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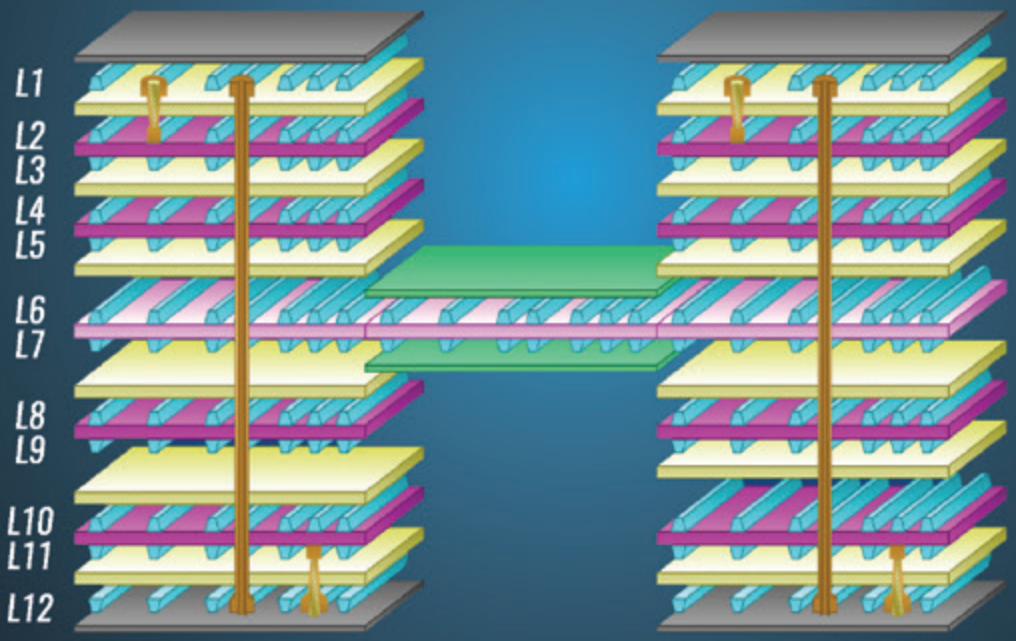

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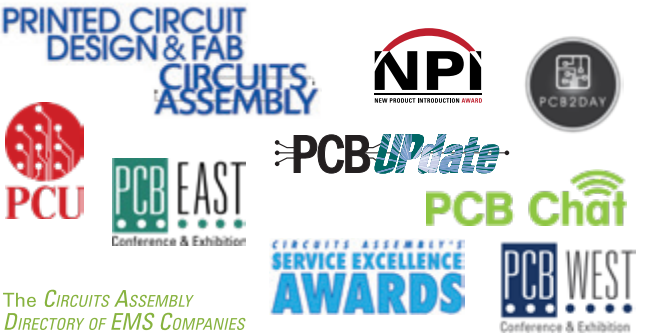

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Grounded! What The Electronics Industry Can Learn from Airlines

ANYONE WHO HAS boarded a plane in the past several months knows this all too well: the near-term operations of airlines are up in the air.

From smallest to largest, all the carriers have been dramatically affected by the post-Covid rebound in passenger air travel. How could it not? After all, Delta and United Airlines each cut 30% of their respective staff in 2020, for instance.

And while many observers point to the attractive buyouts the carriers dangled before critical employees (read: pilots) as a means to cut costs amid the mass groundings during the pandemic, employment has shot up over the past 18 months.

Take Delta, for instance. The second-largest airline in the world has hired 18,000 new employees since January 2021. But even with its staffing back to 95% of what it was pre-Covid, capacity reportedly is some 10 percentage points lower. Reason: It takes time to train the newbies.

"The chief issue we're working through is not hiring but a training and experience bubble," said Ed Bastian, CEO, Delta.

And the more complicated the job, the longer the training period. Which reveals yet another crack in the fuselage: a lack of trainers. To wit: American says its pilots are basically stuck waiting for space in training classes to open, as the number of new hires far outpaces the available slots. The backlog is said to be six months or more.

The issue runs so deep, it has its own name: the Juniority problem.

United has gone on the offensive, blaming – who else? – the government. United chief operating officer Jon Roitman estimates "over 50% of our delay minutes and 75% of our cancels in the past four months were because of FAA traffic management initiatives."

But all this comes back to the industry's lack of foresight – some say unwillingness – to continue to invest in its workers during the inevitable cycles.

You know where I'm going with this.

The PCB industry is historically boom/bust. We are coming off a run of very strong years, and the forecast, according to Dr. Hayao Nakahara, the preeminent researcher in the industry, continues to look bright (https://www.pcdandf.com/pcdesign/index.php/editorial/menu-features/16699-the-unsinkable-unstoppable-pcb-market).

But the graying of the industry is very real, and it's long past time OEMs invested in recruiting and training the next generation of designers, design engineers and manufacturing engineers. And yes, I am pointing at OEMs, since they are top the of the pyramid, and ultimately their needs are the driver for the rest of the supply chain's decision-making.

While we are excited at the prospect of new electronics engineering curricula finding its way into classrooms from New York to California, what's available today is nowhere close to meeting the long-term needs of the industry. And it goes without saying more is needed in the way of practical training, be it in design, fabrication or assembly.

At PCB West (pcbwest.com) this October, designers and engineers can get that hands-on training. The program was developed to cross the spectrum from packaging to board design to fabrication to assembly and test to ensure needs of each segment are communicated bidirectionally across the chain. With more than 110 hours of training scheduled, it's the largest conference of its kind.

Unlike many conferences, PCB West focuses on in-depth training, as most presentations are at least two hours. It includes some of the leading experts on signal integrity and noise control, PCB layout, and manufacturing. Presentations will cover all sorts of new possibilities in design and manufacturing such as additive manufacturing, new substrate material choices, routing of DDR memory, and component selection, which is highly relevant given the current supply chain conditions.

Because PCB West is where the best design engineers in the country meet up, this is a chance to gain access to that knowledge. There is a real cost to "doing nothing" in terms of a company's ability to stay on top.

Industry has asked a lot of their employees over the past couple years. As we learned in our annual salary survey this year (results are in this issue and at pcea.net), design engineers cite keeping up with technology changes and company support for professional development workload as among the biggest professional challenges they face.

Let's learn from the airlines, or, more precisely, their mistakes. It's time for the push to onboard the next generation of engineers to take flight.

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PCDF People

American Standard Circuits appointed **John Johnson** director of business development, with a special focus on the growth of Averatek's A-SAP technology. He has held several significant leadership positions, including president of PCB fabricator Electrotek and vice president of sales and customer support at Averatek.

Ivor Langston, 95, founder of Fine Line Circuits, has passed away.

Nano Dimension named **Dale Baker** president of Nano Dimension – Americas. He previously worked at General Electric & Trading and in GE's Electrical Distribution and Control business, and GE Capital, where he was senior vice president and manager, responsible for investing in M&A. He also has served as the CEO or president of seven companies.

Nano Dimension named **Matt Wuensch** account manager. He previously spent nearly five years at Anark as director of enterprise sales, and has held positions in sales, business development and engineering at Honeywell, Mentor and Motorola in his 37 years in electronics.

Schmid Systems promoted **Michael Scarfia** to customer service and named **Jeremy Malicowski** field service engineer.

Stevenage Circuits appointed **Christoph Boueke** managing director. He brings 24 years of senior management experience in the UK, Germany and North America.

Uyemura promoted **Troy McNulty** to national sales manager.

PCDF Briefs

Additive Circuits Technologies signed a new equipment financing facility with **Liberty Commercial Finance** to refinance existing debt and provide funding for future capital expenditures. ACT owns **Winonics** and **Bench 2 Bench.**

Advanced Circuits has called off its previously announced agreement to be sold to **Tempo Automation.** The deal, which was announced Oct. 13, was contingent upon Tempo being acquired by a publicly traded special purpose acquisition company. Due to continued delay in closing the latter transaction, Advanced Circuits and its parent company, **Compass Holdings,** elected to terminate the agreement.

Cisel, an Italian flexible circuit board maker, is using cobots to automate electrical testing of boards used in the power steering

A Sustainable and Cost-Efficient Solution to Replace Etching Processes

RHINE-NECKAR, GERMANY – InnovationLab announced a new additive manufacturing process for printed circuit boards said to meet higher environmental standards while also reducing costs.

Within the research project SmartEEs2, InnovationLab and its partner ISRA have developed a novel manufacturing process for copper-based solderable circuits. The circuits are screen-printed and are compatible with conventional reflow processes.

Producing printed electronics is an additive process free of toxic etchants, and runs at temperatures of around 150°C, thus reducing energy consumption versus conventional wet processing. Moreover, the substrates used in additive PCB manufacturing are up to 15 times thinner, compared to conventional techniques, which reduces material consumption and waste.

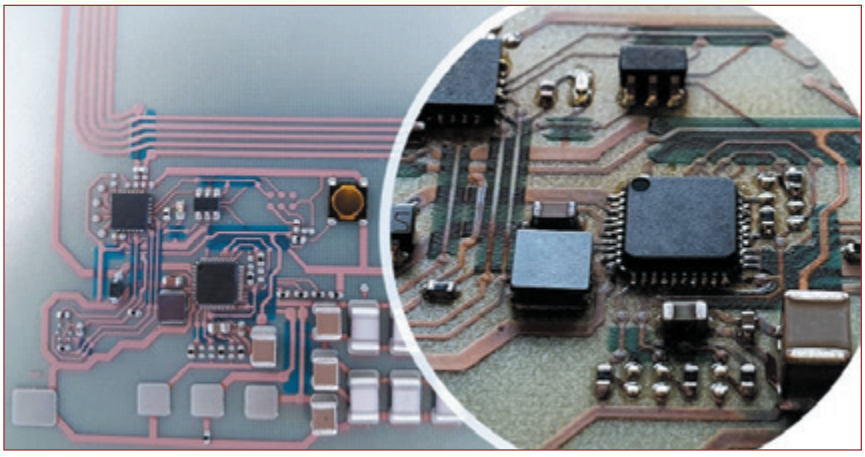
InnovationLab has so far produced a physical prototype, which includes all the important blocks of a smart label. It uses a copper ink for high conductivity. Component attachment can be performed using conventional reflow soldering, which enables manufacturers to switch to the new technology without investment in new equipment.

Multilayer printing of metals and dielectrics was used to produce the target functionality: a low power temperature sensor and logger, an NFC communication interface via a printed antenna, and a compact battery that is charged from a printed solar cell, making the device completely self-sufficient. The new process can produce both standard and flexible PCBs with up to four layers and can be used in product and process development for hybrid electronics.

"This is a state-of-the- art production process that will decrease costs and reduce logistical dependencies on suppliers while delivering three key benefits for the environment: consuming fewer materials, using less energy, and producing less waste," said Dr. Janusz Schinke, head of Printed Electronics, InnovationLab. "By the end of this year, we expect to have scaled this process to high volumes, meeting customer demands of a million solderable tracks or more."

SmartEEs2 is a project funded by the European Union's Horizon 2020 research and innovation program. Its objective is to provide acceleration support to innovative companies for the integration of flexible and wearable electronics technologies, and thus to help European industry's competitiveness.

InnovationLab was founded in 2008 as a one-stop shop for printed electronics, with a focus on flexible pressure and other environmental sensors, and has the capability to design and produce fully integrated hardware/software systems.



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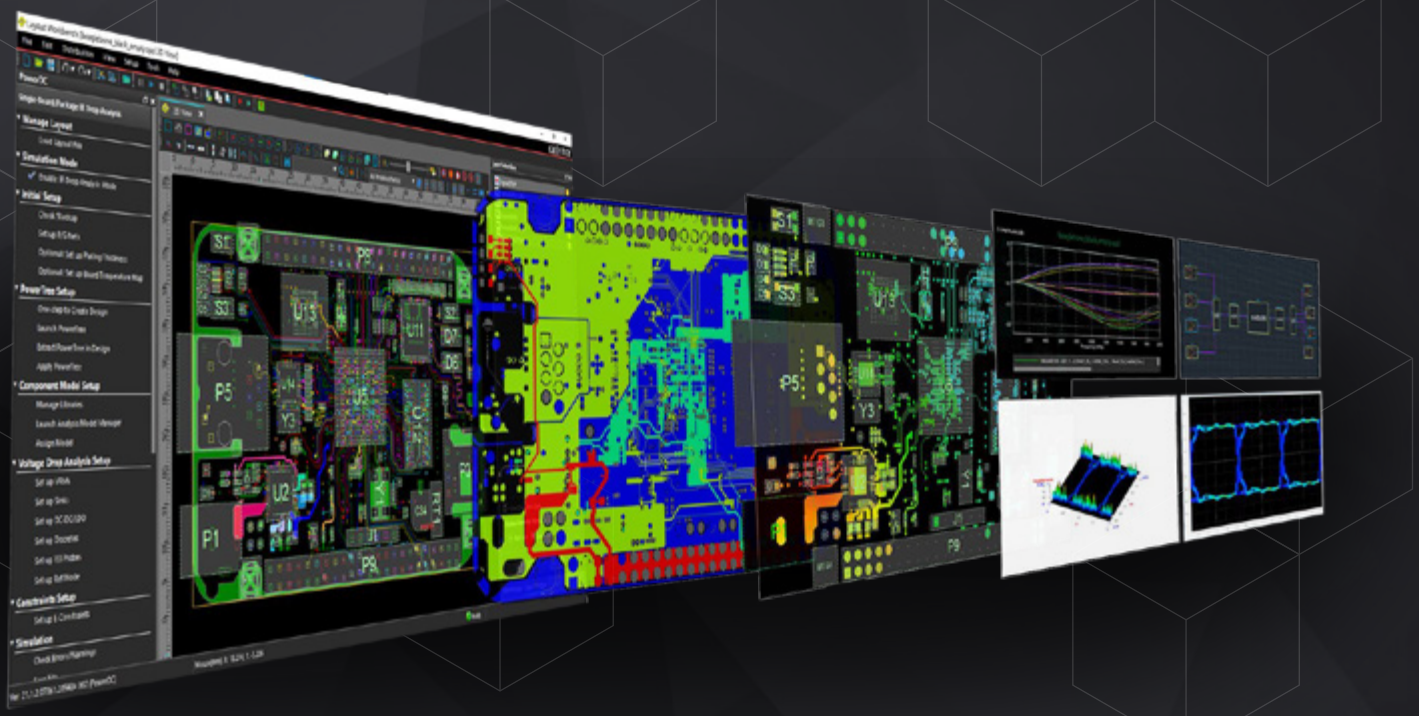

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Elepahntech has spent $40 million to develop a technology based on inkjet printing and plating to additively manufacture flexible PCBs on polyimide and PET materials. This hybrid approach ensures bulk-level conductivity similar to PCBs and soldering can be used without the challenges faced by conductive inks.

Flux is looking for beta testers for its programmable simulator for PCB design.

Google is reportedly switching to ceramics as the primary material for its future Pixel phones, foregoing the traditional glass, metal, and plastic combo.

HDP has launched Phase 7 of the Lead Free PWB Materials Reliability Evaluation. Over 80 materials have been evaluated in the previous six phases.

MKS Instruments in August completed its previously announced acquisition of **Atotech** for approximately $4.4 billion in cash and MKS common stock.

TTM Technologies expects its PCB fabrication operation in Penang to generate 10% of its revenue in the future.

Zhen Ding chairman Shen Qingfang predicts that by 2030 it will have 10% of the world's PCB market share.

