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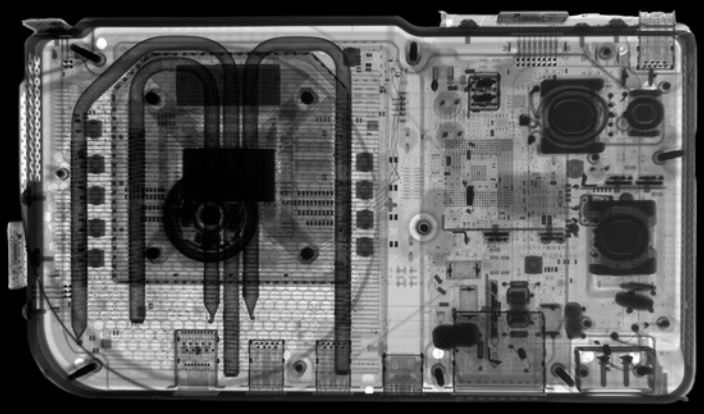

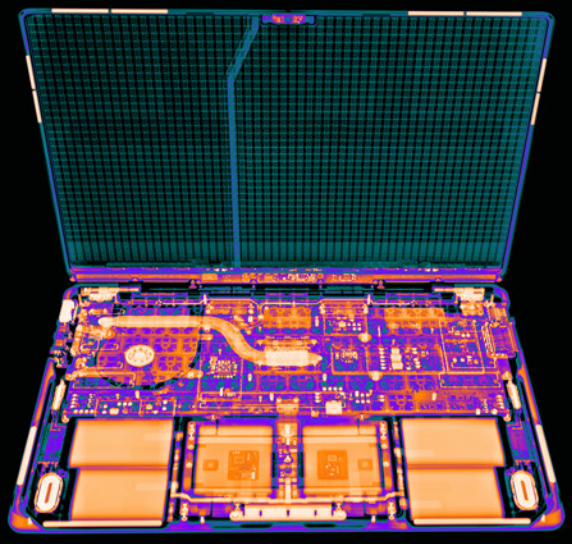

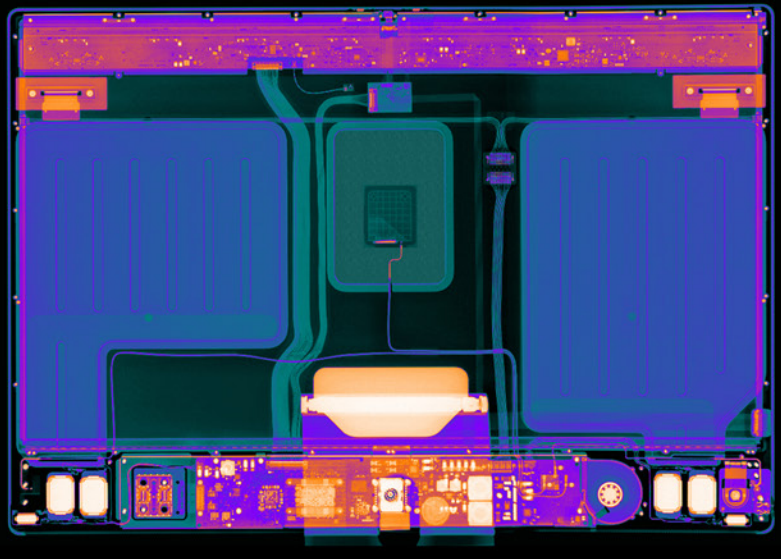

Do You Have X-ray Vision?

X-ray Vision Is No Longer a Novelty, It's a Necessity

"A concise, comprehensive, and very readable primer on X-ray and its use in electronics assembly."

Phil Zarrow
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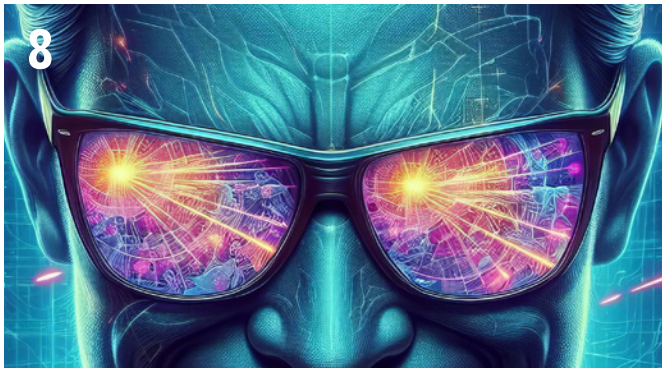
I-007e Books

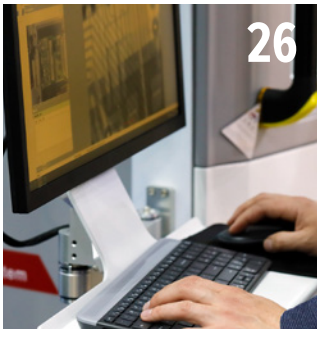
Look Inside

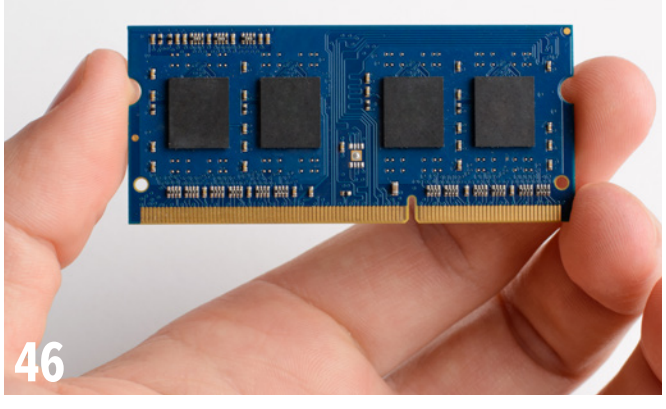
SMT007 MAGAZINE

Do You Have X-ray Vision?

As a technology, X-ray is ancient (a 19th century invention that revolutionized 20th century medicine) but it's finding a new application in the 21st century on the EMS provider's shop floor. As component packaging continues to evolve, inspecting through components is crucial. Has X-ray's time finally come in electronics manufacturing?







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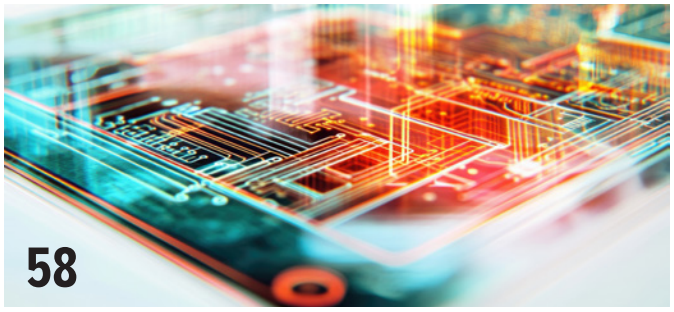

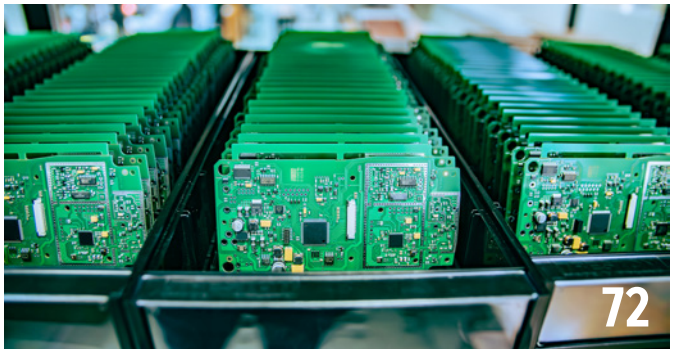

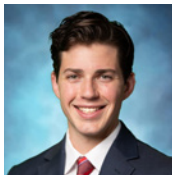

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Looking Deep Into the Future With X-ray

Nolan's Notes

Feature Column by Nolan Johnson, I-CONNECT007

We're talking about catching the vision of X-ray technology in this issue of S*MT007 Magazine*, and it's the perfect opportunity to recall those back-of-the-comic books "X-ray glasses" we all fell for as kids. Our hopes and dreams of seeing through walls were quashed by the realization that our new specs were merely a rainbow filter encased in cardboard. Let's be honest with each other, because we're all in this business with a similar mindset: You bought some, didn't you? It's okay and only natural. It's what we did with our "Fantastic Four" ambitions and "paper route" finances.

As a diagnostic tool, X-ray has been around for over a century, and available to EMS inspection for some years. It seems the industry has moved far enough forward to fully embrace X-ray on the assembly line. I'm reminded of Wayne Gretzky's famous comment about the secret to his scoring success: "I skate to where the puck will be, not where the puck is." I liken that to X-ray inspection, which has been standing here all this time waiting for the industry to catch up. Has X-ray's time finally come in electronics manufacturing?

We've just returned from IPC APEX EXPO 2025 in Anaheim; you'll find my impressions on the show on page 64. I want to take a moment to reflect on the momentum I see recently with line equipment R&D. New packages are pushing pick-and-place machinery to either handle very large components or very, very small ones. New high-performance materials are tweaking the tried-and-true soldering processes. Those large packages are hiding all their solder joints underneath the package itself. None of this is really new; rather, it's the

magnitude that's new, and it's the magnitude that brings X-ray into focus.

To highlight this month's theme, I start with an excerpt from a new book published by I-Connect007 by Creative Electron's Dr. Bill Cardoso, *The Printed Circuit Assembler's Guide to... X-ray Inspection*. The book starts with some X-ray history and discusses its practical applications for EMS providers. It is free to download here. Also, in this issue, I've included an interview I had with Bill on the IPC APEX EXPO show floor.

To further the topic of X-ray inspection applications, you'll find two technical papers on X-ray applications that address what we're seeing with X-ray inspection today. While one speaks to X-ray's role in the future of advanced packaging, the other talks about DRAM damage due to X-ray inspections in the post-PCB assembly process.

With automated optical inspection, X-ray is coming into its own. It would seem it's only a matter of time before artificial intelligence starts to put the AI in AOI, making AOI much faster and reducing the risk of human error. But each application has its own merits. As a reference, one of the award-winning papers at this year's APEX EXPO Technical Conference was by Ben Rachinger about creating a federated database of inspection images that can be shared amongst multiple EMS companies even while protecting the proprietary information. For those of you following AI closely, this paper is a good read.

Columnist Mike Konrad moderates a discussion on X-ray applications with Jesper Lykke, president and CEO of Viscom, and Robert Boguski, CEO of Datest. This roundtable-style discussion provides some insight into user perspective on the use of X-ray inspection.

Our other columnists touch on their areas of expertise as well. Dr. Jennie Hwang continues her series on AI, new columnist Josh Casper writes on additive manufacturing, Nash Bell discusses the basics of proper lead tinning, and Tom Yang considers "Redefining Connection and Responsibility in Digital Transformation." While perhaps not exactly on the topic of X-ray, these columns address adjacent issues that are key drivers of change on our shop floors in their own right.

All this X-ray goodness, however, is built into some "big iron" capital equipment. We're not wearing this technology on our faces in the form of a pair of X-ray specs—not yet, at least. Nevertheless, new challenges in AOI require new inspection techniques and the thoughtful application of tried-and-true technology in new ways. So, turn on those comic book X-ray glasses and look deep into the future. **SMT007**

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.

Artificial Intelligence Part 5: Brain, Mind, Intelligence

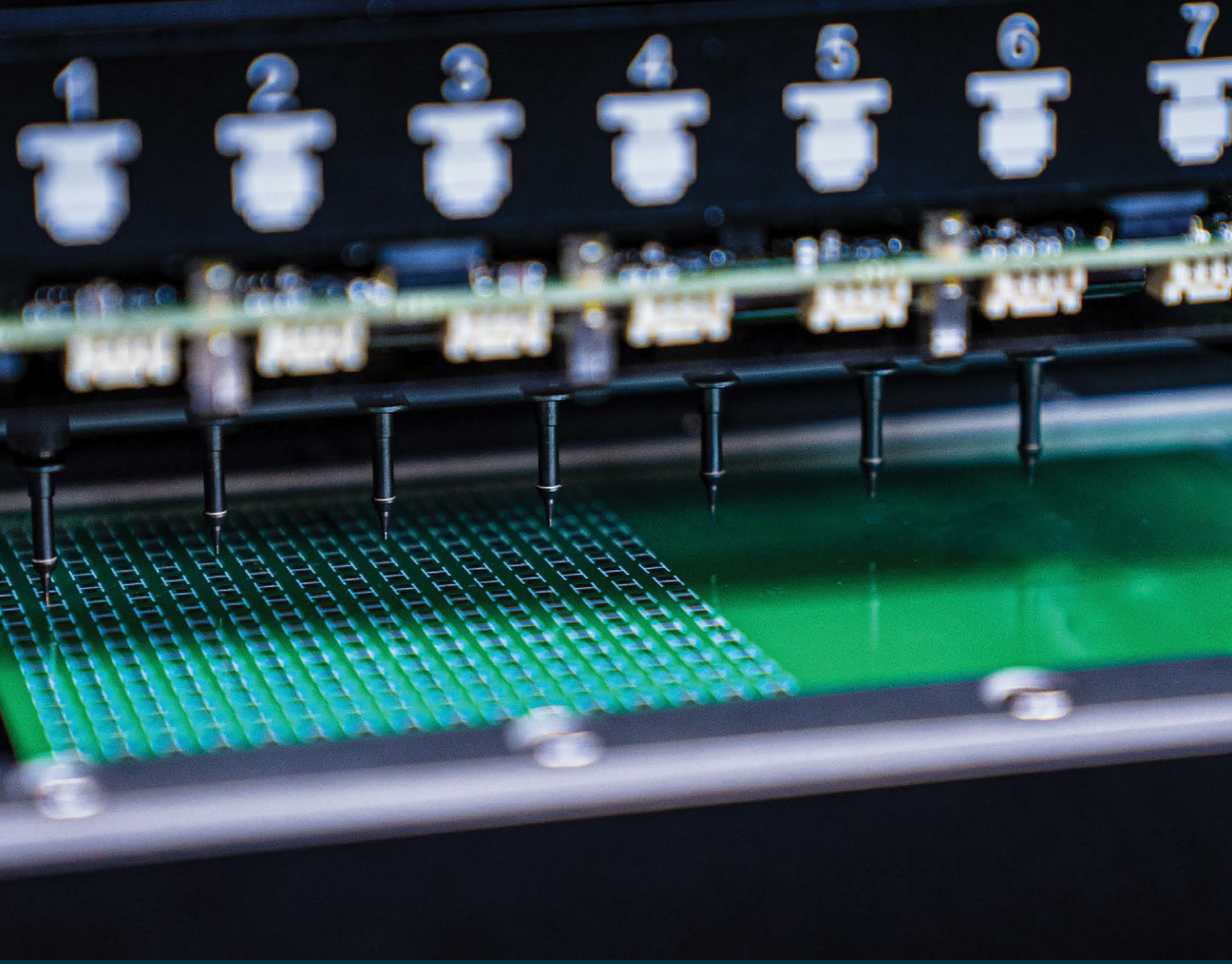
SMT Perspectives and Prospects

by Dr. Jennie S. Hwang, CEO, H-TECHNOLOGIES GROUP

Filmmaker James Cameron, who directed "The Terminator," "Avatar," "Titanic," and other award-winning movies, equates generative artificial intelligence (AI) with human dreams. Can we explain dreams' origins, content formation, and links to real events, emotions, and memories? Are dreams the result of the brain interpreting neural signals during sleep?

Although it is generally understood that dreams are the confluence of neurological, psychological, and physical processes during sleep, can we answer the above questions through experiences or science?

Experts widely agree that early childhood is the most sensitive period for forming strong neural connections and establishing foundational neural architecture, making it the most important period for brain development. Early childhood lays the foundation for future learning, behavior, and emotional well-being. The brain has all the power in connections, wiring, storage, memory, and processing to function as a human being. The human brain also requires a lot of fuel; it reportedly reaches its peak with approximately 100 billion nerve cells or neurons, and it takes 20W to power a brain[1].



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If transmitting and receiving electrochemical signals via neurons are essentially the thoughts, emotions, actions, and automatic functions of the human body, then the neurons' knowledge controls how to use the combined power of the conscious and unconscious mind to think in a healthier, more flexible, resilient, and goal-supporting way. Is thinking linked to electrical signals zooming inside our heads, forming a complex code carried by our neurons? Can we say the brain is the hardware, the mind is the software, and the operating system gathers, stores, and manages information by using our brain's massive processing resources and capacities as the basis of human intelligence?

What is artificial intelligence, and what is human intelligence?

Artificial Intelligence vs. Human Intelligence

Currently, there is no single established test that can authoritatively measure artificial or human intelligence. Humans generate data, acquire information, and translate it into knowledge. Cumulative knowledge builds intelligence. As such, it is plausible to define human intelligence as the capacity to acquire knowledge and the ability to apply it to achieve desired outcomes.

Computer science defines artificial intelligence as any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals. It also includes a system's ability to interpret correctly external data, learn from such data, and use what it has learned to achieve specific goals and tasks through flexible adaptation.

At its broadest level, intelligence is the ability to achieve a range of goals in different and unpredictable environments. Higher intelligent systems can fulfill a wider range of goals in a wider range of predictable and unpredictable environments.

A marvel of the human brain is that it can deal with the unexpected. Today, we need to advance the understanding of the brain to advance AI. Meanwhile, AI is fostering brain research.

Brain Research

AI enables new kinds of research[2]. The capacity of modern computer systems to process more data than in the past opens immense possibilities. Mathematics makes many kinds of AI possible, such as cluster models. One example of this methodology is to amass a pool of data that groups people into different clusters and uses artificial neuron networks to interpret the electrical signals of hundreds of neurons in the brain. The research's main finding was that the actual substance of thought and the patterns that constitute the mind we use to read is dynamic electrical activity in our brains, rather than something physically anchored to neurons. This is an important finding. It perhaps points to the immense complexity, nuance, and intricacy of brain dynamics—our mind, thoughts, and the mechanism of thinking and reasoning.

While neural networks in the brain are vastly more complicated, the result of this simulation is a model system that is both close enough to its biological equivalent and simple enough to offer hints about how the brain works.

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AI in Brain Research

Brain study and neuroscience continue to advance. Two notable clinical research trials are being conducted at Neuralink and AI at Meta labs. Reportedly, a second human (as of this writing) has received a Neuralink brain implant, which could lead to a potential milestone in developing brain-computer interface technology. The implant device is one-fifth the thickness of a human hair and is designed to sit on top of the brain and detect neuron spikes by detecting signals from individual neurons inside the brain—a potential advance that could decode higher-quality brain signals. A brain-computer interface, such as a brain implant, allows humans to have direct control of a computer or external device solely using human thoughts. It is a set of tiny electrodes (e.g., platinum) embedded in a thin film that conforms to the surface of the brain. Each electrode listens to the electrical activity underneath the brain and takes an electrical video in real-time of the thoughts taking place on the brain's surface to record, amplify, digitize, and then transmit them using AI to compute the vast number of signals in real-time to aid studies.

Separately, the Meta AI lab studies how to read mind and brain activity using a self-supervised learning model that can extract meaning from giant pools of data without human instruction. The goal is to create a "speech decoder" that can directly transform our brain activity (our thoughts) into words.

Present and Future

How neurons in our brains communicate and explore the nature of cognition is still an enigma and human intellect is still intriguing. Take the stock market as an example. One can use a computerized analysis of market data to detect hidden patterns and write AI algorithms to pick stocks[3]. However, at present, no AI model can consistently and reliably predict the stock market. This, in part, is a result of the stock market data being "noisier" than language and other data, making it harder to explain or predict how the market moves[4].

In his book *The Transcendent Brain: Spirituality in the Age of Science*, author Alan Lightman writes, "Some human experiences are simply not reducible to zeros and ones." This reflects the current and future challenges of AI to reach the capacity and capability of the human brain, dubbed Artificial General Intelligence (AGI).

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Is the concept of and the technology behind the large language models (LLMs) that mimic the way humans think, act, read, write, and reason a promising path to achieve AGI and beyond?

Can we turn the human brain into a machine or, when can we turn the human brain into a machine?

This is an opportune moment to quote Albert Einstein, who noted, "Computers are incredibly fast, accurate, and stupid. Humans are incredibly slow, inaccurate, and brilliant. Together, they are powerful beyond imagination." He was correct then, and he's still correct today. **SMT007**

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2. "A new era in cognitive neuroscience: the tidal wave of artificial intelligence (AI)," by Z. Chen and A. Yadollahpour, BMC Neurosci 25, 23 (2024).
3. *The Man Who Solved the Market: How Jim Simons Launched the Quant Revolution*, by Gregory Zucherman, Portfolio, 2023.
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Appearances

Dr. Jennie Hwang will present two webinar courses for IPC: "Reliability of Electronics—Solder Joint Voids—All You Should Know" May 13 and 15; and "Artificial Intelligence—A Primer and Essentials," June 17 and 19.

Dr. Jennie S. Hwang, an international businesswoman, speaker, and business and technology advisor, is a pioneer and long-standing leader in SMT manufacturing since its inception, and in developing and implementing lead-free electronics technology and manufacturing.

She has served as chair of Artificial Intelligence-Justified Confidence for DoD Command and Control study, chair of AI Committee of the National Academies, and Review Panels of NSF National AI Institutes and Committee of Strategic Thinking for Engineering Research. An International Hall of Famer (Women in Technology), she has been inducted into the National Academy of Engineering, named an R&D-Stars-to-Watch, and received the YWCA Achievement Award. She has held senior executive positions with Lockheed Martin Corp., and was CEO of International Electronic Materials Corp. She is currently CEO of H-Technologies Group, providing business, technology, and manufacturing solutions.

She has served as chair of the Laboratory Assessment Board, the DoD Army Research Laboratory Assessment Board, and the Assessment Board of Army Engineering Centers. She is on the board of Fortune-500 NYSE companies and civic and university boards, Commerce Department's Export Council, National Materials and Manufacturing Board, NIST Assessment Board, various national panels/committees, and international leadership positions.

She is the author of 10 books (four as co-author) and 750+ technical/editorial publications. She is a speaker and author on trade, business, and education issues. Her formal education includes four academic degrees (Ph.D., M.S., M.A., B.S.), as well as Harvard Business School Executive Program and Columbia University Corporate Governance Program. To read previous columns, click here.

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Book Excerpt: *The Printed Circuit Assembler's Guide to... X-ray Inspection*

by Bill Cardoso,
CREATIVE ELECTRON

"If the hand is held between the discharge tube and the screen, the darker shadow of the bones is seen within the slightly dark shadow-image of the hand itself... For brevity's sake, I shall use the expression 'rays'; to distinguish them from others of this name, I shall call them 'X-rays.'"

