the most warped and least warped points occurred under different conditions between the two sample sizes.

Quantitatively, the data is first summarized by the most basic gauge available here, coplanarity. In order to summarize the data, each sam-

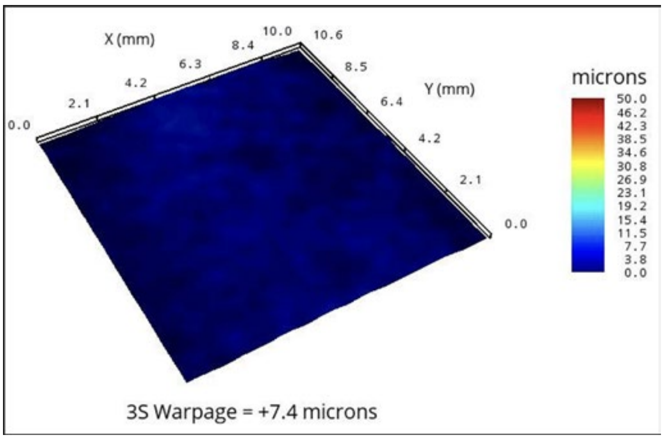



Figure 6: 10 x 11 mm, MSL3, 200°C cool down, low warp.

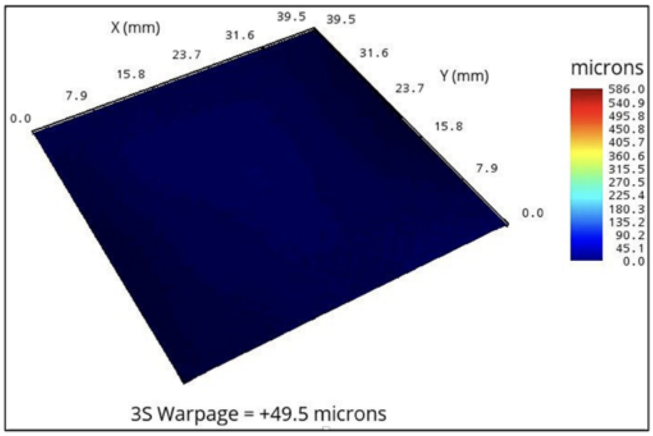



Figure 8: 40 x 40 mm, MSL3, 175°C heat-up, low warp.

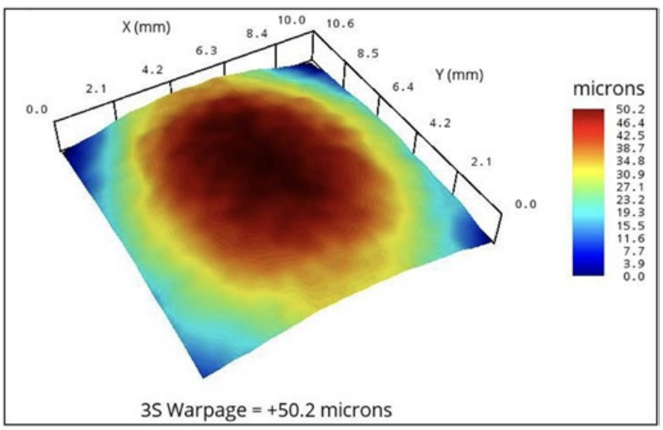



Figure 7: 10 x 11 mm, MSL4, 217°C heat-up, high warp.

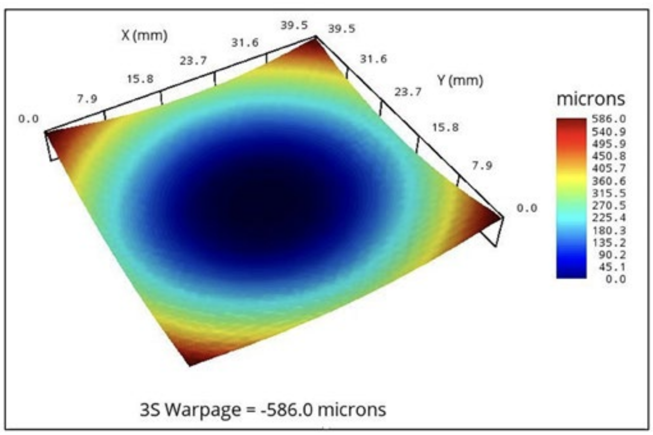



Figure 9: 40 x 40 mm, MSL3, 250°C peak, high warp.

ple type is averaged with the other three to four units in the test at each temperature. With easily over 1,000 warpage measurements throughout the test, this makes the data quantity feasible to analyze. Figures 10 to 15 show average coplanarity over temperature for all six sample types respectively. The different moisture conditions are shown as four different series on the graphs.

Some "W" shape patterns can be seen in the graphs. This is a result of looking at the data without any sign association. Each of the 89 different samples used in the study went through a transition between positive and negative at some point during the reflow profile. The transition point varies a bit between the different samples but is more often in the 150–200°C range on both heat and cool sides of the profile. For the smaller samples, this trend is harder to visualize due to the lower warpage levels of the sample. Looking closer at the individual sample plots on the 40 mm samples at MSL4, all

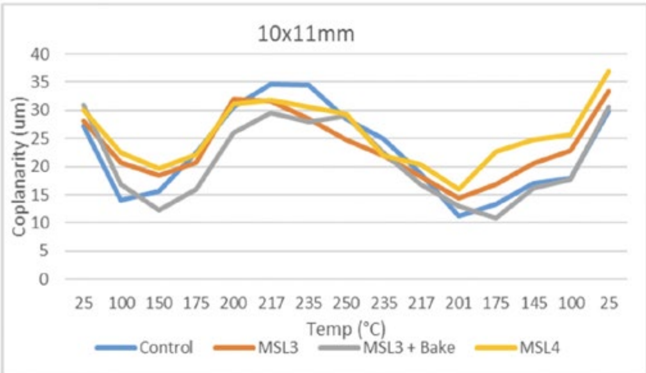



Figure 10: Average coplanarity over temp, 10 x 11 mm.

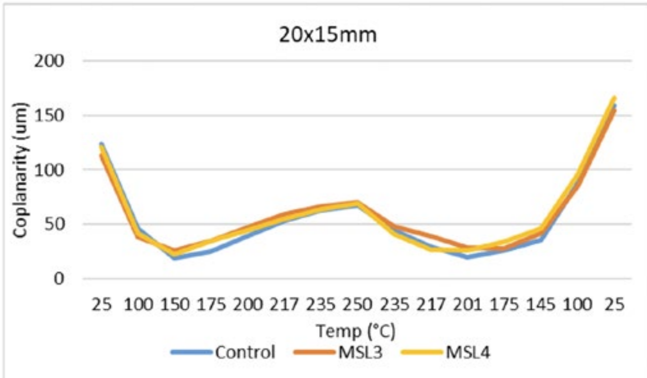



Figure 13: Average coplanarity over temp, 20 x 15 mm.