CA People

AIM Solder appointed **Levente Liszka** Eastern Europe sales manager. He has over 10 years' experience in the electrical, electronics and automotive industries and a degree in mechanical engineering. AIM also promoted **Petr Bettinec** to business development manager, Europe.

Charlie Barnhart, a former EMS executive turned market researcher, has passed away.

Dr. Jennie Hwang has been appointed chairman of the Laboratory Assessment Board of The National Academies of Sciences, Engineering, and Medicine.

Pegatron named **Johnson Deng** and **Gary Cheng** co-CEOs, replacing **SJ Liao**.

Nordson Electronics announced **Parker Abdo** as key account sales manager for the southwestern US. Before joining Nordson, he sold back-end semiconductor manufacturing and testing systems at Chalman Technologies, including equipment from Nordson March and Dage. He holds a bachelor's in mechanical engineering.

Nordson to Acquire CyberOptics, Further Consolidating SMT AOI Market

WESTLAKE, OH – Nordson in August signed a definitive agreement to acquire CyberOptics in an all-cash transaction valued at $54 a share, or approximately $380 million net of cash.

The closing price reflects a valuation of 18.5 times CyberOptics' trailing 12 months EBITDA, and 14.5 times net of cost synergies. The transaction is expected to close in Nordson's first quarter fiscal 2023, pending applicable regulatory and shareholder approvals.

"We are looking forward to welcoming CyberOptics' nearly 200 employees to Nordson. The company's leading-edge 3D optical sensing technology and market leading wireless measurement sensors will expand Nordson's current test and inspection capabilities, allowing us to offer new differentiated solutions to our semiconductor and electronics customers. We will invest in CyberOptics' greatest opportunities for profitable growth while also providing the advantages of our global business infrastructure and customer-centric model," said Sundaram Nagarajan, president and chief executive.

Headquartered in Minneapolis, CyberOptics generates approximately $100 million in annual revenue. It makes sensors used for semiconductor and SMT inspection and metrology, and AOI equipment for board and component inspection.

"Our global Test & Inspection division within the Advanced Technology Solutions segment predominantly serves the electronics market in diversified end customer applications and has been delivering consistent, profitable growth," said Joseph Kelley, executive vice president and CFO. "The differentiated technologies of CyberOptics combined with Nordson's global sales, applications and service infrastructure will enable accelerated growth rates and the realization of $6 million in net cost synergies."

Naprotek Acquires MicroFab in EMS Rollup

SAN JOSE – Naprotek in August completed the acquisition of privately held MicroFab, adding RF products and services to its electronics manufacturing mix. The business and entire MicroFab team will be integrated into the East Coast operations at SemiGen, which Naprotek acquired last fall. Financial terms were not disclosed.

Naprotek now offers an array of custom build-to-print thin film products, supported by enhanced capabilities and a wider spectrum of thin film technologies.

Edgewater Capital financed the deal for Naprotek.

Manchester, NH-based MicroFab was founded in 1999 and provides of precision RF circuit fabrication and atomic-level micromachining services. The company provides ion beam etching, plating, dicing, and micromachining services and thin film components for communications, microwave, biomedical sensors, and fiber optics applications serving the defense, medical, and telecom markets.

"Our team continues to excel across the Naprotek platform, increasing our strengths with differentiated technologies spanning from SMT to RF/microwave and advanced microelectronics. With a careful execution strategy, the integration of MicroFab into SemiGen strengthens the end-to-end RF Solutions for the East Coast operations of Naprotek," said Daniel Everitt, president and CEO, Naprotek.

"The acquisition of MicroFab adds distinct manufacturing processes and products that will further complement our comprehensive product and service offering," said Tim Filteau, president, SemiGen. "Our business has continued to grow rapidly with ever increasing technical requirements from our customers. Facing this demand, we are confident that MicroFab will immediately augment our RF Solutions capabilities, and we are excited to welcome John Kelley, Wayne Stauss and the entire MicroFab team to SemiGen."

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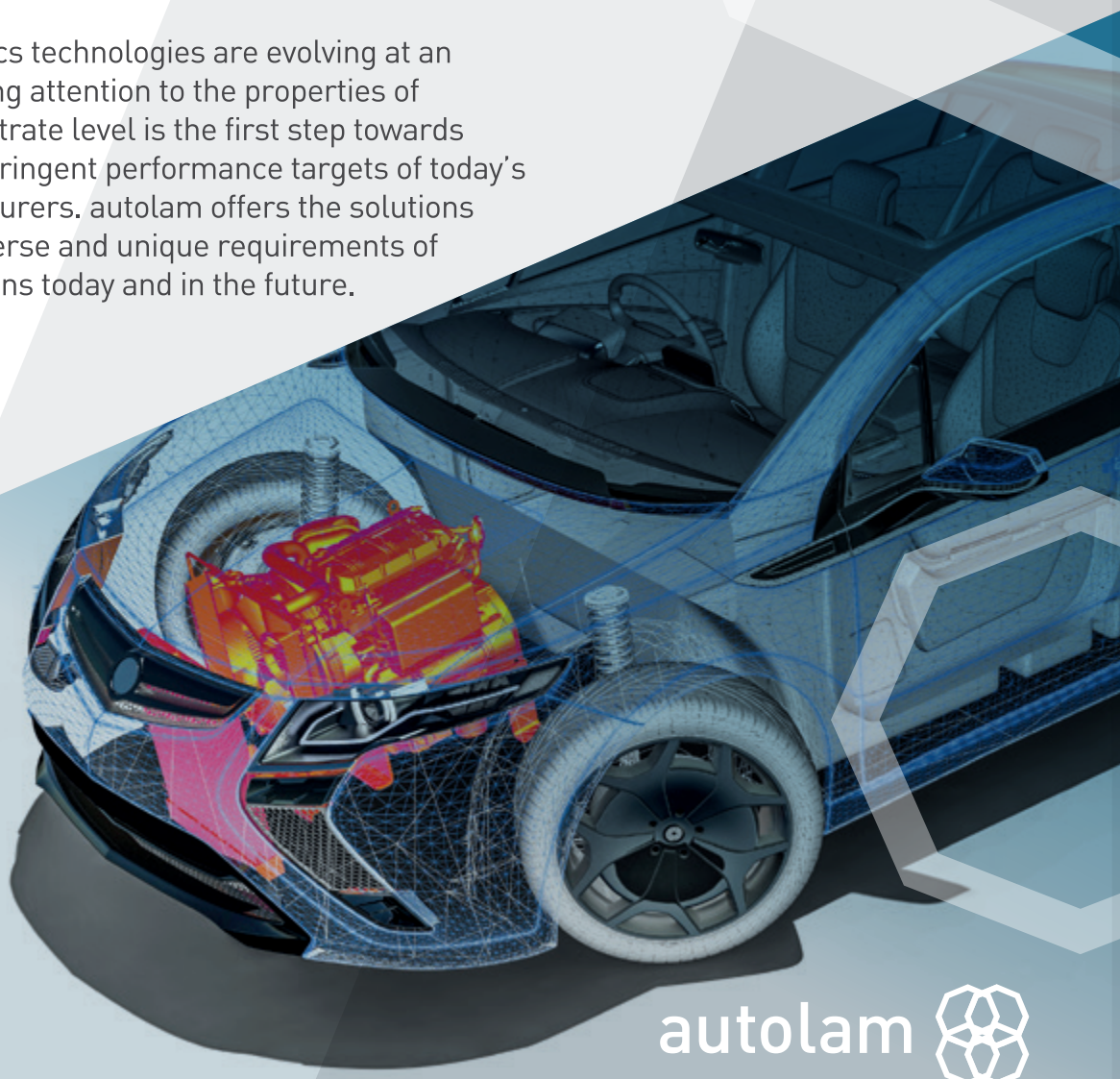

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Saki promoted **Eddie Ichiyama** to chief sales manager for overseas and **Ken Katsumi** to chief sales manager, responsible for maximizing sales in markets outside of Japan.

Sigmatron president **James Barnes** has resigned to pursue another business opportunity. In the interim, chief executive and chairman **Gary Fairhead** will serve as acting president.

Wago hired **Jeffrey Govek** as senior sales and application engineer.

CA Briefs

American Pacific Group invested in EMS provider **Concisys.**

Aurelius Technologies commenced production for a newly acquired customer in the multicomponent IC business, after installing four fully automated SMT lines in its existing Plant 2.

Bittele Electronics has expanded its Markham, Ontario, PCB assembly facility.

BTU named **Closed Loop Technology** manufacturers' representative in Southern California.

Circuit Technology Center released a technical paper discussing key process steps for gold plating removal from the solderable surfaces of electronic components using a robotic hot solder dipping (RHSD) process (www.circuitrework.com/features/1063.html).

Data Device purchased a **Hentec/RPS** Odyssey 1325 robotic hot solder dip component lead tinning machine.

Egypt has signed an agreement with **Nokia** and **EAI Factory for Advanced Industries** to produce Nokia phones in Egypt.

Foxconn plans to invest about $800 million in **Tsinghua Unigroup,** which offers Foxconn access to its mobile chipset or memory expertise, with the auto market as its target.

Foxconn is confident the company will improve its gross margin to 10% by 2025, mainly buoyed by growth at its new businesses, according to chairman Young-Way Liu.

Henkel and **Chip Integration Technology Center (CITC)** have formalized an agreement to collaborate on the development of high-thermal die attach solutions for RF and power electronics. Under the terms of the partnership, Henkel will supply commercialized and developmental pressureless sintering die attach formulations and CITC will provide testing and analysis of the materials within next-generation package designs.

Henkel opened its South China Application Engineering Center (SCAEC) in Dongguan, Guangdong Province, featuring advanced testing, analytical and research labs, and joint development labs. The lab aims to better support Chinese consumer electronics customers.

Indian governmental authorities have given approval to **Reliance Strategic Business Ventures'** planned majority stake in **Sanmina-SCI India.**

iNEMI's Development of an Imaging AOI + AI Ecosystem project will address the electronics manufacturing industry's need for comprehensive image libraries (datasets) to train AI models for AOI and AXI.

KMC Controls invested in an **Ersa** Versaflow 335 selective soldering machine.

Oppo has decided to expand investment and strengthen its manufacturing ecosystem in India amid the local government's increased scrutiny of Chinese smartphone makers.

PK Sound, a robotic line array company, is now fully operational in its new 50,000 sq. ft. headquarters and electronics manufacturing facility in Alberta, Canada.

Plexus in August opened its $60 million, 400,000 sq. ft. advanced manufacturing facility in Bangkok, its 26th worldwide.

Scanfil has signed a deal to take over medical device manufacturing for **Qlife.**

Wallbox, a provider of electric vehicle charging and energy management solutions, announced the acquisition of **Ares Electronics,** a contract electronics manufacturer.

Walton opened its second PCB assembly plant in Bangladesh, doubling its motherboard production capacity.

Wistron has disclosed plans to expand server production capacity in Taiwan and Mexico.

WPI Vision appointed **Southwest Systems Technology** manufacturers' representative in Texas, Oklahoma, Arkansas and Louisiana.

Xiaomi opened a smartphone manufacturing plant in Gazipur, Bangladesh.

GPV Says New Mechanics Factory in Thailand on Schedule

BANGKOK – Construction of GPV's new mechanics factory here is rapidly progressing, the electronics manufacturing services company said in mid-August.

As of July, pilings for the new factory in Thailand had been completed and the lobby, second-floor office and cafeteria, high-precision area, utility building and loading bay are progressing according to plan. The factory roofing is expected to be finished this month.

All work with the precast materials, such as columns, beams and walls, as well as steel structure are manufactured, and progress continues as planned. Moreover, the piping for the fire protection sprinkler system and sanitary system, along with the electrical work, are also progressing as planned.

"Even though there have been minor delays, we expect the new factory to be finished by mid-March 2023 as planned. We are very much looking forward to moving into the new facilities and to serve our customers from there," says Bjørn Fiskers, managing director, GPV Electronics TH and Mechanics TH.

When the new mechanics factory is finished, and the mechanics production has moved into its new facilities, the current facilities will be refurbished into an extension of the Electronics TH factory.

The GPV mechanics factory in Thailand is currently 76,423 sq. ft., and the GPV electronics factory in Thailand is 15,000 sqm. When the construction is finished, the mechanics factory will be 129,000 sq. ft., and the electronics factory will be 236,800 sq. ft.

After the expansion in both Sri Lanka and Thailand, GPV will have a 1.08 million sq. ft. in total.

"The construction projects in Thailand are important steps on our growth journey. The new factory facilities will help us to meet our customers increasing demands and continue to deliver high-quality products," says Bo Lybaek, CEO, GPV. □

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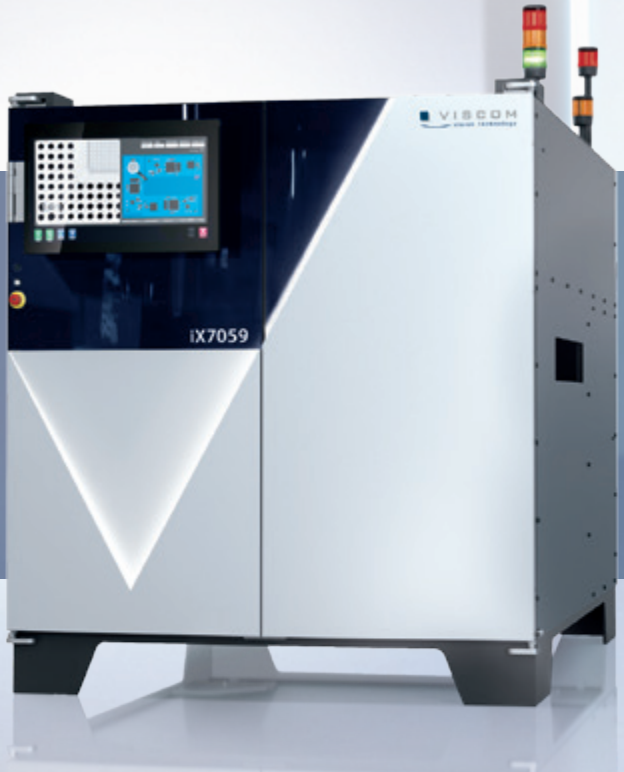

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Chapter News

Orange County, CA. We held our first in-person Lunch-N-Learn meeting event in 2.5 years on Jul. 26 in Santa Ana, CA. It was hosted by Insulectro and attracted an audience of 44 designers, engineers, and fabricators to listen to three educational presentations.

Two topics were presented by Chris Hunrath (pictured), vice president of technology at Insulectro: "Signal integrity Applications in Layout" was very detailed in applying SI theory to a layout, where he covered EM fields, laminates, copper profile, uninterrupted GND return path, impedance discontinuities from your routing, and proper shielding; "Advanced Via Solutions Using Ormet Pastes" discussed applications for addressing z-axis interconnects for multi-lam HDI, backdrill elimination, solving high aspect ratio plating on high-layer-count boards, and any-layer-via usage. A variety of different stackup constructions were shown, which got many designers thinking how this sintered metal process could bring a variety of solutions to the designer. This is a mature process that could provide improved cost and performance in many applications in comparison to the standard PCB multilayer process.

Also, "Overcoming Flex Design Challenges" was presented by Geoffrey Leeds, CID, flex product manager at Insulectro. Leeds spoke of overcoming flex design challenges by understanding the building blocks; pitfalls to avoid during layout; dynamic vs. static design constraint; and the proper materials and their applications. Many designers in the audience were unfamiliar with flex circuit design practices, so this presentation was a well-received learning experience.