—Wilhelm Conrad Roentgen, Munich, 1895

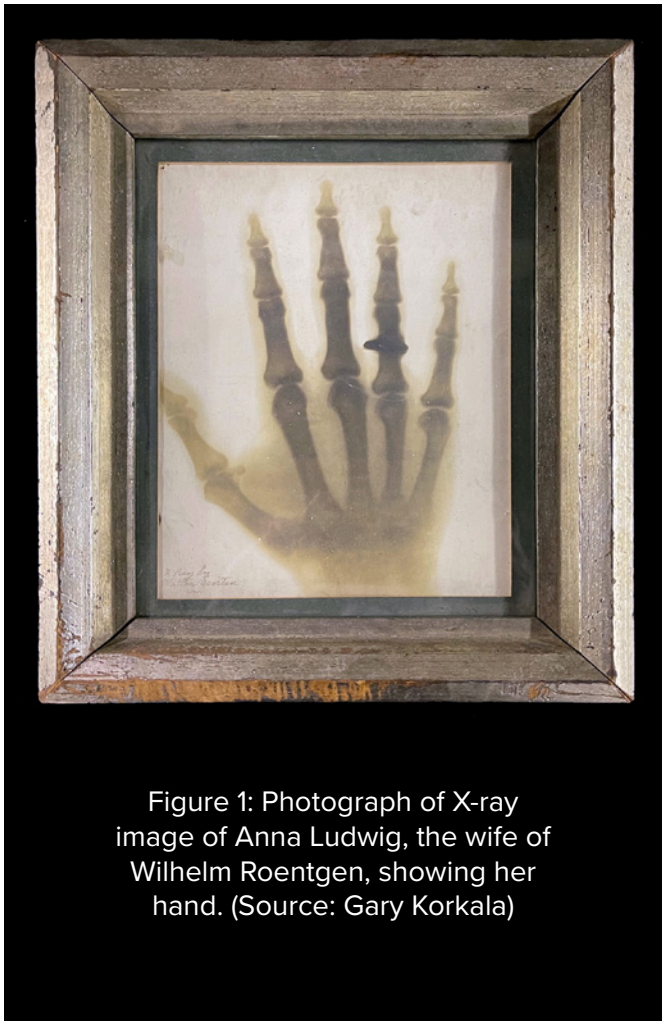

Figure 1: Photograph of X-ray image of Anna Ludwig, the wife of Wilhelm Roentgen, showing her hand. (Source: Gary Korkala)

Introduction: A Brief History of X-rays

It was the late part of the 19th century, and scientists around the world were fascinated by a new device called the Crookes tube (Figure 2). First shown to the world in 1878 by English scientist Sir William Crookes, the device's mysterious properties intrigued the best minds. One of these scientists was J.J. Thompson, who, in 1897, figured out that the cathode rays inside the tube were negatively charged, which led to the discovery of the electron. He also figured out that a magnetic field could steer this stream of electrons, and with that, he paved the way for the invention of the television.

As you can tell, a lot happened in the 1890s. For the context of this book, we'll focus on another scientist playing with Crookes tubes near Munich, Germany. Wilhelm Roentgen was curious why a fluorescent screen on the other side of his lab was glowing when the tube was on. He shielded the tube, and the glowing kept happening. He also noticed that the photographic paper in his lab was developed with weird shadows. His "Eureka!" moment was realizing that his Crookes tube was generating new rays that could go through matter. Not knowing what to call it, he called it "X"—as in the unknown variable of an equation. And that's how "X-rays" were discovered.

He promptly volunteered his wife to place her hand between the tube and some photographic film, and the first X-ray was created (as seen in Figure 1). To Roentgen's credit, he decided not to patent his findings. He recognized that X-rays were such an impor-

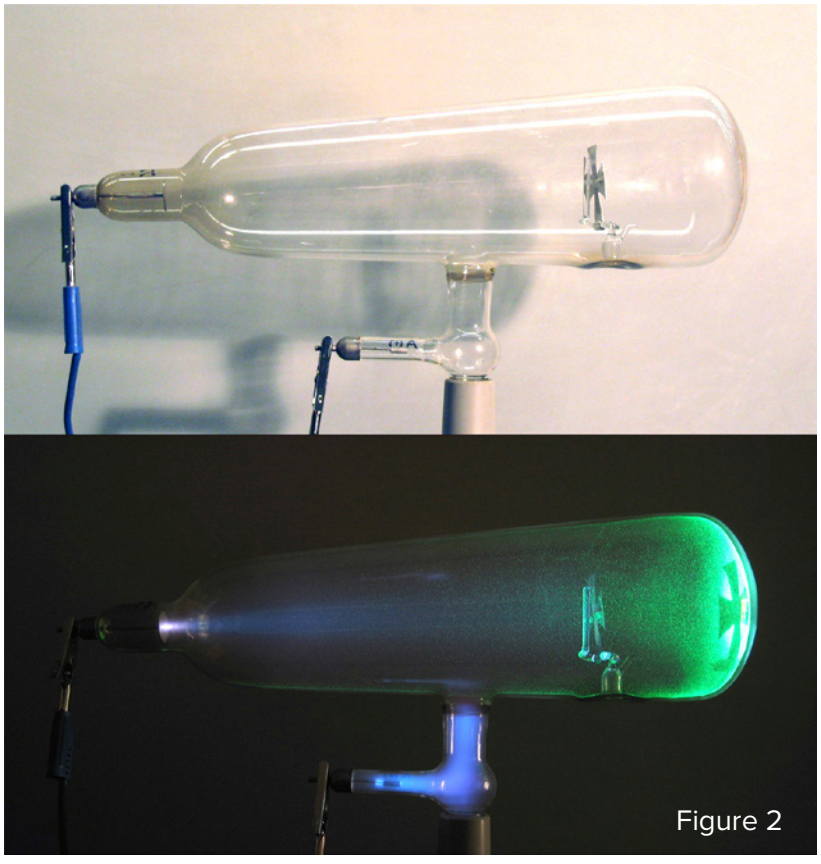

Figure 2

tant discovery that society should be able to take advantage of it as soon and as freely as possible. And he was right. As early as 1896 (a year after the discovery of the X-rays in Munich), physicians at Dartmouth College in New Hampshire were taking X-rays of their patients. That's an astounding adoption time for a new technology! Consider this took place before emails, fax machines, TV, or even radio! Remember that those Crookes tubes were in dozens of laboratories worldwide, so when word went out that they created these weird invisible rays that penetrated objects—well, you can imagine everyone wanted to see it for themselves.

Another prominent figure of the 19th century was Alfred Nobel (Figure 3). His claim to fame is less humanitarian: He invented dynamite in 1867. The invention was initially used for construction projects but quickly became used in military applications. Nobel made a lot of money with his patents related to exploding things. Not particularly happy with his legacy, in 1895, he learned about the German scientist who gave up a fortune to help society benefit from his invention. Soon after that, Nobel directed his will to establish and fund the Nobel prize. Who was the first recipient of the Nobel Prize? Yes, Wilhelm Roentgen.

The Modern X-ray Machine

Since Roentgen's discovery in 1895, X-ray machines have been used in various applications, from the inspection of seeds to car chassis—and everything else in between. To cover even a fraction of these applications would fill several books, so we'll focus on the X-ray inspection of electronic assemblies. We designed this book to follow the same process we use when designing an X-ray machine. The first step is to define the X-ray imaging train needed, namely the proper X-ray source and sensor. The second step is to determine how the sample will move in and out of the machine and how the sample will move inside the machine. Lastly, we need to decide who (or what) will make pass-and-fail decisions based on the tests performed on the X-ray images.

Imaging

The first step in defining the best X-ray inspection system for your application is to determine whether the machine will produce images that will reveal the defects in your samples. The following two steps in this process (motion and decision) are irrelevant if you can't see what you need to see.

The question we are often asked is, "How do I get a good X-ray image?" We thought this was an excellent question to help us guide this book. Once you understand the principles of X-ray inspection—which you'll need to do so you know how to get a good X-ray image—the applications of the technology

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will be seamless. Once you appreciate the difference between the voltage and the current in the X-ray tube and how these parameters impact the focal spot size in the target, you'll be able to assess which X-ray tube your application requires based on the density and size of your sample. The same analysis is extended to the X-ray sensor, where the exposure time, type of scintillator material, type of sensor, and pixel size are some of the many parameters you'll need to consider to properly select which imaging train will produce the best image.

Motion

Upon the determination that you have the proper imaging train—X-ray sensor and source—to image your samples, it's time to understand how your samples will enter, move, and exit the machine. The mechanics involved in the motion of your samples significantly impact the design of the X-ray system. From manual systems where you'll feed the samples into the machine by hand, to fully automated systems with conveyorized feeding mechanisms, the range of automation solutions is as vast as the applications they solve. The main drive to determine the type of automation your application requires is the number of boards you must inspect daily. Manual X-ray machines can process dozens or hundreds of boards, while automated systems are deployed when hundreds to thousands of boards are checked daily. Robots are also being utilized in semi- and fully automated X-ray systems.

Decision

The last step determines how the data will be processed. This is the last step of the process after you have captured good images and are collecting data as fast as you need and from all the places on the board you're interested in inspecting. Now that you have all these data, how are you transforming it into information? Remember, information

Figure 3

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is data you can act on. Data you can't act on have another name: noise. You'll need fully automated decision-making software (based on computer vision or artificial intelligence) if you're deploying a fully automated system producing vast amounts of data per second. At the other end of the spectrum is a system that delivers data much slower than a manual system. In this case, it is possible to have the operator make the pass/fail determination (upon proper training).

The X-ray machine industry drastically changed when the ball grid array (BGA) package was invented in the early 1980s. Before that, X-ray machine manufacturers followed Steps 1, 2, and 3 (imaging, motion, and decision) to design a solution for an electronic manufacturing supplier (EMS) or contract manufacturing company (CM).

The invention of the BGA kicked off the bottom terminated component (BTC) revolution, which triggered a convergence in the design of X-ray machines. The myriad BTC designs simplified and unified the problems X-ray machines would reveal. In turn, it allowed the convergence of software and hardware to find these defects.

Continue reading this book here.

Reporting on the Future of X-ray Technology

Bill Cardoso, CEO of Creative Electron, talks about the changing landscape of X-ray technology. He says the rise of miniaturization and complexity in assemblies, along with the introduction of fully automated 3D X-ray machines to meet U.S. demand are driving the technology. Bill predicts a future where X-ray technology becomes more affordable and widespread.

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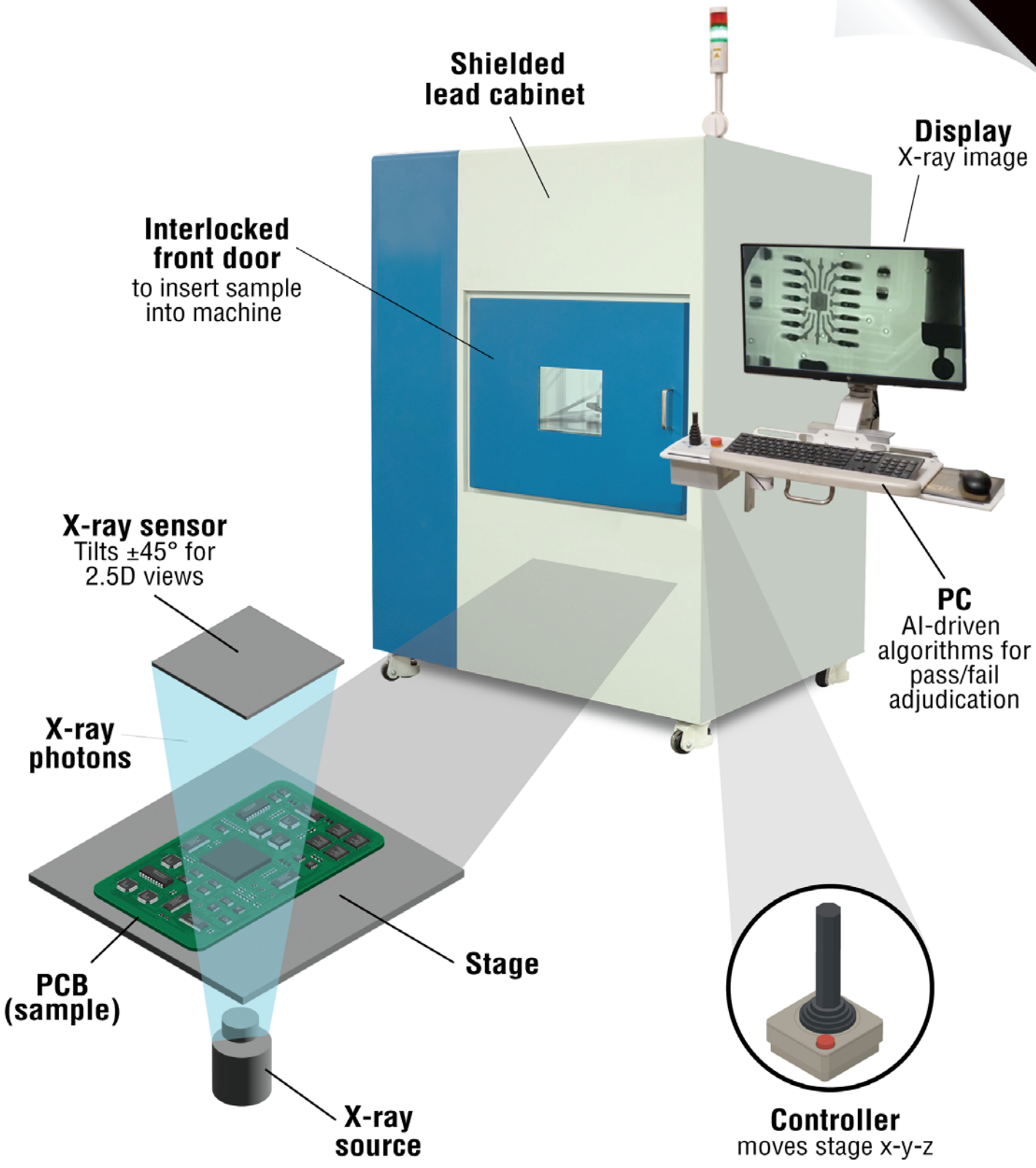
Anatomy of X-ray Inspection



Source: Creative Electron

Unlocking the Invisible: The Critical Role of X-ray Technology

The Knowledge Base

Feature Column by Mike Konrad, SMTA

From detecting voids under BGAs to solder defects in high-reliability applications, X-ray inspection has become an indispensable tool in modern manufacturing. But how is the technology evolving? What challenges do experts face in deploying X-ray inspection effectively and what does the future hold for this critical quality assurance method?

To answer these questions, I spoke with two experts in the X-ray industry, each bringing a unique perspective to the conversation. Jesper Lykke is the president and CEO of Viscom, a manufacturer of X-ray equipment, specializing in developing cutting-edge inspection technology. Jesper provides insight into how hardware and software innovations are shaping the next generation of X-ray systems and what manufacturers can expect in terms of capabilities and usability.

On the other side is Robert Boguski, CEO of Datest, a user of X-ray technology, operating a contract testing company that relies on this equipment daily to ensure product reliability. Their perspective highlights the practical challenges and benefits of implementing X-ray inspection in real-world production environments, from detecting hidden soldering defects to meeting industry standards for quality assurance.

Together, these two viewpoints offer a comprehensive look at X-ray technology's current state and how it is evolving to meet the increasing demands of the electronics manufacturing industry.

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Questions for an X-ray Equipment Manufacturer:

What are the most significant advancements in X-ray inspection technology in recent years, and how have they improved defect detection in circuit assemblies?

Jesper Lykke: X-ray technology hasn't changed significantly, but the software that processes the images has advanced considerably. With AI-driven defect detection, identifying flaws, even those traditionally hard to spot, has become much easier. AI can filter out noise, assess the area based on experience, and indicate whether a potential defect is present. This allows operators to focus primarily on the most challenging defects, while AI efficiently handles routine detections. It's a win-win: Operators are not overwhelmed by excessive defect calls, and the company can maintain high product quality with greater ease.

How do you guide electronics manufacturers in selecting the right X-ray system for their specific inspection needs, such as quality control, failure analysis, or process monitoring?

Lykke: Through conversations, we aim to understand exactly what the customer expects from the machine. This involves asking numerous practical questions, such as:

- Will the system be used inline or offline?
- What inspection speed is required?
- What type of defect/process control does the system need to handle?
- How many boards need to be inspected daily?
- What are the space constraints on the production floor?
- Is this for a new line setup or integration into an existing line?
- What are the customer's specific process requirements?


Jesper Lykke

By gathering this information, we can effectively guide the customer toward the best solution for their needs. This is not a quick, five-minute conversation. Our goal is to provide comprehensive support, ensuring we fully understand the customer's needs and expectations.

Can you explain the key differences between 2D, 3D, and CT X-ray imaging, and in what scenarios each technology provides the greatest value?

Lykke: The key difference lies in the level of detail: 2D provides fewer details, while CT offers the most comprehensive view. This all depends on the number of images captured for each area of interest; the more images, the clearer the solder joints or defects will appear. However, this comes with a tradeoff: CT takes longer than 2D. Choosing the right method is about balancing speed and inspection goals. For manual or semi-automated X-ray inspection in a lab environment, maximizing detail is often the priority since time is less critical. Conversely, for inline X-ray inspection, speed is essential, making 2D or 3D more suitable.

What role does automation and AI-driven analysis play in modern X-ray inspection systems, and how does it impact efficiency and accuracy in defect detection?

Lykke: This role is significant. As mentioned earlier, AI greatly simplifies defect detection, requiring far less effort while improving accuracy. Refer to the explanation above for more details.

With miniaturization and ultra-high-density interconnects (UHDI) becoming more common, how is X-ray technology evolving to keep up with these challenges?

Lykke: There are several ways to approach this, or even a combination of methods. One option is using higher-resolution X-ray technology, now capable of sub-1 micron focus spots, which generally improves the detection of smaller objects and defects. Additionally, AI plays a crucial role here for the same reasons mentioned earlier, enhancing detection accuracy with minimal effort.

Product design also impacts inspection results. Ideally, designing the product without heavy metal objects directly opposite fine-pitch components can improve visibility. However, this is rarely feasible since boards are typically designed with specific requirements in mind. In challenging cases, achieving sufficient visibility may require higher tube power, which can risk washing out fine defects.

What are the most common misconceptions about X-ray inspection in electronics manufacturing, and how do you address them when working with customers?

Lykke: **Misconception:** X-ray can detect every defect perfectly.
Reality: While X-ray is highly effective, it's not foolproof. Certain defects, especially those involving subtle material inconsistencies or minimal density differences, can be challenging to detect. AI-enhanced image processing significantly improves detection rates but is still dependent on image quality and inspection parameters.

Misconception: Higher tube power always means better results.
Reality: Increasing tube power may improve penetration but can also wash out fine details as mentioned above, particularly in delicate components or small solder joints. Proper calibration and balancing resolution with power are critical.

Misconception: More images always mean better inspection.
Reality: Capturing excessive images can improve detail but may drastically slow the process. The key is finding the right balance between resolution, speed, and data volume, especially for inline inspection.

Misconception: X-ray inspection is only for complex boards.
Reality: While essential for complex PCBs with hidden joints (e.g., BGA, QFN), X-ray can also improve quality control on simpler boards by detecting solder voids, bridges, or alignment issues.

Misconception: X-ray inspection is too slow for inline production.
Reality: Modern inline X-ray systems are designed for high-speed inspection, especially with AI algorithms that reduce processing time by quickly identifying areas of concern.

Misconception: All X-ray systems provide the same results.
Reality: Different X-ray technologies, 2D, 3D, and CT vary in detail, speed, and suitability for certain applications as described above. Choosing the right method is crucial for achieving optimal results.

Questions for a Contract Testing Company:

As a contract inspection provider, what are the most common reasons customers turn to X-ray inspection services for their circuit assemblies?

Robert Boguski: The reasons would include precise defect detection at higher resolution and magnification (we have a more powerful X-ray system than the customer, and they are skeptical about results from their own system); that X-ray sees what other inspection methods don't (obvious example: underneath BGAs); and failure analysis, meaning that I know a problem exists, because there is an electrical failure, but thus far I haven't been able to verify/validate the root cause. Other reasons include a need for second opinion, lack of X-ray capability at their own facility, and customer feedback, usually in the form of rejections and/or field failures.

Sometimes, the equipment or process isn't working. It's 4 p.m. Friday at the end of the quarter, and money is riding on the problem being resolved. It feels like we're all going to die.

What best practices do you follow to ensure consistency and accuracy when inspecting a wide variety of assemblies from different manufacturers?

Rob Boguski

Boguski: Never take the customer's description of the problem at face value. Frequently we find problems on the board, but in a different location than the customer initially suspects.

I recommend that you look at the entire board. Don't focus solely on the customer's area of interest. Ask the customer at the beginning of the engagement whether our finding nothing wrong would be a good thing or a bad thing. Their answer tells a lot.

Give the customer realistic expectations of the probability of finding the suspected defect. The more realistic the front-end setting, the calmer the relationship. If you manage the time and expectations at the beginning, there are typically fewer surprises and recriminations at the end.

Can you share an example of a particularly challenging inspection case where X-ray technology provided critical insights that other inspection methods could not?

Boguski: We recently did several projects for a medical startup, in which we were asked to X-ray and CT scan human blood vessels for signs of calcified plaque buildup. The images were used in clinical trials of a medical product. We had to design a process to reliably handle human tissue, especially to hold it steady during the imaging process (vibration distorts images). It took several months of trial-and-error engineering to achieve a repeatable, reliable process, but in the end, we did it, and the customer was happy.

How do you work with customers to interpret X-ray findings and help them resolve potential manufacturing defects or quality/reliability concerns?

Boguski: With a customer new to our service, the best way is to review the images of the first job with them, explaining to the uninitiated in X-ray technology exactly what they are seeing, and why what they are seeing either is or isn't a legitimate defect. This can

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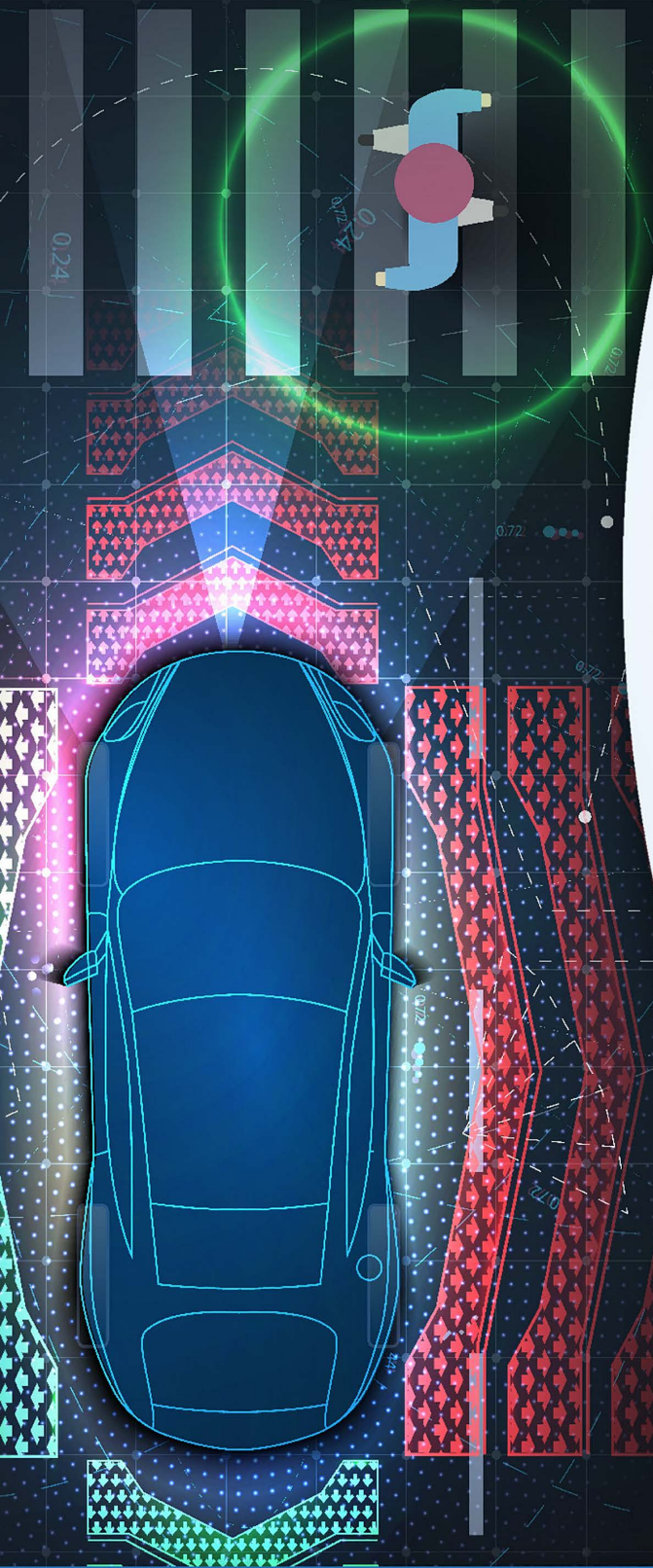

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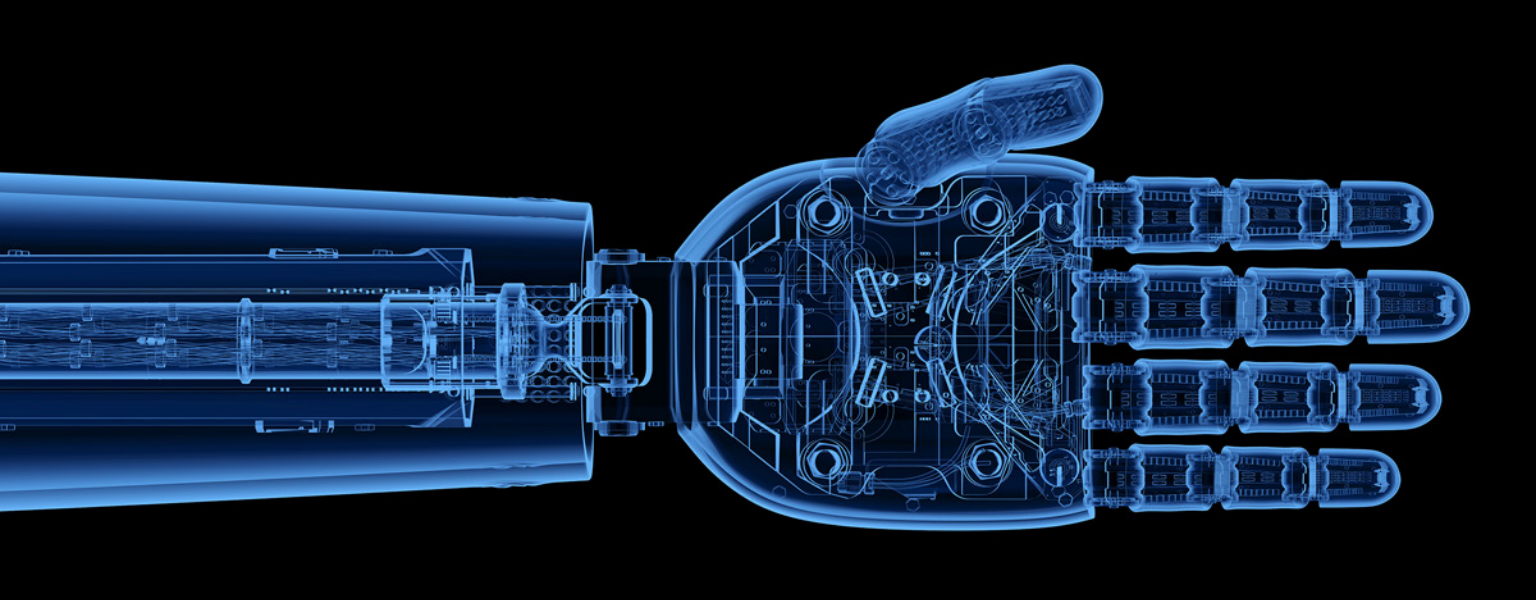

be done either in person or on a virtual call. Knowledge is power, and we believe in transmitting knowledge. An informed customer tends to be a satisfied customer, in our experience. Satisfied customers tend to return and tell others about us.