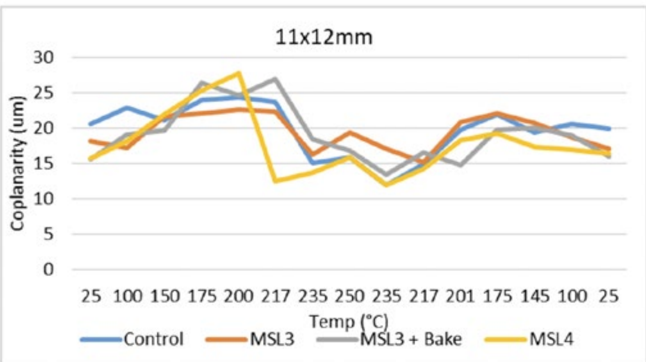



Figure 11: Average coplanarity over temp, 11 x 12 mm.

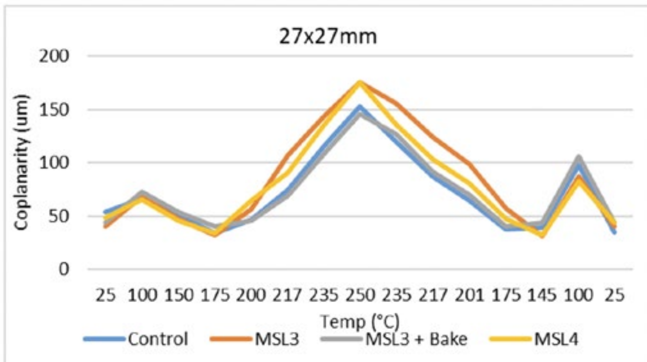



Figure 14: Average coplanarity over temp, 27 x 27 mm.

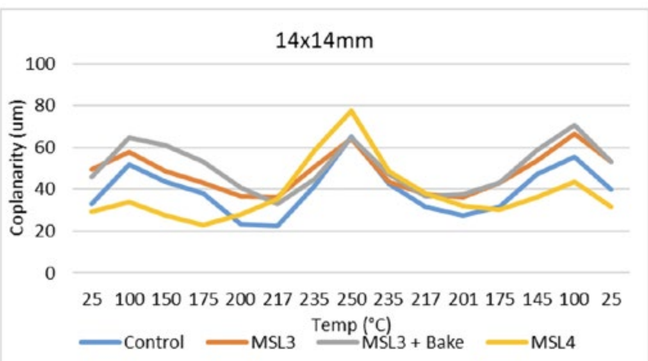



Figure 12: Average coplanarity over temp, 14 x 14 mm.

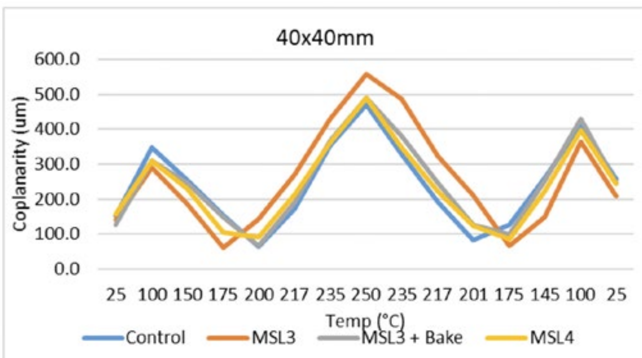



Figure 15: Average coplanarity over temp, 40 x 40 mm.

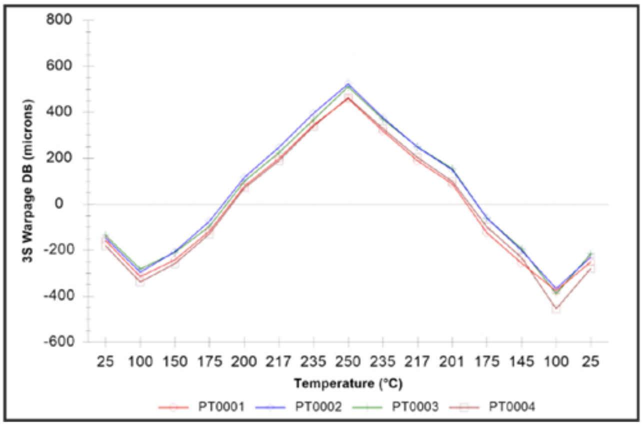



Figure 16: 3S warpage, 40 x 40 mm, MSL4.

samples transitioned from negative to positive in heating between 175°C and 200°C and then back to negative in cooling from 200°C to 175°C. Maintaining good sample temperature uniformity is key to this transition happening consistently. Figure 16 shows 3S Warpage.

The same transition can also be seen in the shape name variable at each temperature. The 40 x 40 mm sample at MSL4 exposure generally transitions from dome (DM) shape to and bowl (BW) shape, but in the transition some other shapes begin to arise, "X-pipe" (XP) and upward twist (UT), as in Table 2.

In some cases, the transition between positive and negative has higher sample to sample variation and is more difficult to find a trend. Here the ability to look at the relative change of the sample is helpful. Figure 17 shows 3S warpage data for the 14 x 14 mm sample at MSL3. The vertical lines on the graph represent "transitional" shapes in the sample data.