We wrapped with a drawing for eight raffle prizes totaling over $1,000, including a Footprint Expert software license from PCB Libraries, restaurant gift cards from Freedom CAD Services, and Amazon gift cards from Siemens EDA and Insulectro.

Silicon Valley. We held our latest meeting Aug. 4 at Siemens EDA (Mentor Graphics), which also sponsored a lunch. It featured Carl Schattke, whose presentation, "The A+ PCB Outline Drawing," showed how to save design teams time and money and prepare them for optimal communication for a fast start to the design process. All the important points of the PCB outline drawing were reviewed.

National. The PCEA annual meeting takes place Oct. 4 at PCB West. All members are invited. Please preregister at pcbwest.com.

Chris Hunrath addresses the Orange County chapter.

PCB West Technical Conference Early Bird Discount Deadline Looms

PEACHTREE CITY, GA – Printed circuit engineers are ready to get back to face-to-face events, and the PCB West technical conference has all the reasons they need to make their return to live interaction more than worth their time.

Registrants who sign up at pcbwest.com by Sept. 6 can take advantage of the Early Bird Special discounts for the conference, which features 40 presentations spanning more than 110 hours of classroom time.

Among the industry experts on tap for this year's show are Rick Hartley, Susy Webb, Tomas Chester and Dan Beeker, headlining a stellar list of technical experts presenting at PCB West. The conference will be held Oct. 4 to 7 at the Santa Clara (CA) Convention Center and features classes for every level of experience, from novice to expert.

An exhibition about 100 leading suppliers to the electronics design and manufacturing industry will be held Oct. 5.

The scope of classes includes:

- Controlling noise
- Signal integrity
- Designing and building advanced HDI
- Routing high I/O count chip packages
- Board stackups
- Power integrity, and more.

PCB WEST 2022 Conference & Exhibition

New courses this year include proper PCB layout of DDR, signal energy flowing through a PCB stackup, surface finish selection criteria, understanding high frequency materials test methods for Dk and Df, and PCB design for engineers.

Conference attendees receive free Lunch-N-Learn talks and a Professional Development Certificate.

Booth Sales Open for PCB East 2023

PEACHTREE CITY, GA – PCEA has opened the show floor to exhibitors for next year's PCB East conference and exhibition. The one-day exhibition takes place May 10 at the Boxboro Regency in Boxborough, MA, sandwiched by the three-day (May 9-11) technical conference.

Companies interested in exhibiting may visit pcbeast.com or contact PCEA vice president of marketing and sales Frances Stewart at frances@pcea.net for details.

"We just completed a two-week soft opening exclusive to returning exhibitors," said Mike Buetow, president, PCEA and conference director, PCB East. "Now we are opening the floor to any companies that want access to the vibrant New England electronics design and manufacturing industry." ▫

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Hot Takes

- **DRAM market demand bit growth** will amount to 8.3% in 2023, growing less than 10% for the first time in history, and far lower than supply-side bit growth of approximately 14%. Data indicate the DRAM market to be severely oversupplied through at least 2023, and prices may continue to decline. (Trendforce)
- **Worldwide semiconductor sales** totaled $152.5 billion during the second quarter, up 13% from 2021 and 0.5% over the first quarter. (SIA)
- Total **North American PCB shipments** rose 17.1% in June versus last year and jumped 26.3% sequentially. Year-to-date bookings fell 4.1% from a year ago but increased 14.4% from May. (IPC)
- Global sales of total **semiconductor manufacturing equipment** by original equipment manufacturers are forecast to reach a record $118 billion in 2022, rising 14.7% from the previous industry high of $103 billion in 2021, and increase to $121 billion in 2023. (SEMI)
- **Smartphone shipments** declined 8.7% year-over-year in the June period. (IDC)
- Sales of software for designing printed circuit boards and multichip modules increased 1.4% to $293 million in the quarter ended Mar. 31. (ESD Alliance)
- Worldwide **tablet shipments** reached 40.5 million units during the second quarter, for year-over-year growth of 0.2%. (IDC)
- **Copper prices** have been falling since June, from about $9,500 per ton to the current $7,000, leading Taiwanese PCB shops to reduce inventories. (Science and Technology News)
- The **Germany region book-to-bill for PCBs** was 1.01 at the end of the June quarter, flat sequentially, while backlogs set a net record. (ZVEI)
- **North American EMS shipments** in June fell 7.6% from last year and increased 9.6% sequentially. Bookings decreased 13.9% year-over-year and increased 12% from the previous month. (IPC)

June Swoon: IC Sales Cool in June

SCOTTSDALE, AZ – The IC market recorded its first-ever June sequential sales decline this year, based on data from WEMA, SIA, and WSTS dating to 1976, according to research firm IC Insights. Typically, high single-digit or double-digit sales gains have been the pattern for June IC sales. Even in its previously weakest year (1985), June IC sales increased 1%. Until this year, June IC sales had never declined.

This extraordinary result was startling for at least two reasons. First, June is a quarter-ending five-week month; that alone has historically been enough to generate a sales uptick compared to the four-week month of May. Second, June is normally one of the strongest months of the year for IC sales since OEMs are buying chips to build into their new systems in time for back-to-school and end-of-year holiday sales.

The biggest contributor to June's total IC market decline was the sudden and dramatic drop in memory IC sales.

The second and third quarters are typically the strongest for IC sales. Since 1984, second quarter sales have grown an average of 4.2% and third quarter sales have increased an average of 6.1%.

Second quarter IC market growth was flat, falling below the long-term average. Based on IC Insights' assessments of company sales outlooks for the rest of this year, it appears that second-half sales stand a good chance of falling short of their long-term average growth rates as well.

Much of the current IC market weakness is due to economic concerns caused by rising inflation, ongoing supply chain disruptions, and from suppliers and OEMs working to reduce IC inventory levels. Several semiconductor companies noted that inflation has put a dent in consumer discretionary spending. Weakness was particularly evident for shipments of consumer PCs, low- and mid-level smartphones, televisions, game consoles, and personal electronics devices.

US MANUFACTURING INDICES

	MAR.	APR.	MAY	JUN.	JUL.
PMI	57.1	55.4	56.1	53.0	52.8
New orders	53.8	53.5	55.1	49.2	48.0
Production	54.5	53.6	54.2	54.9	53.5
Inventories	55.5	51.6	55.9	56.0	57.3
Customer inventories	34.1	37.1	32.7	35.2	39.5
Backlogs	60.0	56.0	58.7	53.2	51.3

Source: Institute for Supply Management, August 1, 2022

KEY COMPONENTS

	FEB.	MAR.	APR.	MAY	JUN.
EMS (North America)[1,3]	1.52	1.40	1.36	1.35	1.39
Semiconductors[2,3]	26.2%	23%	21.1%	18%[r]	13.3%[p]
PCBs[1,3] (North America)	1.16	1.04	1.04	1.05	1.03

Sources: [1]IPC, [2]SIA, [3]3-month moving average growth, [p]preliminary, [r]revised

PERIPHERAL VISION

Trends in the US electronics equipment market (shipments only)	% CHANGE APR.	MAY	JUN.	YTD%
Computers and electronics products	0.6	0.6	1.4	5.6
Computers	1.1	-0.4	-0.4	-1.1
Storage devices	6.6	2.0	2.9	13.2
Other peripheral equipment	-11.6	-1.1	17.0	9.4
Nondefense communications equipment	1.5	1.3	0.9	10.4
Defense communications equipment	5.9	-3.7	0.5	10.4
A/V equipment	-1.9	-11.9	-4.0	8.0
Components[1]	0.5	1.9	-1.3	37.1
Nondefense search and navigation equipment	3.6	-2.2	1.7	15.1
Defense search and navigation equipment	0.4	0.7	-0.7	1.8
Medical, measurement and control	1.2	0.6	3.4	0.6

[r]Revised. *Preliminary. [1]Includes semiconductors. Seasonally adjusted.
Source: U.S. Department of Commerce Census Bureau, Aug. 3, 2022

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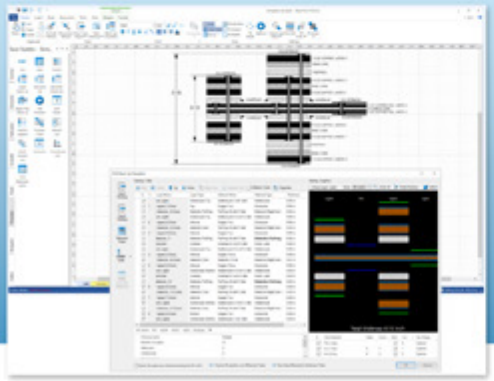
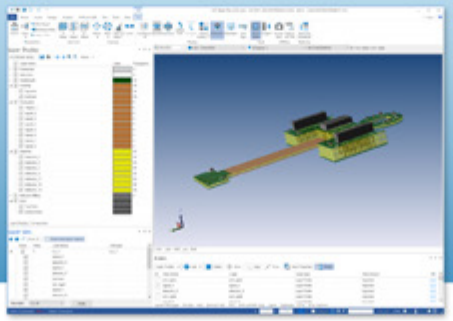
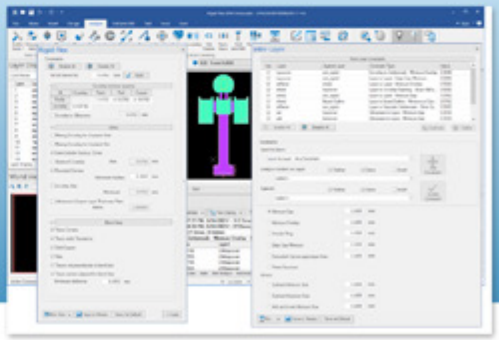
- Use DFM analysis to analyze a flex or rigid-flex design for potential fabrication or bend related defects



Use Stack Up Visualizer and Blueprint's Rigid-Flex Stackup template to easily manage and document rigid-flex stackups.



A rigid-flex design in 3D. Shown with layers spread to improve visualization of the layer stackup.



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Business's Hidden Critical Asset

A sense of urgency most go toward protecting your tribal knowledge.

EVERY BUSINESS KEEPS a mindful eye on critical assets. On any corporate balance sheet those assets are identified, valued and periodically updated. Indeed, business valuations are often tied directly to those assets, enabling companies to borrow money to acquire additional assets. Regrettably, no balance sheet includes or values the most important and valuable (and perhaps invaluable) asset a company has: tribal knowledge.

The term "tribal knowledge" is used to encompass all the knowledge, experience and wisdom a business's combined workforce brings to the game each day. It describes what for centuries has been a key asset of all businesses, especially manufacturers. Despite its importance however, historically it has not been universally acknowledged of value nor viewed as a competitive advantage that contributes to organizational profitability.

Much like DNA, tribal knowledge differentiates one company from another. The combined knowledge, skills and experiences of employees from various companies may be similar, but how they are deployed, the problems they have overcome, and their successes shape the character of the tribe, and contribute to one organization looking and acting different from another.

In many ways, tribal knowledge is intellectual property (IP). A company will invest considerably to develop hardware, software or processes and patent or copyright them to protect them from competitors, or to monetize through sale or license to others. Tribal knowledge may have enabled development of those products or processes. That contribution is either unappreciated or undervalued, however.

Why, then, has tribal knowledge been overlooked as a strategic asset all these years, and why do so many now consider it important? The answer to both questions lies with supply and demand.

Historically, the availability of a qualified work force has been a minor problem. Companies hired when they needed talent, and trained and retained that talent. Occasionally employees would leave for a better opportunity elsewhere. The supply of workers seeking a good job and a long-term career was abundant, however. Such workforce stability resulted in managers developing a sense of security, knowing they could rely on a well-trained and experienced workforce to handle whatever opportunities – or challenges – arose. The ease of finding and retaining people lulled many to discount the value of a stable and reliable workforce, and employees were seen less as an asset and more as a given.

The world has changed considerably over the past 10 to 20 years, especially in the world of manufacturing. Those entering the workforce today have altered visions of their career. Younger workers appear less interested in staying with the same company over the long haul and much more prone to change jobs for an immediate pay increase, or if the work environment or benefits appear better. Thanks to Covid, many opt for employers that allow working from home. In short, access to a qualified workforce is far less than in the past.

Worse is the demand side. With an unprecedented number of Baby Boomers reaching retirement age, demand for talent has never been greater.

With such a gap developing between the talent supply and demand, the fear of losing that tribal knowledge has shifted managers' awareness, alerting them that what they may have taken for granted is in fact one of their business's greatest assets. More important, it is an asset that takes years to train and develop but could walk out the door at any time with almost no notice.

In any business, especially those in our industry, employee talent is essential not just to get quality product out the door and on time – it also is the strategic differentiator between a company and its competition. As such, the workers that make up your "tribe" are the single most valuable asset you have. Unlike any time in recent memory, there is a pressing need to transition that tribal knowledge to the next generation. And that effort must occur with the same sense of urgency that goes into protecting any other corporate asset.

Any transition often means duplication and repetitive costs to ensure the new can overlap with the retiring, to gain as much knowledge as possible. Documenting even the most basic processes and tasks, especially those performed by the most skilled and experienced labor, requires investment of ample resources and commitment from the top to complete – resources and costs that may seem expensive in the short term, but long term will result in extraordinary returns.

All in industry are facing the same challenge: how to preserve the tribal knowledge long earned by the company's entire workforce so that future employees will benefit. The task is daunting, however worth the investment so to preserve what is any company's greatest asset: tribal knowledge. □

PETER BIGELOW
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What is the Real Key to Domestic PCB Industry Success?

The recognition and funds are good. But do they attack an underlying issue?

READING DR. HAYAO Nakahara's annual accounting of the printed circuit board market (which ran in these pages last month), it's hard to believe Taiwan was once dependent on Japan for PCB knowledge.

Years ago, however, it wasn't Taiwan and China battling it out for market dominance; it was Japan and the US. Yet long before China emerged as a player, Taiwan had already identified PCBs as a key area for development.

Fulfilling that goal led to some interesting tactical moves. Nascent Taiwanese board shops, for instance, would entice Japan's PCB engineers with huge financial incentives to moonlight in Taiwan on weekends. Planes would arrive to pick up workers on Fridays and return them to Japan on Sundays. It was lucrative for the engineers, while it aided Taiwan's efforts to close the gap in technical knowledge.

A decade or so later, it was China's turn. Western expats regularly filled the bars and restaurants in Shenzhen, Suzhou and Shanghai, boosting their paydays through overseas assignments teaching the latest PCB technologies to the Chinese. Then the bottom fell out of the Western markets, and when the dust settled, China's market share was larger than that of the US and Europe combined.

Which brings me to the present-day United States. New legislation to boost the domestic PCB industry is making its way around Washington. Called the Supporting American Printed Circuit Boards Act of 2022 (SAPCB), the bill is modeled loosely on a similar statute designed to incent semiconductor manufacturers to raise their investments in the US. Known as the Chips Act, it was just passed by Congress and signed into law by President Biden.

SAPCB would provide approximately $3 billion in funding for American PCB facilities, equipment, and research and development. (An early provision for a 25% tax credit for the purchase of printed circuit boards manufactured in the US was recently removed from the bill. More on that in a moment.)

On one hand, such an act could help rebuild the once robust domestic PCB industry by lowering the cost of investment. And there's no doubt the industry needs to improve its manufacturing capabilities and technologies.