Once the review is complete, we are often asked to recommend process improvements. We are not process engineers, so we must tread carefully when asked this question. Usually, we provide a range of possible causes. If the customer pushes harder and wants to know the specific root cause of a problem, we often refer them to an industry colleague who is a process management consultant.

From your experience, what are the key differences in value between 2D and 3D X-ray technology, and how do you determine which method is best suited for a particular inspection need?

Boguski: 2D is conventional X-ray inspection; 3D is CT scanning. The terms are constantly mixed up and lead to much confusion. Unscrupulous persons often take advantage of this by playing on peoples' ignorance. Conventional X-ray is cheaper by the hour than CT scanning. Most of our inspection engagements begin with conventional X-ray, if for no better reason than as a sanity check (even if the customer wants us to go directly to CT scanning). We usually take this conservative approach because it saves the customer money and arrives at the objective in a quicker and more systematic way. Customers typically are not put out when we save them money.

What advancements in X-ray inspection technology have had the biggest impact on your ability to serve customers effectively, and where do you see the technology heading in the future?

Boguski: The obvious answer is AI. It is removing some of the drudgery from the old school method of having one person reviewing hundreds of images from one board, with the attendant risk that operator fatigue will set in and something crucial will be missed. Having said that, AI does not eliminate the need for skilled, experienced Xray technicians and analysts, with time-based knowledge to distinguish false from true failures, and to evaluate subtle defects and judge their potential to contribute to future catastrophic board or system failures.

Also, digital detector technology in both X-ray and CT scanning systems is constantly improving, thereby enabling us to capture images, and defects, at finer resolutions (often in the sub-micron range), that are essential for today's microelectronics failure analysis.


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What are the biggest misconceptions of X-ray technologies?

Boguski: Confusion in terminology, especially between 2D and 3D X-ray. Shady operators exploit this ignorance to their own advantage. For example, CT scanning is nothing more than the amalgamation of multiple 2D X-ray images into a three-dimensional whole for analysis. A lot of powerful software and computing power is needed to achieve this, and we do it every day.

Another frequent human problem is the know-it-all—a "TechBro" process engineer who has anointed themselves as "God's Gift to Failure Analysis," and who has predetermined the outcome in their own minds. This often begs the question of why they are requesting our services in the first place. People are funny. Beware of anyone who prefaces the discussion with, "In my years of working in this industry, I have never seen a defect such as you claim to see," to which we usually reply, "You need to get out more." It's tough to address a solid-state world possessed of a vacuum tube mindset.

Conclusion

Thank you to Jesper and Robert. In the fast-paced world of electronics manufacturing, the pursuit of reliability and precision is relentless. As circuit assemblies become more complex, with finer pitches, denser components, and hidden solder joints, traditional inspection methods often fall short. This is where X-ray technology steps in as a game-changer, allowing manufacturers to see beyond the surface, identify hidden defects, and ensure the integrity of their products. **SMT007**

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

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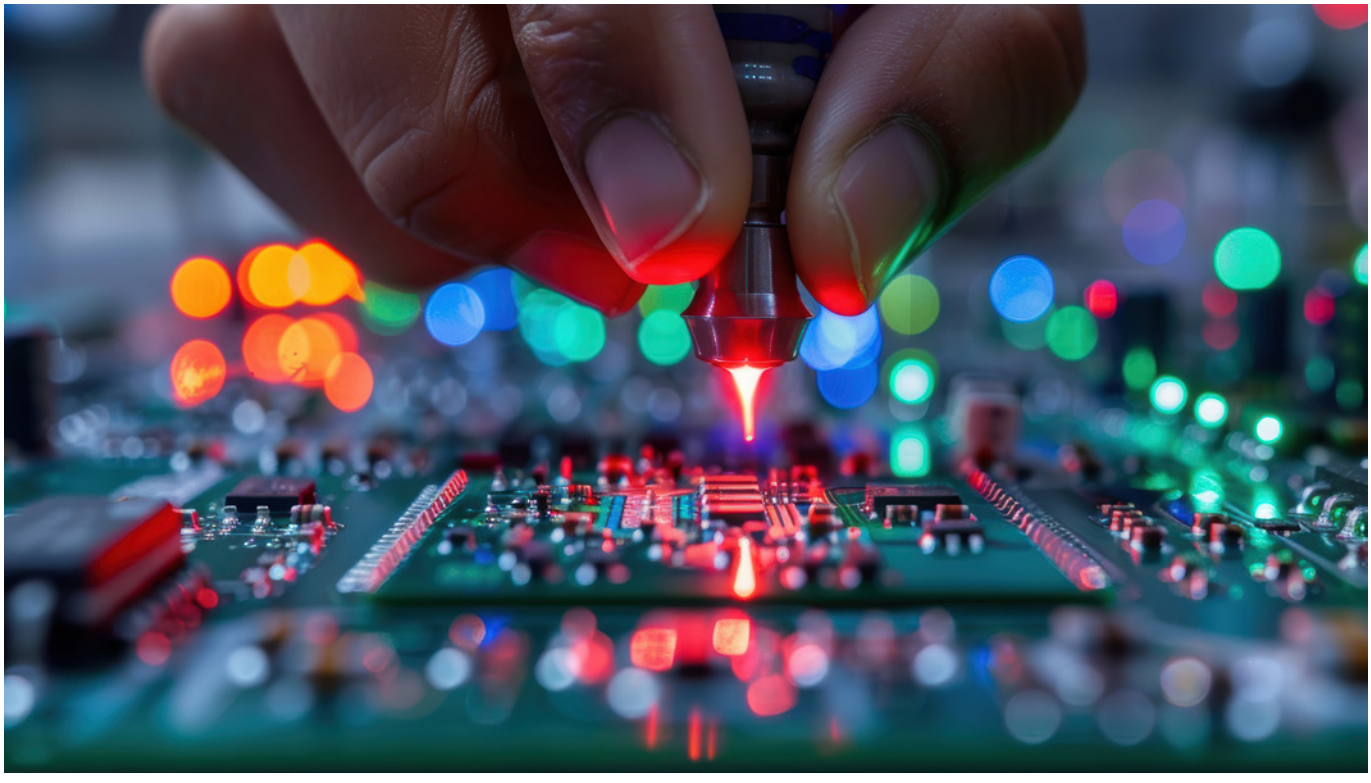
The Future of Advanced Packaging Inspection Is X-ray



Article by David Kruidhof and Kevin Jan
COMET YXLON

Editor's Note: The following is an excerpt from a paper at the 2024 SMTA Wafer-Level Packaging Symposium. For access to the full paper, please refer to the SMTA Knowledge Base at www.smta.org.

Driven by smartphones, high-performance computers, and artificial intelligence, the global demand for high-end computing power is constantly rising. The industry is also facing demands for miniaturization, which creates the need for ever-smaller defect recognition. The semiconductor industry has been identifying and solving these challenges for decades using various optical inspection and SEM tools. However, with the development of 2.5 and 3D packaging, using these optical tools has become less effective and/or time-consuming and expensive. The need to see internal defects has also made these tools destructive.

Detecting and understanding killer defects quickly can decrease time to market, increase yield, and improve process controls, all of which are vital for foundries and OSATs to develop competitive technologies in a fast-changing environment. To continue to find these killer defects requires the change from these typical inspection methods to non-destructive techniques.

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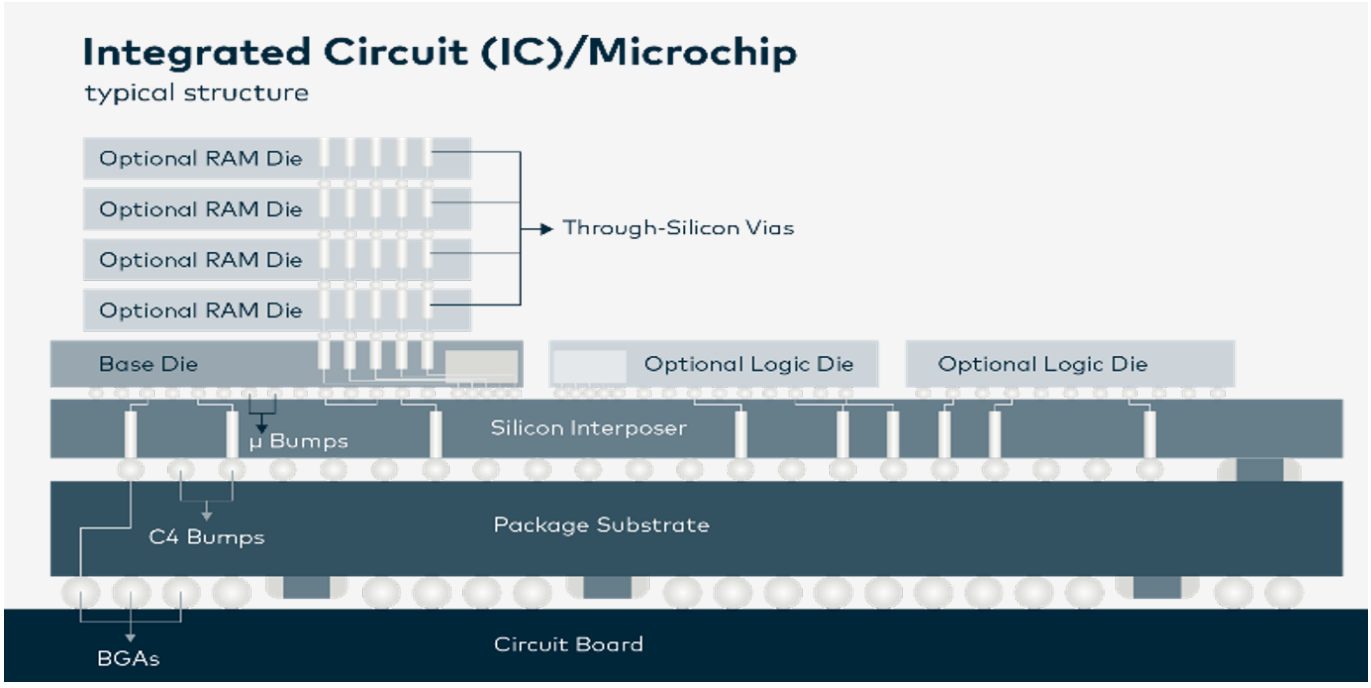

Figure 1: Example of a 3D package with various interconnects.

While historically X-ray inspection was not the preferred technology, advances in image resolution and speed have made it the unique solution for inspecting 3D packaging non-destructively today.

Advanced packaging companies seek non-destructive automated inspection tools that are fast enough to provide value within their production processes, increase yield, and reduce waste at an early stage. This article will give an overview on how X-ray and laminography inspection can provide value-added data and information within minutes instead of weeks, for exactly that.

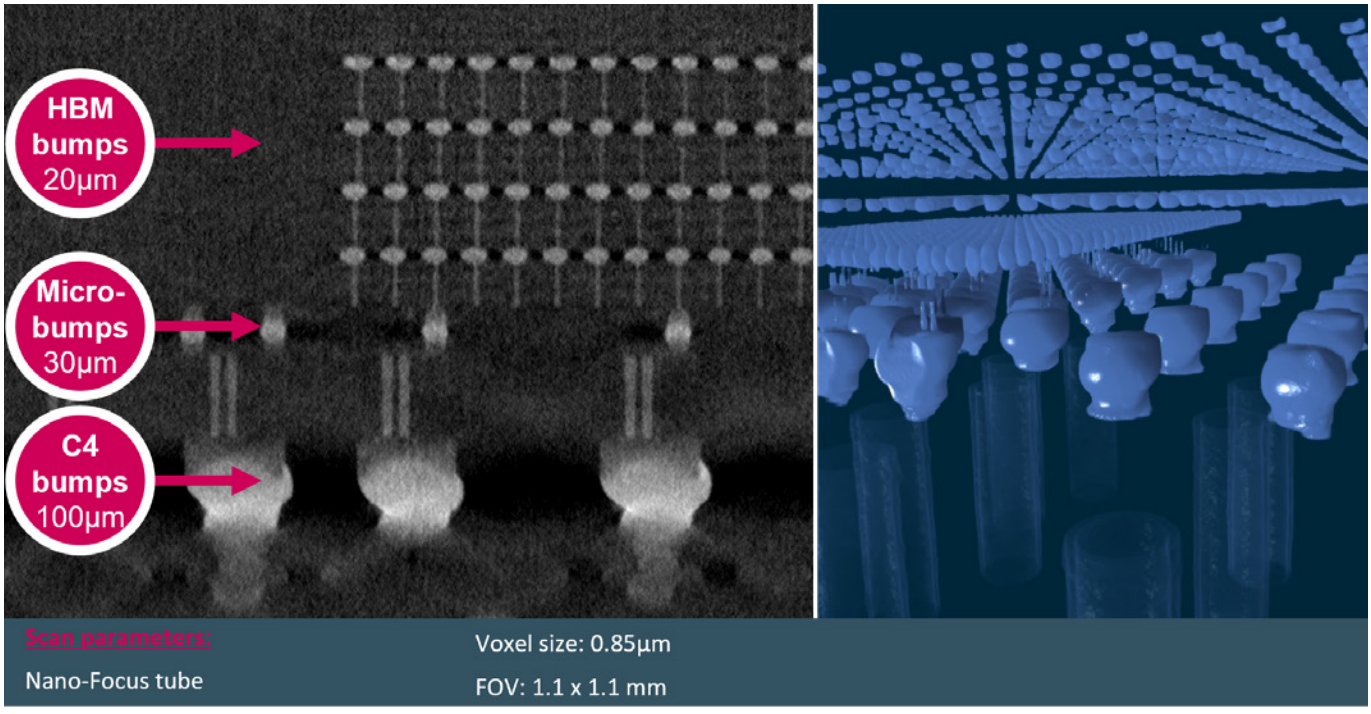

Figure 2: Slice and 3D rendering of GPU with 0.85 µm voxel.

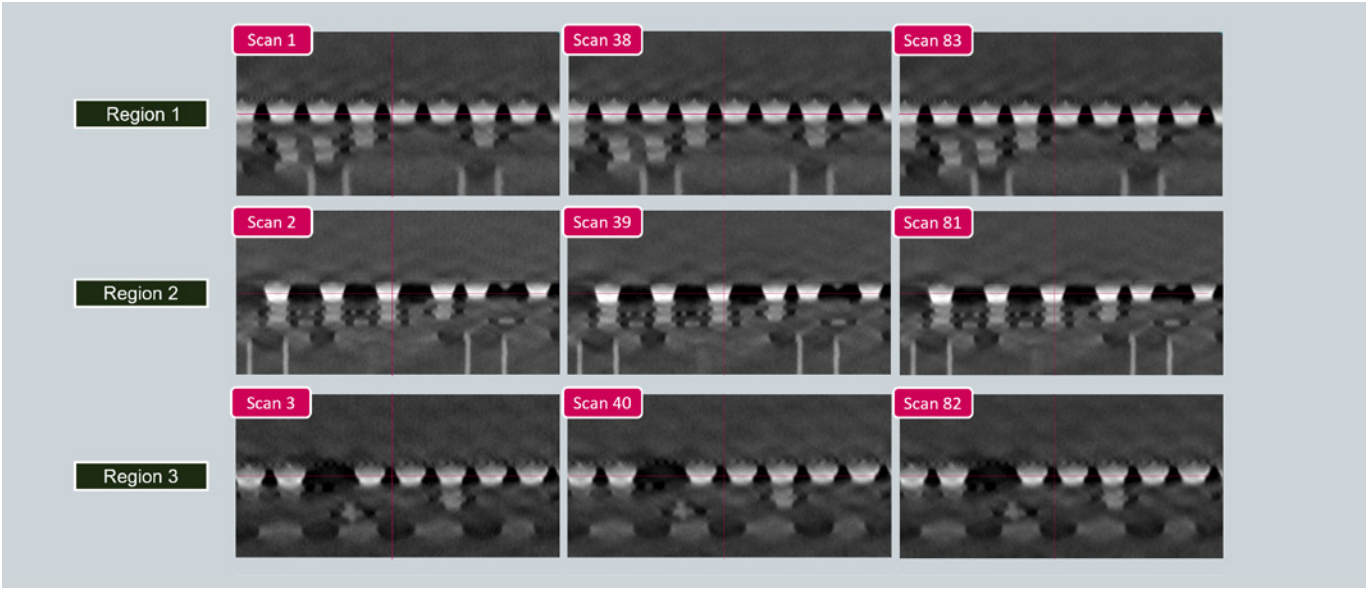

Figure 3: Repeatable results throughout the day are required.

Advances in X-ray Technology

Refinement of spatial resolution

Advances in X-ray tube and X-ray detector hardware have increased resolution in both 2D and 3D inspection of materials. From the perspective of the X-ray tube, there was the need for smaller focal spots as well as improved stability during potentially long scan times, where required. On the other side, the detectors have improved their sensitivity while decreasing pixel pitch without unacceptable losses of sensitive area.

These are only two pieces of the puzzle, and alone, they make great strides for 2D X-ray inspection. However, for the active movement of multiple axes that is required for 3D inspection, there are more precision requirements. That is, every axis needs to move perfectly together. With a simple computer tomography (CT) system, that may start with only one axis and precision control for that is rudimentary at this point. With more advanced CT systems with a flexible rotation axis and with laminography trajectories being put to use, the number of actively moving axes is no longer trivial. Keeping these all moving simultaneously with perfect synchronicity requires precision movement systems.

Completing this incredibly precise task repeatedly with the same results, provides the certainty that the results are reliable.

Laminography allows for high-resolution 3D inspection

Traditional CT inspection requires gathering 2D X-ray images all around an object. Various trajectories have found shortcuts around this, with varying levels of detail loss and the introduction of artefacts. In electronics man-

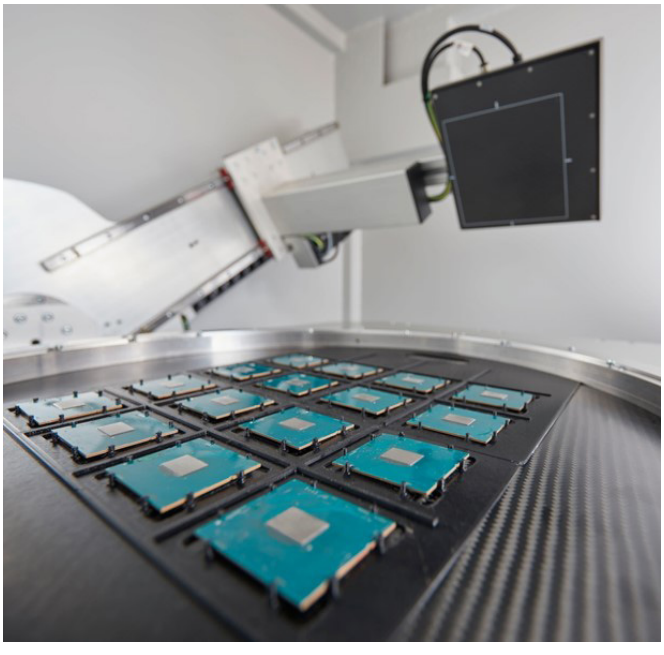

Figure 4: Laminography trajectories allow for batch scans.

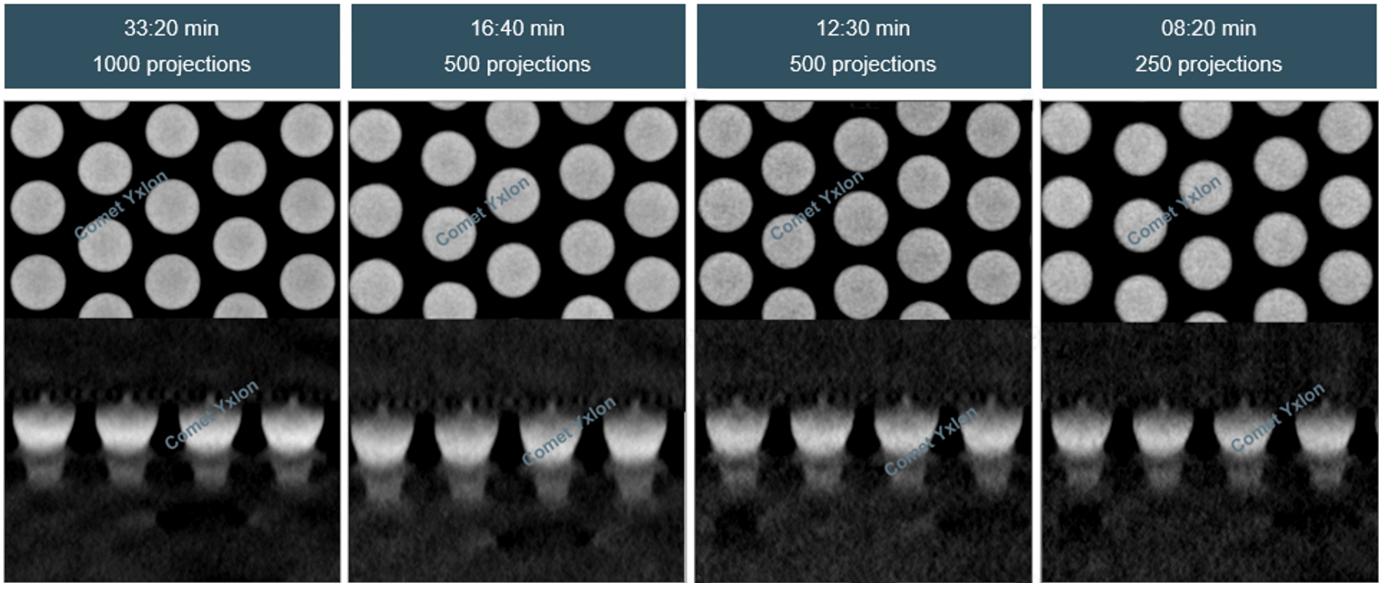

Figure 5: Results of scan times between eight and 33 minutes.

ufacturing, the disproportionate dimensions made it impossible to get enough detail while spinning the board around.