Table 2: Shape names, 40 x 40 mm, MSL4

| Temperature, °C | 25 | 100 | 150 | 175 | 200 | 217 | 235 | 250 | 235 | 217 | 201 | 175 | 145 | 100 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PT0001 | DM | DM | DM | DM | BO | BO | BO | BO | BO | BO | BO | DM | DM | DM | DM |
| PT0002 | DM | DM | DM | DM | BO | BO | BO | BO | BO | BO | BO | XP | DM | DM | DM |
| PT0003 | DM | DM | DM | DM | BO | BO | BO | BO | BO | BO | BO | UT | DM | DM | DM |
| PT0004 | DM | DM | DM | DM | BO | BO | BO | BO | BO | BO | BO | DM | DM | DM | DM |

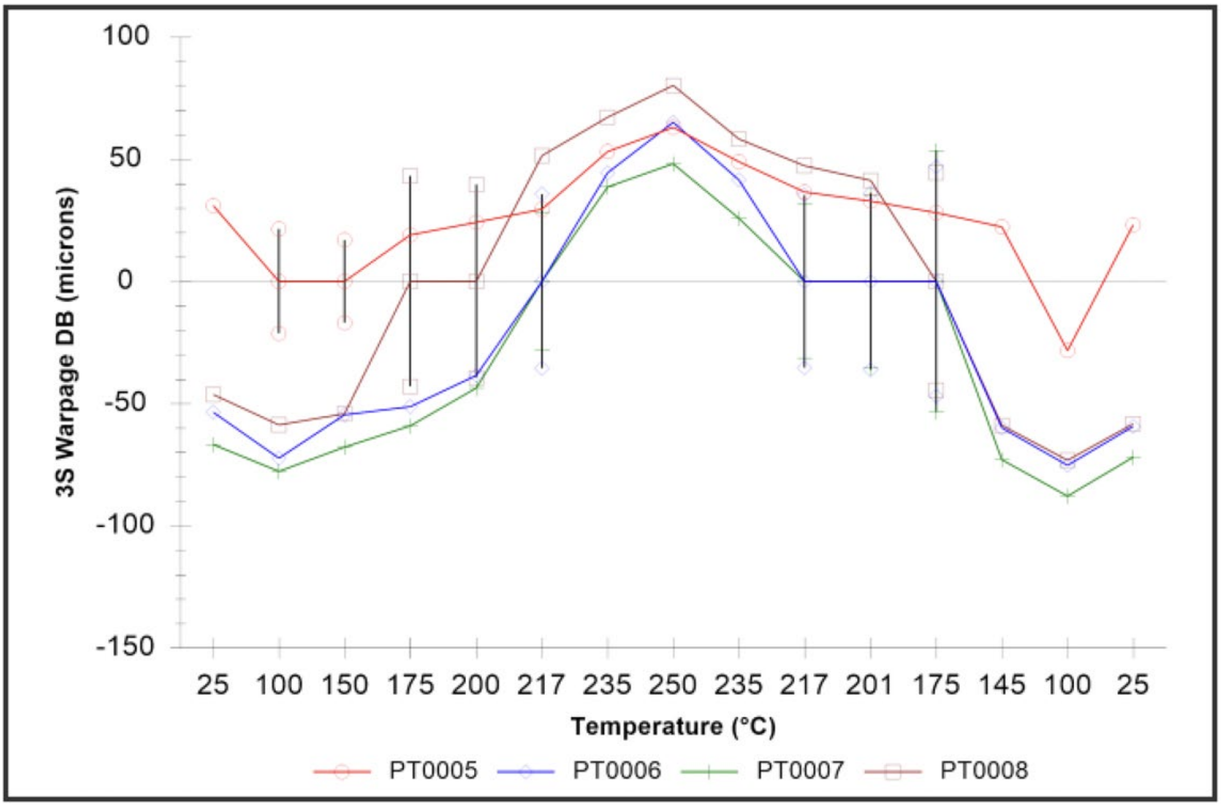
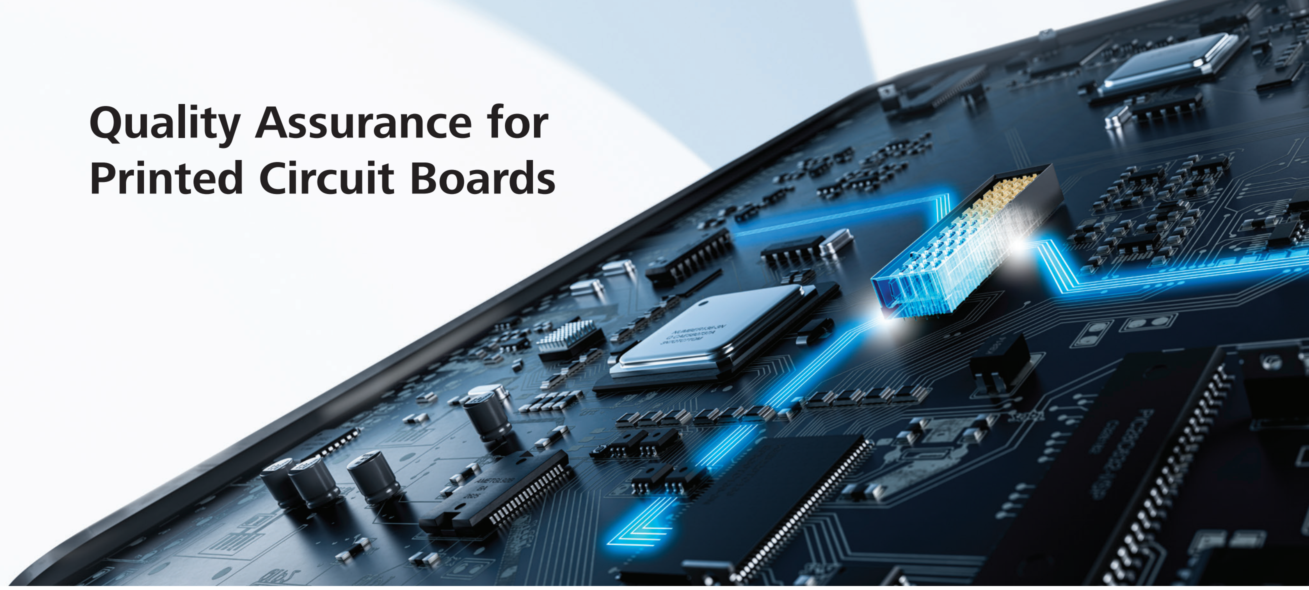



Figure 17: 3S warpage, 14 x 14 mm, MSL3.