Given that PCBs appear in every electronics device and are configure-to-order products, one could legitimately argue that a strong domestic industry is crucial to technological superiority.

Will dollars alone solve the problem? In other words, what thought has been given to *how* an industry transformation might happen? And what will the domestic industry look like afterward?

No legislation, of course, will lay out the roadmap goals in detail, leaving it to the pundits (including yours truly) to opine on what might happen next.

For some clues, we can look to recent comments by the president of the Printed Circuit Board Association of America (PCBAA), Travis Kelly. "National security" is a term that is often bandied about. Kelly, who is also president of Isola, astutely looks past the Pentagon, however, pointing to the severe supply chain issues experienced in many sectors that are key to the US economy, including medical, banking, and 5G infrastructure.

"From an industry standpoint," he says, "when you look at defense spending, and what that means for our microelectronics industry, it is a relatively small portion of the overall sales within the US. As you know, the demand signal is volatile at best; it's high-mix, low-volume, so it's really looking at what can we do to supply certain critical components, as opposed to just looking at defense. Is there a potential way to aggregate that demand signal, so if you're at a domestically located PCB or material supplier, you can actually have some stability with that demand signal, and a demand signal that's big enough where you're willing to invest those capex dollars?"

What this might not mean is an increase in the number of US board manufacturers. Indeed, Kelly has elsewhere suggested possible additional consolidation.

That does not necessarily mean a smaller manufacturing footprint overall, of course. But it leads back to the issue of why PCB buyers go offshore in the first place: in search of capacity or technological proficiency – or both.

You read that right. In my experience, this is not a pricing issue. I've found it very difficult to source domestically (bring back production) because of lack of capacity or technology. I've had customers who were more than willing to pay higher prices to have their boards made in the US. They simply cannot find a domestic manufacturer with the capacity *and* the right technology.

That brings me back to the past international relationships, and how that might play out today.

There's no question federal recognition of critical technologies is a positive. And if the issue is technology

continued on pg. 23

GREG PAPANDREW
has more than 25 years' experience selling PCBs directly for various fabricators and as founder of a leading distributor. He is cofounder of Better Board Buying (boardbuying.com); greg@directpcb.com.

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12 – 24 Layers:	48 Hours

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Via in Pad Standard:	20 Days
Via in Pad Expedited:	3 Days
HDI Standard:	25 Days
HDI Expedited:	5 – 12 Days

FLEX / RIGID-FLEX

Flex 1 – 6 Layers Standard:	25 Days
Flex 1 – 6 Layers Expedited:	5-15 Days
Rigid Flex 4-22 Layers Standard:	25 Days
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Ensuring Proper Alignment of Layers and Components on a PCB

Why a tooling hole remains the answer for an end-to-end process.

TECHNOLOGY MARCHES ON and the result is a decreased margin for error. Even the language must adapt as mils give way to microns, because one thousandth of an inch is too coarse a measure for modern PCB geometry. As traces and spaces shrink to accommodate the latest chips, the onus is on fabricators and assemblers to achieve greater precision in all aspects of manufacturing.

Where does it end? Could Intel's new 2nm fab be the last stop? It seems so but I would not bet on it. Somewhere, somebody is working on angstrom class devices. Why not? Well, a single atom of copper comes in around 0.23nm, so Intel is depositing about eight or nine atoms of copper across the width of a connection. To quote Carl Sagan, "Billions and billions," but we're scaling down rather than up.

Gains made in foundries carry over to the printed circuit board. Thus, we must get better with each generation. Etch processes give way to additive processes to get down to the 25µm lines/spaces realm. That might be enough, for now.

Meanwhile, the PCB stackup must accommodate the increased circuit density one way or another; more traces per layer or more layers overall. Either way, the precision of layer-to-layer alignment is tightening on a regular basis. We're likely to see a greater use of lasers and other means, such as MSAP, to get reliable results at this scale.

The best alignment method for PCB fabrication remains the humble tooling hole. This is a set of non-plated holes with precisely defined locations and even more precise diameter tolerances. They are always non-plated because the plating process is too imprecise for repeatable fixturing. These holes key the board or panel to a matching set of pins on a fixture or, I should say, fixtures.

These precision holes in the bare board align the layers during initial lamination and any subsequent lamination cycles. After the press, the board is placed in another jig for application of solder mask and silkscreen. Yet another fixture will use them for electrical probing to find opens and shorts. Good panels will then be put on a robotic assembly line and then on to a soldering machine using the same holes. Some additional testing and automatic optical inspection (AOI) may follow.

Given all those uses, it is advisable to have the tooling holes in an arrangement that precludes the possibility of putting the board on backwards or upside down. Normally, we want three of them, to ensure only one way to load the board into each fixture. If four holes are used, you want them asymmetric **(FIGURE 1)**. Regardless of the quantity, they should be pushed toward the corners (if there are corners) to make it easy to align the pins and holes each time. On-board tooling holes may get a second life as mounting holes if you're not counting on the hardware for a thermal path.

Back in the good old days, tooling holes came in one size, 125 mils, with a plus/minus tolerance of one mil. Now, there is an 89 mil hole too, because everything in this game shrinks over time. Unilateral tolerances are often applied where the pin will be the nominal value with a plus tolerance but no negative tolerance. The hole then gets zero oversize and a small negative tolerance. The actual numbers come down to what the fab shop can do on a best-effort basis. It's almost an interference fit but not quite.

Smaller boards found in a smartwatch or similar device do not have room for tooling holes on the board, so the holes become a standard part of the assembly sub-panel. The sub-panel is maintained through fab, assembly and test and only broken down once the boards are known to be working to the standard requirements.

Now we're set up for component placement on the assembly line. No, we aren't. The pick-and- place machine has a camera that can find a specific set of features on the board. These features are called fiducial marks, and they help the robotic arm calibrate on the exact location of the components.

A typical board-level fiducial mark, or fid, will consist of a 1mm dot of exposed copper surrounded by a 3mm clearance in the solder mask and other circuit patterns. A solid plane on the layer below the fid is important so the camera can recognize and register on the dot without the distraction of a circuit pattern underneath. No drilling is involved, although to the uninitiated it may look like a hole location.

Fiducials can also come in a smaller size for use as a local fiducial. These are placed just outside of the footprint of any fine-pitch components so the optics can zero in on a more precise location than if it were calibrating over the entire board area. It's advisable to address these early in the design, perhaps even incorporating them with the actual footprint of the fine-pitch/high pin-count devices.

In addition to circles, I've seen squares and crosses used as fiducial marks. I do not recommend them simply because the etch process isn't that good at creating 90° corners, especially inside corners. With etch-defined circuits, a tiny cross comes out looking

JOHN BURKHERT JR. is a career PCB designer experienced in military, telecom, consumer hardware and, lately, the automotive industry. Originally, he was an RF specialist but is compelled to flip the bit now and then to fill the need for high-speed digital design. He enjoys playing bass and racing bikes when he's not writing about or performing PCB layout. His column is produced by Cadence Design Systems and runs monthly.

more like a blob than what is on the artwork. These are more common on device packages where the metal is sputtered onto the substrate. They still come out looking somewhat organic.

Between tooling holes and fiducial marks on the panel or board, we can control placement to the degree the components self-center during reflow soldering. This works best when the pads are identical to one another. Trace width and launch direction play a role in how the capillary action pulls the part to the middle ground while the solder is in its liquid state. Flooding copper over one pin and not the other(s) will undo all that effort.

You could shrink the solder mask of the flooded pad(s) so that it becomes the same size as the non-solder mask defined pads. That mitigates the problem but is not as effective as a fully symmetric design. We look to thermal spokes as a means of evening the thermal load on each pin. Many assembly defects arise from imbalanced solder joints. A perfect placement can be undone by inattention to this detail.

Things will go wrong now and then. The goal is to minimize the number of rejected boards. By the time they are in assembly, we don't have many options other than playing with the solder paste stencil and thermal profile of the soldering machines. It is up to us to keep the process window wide open so fabrication and assembly become boring. That's the best kind of process right there. ❑

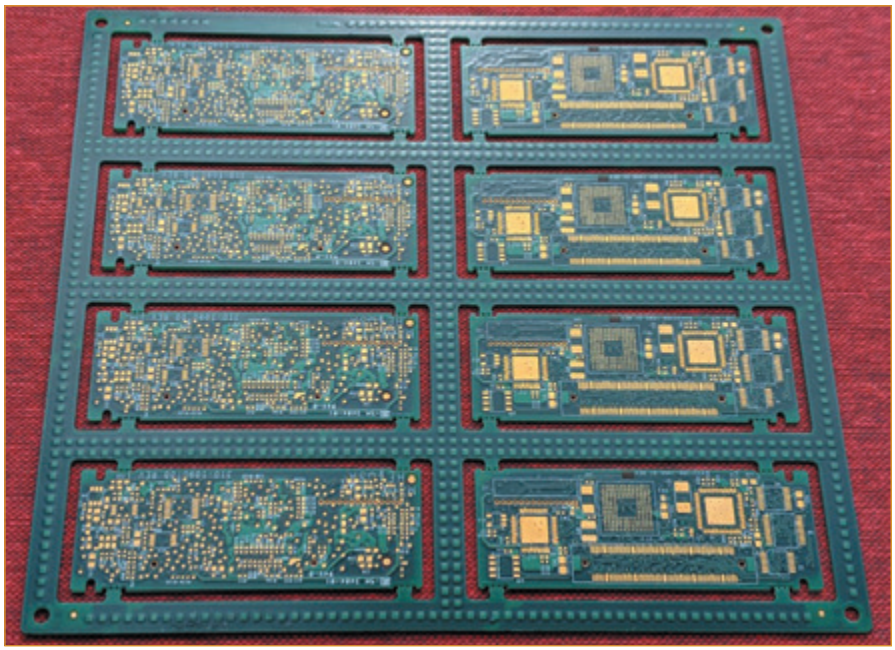

FIGURE 1. While there are four tooling holes, the panel is not an exact square. It must be flipped to complete the assembly. The same paste stencil and x-y data apply no matter which side is up. There are two ways to put this panel on the mating fixture and both are used for what is known as an A-B flip panel.

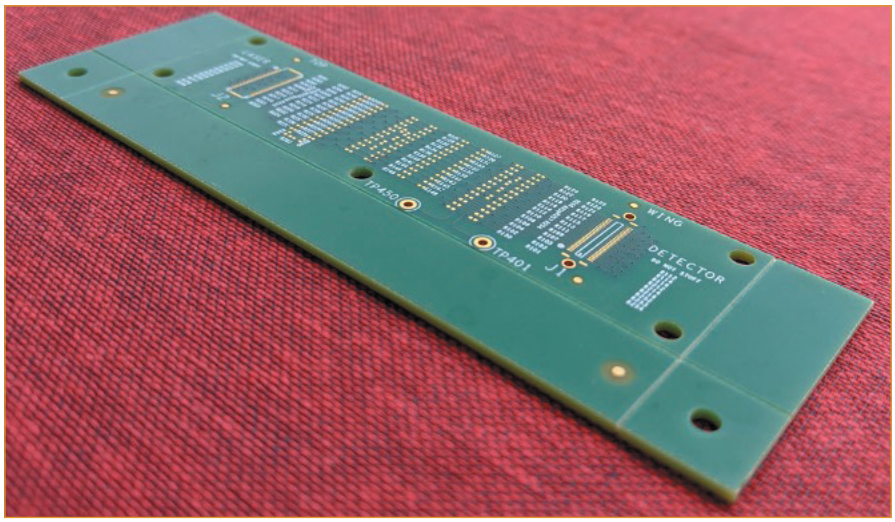

FIGURE 2. The remains of a break-off panel using V-scores. Larger fiducials on the tabs and smaller ones locating the fine-pitch connectors on the actual board.

Board Buying, continued from pg. 19

and capacity, then government greasing the investment wheels just might help solve that. By placing onerous restrictions on outside investment (foreign companies had to partner with domestic ones) and constantly fiddling with its currency, China certainly did that in spades.

But what about the manpower? Lights-out factories might be the ideal answer to lingering issues of available manpower and operator variability, but we aren't there yet. Not even close.

Where are we going to find the people? Even the most concerted of efforts will take a generation to rebuild the domestic expertise in sufficient numbers to meet the supply chain need. Will we take a page from the Southeast Asian playbooks and draw their experts to our shores? And if so, will China (no) or Taiwan (maybe) sit idly by?

I am eager to find out. ❑

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SCHEDULE-AT-A-GLANCE

TUESDAY OCTOBER 4, 2022

Time	Title	Speaker
9:00 a.m. - 10:00 a.m.	Panel: Where is the Design Profession Going?	Mike Buetow, PCEA
10:00 a.m. - 12:00 p.m.	Making Intelligent Material Decisions	Michael R. Creeden CID+, Insulectro
	How to Fight Magnetic Noise Gremlins	Keven Coates, Fluidity Technologies
	Best-in-Class for PCB Design	Stephen Chavez, Siemens
	From DC to AC – Power Integrity and Decoupling Primer for PCB Designers, Situation Today and Outlook for the Future	Ralf Bruening, Zuken
	Back-to-Basics: Understand PCB Fabrication Processes for Traditional, HDI, and Ultra HDI	Chris Hunrath, Insulectro Michael Trammel, Summit Interconnect
10:00 a.m. - 6:00 p.m.	PCB Design for Engineers	Susy Webb, Design Science
12:00 p.m. - 1:00 p.m.	**LUNCH-N-LEARN with Summit Interconnect**	
1:00 p.m. - 4:30 p.m.	PCB Designers Guide for Implementing Advanced Semiconductor Package Technologies- Flip-Chip, WLP, FOWLP, 2D, 2.5D and 3D	Vern Solberg, Solberg Technical Consulting
	Circuit Grounding to Control Noise and EMI	Rick Hartley, RHartley Enterprises
	An Intuitive Approach to Understanding Basic High Speed PCB Layout	Keven Coates, Fluidity Technologies
	Effective PCB Design: Techniques to Improve Performance	Daniel Beeker, NXP Semiconductor
	Printed Circuit Fabrication Today: A More Complex Process	Gary Ferrari, Ferrari Technical Services
6:30 p.m. - 7:30 p.m.	Printed Circuit Engineering Association Annual Meeting	

WEDNESDAY OCTOBER 5, 2022

10:00 a.m. - 6:00 p.m. EXHIBITS OPEN

Time	Title	Speaker
10:00 a.m. - 11:00 a.m.	Optimizing the Tool Chain from Design Through Manufacturing for Printed Electronics	David Wiens, Siemens, and Jeff Bergman, NextFlex
10:00 a.m. - 12:00 p.m.	Cables and Connectors: Design for Signal Integrity (Will They Work?) and EMI	Keven Coates, Fluidity Technologies
	Back-to-Basics: Understand the Surface Charge Model of Electricity	Mark Hughes
12:00 p.m. - 1:00 p.m.	**FREE LUNCH on Show Floor, sponsored by Sierra Circuits**	
1:30 p.m. - 3:30 p.m.	The Mystery of Bypass Capacitors	Keven Coates, Fluidity Technologies
1:30 p.m. - 5:00 p.m.	PCB Antennas for Everyone	Benjamin Jordan, JordanDSP
	Part Placement Choices and Consequences	Susy Webb, Design Science
3:30 p.m. - 4:30 p.m.	Surface Finish Selection Criteria for Next Generation PCB Technologies (5G-HDI-High Frequency-RFMW)- Focusing on Performance & Reliability	Kunal Shah, Ph.D., LiloTree
5:00 p.m. - 6:00 p.m.	**FREE EVENING RECEPTION on Show Floor, sponsored by EMA and Ultra Librarian**	