Fortunately, laminography scans were invented that allowed for a different angle of rotation that was more conducive to parts of this shape. Employing this trajectory for advanced packaging inspection has many advantages over CT.

While CT of even small packages would still require movement away from the X-ray source, decreasing magnification and, therefore, detail, or allowing the highest level of detail to be gathered only in the corners or other limited regions, laminography scans can be achieved anywhere of interest.

This strategy, along with precision movement throughout a large enough system, allows for a tray of components to be inspected in one batch run, increasing productivity many times over.

Scan time variations yield varying results

One of the other variables that affects resulting image quality is scan time. Many tests have been done with acceptable results that were achieved in under 10 minutes. However, longer scan times were also tested, which showed improved quality, eventually producing diminishing returns after an hour or so. Necessary image quality and therefore scan time, will need to be determined on a case by case basis.

Defect detectability

Putting all this technology together yields a system that can detect a wide variety of defects including the following:

- Tilting between layers
- Missing interconnects
- Bridging of interconnects
- Bulging interconnects
- Undersized bumps
- Shifted layers
- Voiding within interconnects

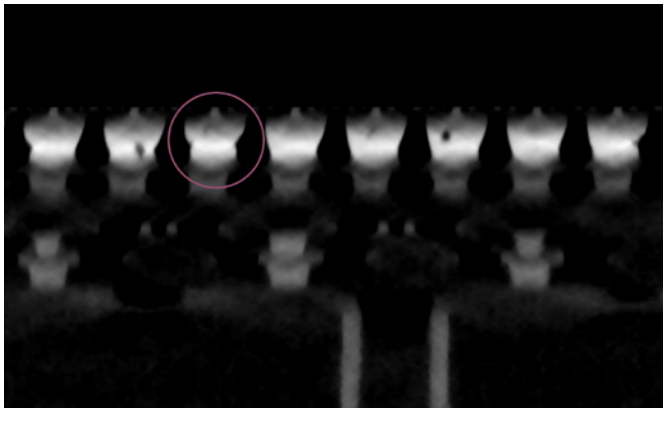

Figure 6: Head-in-pillow defect visible on 65 µm bump.

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Advances in Software Technology

Automated Analysis

With advanced packages being used to run AI tools, the number of interconnects with the chip continues to climb exponentially. Even with the sub-micron detail that is possible to achieve today, the manual inspection of interconnects in tens of thousands is not practical. Fortunately, automation is advancing here as well. Image analysis is no longer only being accomplished at the 2D level, but 3D volumes can be automatically segmented and inspected, greatly reducing the need for human intervention.

Conclusion

Given these advancements, X-ray inspection technology is now the best option for inspecting the interconnects between layers within advanced packaging.

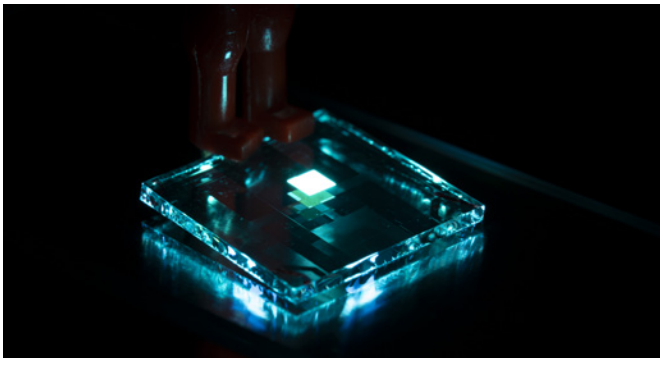
With its unparalleled level of detail with viewable area, diagnosing killer defects while accelerating ramp-up time has never been simpler. Due to the non-destructive nature of the process, chip production lines can be monitored more closely, increasing yields. **SMT007**

David Kruidhof is a technical sales manager at Comet Yxlon in California, and **Kevin Jan** works for Comet Yxlon in Hamburg, Germany.

Hybrid States of Light and Matter May Significantly Enhance OLED Brightness

Researchers developed a theoretical model that predicts substantial increase in the brightness of organic light-emitting diodes (OLEDs) by leveraging novel quantum states called polaritons. Integrating polaritons into OLEDs effectively requires the discovery of new materials, making practical implementation an exciting challenge.

OLEDs are quite slow at converting electric current into light, with only 25% probability in emitting photons efficiently and rapidly. The latter is an important condition for boosting the brightness of OLEDs, which tend to be dimmer than other light technologies. Researchers from the University of Turku, Finland, and Cornell University, USA, have now proposed a predictive model to overcome this problem.



OLEDs are electronic components made from organic carbon-based compounds that produce light when an electric current is applied to them. In OLED displays, the pixels themselves emit light, unlike liquid crystal displays, which use LED backlighting.

When sandwiched between two semi-transparent mirrors, the organic emitters can couple with the confined light, creating new hybrid states of light and matter called polaritons. By fine-tuning these states, it is possible to find a sweet spot where the remaining 75% dark states start becoming bright polaritons instead.

"In this work, we carefully examined where the polariton sweet spot lies in different scenarios. We found that the strength of the polaritonic effect in OLEDs' performance depends on the number of coupled molecules. The fewer, the better," says Associate Professor Konstantinos Daskalakis from the University of Turku.

"The next challenge is to develop feasible architectures facilitating single-molecule strong coupling or invent new molecules tailored for polariton OLEDs. Both approaches are challenging, but as a result, the efficiency and brightness of OLED displays could be significantly improved," Daskalakis explains.
(Source: University of Turku)

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MilAero007 Highlights

I-Connect007 Welcomes New Milaero Columnist Jesse Vaughan ▶

I-Connect007 is excited to announce the addition of a new monthly column, "Beyond the Board," authored by Jesse Vaughan, a seasoned expert in the PCB/milaero sector. Jesse, a third-generation printed circuit board technologist currently working at Summit Interconnect, brings a wealth of knowledge and passion to our publications. His new column, "Beyond the Board," will delve into market and industry trends, workforce engagement, and the processes and technology roadmap within the electronics industry.

RTX's Collins Aerospace Unveils New Engineering Development and Test Center in Bengaluru ▶

Collins Aerospace, an RTX business, opened its new Engineering Development and Test Center (EDTC) at the company's North Gate campus in Bengaluru, India. The new facility streamlines product development, testing, and certification of components locally, bringing aerospace technologies to market faster.

Lockheed Martin, Nokia, and Verizon Advance Defense Capabilities Through 5G.MIL® Collaboration ▶

Lockheed Martin, Nokia, and Verizon announced the successful integration of Nokia's industry-leading, military-grade 5G solutions into Lockheed Martin's 5G.MIL® Hybrid Base Station (HBS). The technology advances new capabilities to integrate commercial 5G connections with military communications systems to provide decisive information for national defense.

Saab Signs MoU with ICEYE to Integrate Advanced Space-Based Radar Data to Military Command Systems ▶

Saab and ICEYE, a leading provider of Synthetic-Aperture Radar (SAR) data and analytics, today announced a Memorandum of Understanding (MoU) to cooperate on the development and integration of advanced space-based radar data in Saab's command and control systems. Space-based sensor capabilities are becoming crucial for modern militaries, providing access to critical information in challenging environments.

NASA Uses New Technology to Understand California Wildfires ▶

Developed at NASA Jet Propulsion Lab (JPL), the science instrument gives researchers a more detailed picture of high-temperature surfaces, such as land scorched by wildfire, than previous infrared instruments. The January wildfires in California devastated local habitats and communities. In an effort to better understand wildfire behavior, NASA scientists and engineers tried to learn from the events by testing new technology.

FAA Certifies Airbus H125 IFR Capability ▶

The H125's single pilot instrument flight rules (IFR) capability has been certified by the U.S. Federal Aviation Administration (FAA), paving the way for first deliveries in 2025 from Airbus Helicopters' assembly line in Columbus, Mississippi. This new feature, developed in collaboration with Moog´s Genesys Aerosystems, consists of an upgraded cockpit and a new autopilot along with redundant hydraulic and electrical systems.

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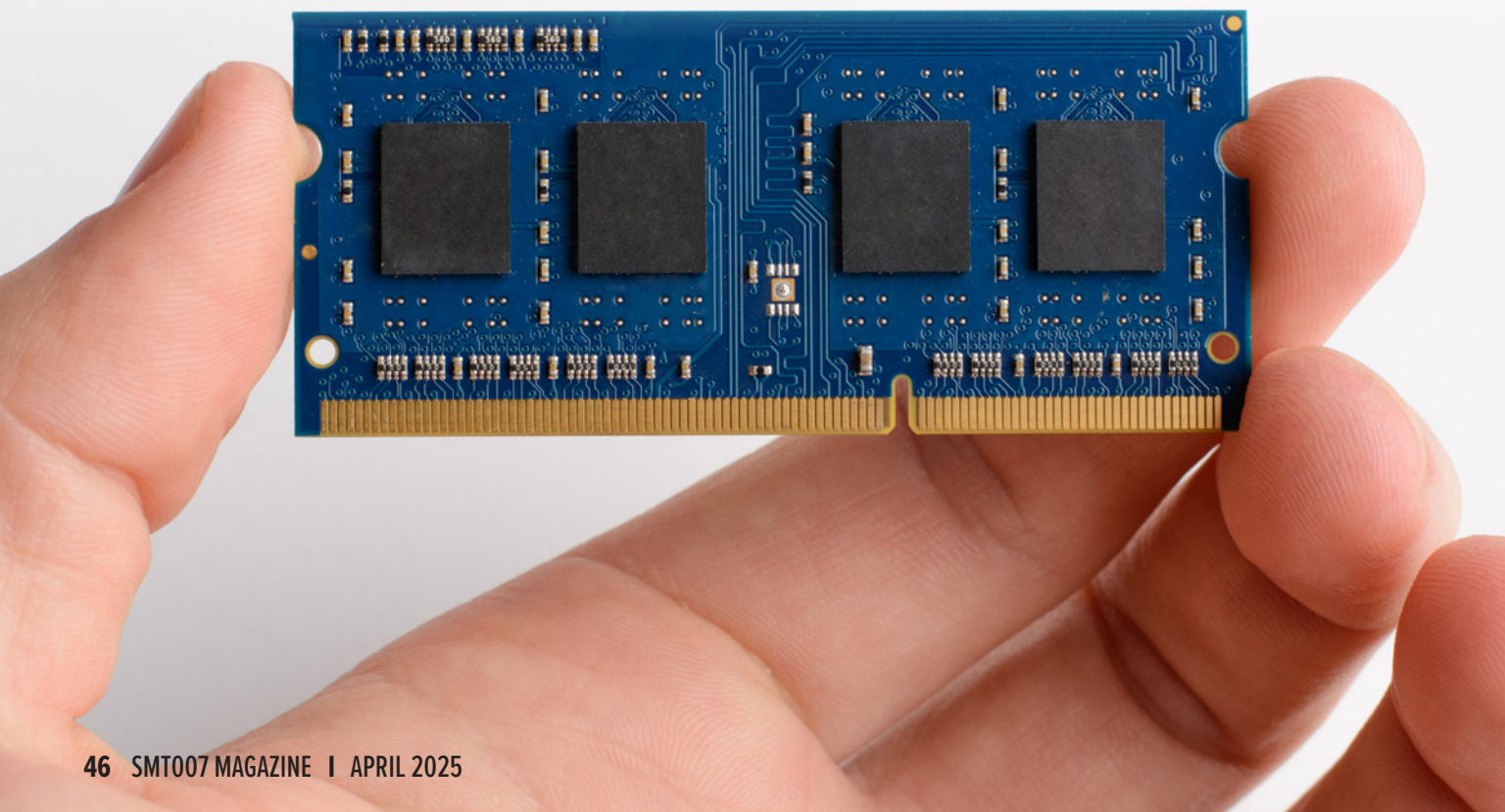
DRAM Damage Due to X-ray Inspections Post-PCB Assembly

Article by Saurabh Gupta, et al
INTEL

(Editor's note: This paper was originally published in the SMTA proceedings.)

Concerns are increasingly being raised about the potential for X-ray inspection steps during manufacturing, such as post-SMT inspections, to cause latent damage to semiconductor components. Several publications[1-3] have stressed the need for users to be aware of the risks associated with X-ray exposure to components, even though the radiation levels involved typically do not cause immediate failures. Defining the thresholds for any type of degradation, however, can be difficult. Users must take care to configure the inspection setup in a way that achieves the best possible imaging results while minimizing any risk of damage to the samples. Although latent damage is a possibility, it is expected to affect only a small percentage of samples, as the majority are likely to have enough tolerance in key or sensitive parameters to alleviate concerns about device failure.

One of the most significant semiconductor devices being used nowadays is the Dynamic Random Access Memory (DRAM). One major use of the DRAM in the current packaging landscape is to have an on-package DRAM close to the CPU to improve the bandwidth and lower latency. Several studies have reported that the critical device parameters of DRAM are sensitive to X-ray irradiation.



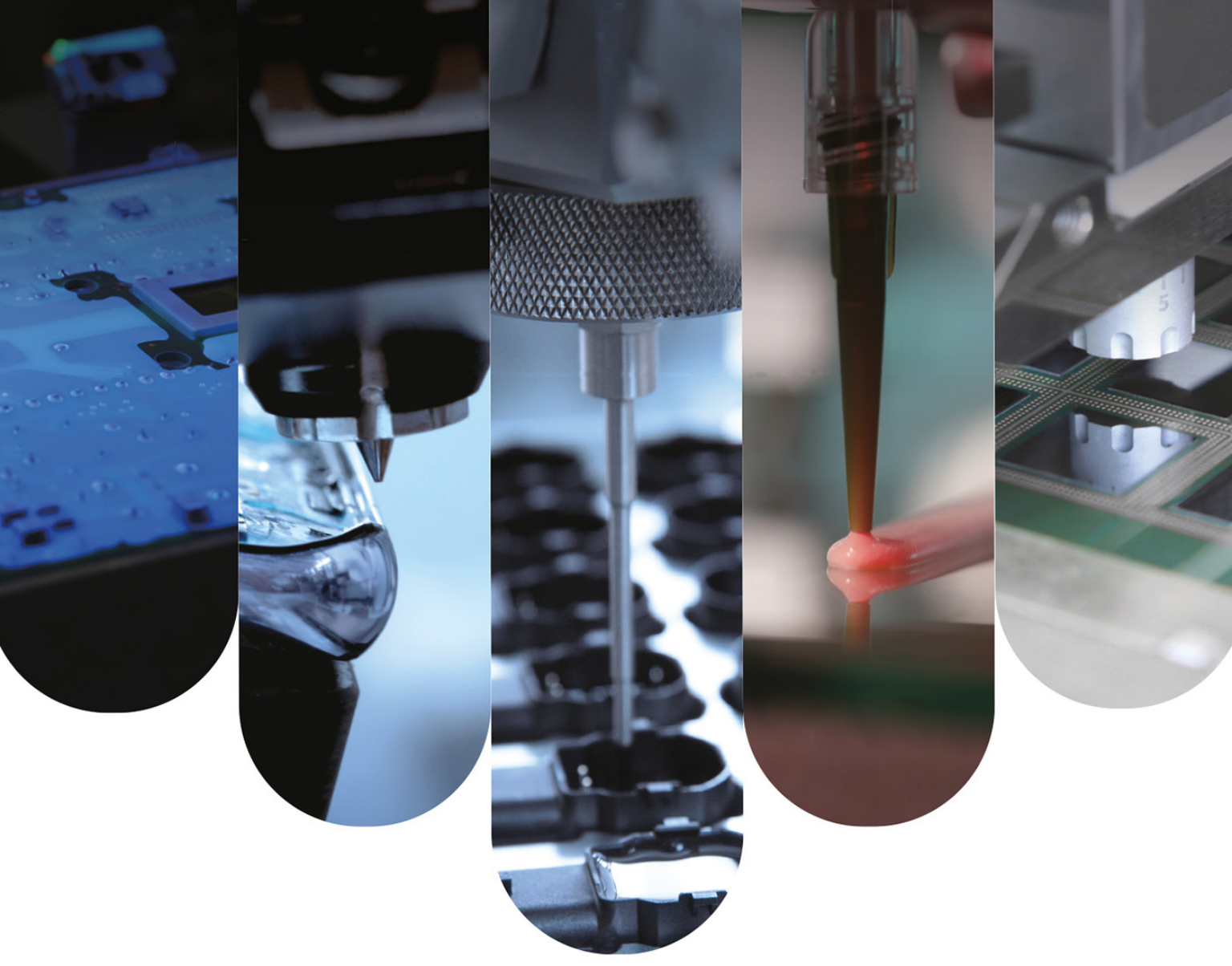


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Table 1: DOE table for radiation exposure

Filter Material	Filter thickness (mm)	Inspection time (sec)	Tube Voltage (kV)	X-ray power (W)	# of Runs	Comments
No Filter	0	55	120	14.5	2	Filter material & thickness
Aluminum	1.6	55	120	14.5	2	
Zinc	1.6	55	120	14.5	2	
Copper	1.6	55	120	14.5	2	
Aluminum	4.8	55	120	14.5	2	
Aluminum	4.8	135	120	14.5	2	Inspection Time
Aluminum	4.8	255	120	14.5	2	
Aluminum	4.8	315	120	14.5	2	
Aluminum	4.8	75	160	20.0	1	Tube Voltage & Power
Aluminum	4.8	75	140	14.5	1	
Aluminum	4.8	75	160	14.5	1	
Aluminum	4.8	75	140	17.5	1	
No Filter	0	75	160	20.0	1	
No Filter	0	75	160	14.5	1	

The static refresh t_{ref} or retention time is the amount of time a DRAM cell or device can reliably hold data; and several studies[4-6] have reported degradation in the DRAM retention time upon exposure to radiation such as X-rays. Measurement of other timing parameters, such as t_{ac} (access time) and t_{rp} (precharge time), had been made in prior X-ray experiments; however, no significant shifts were observed. As such, only t_{ref} appears to be the most sensitive parameter. Since leakage is a strong component of refresh characteristics, it is believed that the increase in reverse junction leakage is the most probable cause for t_{ref} degradation after subjecting DRAM components to X-ray radiation[1].

The DRAM damage due to irradiation poses a significant challenge to the inspections of BGAs with on-package DRAM to produce an image quality that is needed for providing the necessary information regarding the physical defects present, e.g., voids in solder joints after SMT assembly. As BGA pitch reduces, it is becoming increasingly necessary to go to higher magnifications, which reduce the distance between the package and the X-ray source and hence leads to higher dosage. In addition to developing methods to inspect the packages, it is also crucial to characterize the functional performance of DRAM upon X-ray exposure.

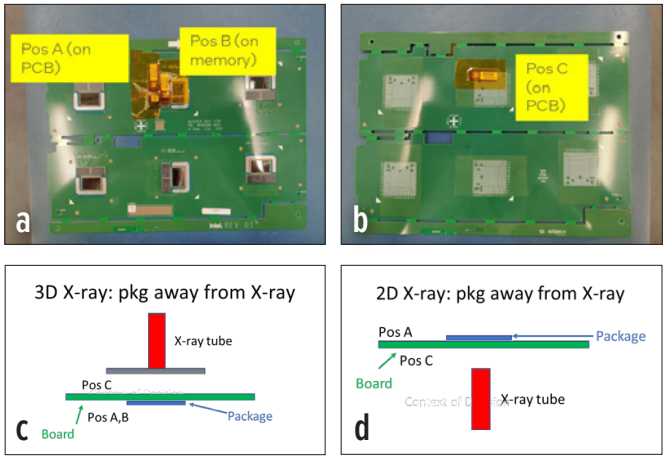
This paper provides an in-depth analysis of the factors influencing X-ray inspec-

Figure 1: Functional test set-up for DRAM performance.

tion of BGAs, focusing on key variables such as the type and thickness of the X-ray filter material, the thickness of the circuit board, and the duration of the inspection process. It also examines the impact of X-ray power and voltage settings on the inspection quality. By understanding how these parameters affect the inspection outcomes, the study aims to optimize the X-ray inspection process for better accuracy and reliability. Additionally, the paper outlines strategies for mitigating radiation damage in BGAs, considering three different construction types. These mitigation techniques are crucial for preserving the integrity and functionality of DRAM during inspection. A test setup was also developed to detect changes in functional performance of the DRAM when exposed to increasing levels of radiation.

Experimental Method

Radiation measurement was performed using a widely used thermo-luminescent detector (TLD) with an accuracy of ±5% and a minimum reportable dose of 0.01 rad. TLDs are a useful dosimeter choice, as they are simple to use and good for measuring integrated dose applications. Their principle of operation is to create "color centers" within their crystal structure when ionizing radiation (the X-rays in our case) are absorbed. Subsequent heating of the TLD material releases the stored photons created by the radiation, as each color center is driven back to its lowest energy state. The results (photons = dose) from the test sample can then be referenced against a calibration table for the TLDs used[4]. The dosimeter was



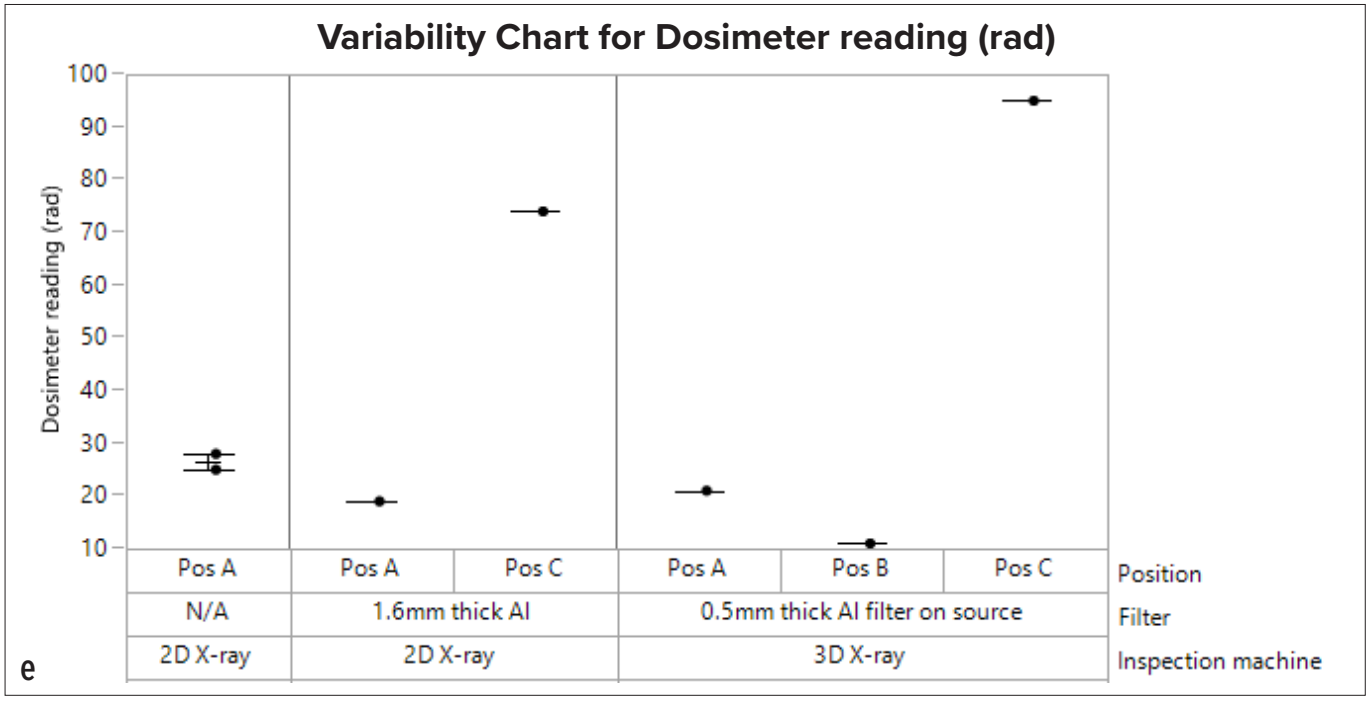
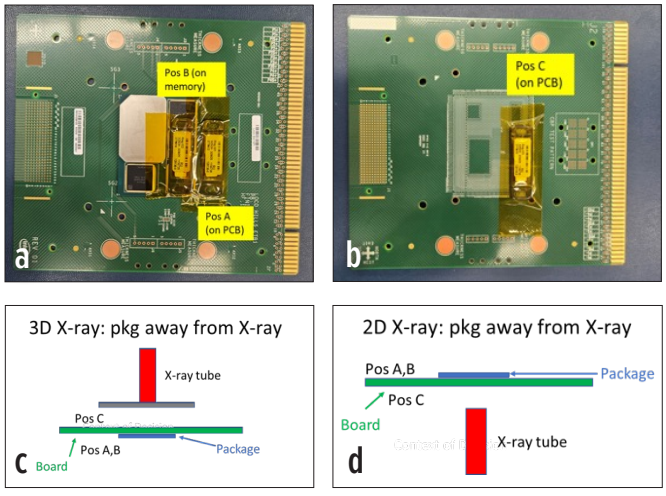


Figure 2: BGA #1 results: (a) and (b) position of dosimeters on the BGA; (c) and (d) position of dosimeters with respect to the X-ray source; (e) TLD readings in 2D X-ray (MXI) and 3D X-ray (AXI) machines with different filters.

attached to the area of interest where radiation needed to be measured using a Kapton tape. Radiation was measured in both types of machines: automated X-ray inspection (AXI or 3D X-ray) and manual X-ray inspection (MXI or 2D X-ray).