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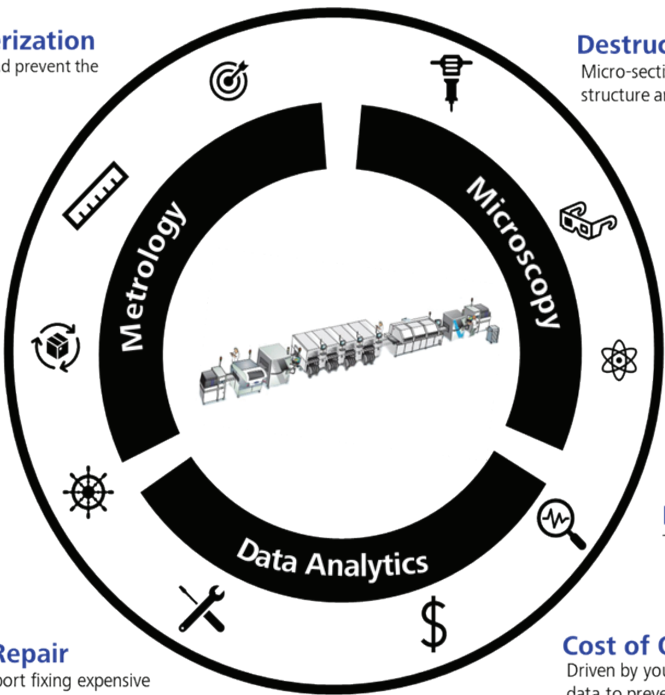


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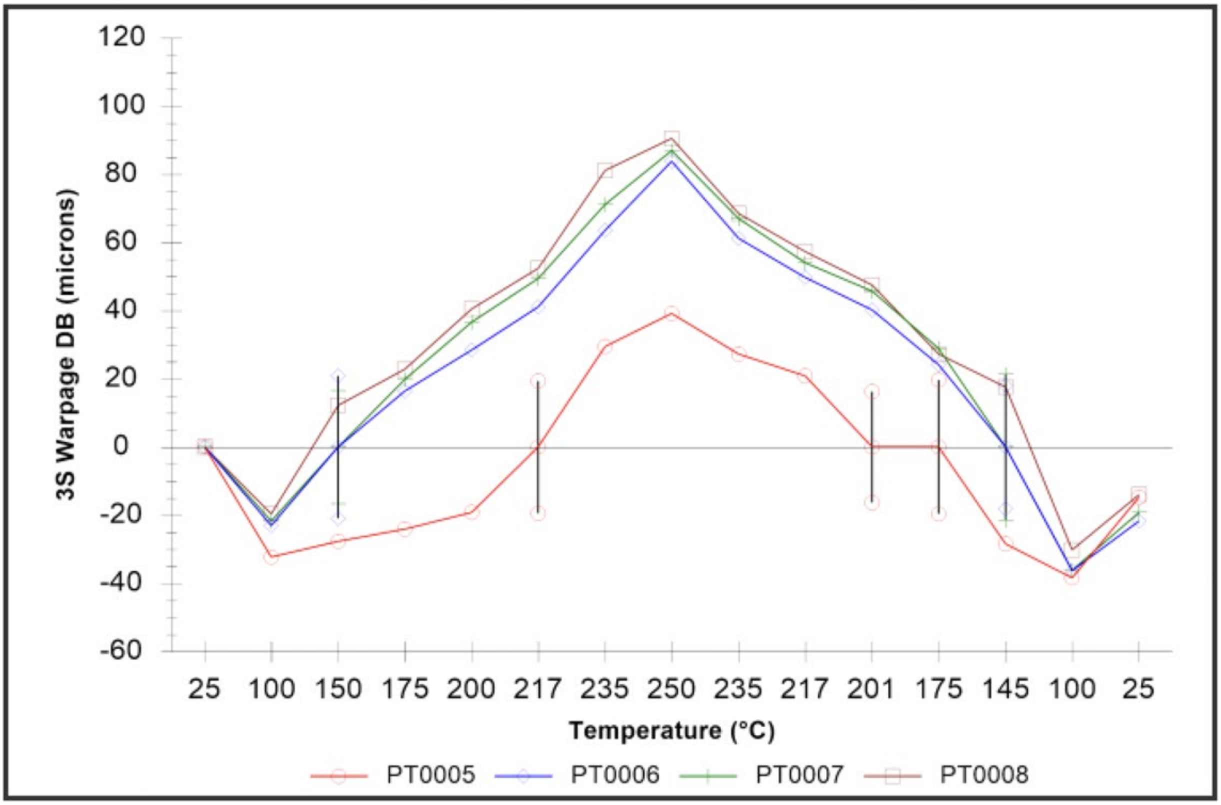


Figure 18: Relative 3S warpage, 14 x 14 mm, MSL3.

This graph is difficult to interpret due to the high sample-to-sample shape variation at room temperature.

However, if we subtract the matrix of the original room temperature shape of each sample, the warpage becomes clearer. The "PT0005" comes out as a clear outlier in this data set. The relative warpage data is plotted against the 3S warpage gauge in Figure 18.

Figure 18 shows that analysis of the data via relative change can be helpful to interpret the data.

## Analysis and Discussion

Further analysis requires a closer look sample by sample, considering the construction of the part, die-to-mold ratios, substrate thickness, and relative shape change of the samples.

### 20 x 15 mm sample

Starting with the simplest case, the 20 x 15 mm sample showed no discernable change from the different moisture exposure levels tested in this study (Figure 13). This is an unsurprising outcome, given that it is also the only bare die sample and contains no mold compound. The die is also quite large relative to the package size. While the package does show shape change as the substrate expands at a faster rate than the die, the shape change is perceivably unaffected by moisture, with no mold to soak up moisture and the relatively thin substrate not holding enough water to affect the warpage.

### 27 x 27 mm and 40 x 40 mm samples

The two larger samples in the study exhibit the most obvious cases of moisture affecting warpage. Both samples have prominently thicker molded areas and small die-to-mold ratios. The higher warpage is clear for MSL3 and MSL4 for the 27 mm package and clear for MSL3, the worst-case moisture exposure, on the 40 mm package. It is unclear specifically why the MSL4 exposure matched better with the control and MSL3 + bake warpage than the MSL3.