WEDNESDAY FREE SESSIONS

10:00 a.m. - 6:00 p.m. EXHIBITS OPEN

Time	Title	Speaker
9:00 a.m. - 10:00 a.m.	Panel: How Heterogenous Integration Affects the PCB Industry	Phil Marcoux
10:00 a.m. - 11:00 a.m.	Dynamic Guidelines for Design with SAP (Semi-Additive Processes)	Tomas Chester, CED, and Tara Dunn, Averatek
	Understanding High Frequency Materials Test Methods for Dk and Df	John Coonrod, Rogers Corp.
11:00 a.m. - 12:00 p.m.	Keynote: Augmented and Virtual Reality, the Next Computer Revolution	Brian Toleno, Ph.D., Meta
12:00 p.m. - 1:00 p.m.	**FREE LUNCH on Show Floor, sponsored by Sierra Circuits**	
1:30 p.m. - 2:30 p.m.	Evaluating Emerging PCB Technologies Through Industry Collaboration	Madan Jagernauth, HDP
	The 21 Most Common Design Errors Caught by Fabrication (and How to Prevent Them)	Ray Fugitt, DownStream Technologies, and David Hoover, TTM Technologies
2:30 p.m. - 3:30 p.m.	Leveraging CFX-QPL to Integrate Equipment and Create a Smart Factory	Ivan Aduna, Koh Young
3:30 p.m. - 4:30 p.m.	The A+ PCB Outline Drawing	Carl Schattke, PCB Product Development
	IPC-2581's Bi-directional Electronically Executable DFx Exchange Accelerates NPI	Hemant Shah, IPC-2581 Consortium, and Dana Korf, Nano Dimension
5:00 p.m. - 6:00 p.m.	**FREE EVENING RECEPTION on Show Floor, sponsored by EMA and Ultra Librarian**	

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SCHEDULE-AT-A-GLANCE

THURSDAY OCTOBER 6, 2022

Time	Title	Speaker
10:00 a.m. - 12:00 p.m.	PCB Layout of Switch Mode Power Supplies	Rick Hartley, RHartley Enterprises
	Electromagnetic Fields for Normal Folks: Show Me the Pictures and Hold the Equations, Please!	Daniel Beeker, NXP Semiconductor
	Ask the Flexperts–Design-Test with Lessons Learned	Mark Finstad, Flexible Circuit Technologies, and Nick Koop, TTM Technologies
	Improving Circuit Design and Layout for Accessibility and Success	Tomas Chester, Chester Electronic Design
10:00 a.m. - 7:00 p.m.	A Guide to RF and Microwave PCB Design	Benjamin Jordan, JordanDSP
12:00 p.m. - 1:00 p.m.	LUNCH-N-LEARN with Polar Instruments	
1:00 p.m. - 2:00 p.m.	Panel: Emerging Technologies and Their Impact on Manufacturing	Tara Dunn, Averatek
2:00 p.m. - 3:00 p.m.	HDI Via Design: Planning the Energy Pipelines	Daniel Beeker, NXP Semiconductor
2:00 p.m. - 5:30 p.m.	Where Does Today's Designer/Engineer Start? Has The Industry Really Changed That Much?	Gary Ferrari, Ferrari Technical Services
	IoT and Low Layer Count PC Board Design	Rick Hartley, RHartley Enterprises
	Heat Management for SMD, LED, and systems 1W to 50W	Keven Coates, Fluidity Technologies
	Designing Boards with Today's BGAs	Susy Webb, Design Science

FRIDAY OCTOBER 7, 2022

Time	Title	Speaker
10:00 a.m. - 12:00 p.m.	Principles of Building a PCB Stackup	Susy Webb, Design Science
	Mechanical Design to Control EMI	Rick Hartley, RHartley Enterprises
	Fan-Out Wafer/Panel-Level Packaging (FOW/PLP) and System-in-Package (SiP)	John H. Lau, Ph.D., Unimicron
12:00 p.m. - 1:00 p.m.	LUNCH-N-LEARN	
1:00 p.m. - 3:00 p.m.	The Mechanical Side of PCBs	Tomas Chester, Chester Electronic Design
1:00 p.m. - 4:30 p.m.	Circuit Design Principles for Flexible and Rigid Flex Circuits- Planning, Design, Fabrication and Assembly Processing	Vern Solberg, Solberg Technical Consulting
	A Multilayered Crash Course in PCB Design	Kirsch Mackey, HaSofu
3:00 p.m. - 5:00 p.m.	Proper PCB Layout of DDR2, 3, 4, etc.	Rick Hartley, RHartley Enterprises

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What's So 'Super' about Supercomputers?

Work continues on quantum machines. But classical computing is here, now, and faster and more powerful than ever.

WHEN FRONTIER, THE latest supercomputer at the US Department of Energy's Oak Ridge National Laboratory (ORNL), went live at the end of May, it became the first to demonstrate true exascale performance, according to the TOP500 organization that benchmarks commercially available computer systems. At 1.102 Exaflop/s (quintillion operations per second), Frontier's performance is three times faster than the previous performance leader, Fujitsu's Fugaku system at the Riken Center for Computational Science (R-CCS) in Kobe, Japan. By breaking the exascale barrier, Frontier is 10 times faster than its ORNL predecessor, Summit.

That's an impressive margin and all the more remarkable, perhaps, in today's post-Moore world, where chip-process advancements alone can no longer deliver the exponential gains computer developers have come to expect. The team at ORNL worked with supercomputer builder Cray and chipmaker AMD to create an incredibly powerful underlying computing platform that converges traditional modeling and simulation with big data analytics and artificial intelligence.

Quantum computers are expected to be 1,000 times more powerful still. Qubits can express much greater complexity than simple binary digital bits, although keeping the system stable for an appreciable length of time is a major challenge that requires supercooling. While conventional wisdom suggests increasing qubit width as the route to greater computing power, there are alternative approaches. Quantum Brilliance, an Australian-German manufacturer, is focusing on accessibility: smaller computers with fewer qubits but compatible with the conventional rack form factor and operable at room temperature.

The quantum community refers to "classical" computers, which may sound insulting to machines like Frontier and Fugaku, whose statistics are truly mind-blowing, as they are empowering researchers to address some of the most pressing scientific challenges of our age. In reality, we need to harness the strengths of all the different computing approaches available to us, and the sheer computing capacity provided by these different apex machines installed in the world's leading centers of excellence, to take us forward.

But what do supercomputers do all day? During its initial bring-up, the Riken Center's Fugaku, delivered in 2020, was tested in the battle against Covid-19. It crunched the numbers to help improve PPE performance and accelerate development of suitable drugs. Subsequently, it has cut the time to analyze cancer genes from months to less than one day.

Currently, ORNL is in the final stages of commissioning Frontier and has slated the platform for early science access in late 2022, to help with challenges such as predicting climate change. In ORNL's brief introduction to Frontier, Institute Director Gina Tourassi suggests a fascinating shift in our approach to chronic diseases such as cancers; using the power of Frontier, we now can get ahead, to improve the quality of life by delaying the onset in would-be sufferers as well as continuing to improve the available treatments.

Classical these computers may be, by quantum standards, but their great advantage is the precision necessary to handle tasks such as modeling cancer cells and the atomic structure of elements, which demand high computational accuracy. On the other hand, they can also be used to accelerate machine-learning algorithms.

Their other advantage is that they are here now and ready to work on the most complex questions we face. We want answers more quickly than ever, and the increased computational workload combined with time pressure are driving up the demand for energy. Frontier is supplied by a 40-MW power system and cooled by 6,000 gallons of water every minute, according to information from ORNL.

It's appropriate, then, that high-performance computing is also our friend as we research new and better ways to secure reliable supplies of energy. Powerful numbercrunching is critical for materials research and could help synthesize novel photo-responsive materials that can significantly increase the conversion efficiency of solar panels. It is also essential to drive simulations guiding advanced nuclear research, such as fusion reactors like the ITER tokamak project in France.

Often referenced as an "artificial sun," the tokamak reactor creates extreme heat and pressure to convert hydrogen to a plasma, within which fusion can take place. The ITER project team reckons that the reactor will release about 10 times as much energy as is required to create the conditions for fusion to occur. In practice, it takes several years after switch-on for the temperature inside to rise to above 100 million degrees Celsius for fusion to occur. With those timescales, development by trial and error is not practicable, so digital acceleration is critical. Simulating the tokamak with high-performance computers helps design com-

continued on pg. 32

ALUN MORGAN
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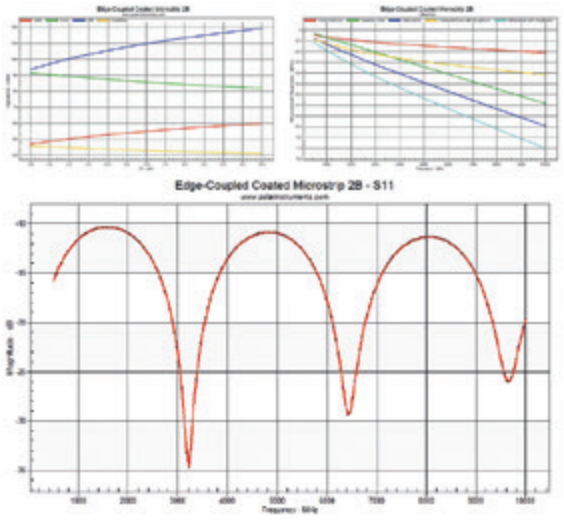
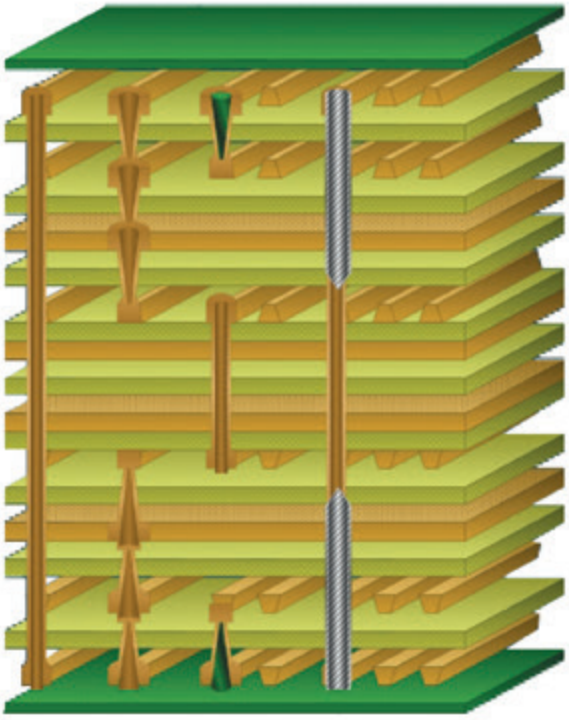
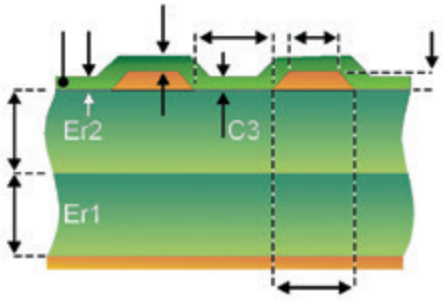




Impedance Measurement

Copper Roughness

Insertion Loss



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The ECAD Industry is Firing on All Cylinders. No Wonder WAGES ARE RISING.

Salaries spiked in the past year. Can it last? by MIKE BUETOW

Inflation is hitting in all corners, but salaries are rising too. That's according to the latest PCD&F/CIRCUITS ASSEMBLY salary survey of printed circuit designers and design engineers.

About 85% of those responding to the annual survey indicated their wages rose at least 1% in the past year, with more than 22% reporting hikes of seven percent or more. That's an acceleration from 2021, when 47% of designers indicated their salaries were on the rise.

PCD&F/CIRCUITS ASSEMBLY surveyed designers and design engineers (for brevity, we will use the term "designers") over a 60-day period between May 19 and Jul. 19 this year. More than 200 designers responded to the survey, which is designed to capture a snapshot of the salary and compensation trends. PCD&F has conducted the survey for more than 25 years.

The sharp uptick – one of the largest seen since we started collecting the data – shows the ECAD industry is in line with broader employment trends. Unemployment in the US stood at 3.6% in May and June, and over the past 12 months average hourly earnings have increased 5.1%, according to the US Bureau of Labor Statistics.[1] Meanwhile, in China the rate stood at 5.5%, and across Europe the rates were falling as well.[2]

For its part, ECAD companies reported employment of 51,328 workers globally in the first quarter 2022, the latest period data are available, up 4.7% increase from the year before.[2] The industry is firing on all cylinders.

This year PCD&F offered two forms of the survey. The shorter version asked 13 questions ranging primarily from basic demographics to compensation.

The full-length version, which follows our traditional survey design, asked 38 questions that captured additional data on the types of boards designers work on, the number of designs produced annually, professional certifications and tool use, among others. More than 90% of respondents opted for the longer version. For the full results, visit https://pcea.net/education.

The Respondents

Of the 206 respondents, more than 29% indicated they are PCB design/senior design engineers, with another 33% reporting PCB designer/senior designer as their title. About 10% are electrical engineers, 12% hardware engineers, and about 4% management **(TABLE 1)**.

Nearly 40% indicated 30 or more years' experience, while on the low end 15% reported five or fewer years on the job **(FIGURE 1)**. The latter is an uptick over previous surveys. About 10% are 30 years of age or less, and 42% are 56 or older. More than 85% are male.

Most respondents were from the US, with about 9% from Canada, 13% from Europe, and a few from Africa, India and South America mixed in. Greater Asia is poorly represented in the results. Our belief is language is a persistent barrier to participation from non-English speaking countries.