Three BGAs with different geometries of board and substrate were chosen for evaluation of the dosage experienced by on-package DRAM. BGA #1 had a 0.58 mm thick substrate and was placed on a 10L 0.6 mm thick PCB. BGA #2 had a 1.56 mm thick substrate and was placed on a 16L 1.58 mm thick board. BGA #3 had a 2.27 mm thick substrate and was assembled on a 28L 3.175 mm thick board. All three BGA construction types serve as test vehicles that have the on-package DRAM memory completely exposed. If there is a heat spreader (IHS), then it could provide additional shielding from the X-ray radiation and that is not in the scope of this paper. The radiation absorbed by the on-package DRAM was characterized for the three BGA construction types in a typical AXI as well as MXI scans.

A 10L 0.5 mm thick PCB with BGA #1 assembled on it was used to characterize the influence of various inspection parameters on the X-ray dosage. Table 1 shows the parameters that were varied to characterize the effect of the radiation. All these DOEs were conducted in a 2D X-ray (MXI) machine so that the various parameters could be controlled more accurately. Three types of filter materials, namely aluminum, copper, and zinc, were evaluated for their efficacy in shielding radiation. The inspection time, X-ray power,



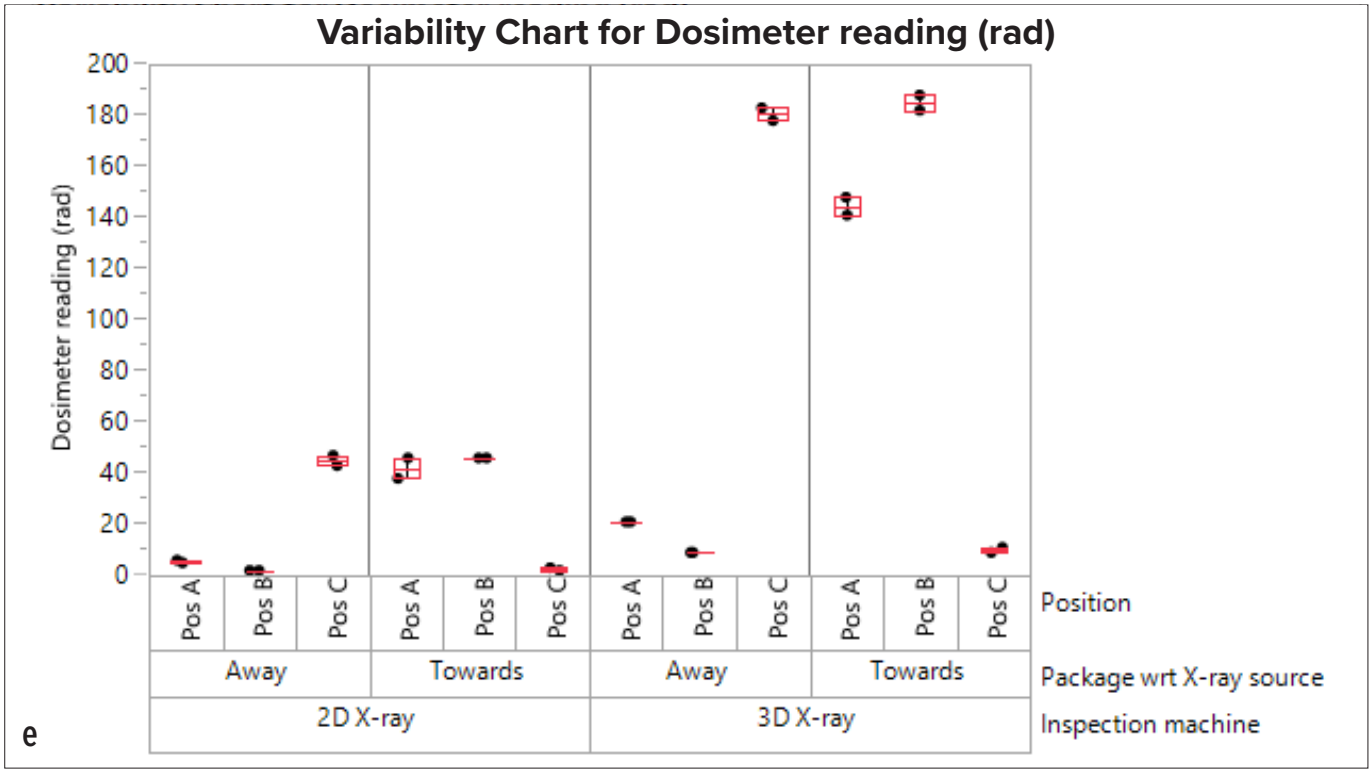


Figure 3: BGA #2 X-ray dosage results.

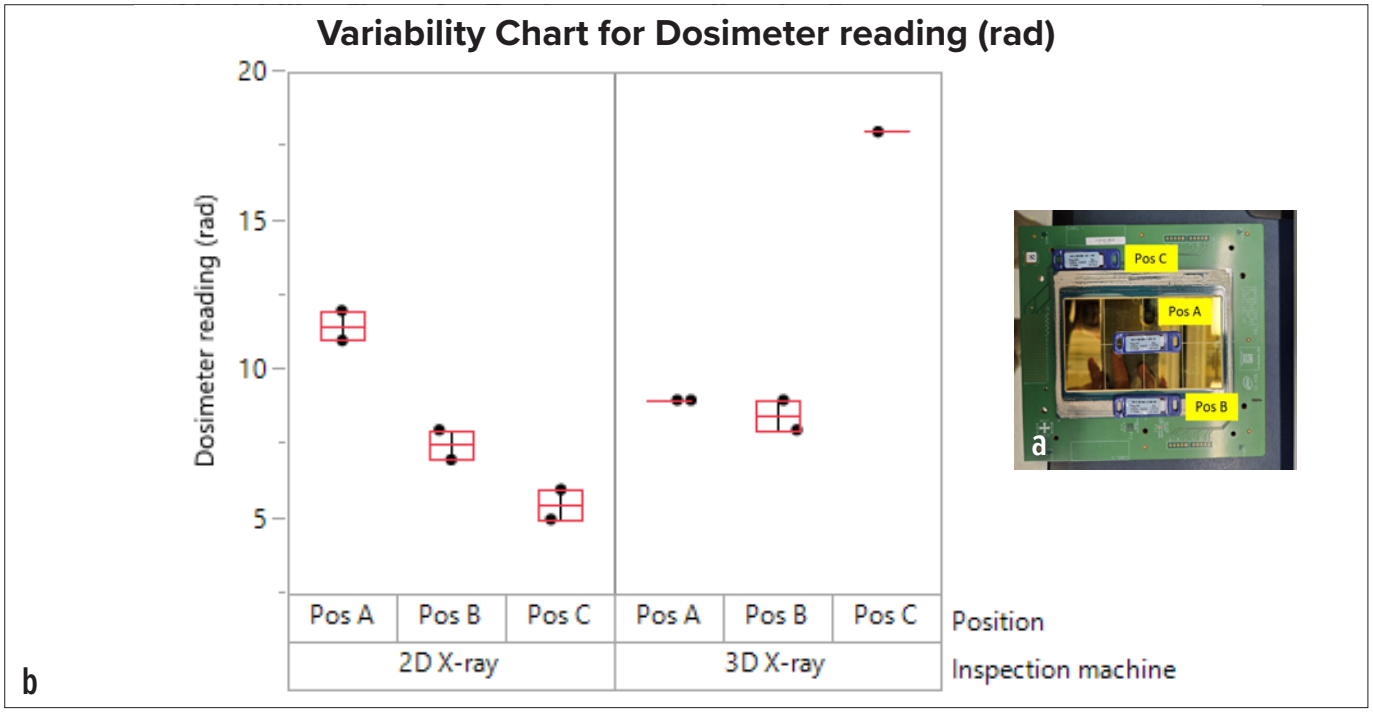


Figure 4: BGA #3 X-ray dosage results. Package is facing away from X-ray source in both machines.

and tube voltage were also varied on the machine. Different board thicknesses were also tested under the same inspection conditions to characterize the impact of the PCB material on radiation absorption.

A functional test was set up using a validation platform hardware that contained a motherboard, heatsink, keyboard, monitor, mouse and SSD. The hardware setup is equivalent to a functional laptop or desktop installed with Windows Operating system. Functional SOC with memory on package will then be installed on this socketed motherboard and tested using MemTest86. MemTest86 is an open-source memory testing tool for memory diagnostics and was used to test if the DRAM had errors upon exposure to radiation.

Results and Discussion

Figures 2a and 2b show the dosimeter locations on BGA #1. Pos A is on the PCB on the same side of the board as the BGA, Pos B is on the memory, and Pos C is on the PCB on side of the board opposite to that of the BGA. Figures 2c and 2d show the locations of the dosimeters with respect to the X-ray source on both the 2D X-ray and 3D X-ray machines. The 3D X-ray machine has a 0.5 mm thick aluminum on-unit filter attached to the X-ray source while additional filters can be added to the 2D X-ray machine as needed. Figure 2e shows the dosage readings for the BGA #1. The readings show that the PCB absorbs a significant amount of radiation and that Al filters help reducing the dosage.

Figures 3a and 3b show the dosimeter locations on BGA #2. Pos A is on the PCB on the same side of the board as the BGA, Pos B is on the memory, and Pos C is on the PCB the side of the board opposite to that of the BGA. Figures 3c and 3d show the locations of the dosimeters with respect to the X-ray source on both the 2D X-ray and 3D X-ray machines. Figure 3e shows the dosage readings for the BGA #2. The readings also show that PCB absorbs a significant amount of radiation and that Al filters help reduce the dosage.

Figure 4a shows the dosimeter locations on BGA #3. Pos A is on the Si, Pos B is on the memory, and Pos C is on the PCB on the same side of the board as the BGA. Figure 4b

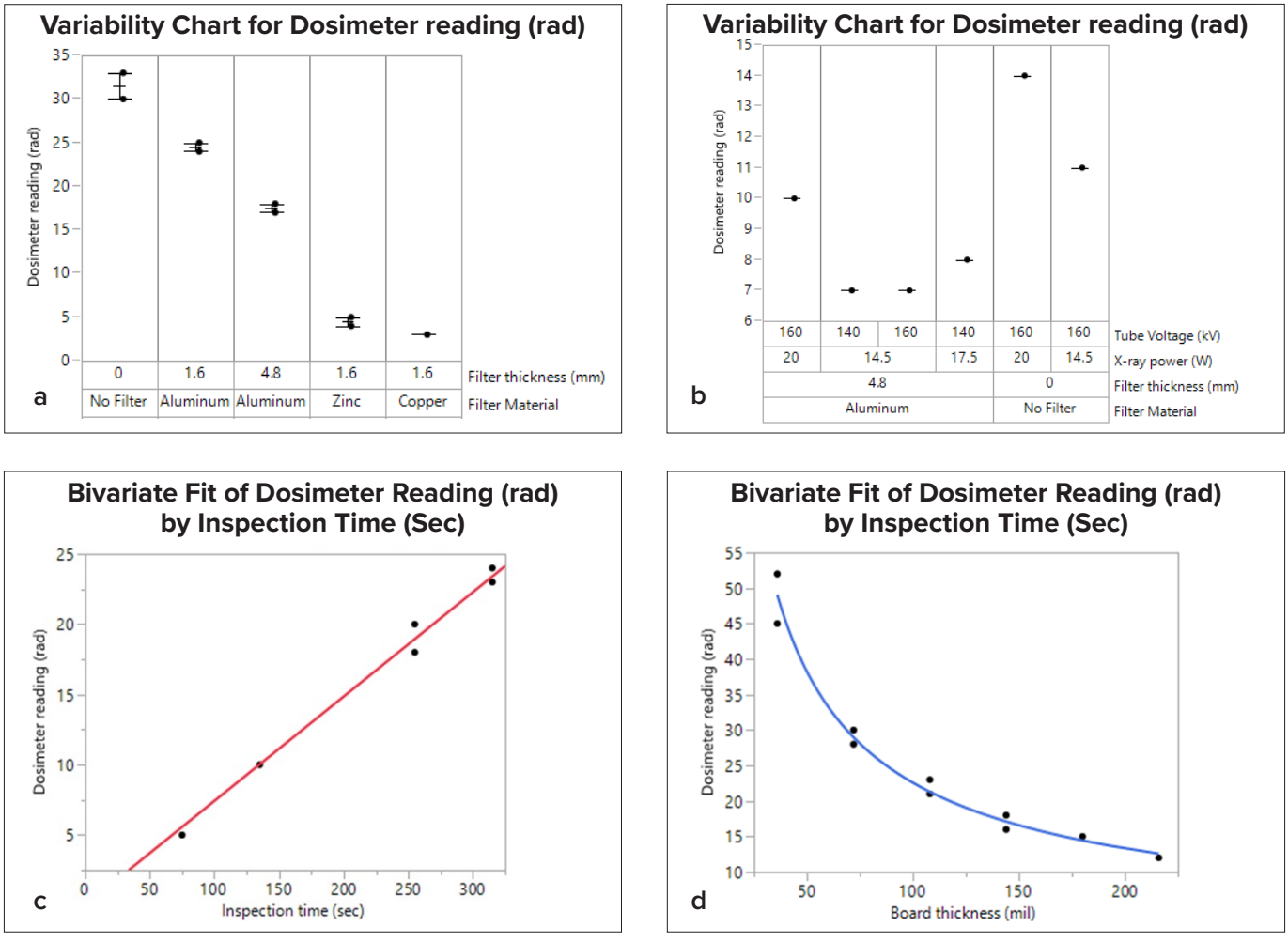


Figure 5: Dependence on dosage on: a) filter material and thickness; b) tool parameters for inspection; c) inspection time; d) board thickness.

shows the dosage readings for the BGA #3. In the case of a 3D X-ray scan, the readings are highest for Pos C, as expected, as there is more material absorbing radiation on Pos A and Pos B. However, for the 2D X-ray, the order of readings is reversed. Pos A sees the highest radiation even though it is the most shielded. This is because the amount of dosage absorbed also depends on the method and the actual path of the X-ray scan.

Figure 5 provides a detailed analysis of various factors affecting dosage in X-ray imaging. In Figure 5a, the impact of different filter materials on dosage is highlighted, showing that copper is the most effective material for reducing dosage. This suggests copper's superior filtering capability in attenuating X-rays compared to other materials. However, Figure 6 shows the image quality with the three materials of equal thickness and, although copper provides the most shielding from radiation, it is quite ineffective to produce the image quality needed for inspection. Aluminum, on the other hand, seems to provide effective shielding and preserve the image quality as seen in Figure 6.

Figure 5b examines the influence of tube power and voltage on dosage. It reveals that while tube power significantly affects dosage at a constant tube voltage, variations in tube voltage have a minimal impact on dosage when X-ray power is kept constant. Figure 5c demonstrates a linear relationship between inspection time and dosage, indicating that longer exposure leads directly to higher dosage. Lastly, Figure 5d illustrates a decreasing

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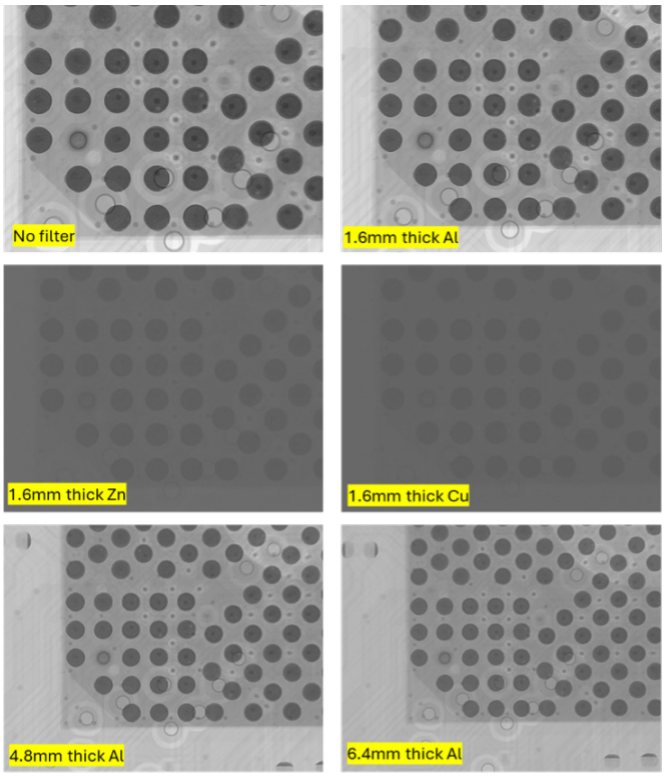

Figure 6: 2D X-ray images with various filter materials and thicknesses.

exponential relationship between board thickness and dosage, suggesting that beyond a certain thickness, increasing the thickness has a diminishing effect of reducing the dosage.

The results from the functional test are shown in Figure 7. The BGA with on-package DRAM was exposed in increments of 50 rad and, after subsequent exposure, the performance was measured using the test setup shown in Figure 1. There were no errors recorded by MemTest86 after any of the exposures as shown in Figure 7. Even after total exposure of 350 rads, MemTest86 gave no errors on the DRAM. The results indicate that even after overexposure to three times the limit provided by DRAM manufacturer, no infant mortality failures were observed. However, the reliability of the DRAM over longer periods of usage may be reduced.

Summary

This paper outlines several mitigation strategies for minimizing radiation dosage during X-ray inspections, particularly in the context of printed circuit boards (PCBs). One key observation is that the PCB itself acts as an effective shield, significantly reducing radiation exposure. This relationship is shown in Figure 8. This protective effect was clearly demonstrated in the experimental results,

Test Start Time	2024-07-10 12:01:37
Elapsed Time	2:04:06
Memory Range Tested	0x0 - 87900000 (34808MB)
CPU Selection Mode	Parallel (All CPUs)
CPU Temperature Min/Max/Ave	-/-/-
RAM Temperature Min/Max/Ave	-/-/-
# Tests Passed	36/36 (100%)

Test	# Tests Passed	Errors
Test 0 [Address test, walking ones, 1 CPU]	3/3 (100%)	0
Test 1 [Address test, own address, 1 CPU]	3/3 (100%)	0
Test 2 [Address test, own address]	3/3 (100%)	0
Test 3 [Moving inversions, ones & zeroes]	3/3 (100%)	0
Test 4 [Moving inversions, 8-bit pattern]	3/3 (100%)	0
Test 5 [Moving inversions, random pattern]	3/3 (100%)	0
Test 6 [Block move, 64-byte blocks]	3/3 (100%)	0
Test 7 [Moving inversions, 32-bit pattern]	3/3 (100%)	0
Test 8 [Random number sequence]	3/3 (100%)	0
Test 9 [Modulo 20, ones & zeros]	3/3 (100%)	0
Test 10 [Bit fade test, 2 patterns, 1 CPU]	3/3 (100%)	0
Test 13 [Hammer test]	3/3 (100%)	0

Figure 7: Reference test from Memtest86 showing the DRAM passing with no errors after an exposure of 350 rads.

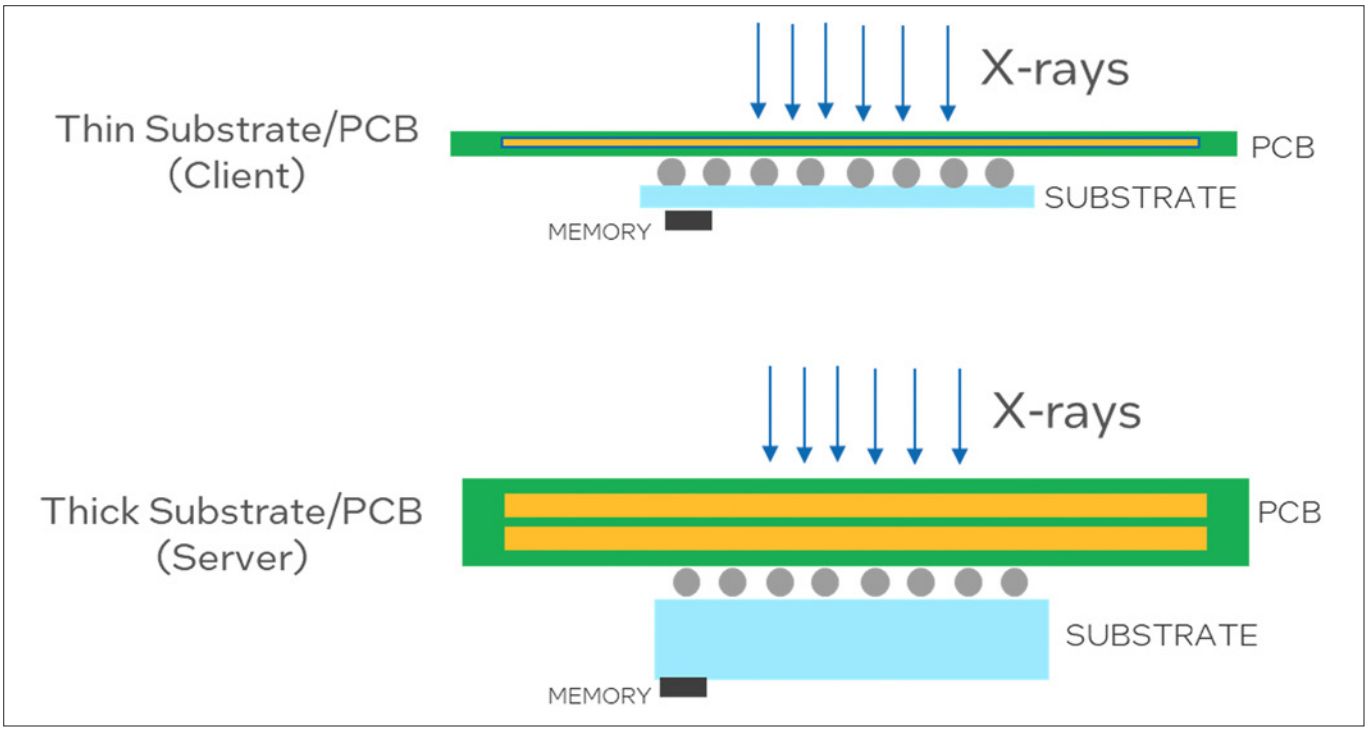

Figure 8: Effect of board and substrate geometries on the X-ray dosage absorbed by DRAM.

highlighting the importance of considering the board's material properties during inspection. The study also examined the impact of inspection time on dosage, revealing a direct correlation: longer inspection times result in higher radiation exposure. This finding emphasizes the need to optimize inspection duration to minimize dosage without compromising the thoroughness of the inspection. Another critical factor discussed is the choice of filter material. Copper was identified as the most effective filter for shielding radiation, significantly reducing dosage levels. However, this reduction in dosage comes at a cost, as the images produced with copper filters were of very poor quality due to the diminished X-ray penetration.