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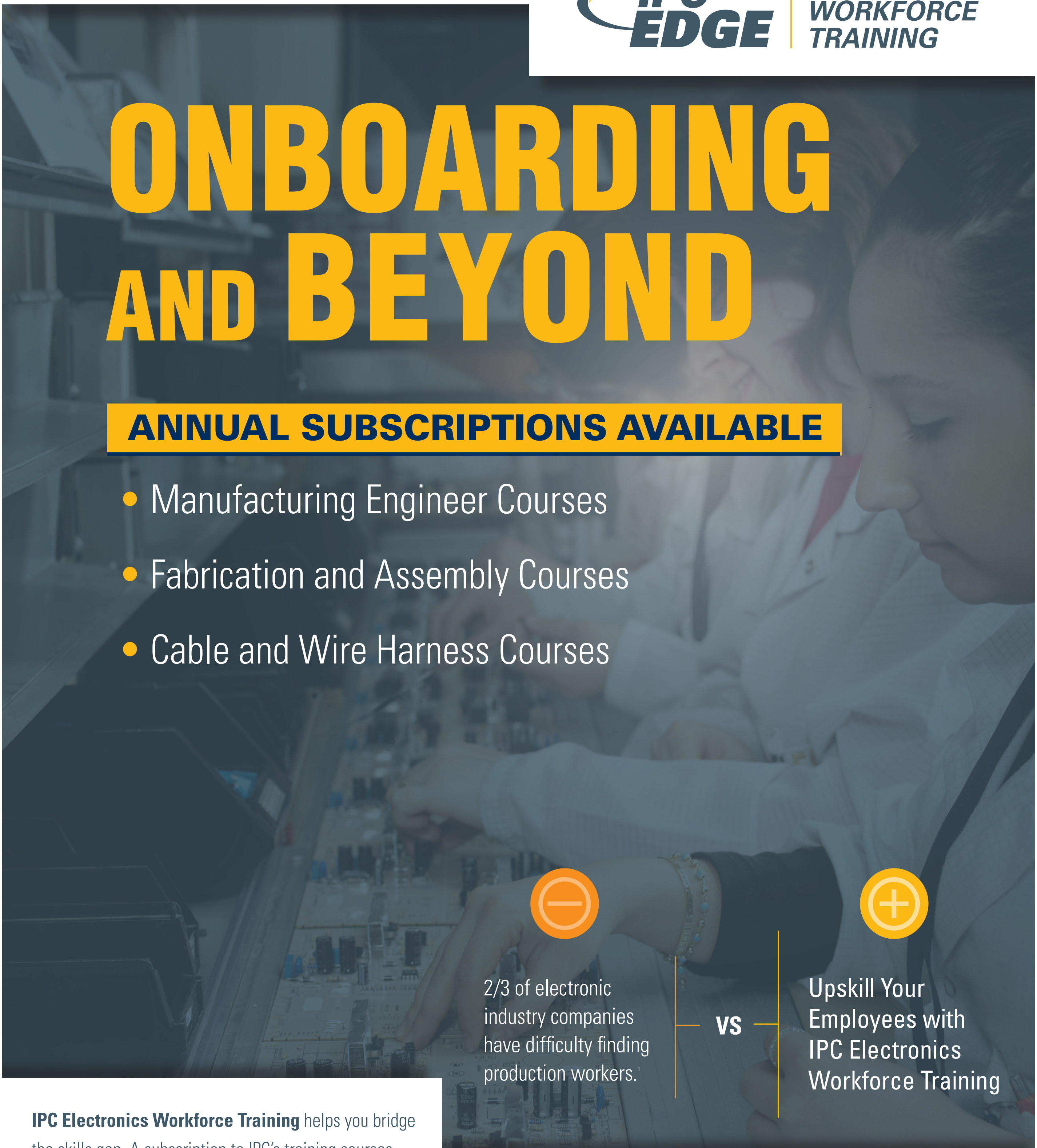

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[1] IPC. (2017). Findings on the Skills Gap in U.S. Electronics Manufacturing.

Additionally, both samples exhibit the ability to reset the moisture condition through prebake. For these samples the number of prebakes and the moisture exposure between them plays no significant role. However, the study does not show the effect of extended exposure to prebake temperatures or numerous cycles in an oven on a sample warpage. With only two prebake cycles it is difficult to exclude the possibility that prebake conditions can affect sample warpage.

### 10 x 11 mm, 11 x 12 mm, and 14 x 14 mm samples

Overall warpage levels of the smaller dimensioned samples, particularly the 11 x 12 mm samples, are much smaller than the larger dimensioned samples. This makes the warpage offset caused by moisture an even larger factor than visually shown in the graphs. Certainly, larger samples will tend to have larger solder balls and solder ball pitch, thus larger allowable warpage[7]. However, the offset here is significant as seen in Figure 19.

Figures 10 to 12 showing warpage over temperature for the different moisture conditions are difficult to interpret. The sample-to-sample variation at starting room temperature plays a large role in the coplanarity variation. In order to better understand the differences in thermal warpage caused by moisture, the coplanarity can be analyzed with all surfaces shown as relative changes from the room temperature shape.

Figures 20 to 22 replicate the data from Figures 10 to 12, but are shown as relative warpage plots instead of absolute shape.

Taken from the relative warpage perspective, the MSL3 data on the 14 x14 mm sample, Figure 22, begins to stand out. This isn't true for the 10 x 11 mm or 11 x 12 mm samples, which seem to show no clear trend in terms of higher warpage with increased moisture exposure. So, there are three package types show-

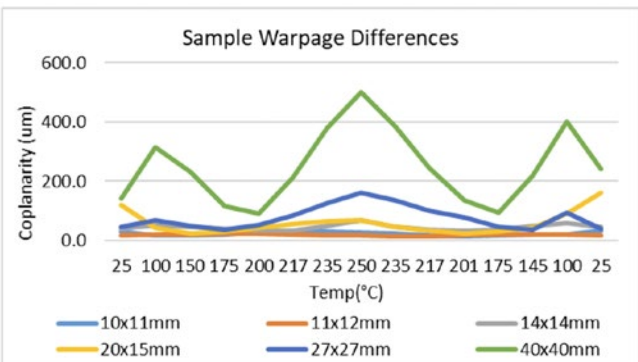


Figure 19: Overall coplanarity by sample size.

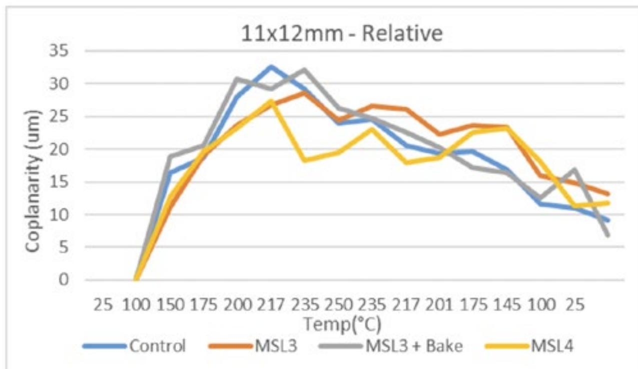


Figure 21: Average relative coplanarity, 11 x 12 mm.

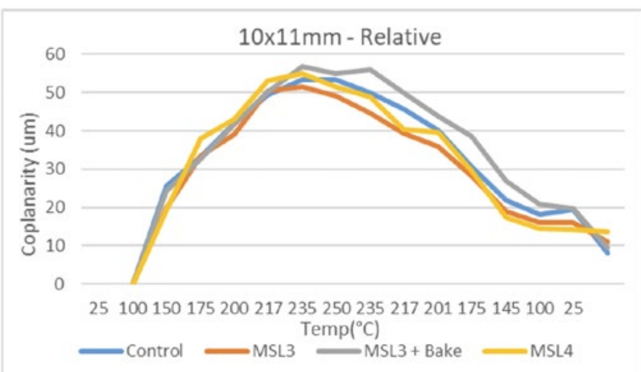


Figure 20: Average relative coplanarity, 10 x 11 mm.