As a percentage of respondents, education level was consistent with previous surveys, as 35% of respondents have a

TABLE 1. Principal Job Function

	2022	2021	2020	2018	2017	2016
PCB design	69%	64%	64%	74%	75%	70%
PCB engineering	11%	14%	13%	10%	9%	10%
Systems design	5%	7%	8%	4%	2%	
Design/layout management	5%	6%	6%	5%	8%	11%
Engineering management	4%	6%	2%	0%	2%	4%
Design support (drafting)	1%	<1%	1%	<1%	<1%	<1%
Applications engineer	1%	1%	2%	1%	1%	2%
ECAD librarian	1%	<1%	2%	3%	2%	2%

Numbers might not total 100% due to rounding. *n* = 206

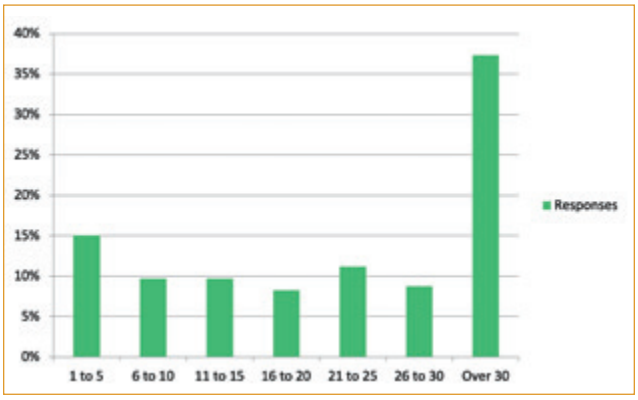

FIGURE 1. Years of experience in printed circuit design/engineering. (n = 206)

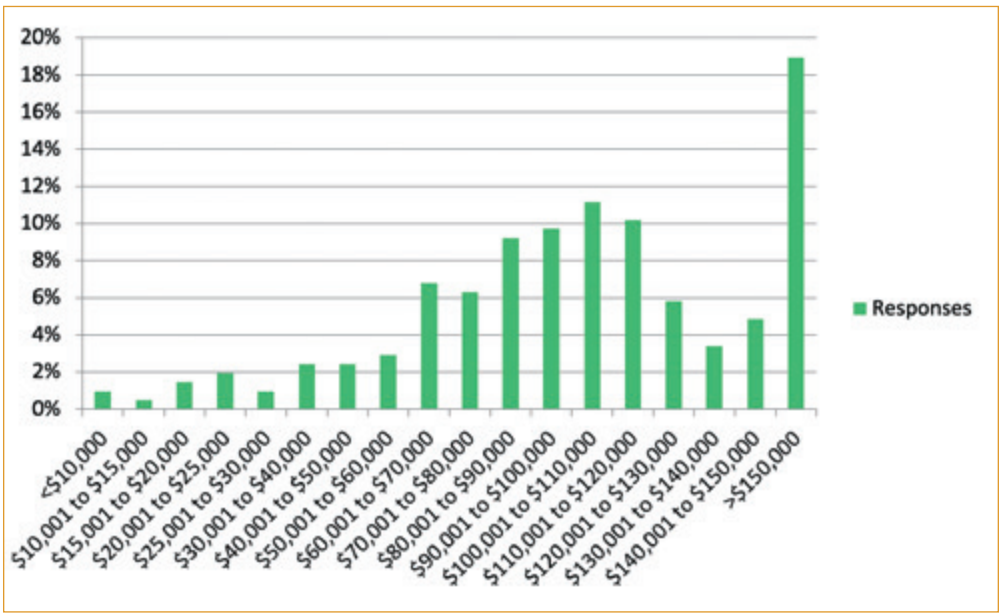

FIGURE 2. Current Annual Salary (in US$). ($n$ = 206)

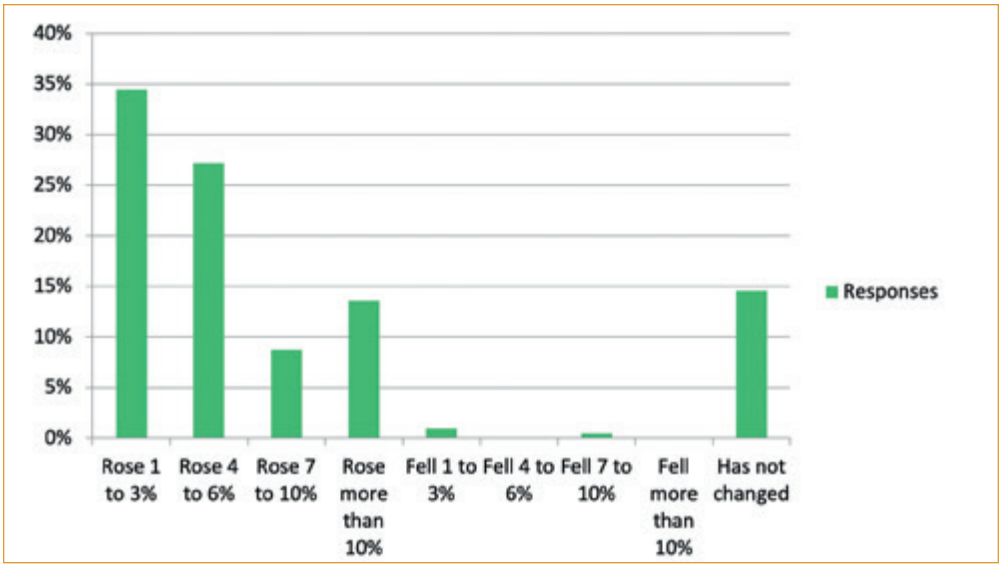

FIGURE 3. Change in salary in the past year. (n = 206)

degree in engineering or a related field, and another 15% have at least a master's degree.

Show Me the Money

The current salary data were eye-popping. As noted earlier, salaries are on the climb, with 27% reporting a four to six percent increase year-over-year and 22% saying it was seven percent or more **(FIGURE 2)**.

The hikes are distending the normal salary curves. Historically, only a handful of respondents reported salaries in excess of $150,000. This year blew that up: 19% said they make more than that, up from 10% last year **(FIGURE 3)**. Another 35% said they earn at least $100,000, with the median response in the $100,000 to $110,000 range. Good times.

Sweetening the pie, more than half said they receive an annual bonus, with 47% of those getting more than 7% in additional compensation.

While more than half (55%) report being at the top of their company's salary range for their position, only 7% reported changing jobs in the past year. Will that hold if pay levels off over the next 12 months?

Working Harder

The median number of new part numbers produced per annum was six to 10, with about one-third of respondents answering five or fewer new designs, and 14% saying they do 21 or more new part numbers each year. More than half perform one to five respins, and 24% perform 11 or more redos each year.

The typical respondent spends at least half of their time each week on board design, including schematic capture, layout, and place and route **(FIGURE 4)**. Fewer than one-fifth of those surveyed indicated spending less than one-fourth of their time on the core design responsibilities.

Two-thirds of design-

ers feel workload is the biggest professional challenge they face this year, followed by keeping up with technology changes and company support for professional development **(FIGURE 5)**.

Other Findings

By tool vendor, the most common regularly used software was Cadence (OrCad and Allegro), at just over 50%. Altium was second, at 48%, with Siemens/Mentor (Pads and Xpedition) third at 24%.

While more than 54% of respondents indicated they are very satisfied in their current jobs, some 42% reported plans to work for five years or fewer. Recruiters, it's time to work your magic. □

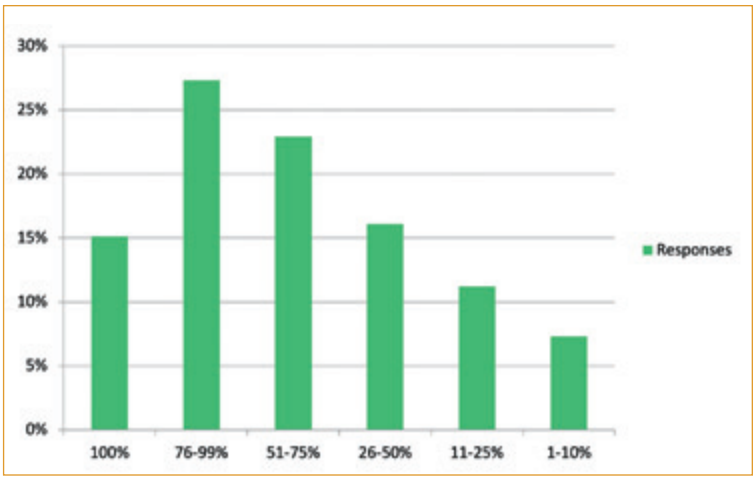

FIGURE 4. Time spent on board design per week. (*n* = 205)

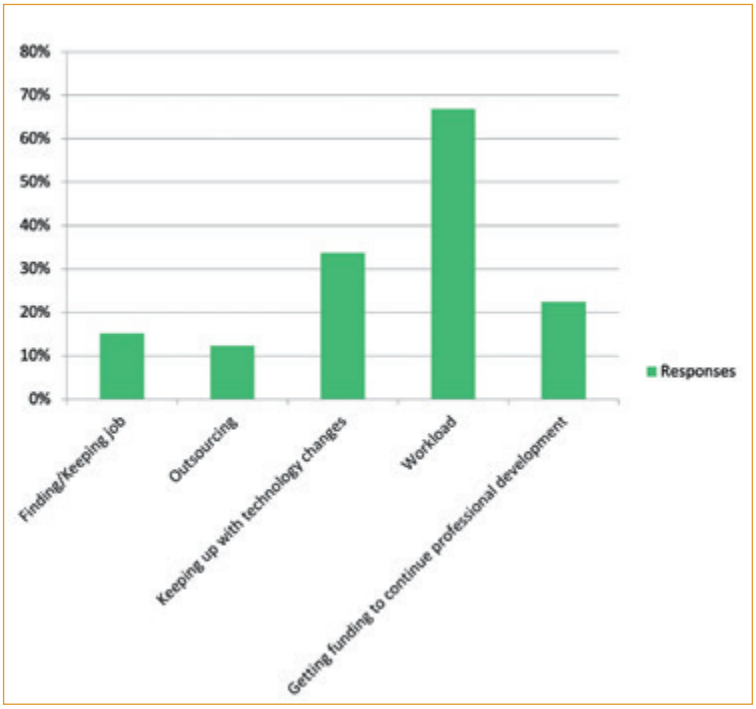

FIGURE 5. Biggest challenges ahead in 2022. (*n* = 178)

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1. US Bureau of Labor Statistics, Employment Situation Summary, Jul. 8, 2022, https://www.bls.gov/news.release/empsit.nr0.htm.
2. Stastista, "Unemployment Rate of the Largest Economies in Europe from 1980 to 2022," Jun. 20, 2022," https://www.statista.com/statistics/1173907/unemployment-in-largest-european-countries
3. Mike Buetow, "PCB Design Software Sales Ticked Up in Q1," PCD&F/CIRCUITS ASSEMBLY; Jul 11, 2022, https://www.pcdandf.com/pcdesign/index.php/editorial/menu-news/market-news/16661-pcb-design-software-sales-ticked-up-in-q1

Ed.: For previous years' surveys, visit https://www.pcdandf.com/pcdesign/index.php/menu-research/pcb-design-engineer-salary-surveys. For additional data on this year's survey, visit pcdandf.com.

MIKE BUETOW is president of PCEA (pcea.net); mike@pcea.net.

Material Gains, continued from pg. 28

plex parts of the reactor such as the electromagnetic control systems needed to contain and manipulate the plasma. ITER is scheduled to turn on in 2025 and will take a decade to reach its operating temperature. So we should know by 2035 whether the computers got it right.

On the other hand, simulation using digital twinning with high-performance computers is also helping to improve the design of conventional nuclear power stations, such as perfecting safety controls, improving fuel efficiency, and reducing waste.

It's easy to focus on the pure performance of these machines and the prestige associated with the world's fastest supercomputer. People love a "new No. 1," but the teams operating them are most excited at how they can help us look after ourselves while looking after the planet, including delivering the answers we need quickly enough to take meaningful action. □

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The course references general CAD tool practices and is vendor-agnostic. Instructors include Mike Creeden, CID+, who has over 44 years of industry experience as an educator, PCB designer, applications engineer and business owner; and Tomas Chester, P.Eng., CPCD, who has designed over 100 circuit boards through all phases of the product lifecycle, and managed a variety of multifaceted, interdisciplinary projects, from simple interconnect designs to complex microprocessors.

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AUTHORS

Mike Creeden | Gary Ferrari | Susy Webb | Rick Hartley | Steph Chavez

Printed Circuit Engineering Professional

Table of Contents:

Why I4.0 AND RESHORING Go Hand in Hand

The path to digitize a factory is both closer and cheaper than most engineers realize. **by MIKE BUETOW**

Reshoring has been a buzzword for a few years now. But when supply chains are undergoing dramatic disruption and inflation is raging worldwide, what is the reality?

According to research firm IDTechEx, it's only a matter of time before an array of sensors and cobots spur far greater automation and flexibility. The firm recently published a white paper titled "Factory of the Future" that summarizes the expected advancements. Indeed, some of these changes are both relatively inexpensive and simple in scope yet open a realm of possibilities for greater process control.

IDTechEx senior technology analyst Matthew Dyson, Ph.D., who co-authored the paper, discussed the key trends in industrial manufacturing and the timeline for adoption with PCEA president Mike Buetow in late July. The following is lightly edited.

Mike Buetow: You just co-authored a white paper titled "Factory of the Future." Lots of people, of course, are considering what that looks like. What spurred your interest?

Matthew Dyson: It's the combination of technologies that we see being developed. The white paper is a compelling use case for them. It's about how you can make manufacturing more efficient to address concerns like reshoring, inflation and so on.

It's about incorporating sensors, incorporating cobots, incorporating predicted maintenance, and is one of these application areas that is both useful to society and includes a lot of different and separate technologies, each interesting in its own right.

MB: In the white paper, you boiled down the next wave of industrial manufacturing to a few key pivotal trends: sensors, additive manufacturing, automation and flexibility, which in your research you talked about AGVs or cobots. How did you arrive at those?

MD: At IDTechEx, we try to work out how technologies are going to evolve over the next five to 10 years. That involves talking to a lot of people and attending a lot of conferences around the world.

What we see is basically these trends that we mentioned in the white paper. There are lots of companies talking about how they can integrate more and more sensors into their equipment. Not just for things like process control, which is pretty standard by now, but also monitoring the machines themselves, which is somewhat less common. These can be all different types of sensors: they can be monitoring temperature or vibration, for example, and feeding back that data continuously so that you can identify this machine is vibrating more than expected, and maybe we need to have a look at that before the whole production line goes down and costs a lot of money.

We've seen lots of other examples of people aiming to integrate sensors into manufacturing processes, even the things that seem kind of prosaic, like keeping track of the number of parts in a parts bay. This can be done by putting a little pressure sensor in there that then automatically orders more parts when the level drops to a certain point. There is a company that makes gaskets that's incorporated an RFID tag so that they can check continuously whether it's been installed correctly, and whether it's been subject to the appropriate amount of pressure. These are all examples of not just monitoring the quality of the product that is produced but monitoring the manufacturing process itself in real time.

I think that's the key kind of stat when you hear people talking about Industry 4.0 and the digital factory and mass digitization and all these kinds of buzzwords. What it's about is continuously monitoring not just the product but the processes involved in producing the product so that you can identify problems early; so you can make small adjustments; so the quality of the product is maintained; so that your supply chain can be as efficient as possible; so that you can check the installation has been done correctly, or repair has been done correctly without having to pay somebody to go around and check manually. All these things will be communicating wirelessly. You will be able to build up these huge datasets that

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will enable the monitoring of any other factors that could be influencing actual quality.

It's that mass digitalization that is the key trend.

MB: Did your research get into the higher-level systems that must be implemented to be able to access that data in a timely fashion? We could be looking at billions and billions of data points in a typical factory that need to then be processed very quickly to adapt in real time.

MD: It's a very interesting point. Our research is focused mainly on the hardware, so I'm coming at this from the materials, sensors and antennas side, but I have looked into the software to some extent. This touches on the idea of AGI, so how can you reduce the amount of data that need to be transmitted, and of course one way is to do some of the processing at the relevant location before they get transmitted.

I suggest that in some cases you don't necessarily need to take readings every 10th of a second or something. If you have a manufacturing line and just want to monitor the vibration or frequency or amplitude of some machine, detecting that every few minutes is probably completely adequate.

FIGURE 1. Sensors, cobots and AGVs make up some of coming automation features.

If there's a problem with the machine, the vibrations are gradually going to get worse over days. So relative to, say, many of the other applications where continuous data monitoring is needed, such as autonomous vehicles, in many cases a factory is more straightforward. In some cases, it can just be a check just after installation. The gaskets I mentioned, someone who installed them could scan them to ensure they are seated correctly, which could be hard to tell once they've been installed.

There's an interesting point in the business models that people are adopting. Some of the manufacturers of large-scale equipment are keen to offer a full solution with all the digital services in there, and they have their own teams of software engineers doing the data management. The other approach is to outsource all that to a separate provider that would provide just the sensors to stick on the machines, and they'll monitor the data for you and give you a dashboard on your phone or computer with a few of the tangible insights.