Additionally, the paper explores the relationship between material thickness and dosage, finding that this relationship follows a decreasing exponential trend. As material thickness increases, the reduction in dosage becomes marginal, indicating diminishing returns with further thickness enhancements.

This paper also investigated the radiation tolerance of PCB assemblies housing BGAs with on-package memory. It was noted that there was no initial degradation of the performance of the DRAM observed even after overexposure to several times the recommended limit of DRAM exposure from manufacturer.

Future Work

More extensive research is needed to fully understand how overexposure affects the functional performance of DRAM. This includes conducting detailed failure analyses to identify specific performance degradation that may occur. Additionally, it is crucial to perform aging studies to assess the long-term reliability of these devices. Such studies will help determine how DRAM components behave over time after being initially exposed to radiation. **SMT007**

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This paper was written by **Saurabh Gupta**, **Howlit Chng**, **Michael Cathcart**, **Christopher Alvarez**, **Jose I Hernandez**, **Jeff Burgess**, all of Intel Corporation.

Peter Bigelow: Perseverance Paid Off

Interview by Barry Matties

After walking off the stage at IPC APEX EXPO, where he received the IPC Raymond E. Pritchard Hall of Fame Award, I caught up with Peter Bigelow to find out how it felt to receive the award and what advice he has for others coming up through the industry.

Barry Matties: Peter, you just received the IPC Raymond E. Pritchard Hall of Fame award. What's that like?

Peter Bigelow: I'm honored, and frankly, quite surprised, to have received the award. I'm excited to say that I've been part of IPC for so many years and have been able to make a contribution to the industry as well as to the association.

With all your years of wisdom and experience, what advice would you give a young person coming into the industry now?

Get involved, and even more, you need to get to know the people that are on the committees and in the industry. They can be a wonderful personal support system. You learn so much more when you get to interact with people who are doing the same thing you're doing but maybe you're coming from a different angle and different perspective.

How long have you been at this?

I've been in circuit boards for 34 years. I've been in the electronics industry since 1977.

Will you share one of the most memorable moments of your esteemed career?

Oh, that's a tough one. I would say it was taking the leap of faith to acquire a company. and work it through very challenging times. The industry was not in a robust state at that time, but just by having patience, working with good people, taking it one day at a time and paying attention to the future, not worrying about the moment, it was a proud time of my career. That has been a proud moment for me.

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The Growing Role of Additive Manufacturing

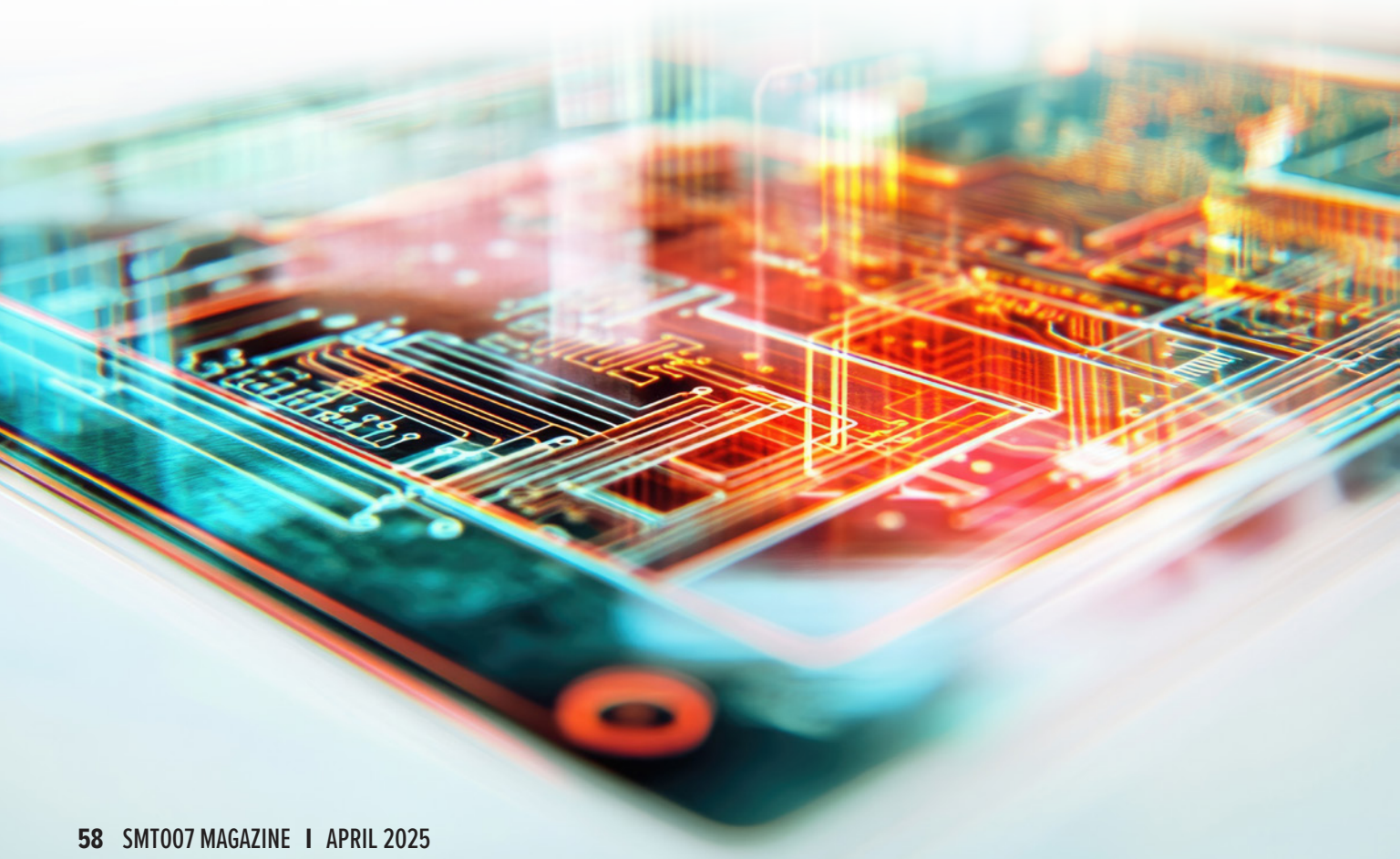
Smart Automation

by **Josh Casper,** Horizon Sales

(Editor's note: Josh Casper is a new columnist for SMT007 Magazine. His columns will focus on the unique challenges and trends in the electronics industry, specifically around automation.)

As additive manufacturing (AM) matures and reaches new business sectors throughout the manufacturing world, electronics manufacturing is beginning to reap the benefits of this ultra-flexible technology. AM (also known as 3D printing) capabilities have now expanded to support a wide range of applications in the electronics industry. The development of materials in additive manufacturing is meeting the demands of high-temperature environments and ESD protection necessary to become a viable solution in electronics manufacturing.

From the production of essential support items such as wave solder pallets and JEDEC trays to the creation of highly customized hand-soldering fixtures and support



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tooling, AM is helping to reduce costs and improve efficiency. Here, we'll explore AM's impact on electronics manufacturing, from the improvements that have made it a viable solution to some of the real-world applications existing today.

Advanced Materials for Higher Temperatures, Strength, and ESD Protection

One of the recent developments of additive manufacturing is the improvement in materials, allowing AM to meet the specific demands of the industry. As electronics manufacturing involves exposure to high temperatures, particularly during processes like wave soldering and reflow, AM materials have evolved to withstand these conditions.

Materials such as high-temperature-resistant carbon fiber PEEK (PolyEtherEtherKetone) enable the production of parts that can endure the heat generated during processes like wave soldering. These materials retain their integrity even at temperatures exceeding 250°C, making them ideal for applications where traditional AM plastics might fail.

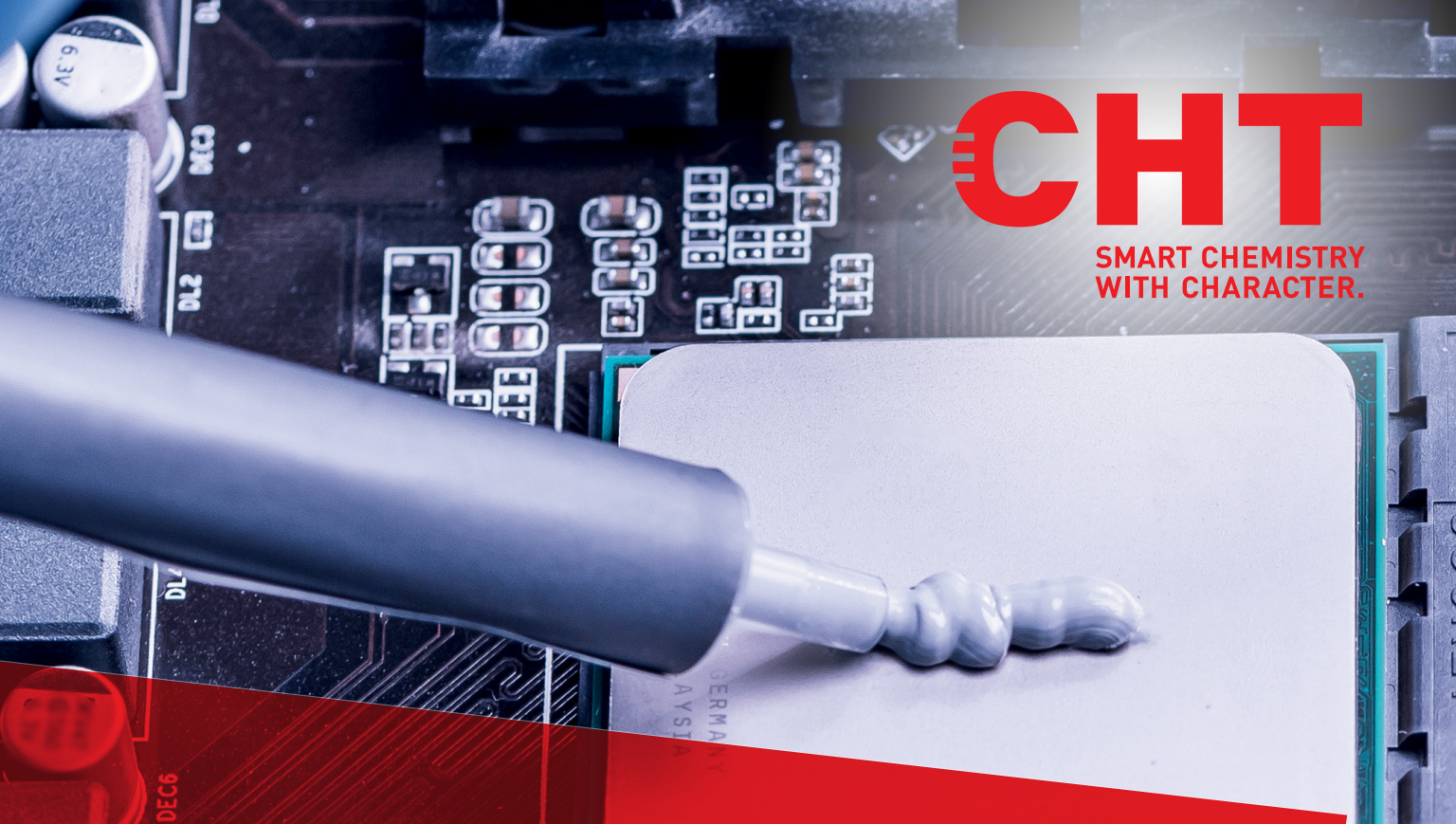
In addition to temperature resistance, the strength of additive manufacturing materials has significantly improved in recent years. Today, manufacturers have access to materials with enhanced strength and durability. This is particularly important in applications where support tooling needs to remain rigid and flat to hold products in place without the risk of warping. Materials like carbon fiber polymers offer significantly enhanced strength, allowing the production of parts that are both lightweight and capable of handling the forces encountered during production processes.

Additionally, with the importance of ESD protection in electronics, additive manufacturing has advanced to include materials with integrated conductive or dissipative properties. AM companies can produce parts that prevent electrostatic buildup and discharge, reducing the risk of damage to sensitive components. These materials can safely be used in applications ranging from JEDEC trays to wave solder pallets, ensuring that all parts remain safe during manufacturing and transport.

Additive Manufacturing and Wave Solder Pallets

Wave solder pallets are typically manufactured utilizing traditional subtractive manufacturing approaches, such as milling, drilling, cutting, etc. This involves the removal of material from a solid block to achieve the desired form. While capable of high precision, these methods can be time-consuming and expensive, particularly when producing intricate parts. These small inefficiencies can create a bottleneck in PCB manufacturing.

Additive manufacturing addresses these limitations by enabling the production of highly customized wave solder pallets. Manufacturers can use design and print pallets tailored to the unique dimensions of the PCB and the components being assembled. This not only provides greater flexibility in production but also allows for quicker turnaround times. Manufacturers can easily iterate and adjust the design of their solder pallets digitally.



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In addition, customization can extend to features like ventilation channels and optimal support structures to further improve soldering quality, something that some traditional manufacturing methods struggle to accommodate.

JEDEC Trays

JEDEC trays play an essential role in the handling, storage, and transport of sensitive surface-mount components. Traditional manufacturing of these trays can be both time-consuming and expensive, particularly when manufacturers require customized designs to accommodate different component sizes.

Additive manufacturing provides a solution to these challenges by enabling the production of JEDEC trays with tailored dimensions, optimized for specific component types. As additive manufacturing technology continues to evolve, it is likely that manufacturers will increasingly rely on 3D printing to produce JEDEC trays that not only protect components but also reduce production costs and improve supply chain efficiency.

The reduction in lead times is another important benefit of additive manufacturing in JEDEC tray production. By printing trays on demand rather than waiting for mass production or custom molds, manufacturers can more quickly respond to changing production requirements and avoid inventory shortages.

Support Tooling: Cost-Effective and Customizable Solutions

Support tooling, such as jigs, guides, and holding fixtures, is used in several assembly processes. It ensures that components are correctly positioned and securely held during operations like inspection, testing, or assembly.

Additive manufacturing provides a cost-effective and highly flexible solution. By designing and printing support tooling in-house, manufacturers can create custom tools that are specifically suited to the requirements of a particular job. Whether it's a jig designed to hold a complex PCB shape, or a guide that helps position a specific component, additive manufacturing makes it possible to quickly produce tools with tailored features.

This ability to design and produce custom support tooling can lead to significant cost savings, as it can significantly reduce the involvement and stress on a manufacturer's labor force. Additionally, additive manufacturing supports rapid design iterations, allowing manufacturers to refine their tools quickly to improve performance and efficiency.

Conclusion

Additive manufacturing is quickly becoming an essential tool in electronics manufacturing. The ability to produce customized support items offers manufacturers greater flexibility, faster lead times, and reduced costs. As this technology continues to advance, additive manufacturing will play an even more significant role in shaping the future of electronics production, driving innovation, and improving efficiency across the industry. **SMT007**

Josh Casper is regional sales manager for Horizon Sales.

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IPC APEX EXPO 2025 REVIEW

The New Normal Looks Like the Old Normal

(LR) Devan Iyer, the Chief Strategist for Advanced Packaging at IPC and Ahmad Bahai, Ph. D, Sr. VP & CTO, Texas Instruments.

Article by Nolan Johnson
I-CONNECT007

At IPC APEX EXPO, my days are filled with either talking or listening from sunup to sundown. I get to ask questions of some of the brightest minds in the business, while also listening and synthesizing what they're sharing with me about the current and future state of the industry. Here are five observations based on these conversations.

1 **The industry is optimistic.** Even in the face of uncertainty, buyers and vendors are moving forward with their plans. One industry insider said, "If they have a strategic plan at all, they're still executing on it." The sentiment seems to be that the upward trend might be shifted by current changes in economic policy coming out of the U.S., but it will not be squelched by it. Naturally, the trade in equipment seemed brisk on the show floor.

2 **The EMS Leadership Summit is improving in value and insight.** I've had the pleasure of attending several of these summits, and each year the agenda gets better. Mark Wolfe, Tracy Riggan, and the rest of the planning committee dial in the program with every iteration. If the objective of the summit is to bring EMS industry leadership together to network, build better

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Mark Wolfe chatting with Tracy Riggan at the EMS leadership dinner.

working relationships, and share the latest industry information, then the summit team raised the bar again this year. I highly recommend attending next year's daylong event.

3 **The developments in adjacent tech sectors will change our manufacturing techniques.** It has always been the case that adjacent industries—semiconductor manufacturing, for example—influence our industry. New component packages are an obvious example. Devan Iyer, IPC chief strategist for advanced packaging, and Dr. Ahmed Bahai, chief technology officer at Texas Instruments and one of the keynote speakers, discussed the new developments in packaging with me at length. The themes in the conversation suggest not a trickle-down but rather a cascading chain of events that will change the components we will handle.

Another key development is shrinking feature sizes on the PCB, for which some of the older semiconductor manufacturing technologies come increasingly into play—for example, interposers. Consequently, some of our PCB fabs are starting to look like the early semiconductor fabs—and they should. We're fabricating in those same feature sizes on the board nowadays that used to be on the chip. New materials require new methods, while some require minor tweaks, and others require the installation of entire lines. New software tools for process control, sensing, tracking, inventory management, scheduling, and more, continue to move us deeper into the reality of Industry 4.0, which leads me to AI.

4 **Artificial intelligence is staying and will earn its keep.** I discount generative AI, however. It's getting all the hype in the mainstream and will likely follow the traditional hype curve. Sure, it has a place, but all we have to do is look at Ben Rachinger's award-winning paper from this year's conference to see that AOI data sets not only can be shared between multiple companies through a federated library to build a more powerful large language model, but that the data can also be stored in tokens, protecting the proprietary nature of the source data. The unexpected insights coming from AI LLM implementations which are properly used is nothing less than mind-boggling. In focused industrial applications, predictive analysis—based on seeing patterns in past data so subtle that humans cannot identify them—will be disruptive (and in a good way).

5 **Regional diversification seems to be unstoppable.** Sure, opinions differ on whether regional development is good for the industry, but it seems like those who are building up infrastructure are bullish, while those losing market share are bearish. India, SE Asia, and Mexico continue to build out. While it's true that much of the investment in these three regions was originally to support automotive and EVs, the available capacity outside China seems attractive to OEMs looking to reshore. Another sign of regional vibrancy is the

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increased involvement of Japan and SE Asia in IPC standards work, etc. Sydney Xiao, IPC president of North Asia, highlights this trend in her *Real Time with... interview.*

Thirty years ago, the PCB portion of the electronics industry was a thriving network of businesses: Many family-owned or similarly small serving a local/regional customer base. This was when the OEMs took a much more active role in moving their designs into fabrication and manufacture. A key part of that highly resilient supply chain was that OEMs of a certain size would build their own fab and EMS facilities, keeping manufacturing in-house and customized to their products. But on a global scale, we threw up obstacles and diverted most of the business to one central region.

I liken it to an analogy of removing dams from our riverways in the western United States. Built originally for various well-intentioned but obsolete purposes, these dams persist in disrupting an ecosystem while no longer providing any benefit in return. It is a biologist's dream to study how a river ecosystem rebounds once the dam is demolished. While it's no surprise that the original ecosystem returns, what is surprising is the rapidity and the robustness with which the regional diversity recovers. Rivers for which the dam had wiped the native salmon population for a hundred years, now have salmon returning to spawn as little as three years later[1].

Like the rivers, our regional diversity is returning. As Chris Mitchell, IPC vice president of global government relations, said in his *Real Time with... interview* with I-Connect007, the world wholeheartedly embraced free trade after the fall of the Berlin Wall. It can be argued that we overdid it, resulting in optimizing the resilience out of our supply chains, diverting too much economic flow away from its natural course, as it were. Chris suggests that the pendulum is swinging back to encourage more regional

(L-R) Dr. Diana Radovan and Alison James

competitiveness. Alison James, IPC senior director for Europe, has been speaking with us about IPC Europe's work with the European Union's Competitiveness Compass.[2] After hearing their remarks, I could see the parallels to the dam removal projects: To reestablish a thriving ecosystem, we need to clear out the barriers, obstacles, and diversions, while also paying attention to sustainability. It was my take-away that the EU Compass work seems intent to remove key strategic economic dams so that European manufacturing can once again flow.