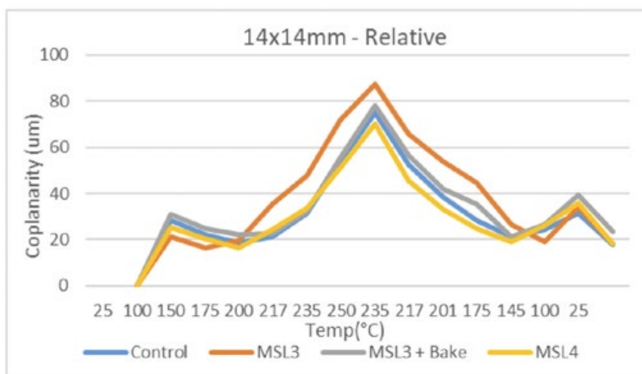


Figure 22: Average relative coplanarity, 14 x 14 mm (with outlier from Figure 18 removed from average).


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Table 3: Die-to-mold ratio of test samples

| Package Type | Package Size | Die/Mold Ratio | Higher Warpage at MSL3 |
|---|---|---|---|
| Molded CSP | 14 x 14 mm | <10% | Yes |
| Molded CSP | 11 x 12 mm | >15% | No |
| Molded CSP | 10 x 11mm | >15% | No |
| Bare Die FCBGA | 20 x 15 mm | N/A (No mold) | No |
| Molded BGA | 27 x 27 mm | <10% | Yes |
| Molded PBGA | 40 x 40 mm | <10% | Yes |

ing signs of higher warpage at MSL3 (14, 27, and 40 mm) and three that do not show higher warpage.

There is another previously undiscussed variable related to the moisture exposure of the samples, which is die-to-mold ratio summarized in Table 3. Exact numbers on die-to-mold ratio are either unknown or kept vague to protect company information.

Adding this variable to our data set, a clear trend is shown that samples with more molded area, relative to die size, will absorb moisture and cause larger effects on thermal warpage at higher temperature.

A final attempt is made to better interpret the 10 x 11 mm and 11 x 12 mm data to see if any trend related to moisture can be found. Using the relative warpage data second-order polynomial, trendlines are fit to the average coplanarity data. The general curve of the relative warpage fits the general second-order curve shape. Figures 23 and 24 show the trendlines

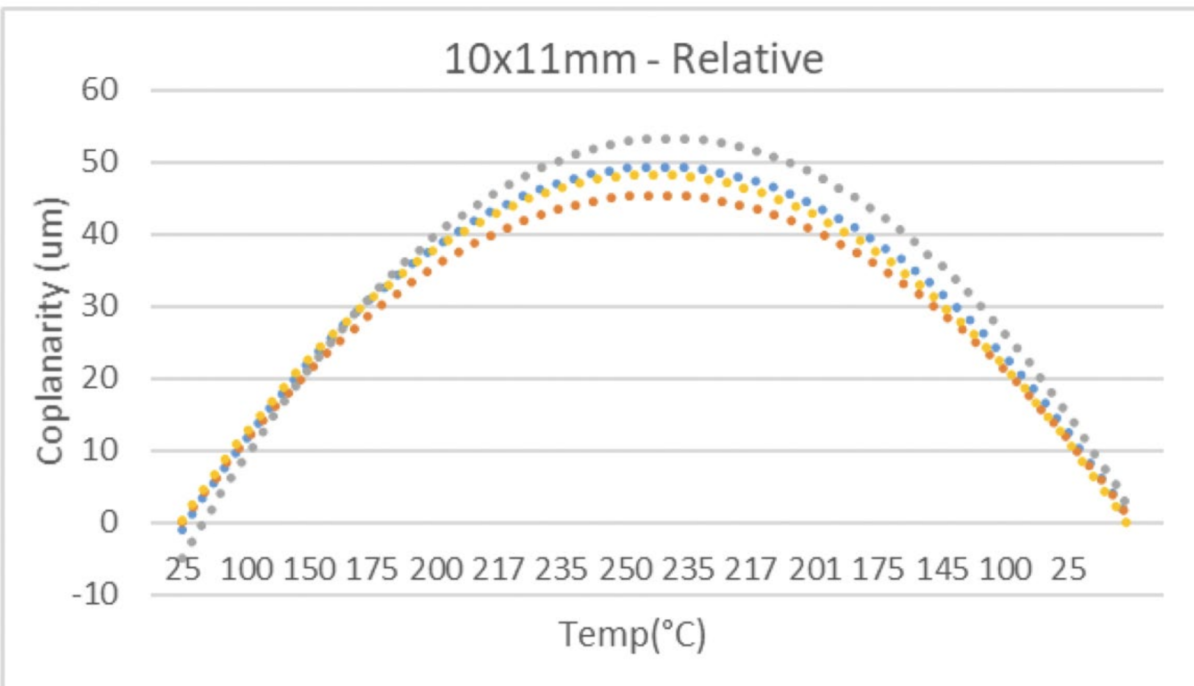


Figure 23: Average relative coplanarity, second-order polynomial fit, 10 x 11 mm.