It depends on the company strategy and software resources they have available as to whether they want to bundle all the digital factory ideas into their products or just work with somebody else and do it afterwards. I think the data challenge is significantly easier than, say, autonomous vehicles.

MB: If I extrapolate then, the combination of sensors everywhere plus some degree of artificial intelligence would learn and anticipate how often sampling would be needed.

MD: Absolutely. You would identify when your sampling would be needed by how quickly these problems evolve. You would also use artificial intelligence, and it doesn't need to be that sophisticated. To take the vibration example, you've got a threshold where you're happy if the vibration is within that range of amplitude and frequency. As soon as it moves out of that frequency or amplitude for a specified period, then some kind of alarm sounds, and a manager or maintenance person is alerted. These kinds of algorithms are not particularly different from what you might get in an intensive care unit where they monitor the patient's heart rate and if it's too much outside the parameters, it will give some sort of alert. It's been around for years, and that's a higher-value use case, but you're applying fairly similar ideas but now much more widely across factories.

MB: I'm guessing you talked to a range of companies, OEMs, product manufacturers and so forth in the course of preparing your white paper and perhaps across a variety of regions as well.

MD: Absolutely. We've spoken with people who make manufacturing equipment, some of which are quite big; sensor providers; research institutes that set up pilot lines that highlight this kind of technology built into them so that companies could see what's possible. Those are happening everywhere, and often SMEs [small- or medium-sized enterprises] are not necessarily aware of what is possible and what the technology can offer them. There's quite a lot of interest from government to facilitate that kind of process by having these pilot lines where you can see all that's automated and all this predictive maintenance that's happening.

MB: Did you uncover any regional differences in what I would say is "current" implementation?

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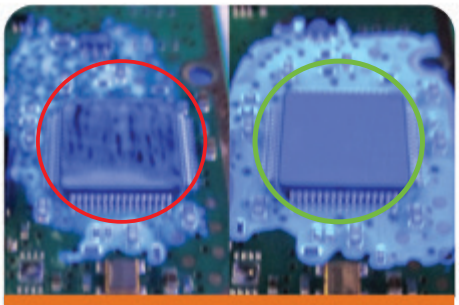

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MD: There's obviously a kind of trade-off with wages. Broadly speaking, it's the more developed economies, where wages are higher, where – probably unsurprisingly – doing more of this kind of factory automation makes commercial sense. That is part of the aim of reshoring, as I just discussed, in that if you're going to bring manufacturing back from lower-wage economies, you've got to automate an awful lot of it to keep it cost-effective.

That's one of the motivations, so you see a lot of interest in high-wage economies like Germany and Scandinavia. A lot of effort is going into it there. I think this reshoring trend is sort of happening in general, and these technologies, at least ideally, should be able to do that without doubling the price of everything. The wages are higher, but you need fewer people to run the lines; it needs repairing less often; maintenance less often; and checked less often, because all of that's being done digitally.

FIGURE 2. Digital dashboards monitoring machines and processes and engaging in predictive analytics will become the norm.

MB: Cost, of course, is a big limiter. Does your research attempt to assess the capex for various-sized operations?

MD: We haven't looked yet at the kind of capital that is required. There are so many different types of factories manufacturing different types of things. We primarily focused on the hardware technologies that would facilitate this transition. To give a few examples, we've seen a Japanese manufacturer with a novel method of making PCBs, and it has a lot of interest from Toyota, which is keen to bring its PCB manufacturing back to Japan. There are all sorts of these supply-chain security concerns, geopolitical tensions and that sort of thing, and there's a price that people want to pay. And these technologies are a way of being able to meet those supply-chain security requirements and geopolitical considerations without having to pay a lot more for everything.

How much does it cost to get all this stuff installed, to digitize a factory, is a difficult question. All factories are different. But technologies are being developed to make that cheaper than you might imagine. You don't have to buy completely new machines. For example, there are some new projects at some German research centers like the Fraunhofer Institute using 3-D printed electronics to make sensor housings that can then be integrated into fully depreciated old equipment that still works well. So if you've got a bit of heavy industrial equipment that is old but works fine and you want to digitize it, you can add sensors to it without having to spend all the extra money on an entirely new piece of equipment.

A lot of these sensors can be quite simple, and people talk about things like sticker electronics, which aren't necessarily quite there yet. But people use these kinds of energy harvesting approaches so that this doesn't need to be wired in. You could get a magnet and stick something on it that will harvest energy from the vibrations and use AGI to send the data back. That whole unit might be a few hundred dollars.

A digital factory doesn't necessarily mean spending millions on new equipment. It can mean: make judicious investments in instruments; have some subscription to some kind of software; and install a selection of relatively low-cost sensors. It certainly shouldn't mean we need to fully refit the factory.

MB: What I'm hearing is, just like there's a wide variety of factory layouts and processes and focuses today, that won't change with Industry 4.0. These sensors and cobots and other things you've mentioned will be implemented in a specific and individual way. We won't see a generic factory where everyone has the same kind of line and information collection and so forth.

MD: I absolutely agree. Just gradually like at your home, more and more things will become digital. Five years ago, I didn't have a smartwatch. Now I do. These things kind of gradually progress, but there's no need to go for a wholesale readjustment. You can identify, "OK, I have this machine. I don't really know why it keeps going wrong. Maybe I could get some advanced warning if I installed some sensors." And probably without knowing it, you've become part of Industry 4.0 because now you [now] have continuous monitoring enabling predictive maintenance on this particular machine.

It's not: "Oh, I have to start with a blank piece of paper and a thick checkbook." It's: "OK, I'm going to make these

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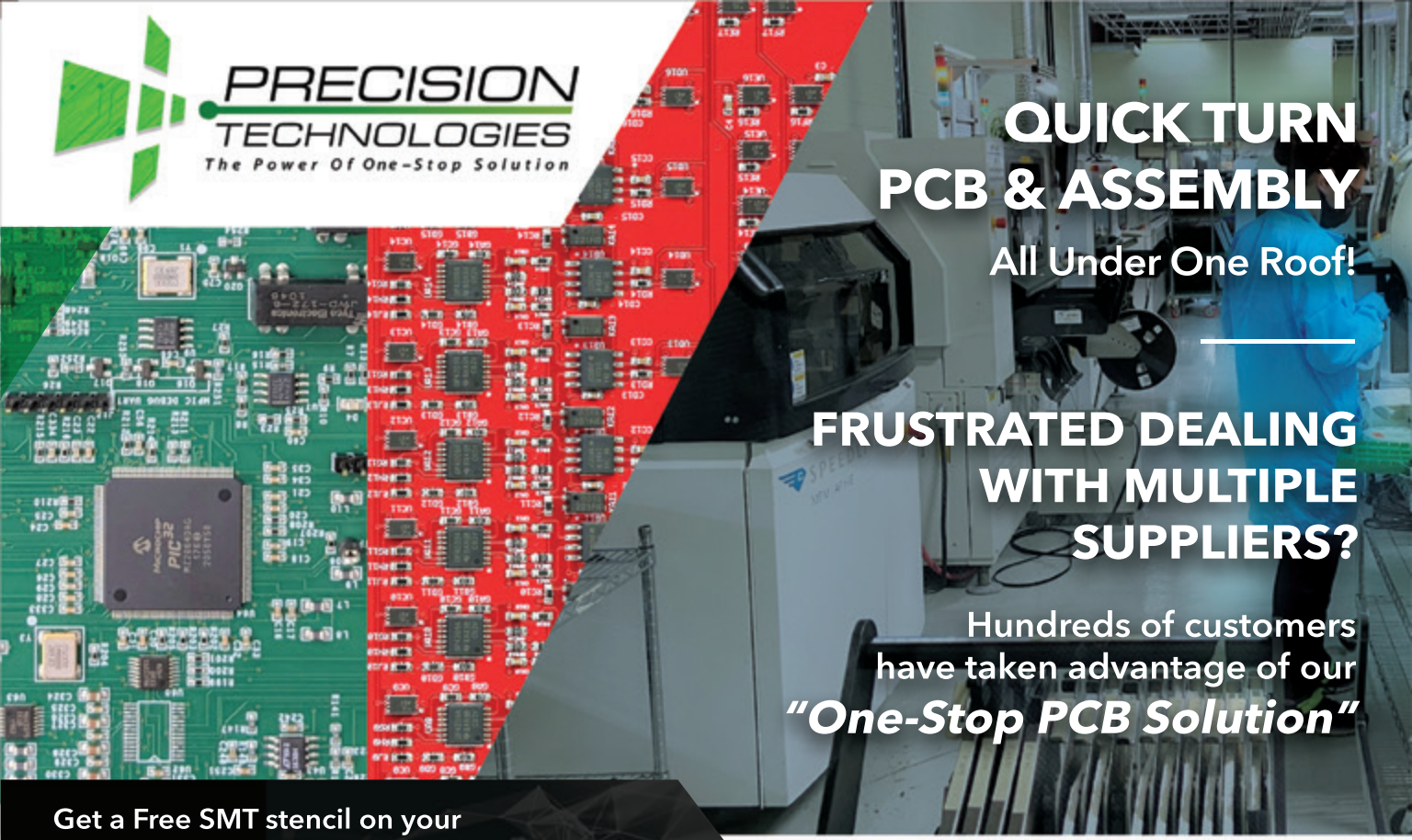

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incremental improvements to take advantage of new, low-cost sensing technology, improvements in energy harvesting, and particularly the lower cost of client services processing, to solve particular problems within my factory." "Oh, I keep running out of this equipment because its use isn't linear, and I don't know when to order. Let's put a sensor in here to track when that's about to run out." "This equipment keeps breaking down. I don't really know why. Can I check that?" "My maintenance people keep making mistakes installing the stuff. Can I put something in to check?"

On the maintenance side, there's also an interesting kind of placebo effect. If you start adding the ability to monitor how effectively maintenance has been performed, you apparently see the maintenance being performed better, even if you don't go and check afterwards. Go back to the gasket example: if you make the gaskets able to record whether they were installed correctly, then a much higher proportion will be installed correctly because people now know they're being monitored. You end up with these unexpected benefits, but by better monitoring how various tasks are performed, perhaps unsurprisingly, people on average will perform them better. And you can still identify the odd mistake.

MB: Is that something that you observed yourself, or something that over the course of your research and interviews was brought to your attention?

Matthew Dyson

MD: This is something I have been told or have seen in presentations from multiple people from different, unconnected companies. In one of the more interesting ones – which isn't quite a factory – a Swedish company developed a device to monitor moisture levels behind tiling in showers. You scan it with an RFID scanner; it's just a coil, and the frequency changes with the amount of humidity. And then they discovered their showers were being installed much better once people started putting the stuff in. The building company was getting far fewer callbacks from people saying "my shower is leaking" once they obliged their staff to install this device. And of course, the device doesn't actually need to work. It could just be a piece of plastic. But if you tell everyone this will enable us to monitor whether your bathroom leaks, you find that people will improve the quality of their work, on average. So there are all kinds of other benefits you wouldn't necessarily anticipate. You can certainly get those in a factory setting as well. The more things that are monitored, the more maintenance tasks that are easy to check, just like you would like in quality control on the product itself, which is already well established; now you get quality control on all these kinds of repair tasks as well.

MB: Never forget: Big Brother is watching.

MD: That is the downside. [laughs]

MB: What role will AI play, and do you think it will vary by region, perhaps in part due to governmental constraints on what algorithms are going to be permitted to do?

MD: I'm not an AI expert, but I think you can get it quite a long way by relatively simple data processing of the kinds that I've described by checking the parameters within thresholds and things like this. When it comes to doing more sophisticated things, you're looking at object recognition and that kind of thing. I don't think that there will be, because you're monitoring an industrial process with employees who are all consenting to be there. I think you're going to get a lot fewer issues than you do in more of a consumer context. It's not quite the same as monitoring people and leading them around to see if they do something. Everyone there is an employee. You're not really monitoring them; you're monitoring the equipment. How that evolves and how automation works its way through the workforce is a much bigger topic than just talking about factories of the future, and how that progresses politically is an open-ended question.

I think in most cases this is technology that can facilitate reshoring because it will enable you to manufacture more efficiently. Given that there's kind of a political tailwind across the West and Japan to bring high-value advanced manufacturing back to the West, these are the kind of technologies that can facilitate that.

If you're a labor union, I wouldn't say this is a threat to our workers' jobs. I would see it as an opportunity to have maybe more jobs, or more manufacturing, because people can do higher-value tasks, and more of the manufacturing currently taking place elsewhere can take place close to home. And we get the environmental benefits of less logistics. I think the pros outweigh the cons. I think data protection issues are less significant than in a consumer setting.

But I don't think it will be this Big Bang moment. I think it will happen gradually; the equipment will become cheaper; it will become more established; people will become more comfortable with data processing and data dashboards, and how they can use this to improve the output and have less downtime, and I think it will just kind of gradually become the norm, like mechanization did one hundred years ago. It will become standard.

When people think of the digital factory, they picture a lot of robots and cobots … maybe an Amazon factory with a lot of stock pickers. That's already started, and that's running in parallel to the things I've described, which are smaller scale. But what I've been describing is also monitoring the health of the cobot – for instance, are any bits wearing out too early? It's about monitoring as much as you can to either stop problems from happening in the first place or identify changes before they become problems. ▫

Au: For a copy of the paper, visit https://www.idtechex.com/en/research-article/factory-of-the-future/26968.

MIKE BUETOW is president of PCEA (pcea.net); mike@pcea.net.

Robust Tacking Material Technology to Reduce Tool and Fixturing Complexity in POWER MODULE ASSEMBLY

A solution for flux-free formic acid reflow? by **JOSEPH HERTLINE**

Growing performance demands for power electronics systems, driven by rapid advancements in application areas such as electric vehicle (EV) technology, present challenges for module design.[1] With increased junction temperatures, current densities and complex thermal packaging solutions, engineers must improve reliability through the design phase and material selection process. This requires constant optimization of the power module design and process flow to produce effective and reliable solutions. For successful power electronics applications, however, the production process is equally as critical as the design to achieve the required quality and cost target. One key element is the use of tooling as it affects the design (e.g., distance and tolerances between dies) and manufacturing processes (cycle time, quality and costs). Process advancements of high-quality reflow techniques with vacuum and formic acid have proven effective to achieve reliability targets,[2,3] but the focus is shifting toward scalability and efficiency to bring up production levels that meet the aggressive needs for these new applications. Due to the constantly increasing power densities in power modules, soldering processes that avoid use of additional flux are becoming more important. The upfront cost in development of processes, unique equipment, and dedicated fixturing to achieve quality is a growing concern that presents both a significant financial burden as well as a time-to-market impact for power module manufacturers introducing new designs.

Vacuum reflow with formic acid reducing atmosphere has proven to be an effective technique to achieve high quality, with solder preforms with a void rate under 1%.[4] With this technique, material cleanliness is critical, and any residue that remains after the assembly process must be removed to prevent performance issues such as increased leakage current or corrosion.[3]

A no-flux reflow process can mitigate issues due to residue and avoid additional cleaning steps that add process time and cost.