There is no doubt this is an exciting time to be in electronics manufacturing. Virtually every aspect of our industry is moving solidly (finally) into the 21st century. It's about time. **SMT007**

References

1. I asked Grok to fact-check this claim, only to find out that river biologists reported migratory fish returning in weeks or months if the conditions were right.
2. 'IPC's Call to Action for the EU Competitiveness Compass', SMT007.com, March 2025

Nolan Johnson is managing editor of *SMT007 Magazine.*

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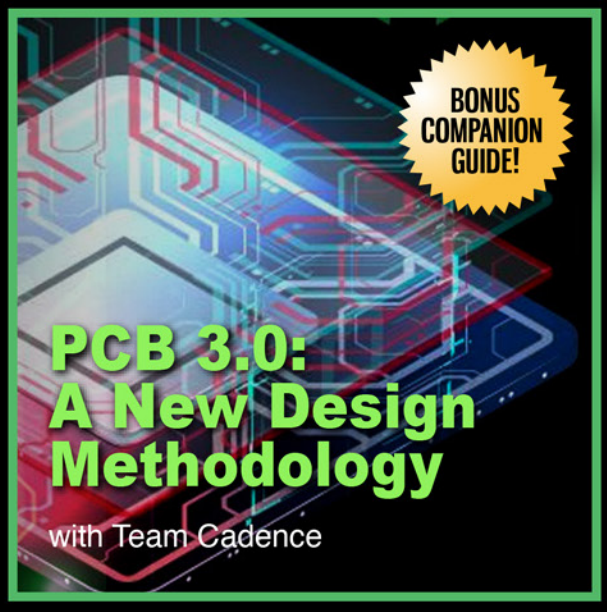

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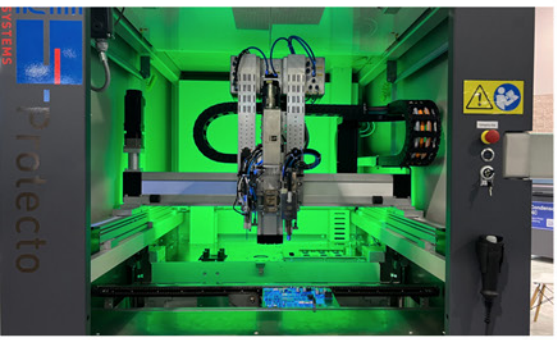
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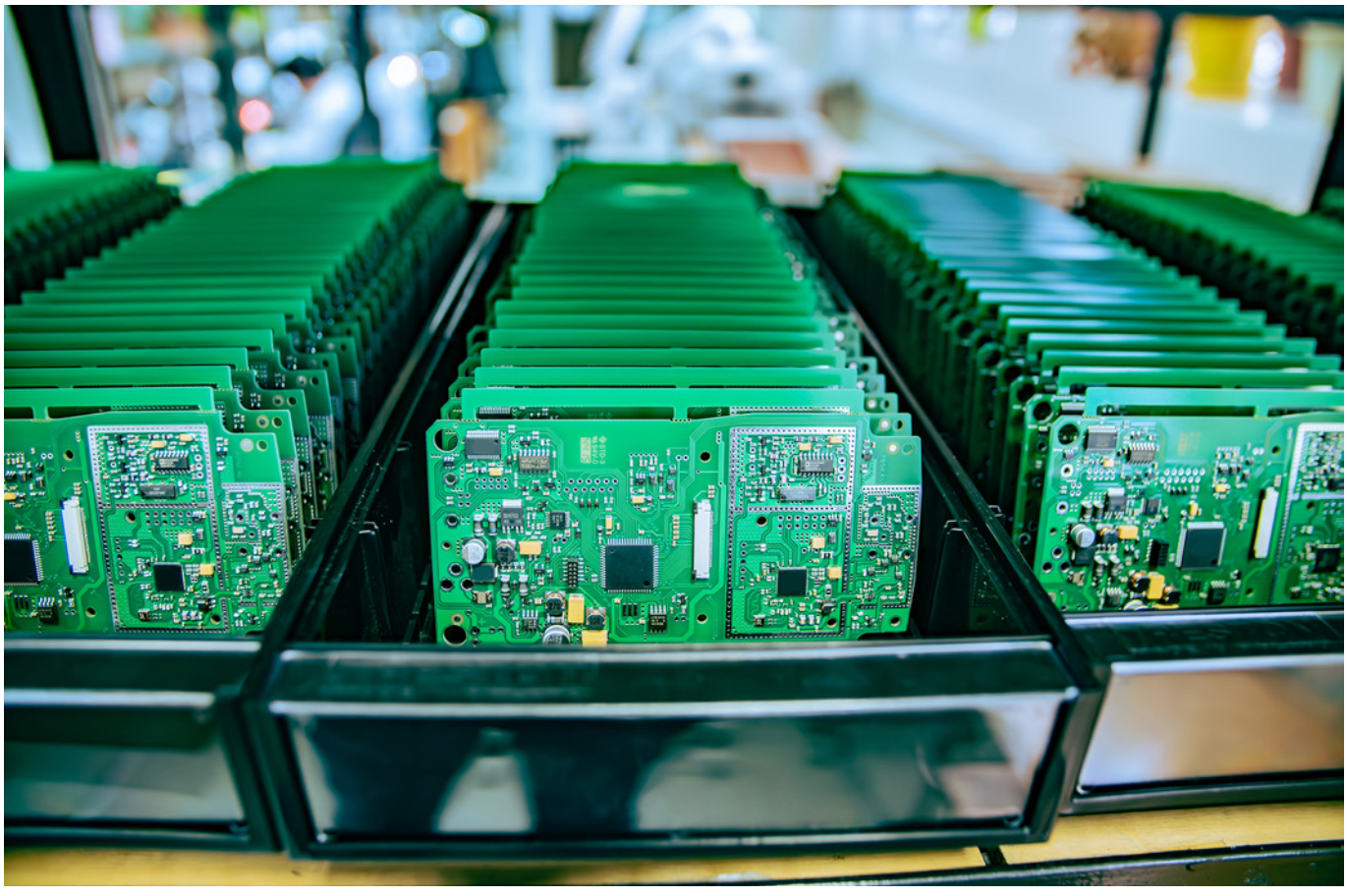

Basics of Component Lead Tinning

Knocking Down the Bone Pile

by Nash Bell, BEST, INC.

The component lead tinning process serves several critical functions, including removing gold plating, mitigation of tin whiskers, reconditioning of component solderability issues, and alloy conversion from lead-free (Pb-free) to tin-lead or from tin-lead to lead-free for RoHS compliance. We will cover each of these topics in more detail in upcoming columns.

Traditionally, some in the electronics assembly industry have utilized a single static solder pot for manual lead tinning. While typically performed as a secondary operation prior to board assembly, this may appear to be economical but has several disadvantages from a quality standpoint.

The use of a single static solder pot for both removal of an original alloy as well as component re-tinning should be avoided. This is not a recommended practice since dross, organic contaminants, flux residue buildup, and accumulation of gold can be transferred to the re-tinned component leads or terminations. Those using this practice rely on outdated standards and procedures that are not in compliance with the GEIA-STD-0006 component re-tinning industry requirements.

A manual re-tinning process typically involves a technician dipping a through-hole or surface mount device multiple times into a static solder pot to remove the original lead

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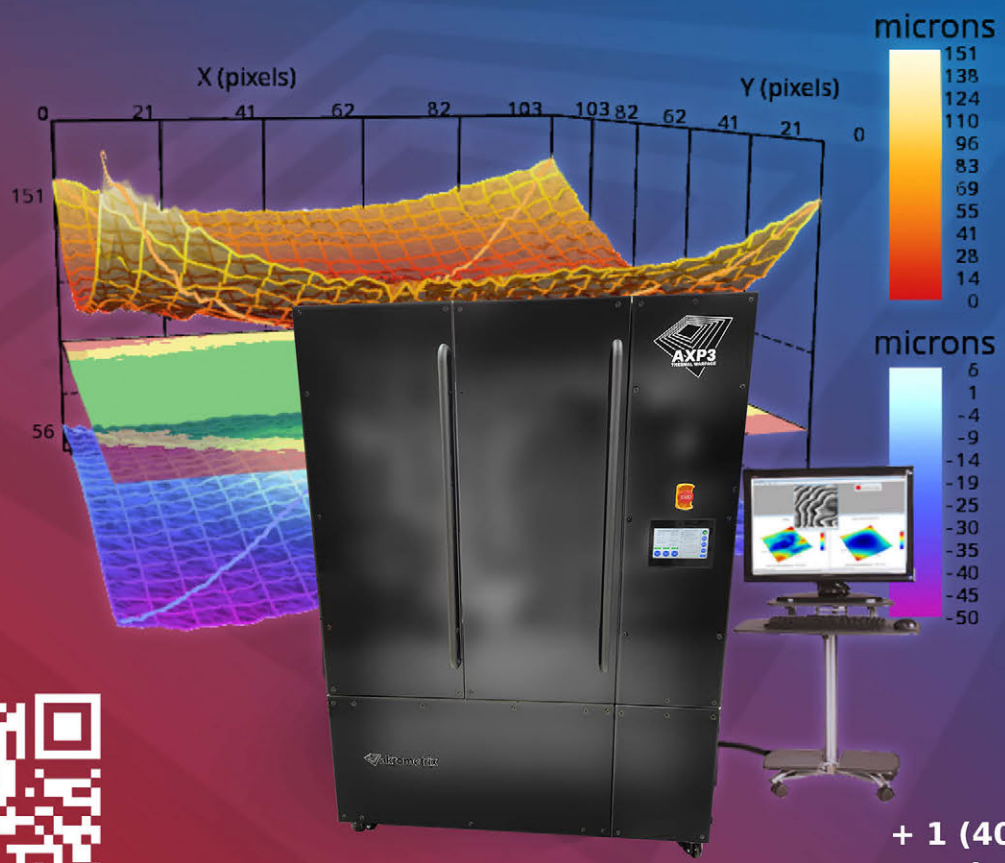

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finish. This is followed by preheating the components on a hot plate, then manually applying RMA flux to the leads before moving each component into the same static solder pot for re-tinning.

When component leads are manually tinned, several issues can arise. The manual tinning process may not create a high-quality intermetallic bond on the lead, leading to a poor base metal and a rough surface finish. When soldering to a printed circuit board, the solder can initially wick up the lead and wet the plated through-hole. However, once the re-tinned surface becomes liquidus, the solder may partially run back down or migrate away from the lead, resulting in de-wetting at the targeted soldering temperature. Thus, the de-wetting at the joint site and poor solderability can often be traced to irregularities from the manual tinning process that negatively impact the intermetallic bond.

An additional disadvantage of using a single solder pot is the risk of contamination. Since there is no circulation within a static solder pot, the composition of the surface level solder is dependent on the specific gravity of the elements present. This is especially problematic when using a static pot to perform both alloy removal and refinishing of a component's leads. If the original lead finish is gold-plated, the gold can dissolve into the static pot, potentially altering the composition of the solder alloy. Furthermore, a static solder pot, as seen in Figure 1, may contain other contaminants, such as dross, RMA flux residues, and oxidation on the surface, which can negatively impact solderability.

Another drawback of repeatedly using a single static solder pot is that organic contaminants, such as mold release agents, can float on the surface of the molten solder. These agents will not be driven off by heat unless temperatures exceed 500°C. The presence of these organic contaminants in the static solder pot can be verified using either atomic absorption (AA) analysis or infrared spectrophotometry with Fourier transform (FTIR).

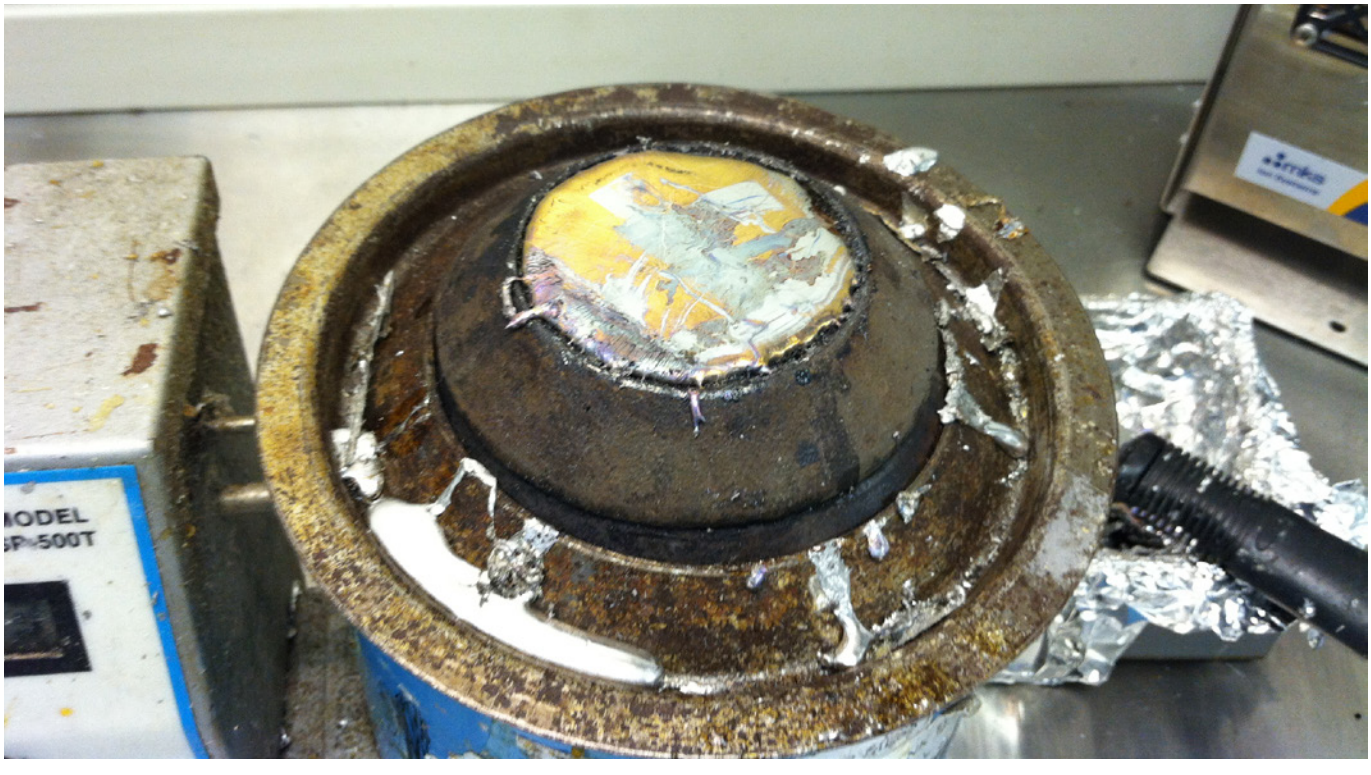


Figure 1: A static pot may contain other contaminants, such as dross, RMA flux residues, and oxidation on the surface, which can negatively impact solderability.

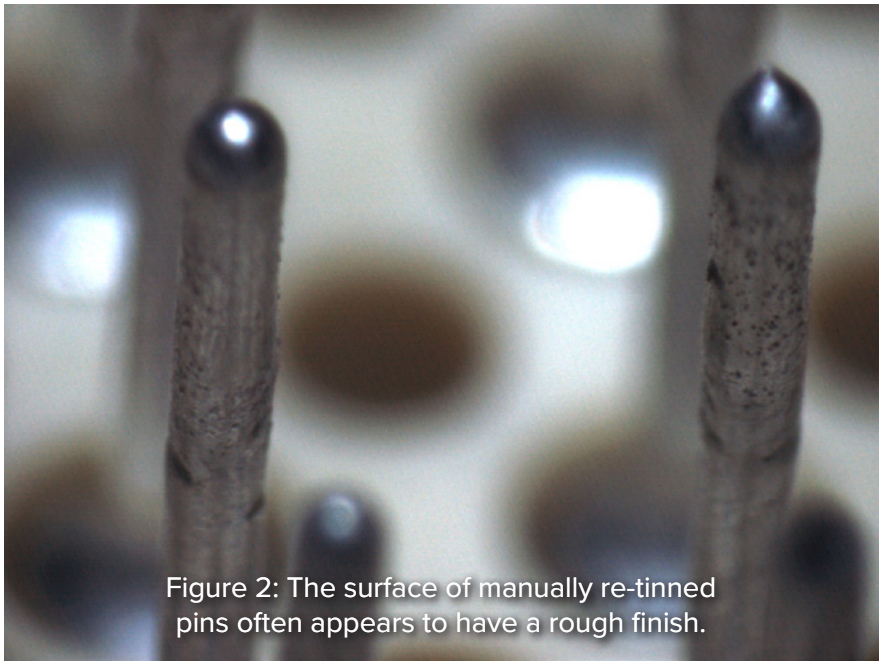


Figure 2: The surface of manually re-tinned pins often appears to have a rough finish.

The surface of manually re-tinned pins often appears to have a rough finish as seen in Figure 2. This is indicative of an uncontrolled lead tinning process due to impurities such as excessive dross, flux residues, and non-optimized immersion dwell and extraction speed.

Figure 3 shows an example of random surface anomalies on the resulting solder joints. These irregularities can be described as alligator skinning, voids, and blow-holes which are more likely to occur with a manual tinning process and are considered solder defects per IPC J-STD-001.

The ideal method to facilitate re-tinning of surface mount or through-hole components is to use the robotic hot solder dip (RHSD) process. It is recommended that this re-tinning operation be carried out using a lead tinning machine utilizing precise flux application, controlled preheating, dual solder pots, nitrogen inerting, and defined process control. A defined process of this type is highly recommended in lieu of manually dipping components into a single static solder pot to reduce solder contamination, minimize non-wetting issues, and enhance solderability.

The RHSD component lead tinning process utilizes two separate solder pots. The first is a cleansing bath of molten solder to remove the original solder coating, unwanted plating, and any residual contaminants. Next, the component leads are preheated and fluxed, followed by a final immersion in a clean solder bath of pure eutectic solder. This provides a homogeneous intermetallic layer with the base metal of the component leads, which increases the overall solderability, thus facilitating improved reliability of printed circuit board assemblies.

All types of through-hole and surface mount components can be re-tinned using the robotic hot solder dip process. Surface mount components with terminations or pads without leads, such as chip components, SOTs, SOICs, LCCs, and PLCCs can be re-tinned using the solder drag process. In many cases fixturing may be required when automatically re-tinning surface mount components to ensure consistency is maintained during the re-tinning process.

Formed multi-side components such as FP and QFP devices, have very delicate leads that can be easily damaged. These are typically re-tinned using a side wave process with

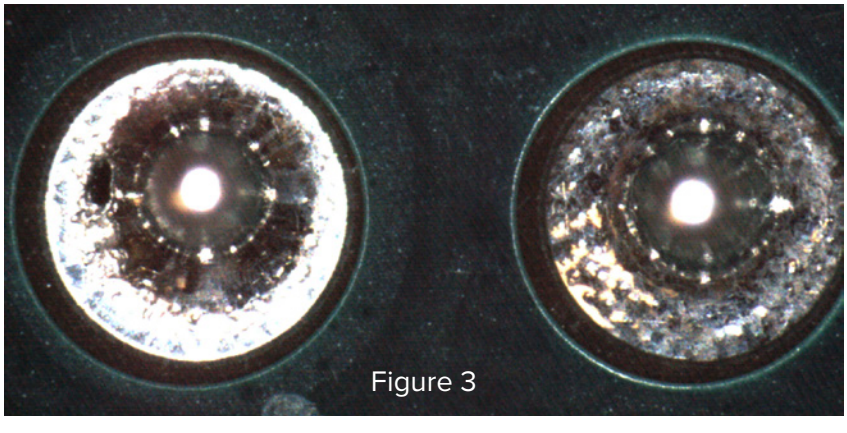
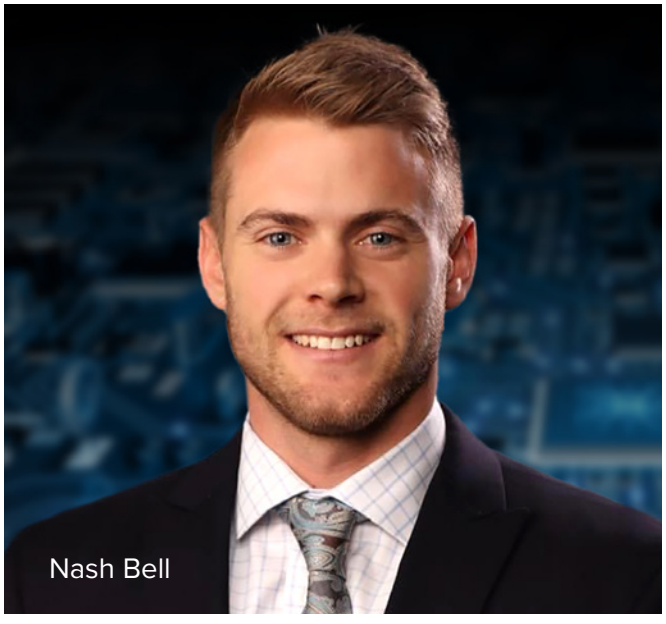


Figure 3


Nash Bell

the components held in position by a multi-axis articulated robot equipped with a rotary vacuum head.

A key issue when re-tinning fine-pitch surface mount devices such as QFPs and no-lead QFNs is to maintain coplanarity across all leads to ensure consistent solder distribution and limit the potential for bridging. X-ray fluorescence (XRF) testing can be used to verify solder thickness, in addition to alloy composition, when determining if a coplanarity issue exists.

Fine-pitch QFPs pose certain challenges but can be successfully tinned with proper process controls in place. These components may range from 6 mm x 6 mm up to 50 mm x 50 mm with a lead pitch as small as 0.012″ making the margin for error very small. Given the tight spacing and delicate nature of these leads, there is the potential for bridging and lead damage when tinning these types of components. Using a controlled automated system with these fine-pitch components will provide significant improvement in achieving consistent and reliable outcomes with limited defects.

Following the robotic hot solder dip process, all re-tinned devices should be cleaned in a batch wash or cleaning system, using the appropriate solvent or aqueous cleaning agent to remove any residual flux residues. Subsequently, components should be dry baked for the applicable component moisture sensitivity level (MSL). This should be followed by solderability testing per J-STD-002.

Ultrasonic cleaning is another common cleaning method that should be used cautiously. Semiconductor devices can be potentially damaged by cavitation resulting from certain frequencies in ultrasonic cleaners which is unsuitable for cleaning electronic components. Ultrasonic cleaners meant for other applications, such as cleaning of small mechanical parts, should not be used for cleaning these components. If an ultrasonic cleaner is used, it should be a continuous variable frequency (CVF) type designed specifically for cleaning of electronics.

In conclusion, the component lead tinning process is essential for enhancing solderability and ensuring the reliability of electronic assemblies. While traditional manual methods using a single static solder pot may seem cost-effective, they are fraught with challenges that can negatively impact the quality of work, including the transfer of contaminants and the creation of de-wetted solder joints.

To achieve optimal results, employing advanced techniques like the robotic hot solder dip process is strongly recommended. This method provides better control over the re-tinning process, safeguards against contamination, and ensures a consistent, high-quality intermetallic bond. By adhering to industry standards and utilizing proper equipment, manufacturers can significantly improve solderability and reliability, ultimately leading to more dependable electronic components and assemblies. **SMT007**

Future columns will delve deeper into each aspect of the lead tinning process, providing further insights, and best practices to enhance quality and performance in the assembly of electronic devices.

Nash Bell is president of BEST, Inc. To read past columns from this company, click here.

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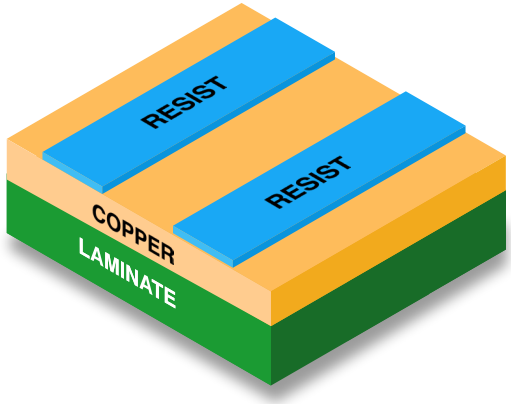
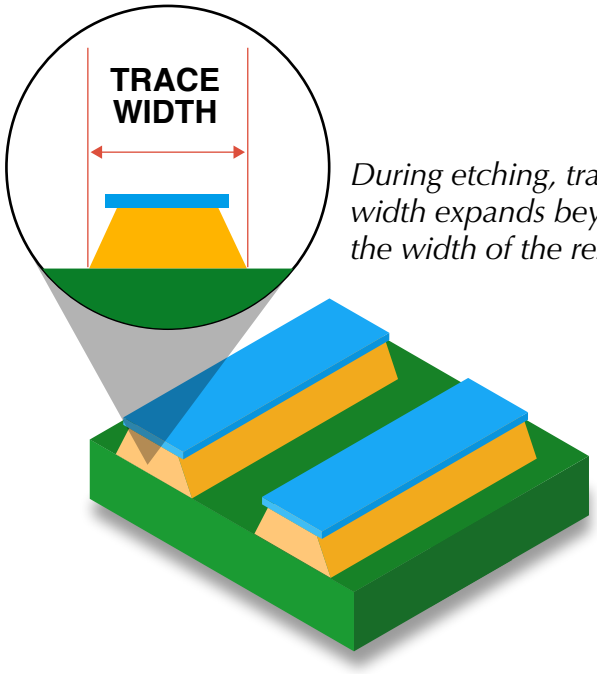
Design tips:

- 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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Redefining Connection and Responsibility in Digital Transformation

Global Citizenship

by Tom Yang, CEE PCB

The fusion of technology and global citizenship has fostered unprecedented collaboration and exchange. Digital tools offer new ways to connect but also challenges that require a mindful and ethical approach. While these technologies bridge gaps, enhance inclusivity, and encourage cross-cultural understanding, we must also consider the accompanying ethical responsibilities.

Digital tools allow businesses and individuals around the globe to collaborate seamlessly through a variety of tools, including videoconferencing, collaborative software, and project management platforms. This has proven transformative, particularly in education and professional development. For example, online courses allow individuals in remote areas to access high-quality education, while freelance marketplaces open up job opportunities worldwide.

Global collaboration also fosters a sense of inclusivity. Products, policies, and strategies benefit from the diverse perspectives shared on online forums. This strengthens cultural exchange and diversity and can offer comprehensive solutions to global challenges. Digital inclusivity provides for unique perspectives, making products and services that reflect diverse user bases.