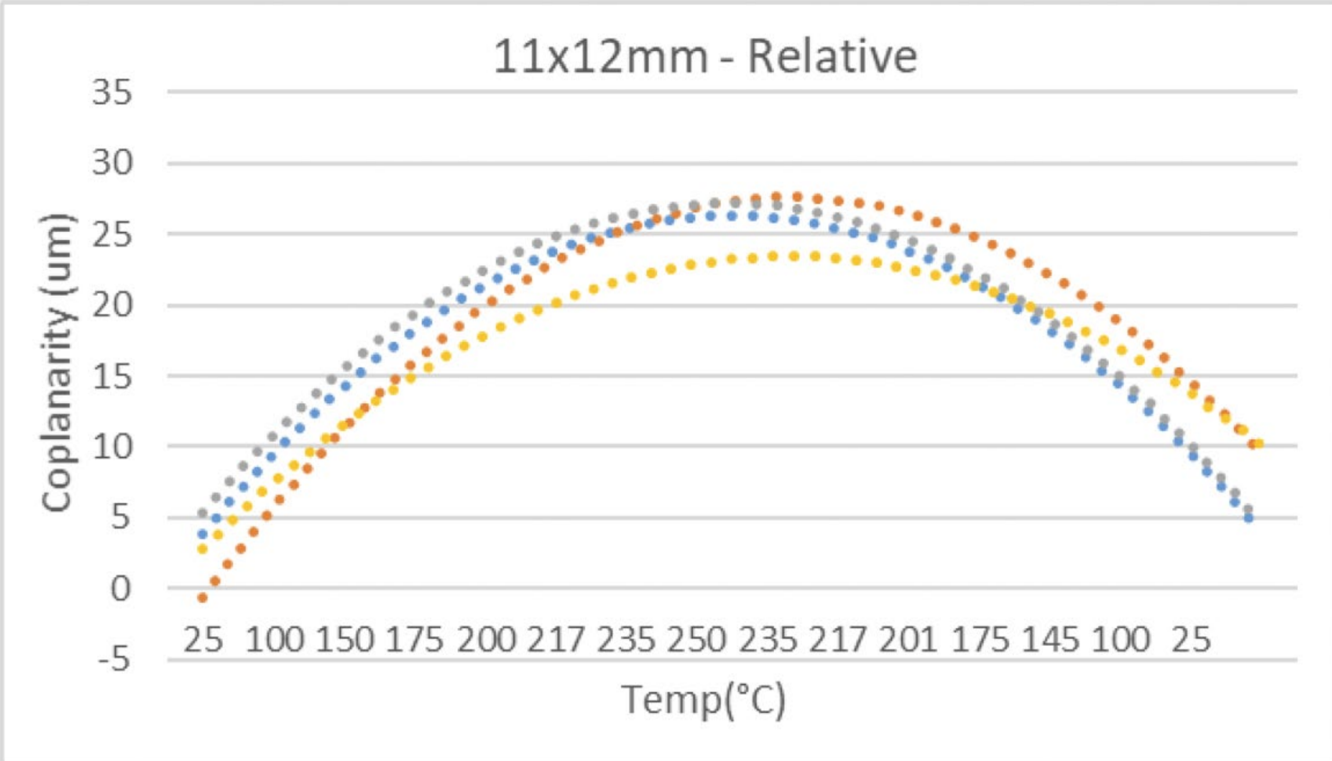


Figure 24: Average relative coplanarity, second-order polynomial fit, 11 x 12 mm.

for the different moisture conditions using the same color scheme as before, with orange and yellow as MSL3 and MSL4, respectively.

While little can be concluded from Figures 23 and 24 in terms of sample behavior over warpage, the trendlines do show a minor pairing with MSL3 and MSL4 slightly separated from the trend of the Control and MSL3 + Bake data. More than anything this helps to justify the validity of the data set and the conclusion that moisture is not having a significant effect on the overall warpage of these samples with higher die-to-mold ratios.

## Conclusions and Summary

Unlike previous studies in the space of package moisture vs. thermal warpage[5], a tangible correlation between warpage and moisture was found for certain package types. This is possibly due to better variable control with increased understanding over time as it relates to different conditions that can affect thermal warpage.

For the samples in this study, those with larger mold volumes relative to die size exhibited specifically higher warpage levels near and above reflow temperatures. As expected, the longer MSL3 moisture soak showed higher warpage levels than the MSL4 exposure. Samples with less mold and more substrate and die exhibit no relevant variation in thermal warpage due to moisture exposure. Certainly, the larger samples also showed higher warpage overall, as is to be expected.

Samples that were prebaked, subject to MSL3 and then prebaked again, or "reset," correlated with the control data set which went through a single prebake. This shows the ability for a sample to be exposed to moisture then prebaked again, without playing a tangible role in thermal warpage.

## Next Steps

More samples can, of course, be tested using a similar setup. Further sample types would help to enforce the correlation between die-to-

mold ratio and higher warpage at elevated temperatures. In particular, a larger sample with higher die-to-mold ratio and a smaller sample with a lower die-to-mold ratio would be valuable, though possibly difficult to find.

## Acknowledgments

The author would like to acknowledge Brian Roggeman of Qualcomm for help in multiple aspects of the study and data analysis, Han Wu of HB Fuller for supporting MSL conditioning, Leon Weaver and Charly Olson of Akrometrix for thermal shadow moiré testing, and Ryan Curry of Akrometrix for applications support and editing. SMT007

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**Neil Hubble** is president of Akrometrix.

# TOP TEN EDITOR'S PICKS

## Growth Potential: Electronics Manufacturing Driving Massive Surge in Manufacturing Investment

In 2023, manufacturing investment in plants and other production facilities in the United States rose nearly 63%, the biggest yearly gain since 1951. This surge in investment underscores an unparalleled confidence in the growth potential of the U.S. manufacturing sector that looks beyond any short-term variability.

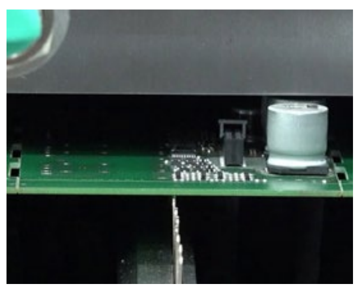
## MacDermid Alpha Electronics Solutions' New Book Now Available for Download


I-Connect007 is pleased to announce the launch of *The Printed Circuit Assembler's Guide to... Encapsulating Sustainability for Electronics* by Beth Turner at MacDermid Alpha Electronics Solutions. The latest in a series of educational books published by I-Connect007, this book is an introductory guide to understanding encapsulation resins and a tool for application troubleshooting.

## NextFlex Announces $5M Education Fundraising Effort: First Spotlight—Transforming the Landscape for Women in Technology

NextFlex Learning Programs, the education-focused arm of the NextFlex® Hybrid Electronics Manufacturing Innovation Institute, announces its first spotlight effort, "NextFlex Supports Women in STEM" to increase the number of women in STEM fields, which could accelerate U.S. GDP growth by boosting women's cumulative earnings by $299B and adding $5.9T to the global stock market within 10 years according to S&P Global.

## Reducing Nitrogen Consumption in Convection Soldering With Rehm Thermal Systems' Patented Mechatronic Curtain



In electronics manufacturing, the variety of component geometries presents a challenge: differences in assembly height require a variable throughput height in convection soldering systems. Current developments indicate a need for larger throughput heights due to the trend towards e-mobility, which in turn increases nitrogen consumption for process inertization. Rehm Thermal Systems responds to this issue with an innovative solution: the mechatronic curtain.