Artificial intelligence (AI) has become a

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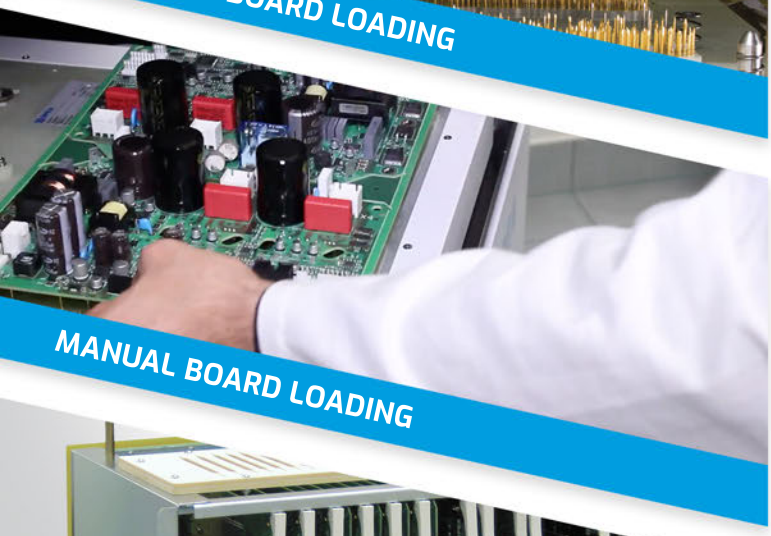

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foundation for businesses and organizations seeking to understand and predict global consumer behavior. By analyzing large data sets, AI can help businesses customize their offerings to different cultural groups. From e-commerce to entertainment, AI algorithms personalize user experiences and help companies keep track of diverse consumer bases. For example, streaming apps like TikTok use AI to recommend content that resonates with individuals, but also adjust these algorithms for different countries based on local trends and preferences. This has enabled companies to reach wider audiences, creating a truly global impact. However, AI also raises ethical questions and privacy issues.

Social media has become a key driver of global citizenship, offering platforms for dialogue across cultures, with organizations, activists, and influencers using them to engage with audiences around the world. The ability of social media to amplify overlooked voices makes it valuable for inclusivity and social change.

Social media can also engage diverse audiences simultaneously. Campaigns like #ClimateAction have gained global traction because they resonate across borders. Social media platforms also enable people to learn about environmental issues, which fosters empathy and global responsibility. However, social media companies have a responsibility to prevent misinformation and respect user privacy, which is an ongoing challenge. Every online click and interaction generates data that is valuable to businesses but potentially invasive to individual privacy. Global citizenship in the digital age requires an ethical approach to data collection and analysis. Companies must take responsibility for how they gather, store, and use consumer data while still respecting individuals' rights and privacy.

The EU's General Data Protection Regulation (GDPR) is designed to protect data privacy. It has set a global standard, influencing other countries to adopt similar regulations. However, the challenge is how to balance using data for innovation while still respecting users' privacy. Individuals are demanding transparency and accountability from organizations. For businesses and organizations committed to ethical practices, respecting data privacy is not only a legal obligation; it's essential to building trust with global audiences.

Despite the promise of digital transformation, access to technology remains unequal. Billions worldwide still lack internet access or digital tools, especially those in low-income regions where infrastructure and resources are limited. For global citizenship to be fully inclusive, we must address these digital divides.

Governments, organizations, and tech companies are taking steps to address these gaps. However, achieving digital equity requires building sustainable infrastructure, fostering local tech ecosystems, and ensuring affordability. Only by dissolving these disparities can we create a digital landscape of inclusivity and equality, which is the core of global citizenship.

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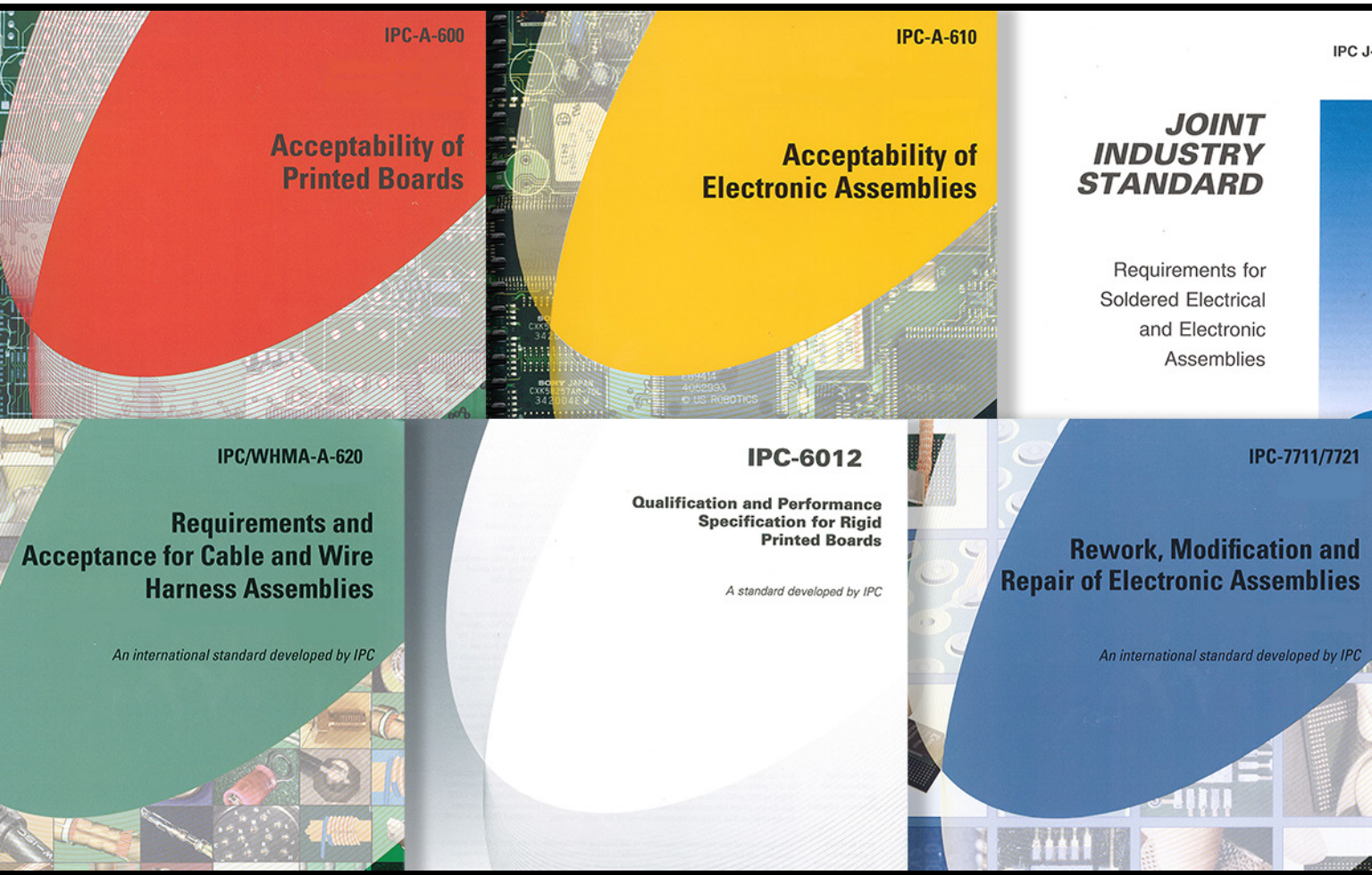

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tal transformation to create a global impact. Through social media, online portals, and data analysis, they provided real-time updates, debunked misinformation, and coordinated efforts to distribute medical resources globally, which saved lives.

Another example is IBM's blockchain technology to improve transparency in supply chains. IBM and its partners can track products from origin to consumer, ensuring ethical sourcing and reducing the risk of fraud, exemplifying how technology can enhance ethical practices. This benefits consumers and the environment.

These examples underscore how digital tools can extend the principles of global citizenship—such as transparency, responsibility, and inclusivity—into practical applications with far-reaching impact. As more organizations adopt digital transformation strategies, the potential for positive global change grows, but so does the need for ethical vigilance. AI, for instance, offers the potential to solve global problems, but also comes with risks as the biases inherent in AI algorithms can be discriminatory. In addition, the proliferation of surveillance technologies raises privacy concerns.

To navigate these ethical complexities, organizations must adopt frameworks that guide responsible innovation. For example, Google's AI ethics board, though short-lived, understood the need for accountability. Companies can also prioritize ethical principles by involving different voices in decision-making processes.

The balance between innovation and ethics also extends to environmental responsibility. Digital transformation has a significant carbon footprint. Data centers, cloud computing, and digital devices use a lot of energy, so individuals and organizations must consider the sustainability of their tech practices, adopt energy-efficient solutions, and reduce digital waste.

True global citizenship in the digital age goes beyond leveraging technology for convenience or profit. It calls for thoughtful engagement and awareness of our collective responsibility to the planet. By balancing innovation and ethics, we can foster a digital landscape that benefits all while upholding the inclusivity, empathy, and respect that define true global citizenship. **SMT007**

Tom Yang is CEO of CEE PCB. To read past columns, click here.

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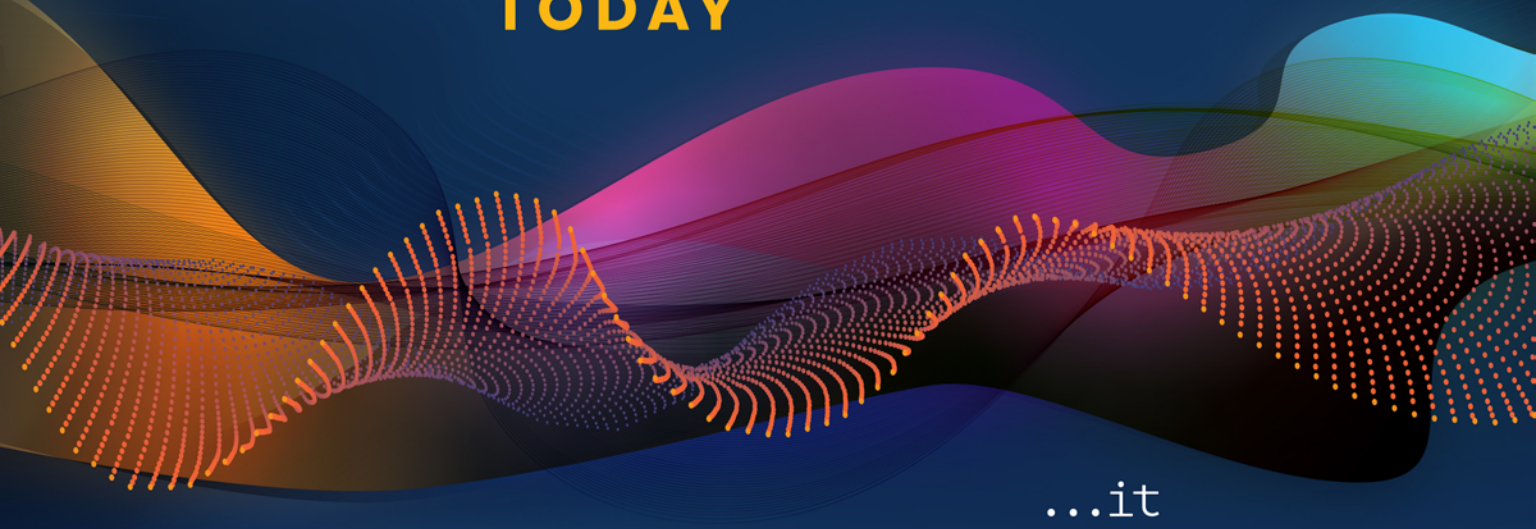

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TOP TEN

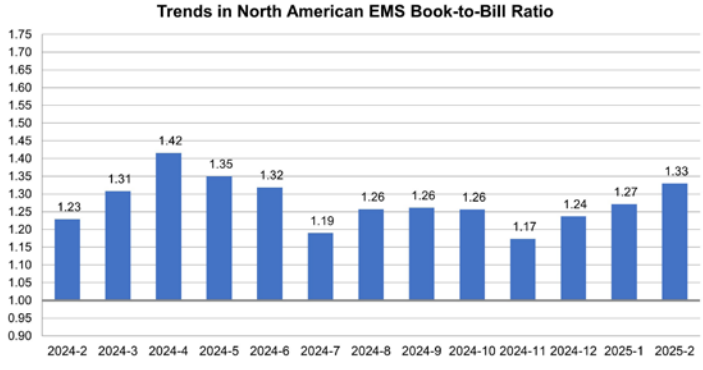
EDITOR'S PICKS

Finding Strength Through Laughter: IPC Women in Electronics Reception Inspires and Engages

The IPC APEX EXPO 2025 Women in Electronics Reception brought together women for an insightful presentation by keynote speaker Jody Urquhart, a motivational speaker, comedienne, and author. A central theme of Urquhart's talk was the challenge of belonging in male-dominated work environments. She encouraged women to embrace their natural strengths—empathy, compassion, and emotional intelligence– not only foster stronger connections but also enhance leadership effectiveness.

North American EMS Industry Up 1.7% in February

"The EMS sector saw a pickup in bookings in the last month, bringing the strongest book-to-bill ratio since May 2024," said Shawn DuBravac, IPC's chief economist. "While year-to-date trends remain down for 2025, demand continues at a robust pace."



Standards Driving Factory of the Future

Thomas Marktscheffel is enthusiastic about what is possible today with manufacturing's use of data and how that is an evolved vision for Factory of the Future. Though this industry buzz phrase is currently focused solely on EMS, it is reflective of what is coming for PCB fabricators as well.

Roadmapping Sustainability: Paving the Way for Eco-friendly Electronics

In light of ongoing climate challenges, the electronics industry is poised for a transformative shift driven by heightened consumer and corporate awareness of sustainable practices and circularity. INEMI (International Electronics Manufacturing Initiative) enlisted the help of the electronics industry to roadmap that transformation in electronics manufacturing. This article provides an overview of the resulting sustainable electronics roadmap and how to get involved.

SMTA Announces Expanded Program for High Reliability: Strategic Technology Advancement Research Forum

The SMTA announced the finalized program for the High Reliability: Strategic Technology Advancement Research Forum which takes place April 30-May 1, 2025, in Olathe, Kansas. The event, now in its third year, addresses challenges for electronics manufacturers in the high-reliability sector.

IPC Releases Latest List of Standards and Revisions

To view a complete list of newly published standards and standards revisions, translations, proposed standards for ballot, final drafts for industry review, working drafts, and project approvals, visit ipc.org/status. These are the latest releases for Q1 2025.

IPC's Call to Action for the EU Competitiveness Compass

The European Union Competitiveness Compass is a strategic roadmap adopted by the European Commission to guide priorities for the next five years. In this interview, Alison James, IPC senior director of Europe government relations, explains how IPC has been proactive in aligning with the roadmap.

European EMS Market Experiences Double Digit Negative Growth in 2024, But May Experience Slight Positive Growth in 2025

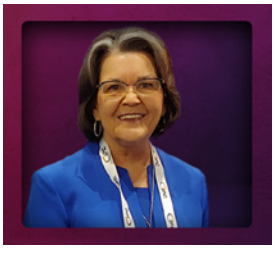
The full report, "Annual Survey of the European EMS Industry 2025," authored by Dieter G. Weiss and Dr. Mareike Haass can be purchased directly from in4ma at www.in4ma.de.

The Training Connection LLC Unveils New Website to Enhance Test Engineering Training Accessibility

The Training Connection, LLC (TTC-LLC) is excited to announce the relaunch of its official website, TTC-LLC.us. The updated platform enhances the user experience with real-time class availability, dynamic scheduling, and streamlined access to course information—bringing TTC-LLC's training services into a new era of digital accessibility.

Real Time with... IPC APEX EXPO 2025: Navigating Aerospace Training Trends With Blackfox

Sharon Montana-Beard of Blackfox discusses key industry trends and geopolitical factors affecting aerospace training. She emphasizes the significance of IPC WHMA-A-620 training and NASA certification for private aerospace contracts. Blackfox operates training centers



across the U.S., Mexico, and Southeast Asia, responding to the rising global demand for space hardware training and offering courses in Spanish with international trainers.

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Various Positions

For 40 years, Technica USA has been providing products, equipment, and services to the printed circuit board fabrication and assembly markets. Working with our worldwide partners, we offer our customers solutions through best-in-class product lines. Technica has offices in San Jose, Calif, and Rancho Cucamonga, Calif.

We are expanding and looking for highly qualified Business Development/Account Managers for both the PCB and PCBA markets.

We are adding to our growing national equipment service coverage and looking for experienced Equipment Service Technician/Engineers.

Are you a PCBA equipment applications expert with experience in component placement and inspection? We are looking for Equipment Product Specialists to work within our San Jose, Calif., PCBA Equipment Demo center.

Please visit www.technica.com/careers to learn more about these positions and submit your resume today!

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Sales Applications Engineer

The Sales Applications Engineer is responsible for working with customers and managing inquiries to result in an accurate quote for business and ongoing customer support. The Sales Applications Engineer reports to the Application Engineering Manager.

Essential Job Duties:

- Interface with customers via direct contact, sales calls, email, and phone to determine need, provide design assistance and provide a quote for business
- Management of programs from key customers from initial purchase order to end of life
- Interface with customers regarding all aspects of a program
- Serve as liaison with All Flex regarding customer issues related to a specific situation

Qualifications:

- Degree in engineering, math or science or equivalent work experience.
- Prefer 5-8 years of product and/or manufacturing experience with flex circuits, flex heaters or circuit board industry
- Knowledge and understanding of concepts, contents, and application of ISO 9000 helpful
- Proficient in Microsoft Office applications and data entry. NetSuite experience preferred
- Must be a U.S. Citizen or U.S. Permanent Resident

We offer a competitive base salary in the $80,000 to $85,000 range, based on experience and qualifications, along with bonus and profit-sharing opportunities tied to performance.

If interested, please email resumes to joseph.janasz@allflexinc.com.

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Career Opportunities

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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American Standard Circuits
Sunstone Circuits

Sales Coordinator

Come join the sales team at ASC Sunstone Circuits in Mulino, Oregon, as our Sales Coordinator! This position is responsible for ensuring the seamless processing, tracking, and delivery of customer orders while providing exceptional client communication and internal coordination. Some of the duties include:

- Order processing
- Order tracking and status updates
- Customer communication
- Internal coordination with sales, production, and shipping
- Administrative support

Education & Experience

A high school diploma or GED is required for this role. In addition to the education requirement, a minimum of two years of related experience in an administrative or support role, within a sales or customer service environment, is required. An equivalent combination of education, training, and experience may satisfy these requirements.

Knowledge, Skills, and Abilities

The ability to adjust to new situations, environments, and changing priorities, to effectively convey information and ideas through written, verbal, and non-verbal means; and proficiency in Microsoft Office Suite or related programs are essential.

Benefits

- 401(k) matching
- Dental insurance
- Employee assistance program
- Flexible spending account
- Health insurance
- Life insurance
- Paid time off
- Vision insurance

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Career Opportunities

PCB Manufacturing Technician

Join the Team at Accurate Circuit Engineering!

Located in Santa Ana, California, Accurate Circuit Engineering (ACE) delivers high-quality PCB solutions with a focus on innovation and precision.

Role: Accurate Circuit Engineering is looking for detail-oriented PCB Manufacturing Technicians for all areas in PCB manufacturing. Responsibilities include operating manufacturing equipment, performing quality checks, and documenting production data.

Qualifications:

- High school diploma or equivalent; technical training preferred
- Experience in PCB manufacturing or electronics assembly a plus
- Strong attention to detail and ability to follow instructions
- Familiarity with PCB manufacturing and testing tools is advantageous

What ACE Offers:

- Competitive wages and benefits
- Career growth opportunities
- Supportive work environment with comprehensive training

To apply, send your resume and cover letter to sales@ace-pcb.com with the subject "PCB Manufacturing Technician Application."

Accurate Circuit Engineering is an equal-opportunity employer and values diversity in the workplace.

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Service Engineer: Chicago

Join the Schmoll America Team as a Service Engineer—Where Innovation Meets Customer Excellence! Are you a technical mastermind with a passion for solving complex problems and delivering exceptional customer experiences? Look no further than Schmoll America!

We're looking for engineers to work in the Chicagoland area.

As a Service Engineer, you'll be the driving force behind our customers' success, providing top-notch technical support and maintenance services for our PCB industry-leading equipment.

What you'll do:

- Install, commission, and maintain Schmoll equipment at customer sites
- Troubleshoot and repair equipment with ease and precision
- Provide technical training and tailored applications solutions to customers

What we offer:

- A dynamic and supportive work environment where your voice matters
- Opportunities for professional growth and development in a cutting-edge industry
- A competitive salary and benefits package
- The satisfaction of knowing you're making a real difference in our customers' lives

What we're looking for:

- Engineering degree preferred
- 3+ years of experience in an engineering role
- Strong technical knowledge of electrical and mechanical systems
- Excellent problem-solving and analytical skills
- Willingness to travel (up to 75%) to customer sites and HQ in Germany

If you're a motivated professional looking for a challenging and rewarding role, we want to hear from you! Please submit your resume and cover letter to HR@SchmollAmerica.com.

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Career Opportunities

The Test Connection, Inc.

Sr. Test Engineer (STE-MD)

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

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

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

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

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The Test Connection, Inc.

Rewarding Careers

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

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

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

Associate Electronics Technician/ Engineer (ATE-MD)

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

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

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Career Opportunities

BLACKFOX
Premier Training & Certification

Sales Manager
Longmont, CO

This is a full-time, on-site role for a Sales Manager at Blackfox Training Institute in Longmont, CO. We are looking for a Sales Manager with a strong track record of B2B sales management experience. The Sales Manager will be responsible for day-to-day sales activities, developing sales strategies, building and maintaining client relationships, and achieving sales targets. Additionally, the Sales Manager will participate in industry events, represent the company at trade shows, and collaborate with the marketing team.

Qualifications:

- Sales Strategy Development, Client Relationship Management, and Sales Target Achievement
- Experience in B2B sales and a proven track record of meeting sales goals
- Structured and growth-oriented approach to Sales Leadership
- Excellent communication and negotiation skills
- Knowledge of the training or education industry a plus
- Able to work effectively in a team and independently
- Bachelor's degree in Business Administration, Engineering or related field
- Proficiency in CRM software such as Hubspot
- Services sales experience will be a strong plus

Contact Jamie Noland to apply:
jamien@blackfox.com

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INSULECTRO

Are You Our Next Superstar?!

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

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

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Career Opportunities

MivaTek Global

Field Service Technician

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

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

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

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

More About Us

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

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

Qualifications and skills

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

Benefits

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

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Career Opportunities

Prototron Circuits

Sales Representatives

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

Reasons you should work with Prototron:

- 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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YOUR JOB AD HERE

For information, please contact:
BARB HOCKADAY
barb@iconnect007.com
+1 916.365.1727 (PACIFIC)

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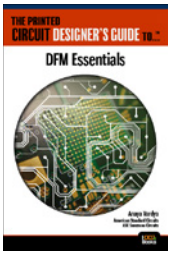
I-007eBooks The Printed Circuit Designer's Guide to...

More Secrets of High-speed PCBs

by Martyn Gaudion, Polar Instruments

This book emphasizes the most effective methods for transitioning quality designs from prototype to production with a focus on signal integrity. In the realm of signal integrity, the most skilled designers and fabricators consistently measure, model, and then measure again to guarantee the highest quality and predictable signal integrity in their designs and products. **Read it now!**



DFM Essentials

by Anaya Vardya, American Standard Circuits, ASC Sunstone Circuits

One of the biggest challenges facing printed circuit board designers is not understanding the cost drivers in the PCB manufacturing process, particularly the manufacturing of advanced technology PCBs. The guidelines offered in this book are based on both ASC recommendations and IPC standards. **Download your copy today.**

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