## SMTA Conducts First UHDI Symposium

SMTA's first UHDI Symposium in Peoria, Arizona, on Tuesday, March 26, featured a standout full-day technical program with 11 separate presentations on what will be required for our companies to move toward ultra HDI manufacturing.

## I-Connect007 Adds to Technical Library With Book on Factory Analytics by Cogiscan

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## Creators of SMT UHDI Test Board Vehicle Discuss this Important Project

Chrys Shea of Shea Engineering and Altium's David Haboud educate us on the latest revision of the SMT test board for UHDI testing, presented at the SMTA UHDI Symposium on March 26 in Arizona. She and David discuss recreating the test board to be appropriate for UHDI, and why industry members should make use of it to benchmark their processes.

## The Need for a Holistic Global Sustainability Standard

Michael Ford

*(Editor's note: This article was written in December 2023 when Michael Ford was co-chair of the 2-12D Task Group. He passed away in January 2024.)*

No one can deny that the resources of our fragile planet are finite. The environment seems like a third party, subject to constant degradation. We're acutely aware of the effects of pollution on our climate, and despite our "throw-away" culture, recycling and recovery of materials has remained relatively expensive, even as we use more energy just to survive.

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## iNEMI/IPC White Paper on Complex Integrated Systems Highlights Future Technology and Manufacturing Ecosystem Needs

iNEMI and IPC have recently published a white paper, "Complex Integrated Systems: The Future of Electronics Manufacturing," intended to guide and focus cross-industry efforts and partnerships in the necessary research and development, as well as the manufacturing capability scale-up that will be critical to success.

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## Europe Technical Sales Engineer

Taiyo is the world leader in solder mask products and inkjet technology, offering specialty dielectric inks and via filling inks for use with microvia and build-up technologies, as well as thermal-cure and UV-cure solder masks and inkjet and packaging inks.

**PRIMARY FUNCTION:**

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

**ESSENTIAL DUTIES:**

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

**QUALIFICATIONS / SKILLS:**

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

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

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# Career Opportunities

BLACKFOX
Premier Training & Certification

## IPC Instructor

### Longmont, CO

This position is responsible for delivering effective electronics manufacturing training, including IPC certification, to adult 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 primarily conduct training at our public training center in Longmont, Colo., or will travel directly to the customer's facility. It is highly preferred that the candidate be willing to travel 25–50% of the time. Several IPC certification courses can be taught remotely and require no travel or in-person training.

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

**Salary:** Starting at $30 per hour depending on experience

**Benefits:**
- 401k and 401k matching
- Dental and Vision Insurance
- Employee Assistance Program
- Flexible Spending Account
- Health Insurance
- Health Savings Account
- Life Insurance
- Paid Time Off

**Schedule:** Monday thru Friday, 8–5

**Experience:** Electronics Manufacturing: 5+ years (Required)

**License/Certification:** IPC Certification–Preferred, Not Required

**Willingness to travel:** 25% (Required)

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Prototron Circuits

## Sales Representatives

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

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

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

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# Career Opportunities

EMA Design Automation®

## Technical Marketing Engineer

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

**Requirements:**

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

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

Send Resumes to: resumes@ema-eda.com

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ARLON ELECTRONIC MATERIALS

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

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

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

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

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

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

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# Career Opportunities

## Are You Our Next Superstar?!

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

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

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## Field Service Technician

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

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

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

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

### More About Us

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

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# Career Opportunities

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

## CAD/CAM Engineer

### Summary of Functions

The CAD/CAM engineer is responsible for reviewing customer supplied data and drawings, performing design rule checks and creating 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 CAM tooling software, Orbotech GenFlex®.

### Physical Demands

Ability to communicate verbally with management and coworkers is crucial. Regular use of the telephone 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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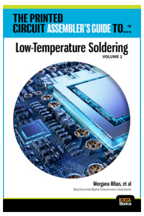
## Educational Resources

## PODCAST! Designing for Reality with ASC Sunstone


In Season 2, listeners can expect in-depth conversations with VP/manager and published author Matt Stevenson about the specifics that can affect your circuit board during the manufacturing process. Part tutorial, part tips and tricks, Stevenson details the interrelationships between design, fabrication, yields and cost optimization.

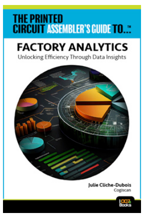
## I-007eBooks




### *New! Low Temperature Soldering, Volume 2*

**by Morgana Ribas, Ph.D., et al., MacDermid Alpha Electronics Solutions**

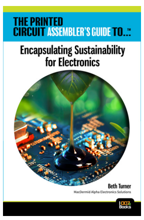
Since the first volume of *The Printed Circuit Assembler's Guide to...*™ *Low-temperature Soldering* was published over five years ago, considerable changes have occurred in the low-temperature soldering landscape. Here, the authors review the evolution of solder alloys from traditional eutectic SnBi solder to the fourth-generation HRL3 low-temperature solders. Read about innovations and challenges for achieving optimal processing with low-temp solder pastes, as well as what's next in LTS.




### *New! Factory Analytics: Unlocking Efficiency Through Data Insights*

**by Julie Cliche-Dubois, Cogiscan**

Using and understanding factory analytics is the future for electronics manufacturers. Those who strategically prioritize analytics and properly leverage the insights generated throughout their entire operation systematically will stand the test of time. In this fast-changing, deeply competitive, and margin-tight industry, factory analytics can be the key to unlocking untapped improvements to guarantee a thriving business.




### *New! Encapsulating Sustainability for Electronics*

**by Beth Turner, MacDermid Alpha Electronics Solutions**

This is a guide to encapsulation resins and their use in ruggedizing electronics. Learn about aspects such as their chemistry, application, and relevant test methods in different industries. The book also discusses the growing demand for sustainable solutions in the market and highlights examples of bio-based resins and the demand from emerging technologies.


### *Process Control*

**by Chris Hunt and Graham K. Naisbitt, GEN3**

In this book, the authors examine the role of SEC test and how it is used in maintaining process control and support for objective evidence (OE.) Issues, including solution choices, solution sensitivities, and test duration are explored.


### *Manufacturing Driven Design*

**by Max Clark, Siemens**

This book introduces a new process workflow for optimizing your design called Manufacturing Driven Design (MDD) and is a distinct evolution from DFM. Manufacturing certainly plays a critical role in this process change, and manufacturers do certainly benefit from the improved process, but it is design teams that ultimately own their overall product workflow; they are the ones who need to drive this shift. Get empowered now!

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

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