Solder Reflow Tooling Requirements

Improper alignment of the solder preform during assembly can lead to latent defects in the solder joint, including tilt, mechanical stress, uneven heat transfer and thermal stress, resulting in delamination failures that reduce lifecycle reliability. To overcome this, designers typically develop sophisticated placement and alignment equipment upfront in the new product introduction process to prevent movement and misalignment during manufacturing assembly. These elaborate fixturing systems require focused design and development and create many design for manufacturing (DfM) constraints for the power module and assembly process, such as the use of advanced materials to mitigate the effects of CTE.

The design and sourcing effort not only comes at a premium cost, but also impacts the lead time and market introduction of new power module projects. Last, these tooling and fixturing systems tend to be unique for a given module product or assembly sequence, with little opportunity for reuse, impacting the return on the upfront capital investment, particularly for manufacturers with limited production capacity and high mix in product configurations. **FIGURE 1** summarizes the typical power module assembly and reflow sequence.

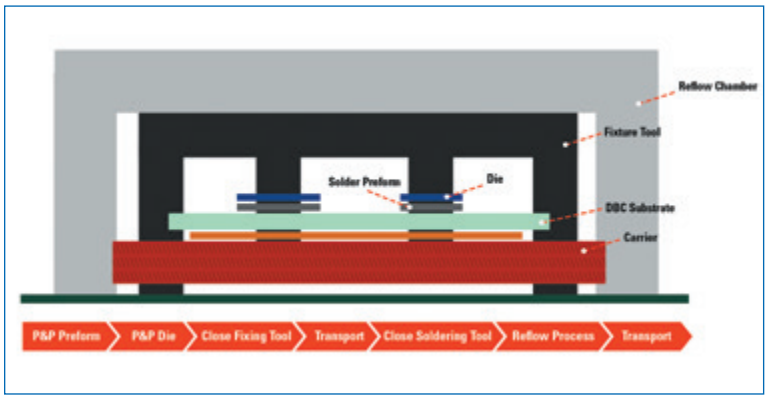

FIGURE 1. Typical power module assembly sequence.

Tooling Alternative

To overcome this manufacturing constraint, a novel material technology has been developed for solder preform assembly to enable precise placement without dedicated tooling and fixturing equipment. This material, when dispensed during assembly, provides robust tackiness to maintain consistent alignment of the solder preform and assembly components, thus preventing uneven stress distribution or thermal concentrations. **FIGURE 2** illustrates this tool-free concept for a typical power module assembly, specifically with the tacking material dispensed at the die and direct bond copper (DBC) substrate/baseplate solder preform interfaces.

The tacking material used in this application contains no fluxing properties; instead, it is completely consumed during the reflow process with no remaining residue, avoiding the need for post-process cleaning steps and making it a solution for flux-free formic acid reflow techniques that are widely used in power module production.

Tacking Material Assessment

First, the robustness of the attachment properties for the novel material were analyzed using a conventional tack testing method commonly used for electronics assembly materials:

- Circular deposits of material printed
- Measurements every two hours over a 24 hr. period
- 20% relative humidity, constant.

The novel tacking material was tested against a conventional tacky flux and isopropyl alcohol (IPA) variants as a baseline. As demonstrated in **FIGURE 3,** the novel material shows high tack strength even when compared to a typical solder paste. The high tack is maintained over time, demonstrating consistent properties over a long working time. The IPA solutions tested in this setup exhibited a relatively low tack strength and significant degradation over a short period of time, thus reducing the viability of IPA as a tool-free material alternative.

Residue. To further evaluate the viability of the tacking material, a series of tests were performed to simulate a typical power module reflow process leveraging vacuum and formic acid. First, a TGA was performed to analyze the potential residual components after the material had reached the target processing temperature. As shown in **FIGURE 4,** the tacking material was completely consumed with zero weight % after exposure to a temperature of approximately 230°C. With typical soldering alloys for power module assemblies including SAC, SnSb or high-Pb, the risk of contamination from residue during a flux-free soldering process is low, as the processing temperatures for these alloys are generally much higher than the curve captured from the TGA.

To further evaluate the risk of residue contamination, the tacking material was evaluated against a typical analysis suite for electronics assembly cleanliness through a collaboration with Zestron. The scope of this testing included surface analysis with ion chromatography, energy dispersive x-ray (EDX) analysis, and Fourier-transform infrared spectroscopy (FTIR) analysis, and samples were generated for a die-attach application with solder preforms, dies and DBC. For a baseline comparison, samples produced with the tacking material were compared to samples produced with no tacking material under the same formic acid reflow process. These samples were also compared to "bare" assembly components (before reflow). **FIGURE 5** provides a summary of surface analysis results, focusing on the presence of typical contaminants. The following samples were analyzed:

1. Bare DBC, before reflow
2. Bare DBC, reflow only, no solder
3. DBC with tacking material, no solder
4. DBC with tacking material, soldered
5. DBC and die with tacking material, soldered.

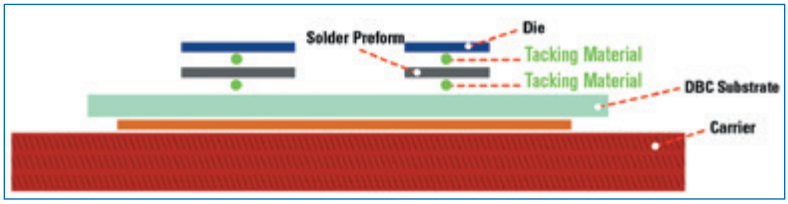

FIGURE 2. Tacking material application for power modules.

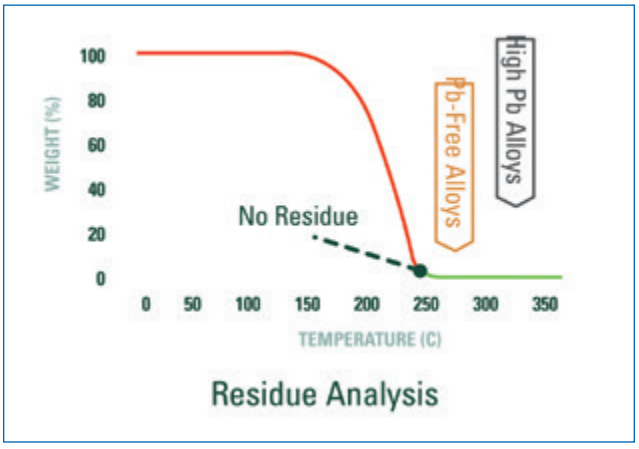

FIGURE 3. Tack testing results.

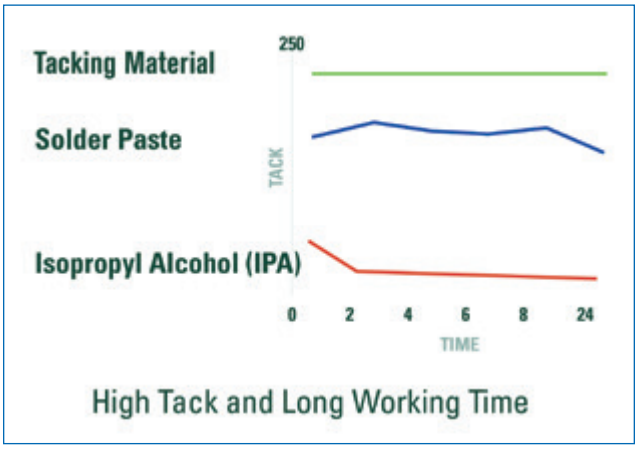

FIGURE 4. TGA analysis of tacking material.

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Based on this summary table, levels of typical contaminants were well within control limits for all samples and demonstrated no contamination. In addition, there was no significant difference in levels measured with the tacking material samples compared to the baseline samples.

Further, FTIR and EDX analysis of the samples with tacking material also demonstrated consistent results when compared to the baseline results in **FIGURES 6** and **7,** respectively.

Soldering Performance

Finally, the soldering performance was characterized within a flux-free reflow environment using vacuum and formic acid. To simulate a typical power module configuration, a Sn95/Sb5 alloy was selected for the solder preforms tested for both die-attach and substrate-attach interfaces. The tacking material was then applied in accordance with the optimal application parameters described earlier. **FIGURE 8** summarizes the formic acid reflow profile used, including temperature, atmosphere, and time duration parameters.

The evaluation consisted of wetting and voiding analyses **(FIGURE 9)**. The wetting test samples demonstrated good uniform coverage on the surface, and good edge definition consistent with high-quality soldering performance that is typical in flux-free power module processes. In concert with the positive wetting results, the voiding performance of approximately 1% over the solder interface area was comparable to typical production quality results for power module assemblies.

Contamination in µg / cm²						
Anions	**#1**	**#2**	**#3**	**#4**	**#5**	**Reference values**
Bromide	ND	ND	ND	ND	ND	1.55
Chloride	0.07	0.03	0.07	0.02	ND	0.93
Fluoride	ND	ND	ND	ND	ND	0.47
Nitrate	0.05	0.01	0.03	0.01	ND	0.47
Nitrite	ND	ND	ND	0.01	ND	0.47
Phosphate	0.01	ND	ND	ND	ND	1.09
Sulfate	ND	0.01	0.03	0.02	0.02	0.47
Weak org. acids						
Acetate	0.03	0.02	0.04	0.03	0.02	
Adipate	ND	ND	ND	ND	ND	
Formate	0.06	0.02	0.05	ND	ND	
Glutarate	ND	ND	ND	ND	ND	∑ 3.88
Malate	0.01	ND	ND	ND	ND	
Methanesulfonate	ND	ND	ND	ND	ND	
Succinate	ND	ND	ND	ND	ND	
Total	0.10	0.04	0.09	0.03	0.02	
Cations						
Ammonium	0.01	0.01	0.01	0.01	0.01	0.47
Calcium	0.05	ND	ND	ND	ND	0.16
Potassium	0.09	ND	0.02	ND	ND	0.47
Lithium	ND	ND	ND	ND	ND	0.47
Magnesium	0.02	ND	0.02	ND	ND	0.16
Sodium	0.03	ND	0.02	ND	ND	0.47

FIGURE 5. Contamination analysis.

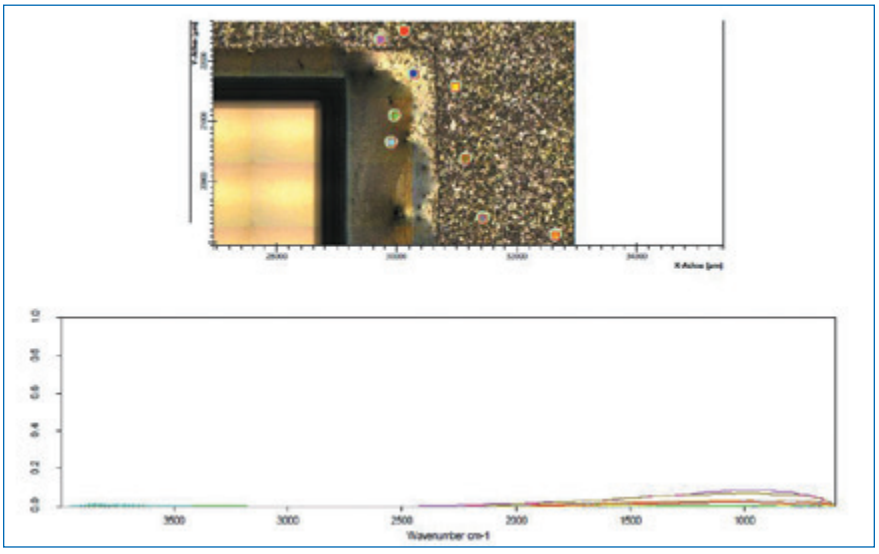

FIGURE 6. FTIR analysis: No evidence of contamination.

Conclusions

The tests show the tool-free concept analyzed through this effort, featuring a novel no-residue tacking material, to be a viable alternative to fixturing and alignment jigs in power module manufacturing. Positive mechanical properties with tack strength and working time demonstrate the ability to maintain precise preform and assembly alignment during manufacturing. In addition, the absence of residue and temperature processing characteristics make this material a solution for no-flux reflow techniques used in power module manufacturing. Results indicate no impact to soldering performance or quality when this tacking material is used in lieu of fixturing. Finally, the reduction in fixturing design effort, material costs, process time, and complexity with the tool-free assembly concept make this a promising approach to reduce the overall cost of ownership for power module manufacturers and presents an opportunity to scale production more readily.

Outlook

Initial tests to leverage this tacking material for other applications such as pressure silver sintering are currently ongoing. The benefit of the tacking in this case is the avoidance of the hot-die placement, which is akin to another heating/drying step at the sintering processes. Results from this testing will be a focus of future work. ▫

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The rapid evolution of enabling technologies requires the independent evaluations of new PCB fabrication, assembly, and test technologies; such evaluations are time-consuming and require significant resources. A collaborative approach offers opportunities to perform evaluations efficiently, reducing cost and improving time-to-market for the ever-increasing demands for higher performance, higher speed, higher density packaging and improved reliability.

High Density Packaging User Group (HDP) provides its members with opportunities for unbiased comparisons not found in the literature through member-driven projects. This presentation provides a view of the opportunities for industry collaboration in several areas: for example, new materials for high-speed packaging, next-generation optical integration, next-generation solder alloys, new package technologies, new methods for reliability assessment and higher copper density technologies.

Speaker
Madan Jagernauth, Marketing Director, High Density Packaging User Group

Email

HDP User Group is dedicated to reducing the costs and risks for the Electronics Manufacturing industry when using advanced electronic packaging and assembly. This international industry-led group organizes and conducts R&D programs to address the technical issues facing the industry.

: www.hdpug.org : info@hdpug.org

Webpage

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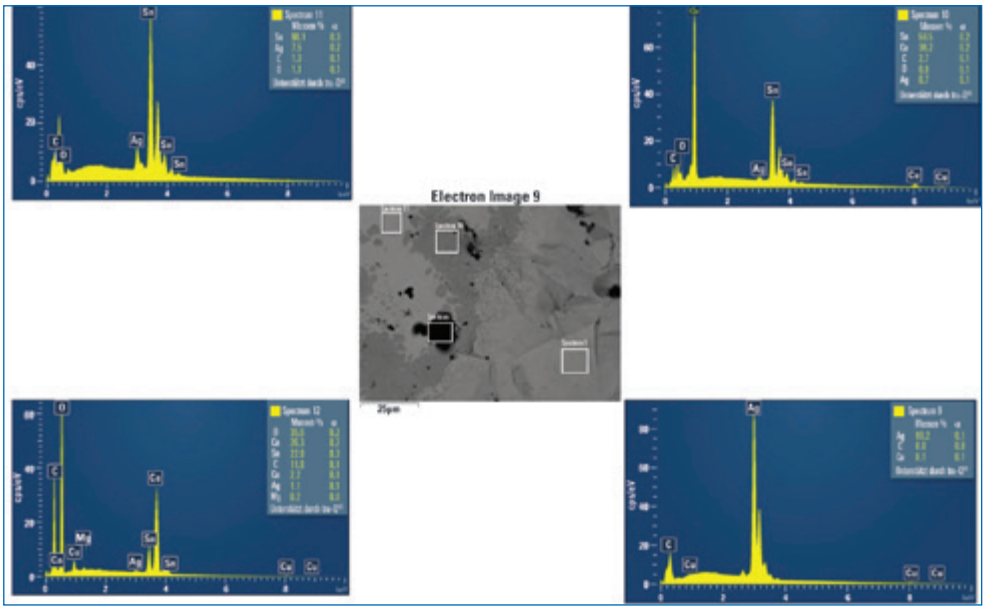

FIGURE 7. EDX analysis: The samples after reflow showed less contamination than before reflow.

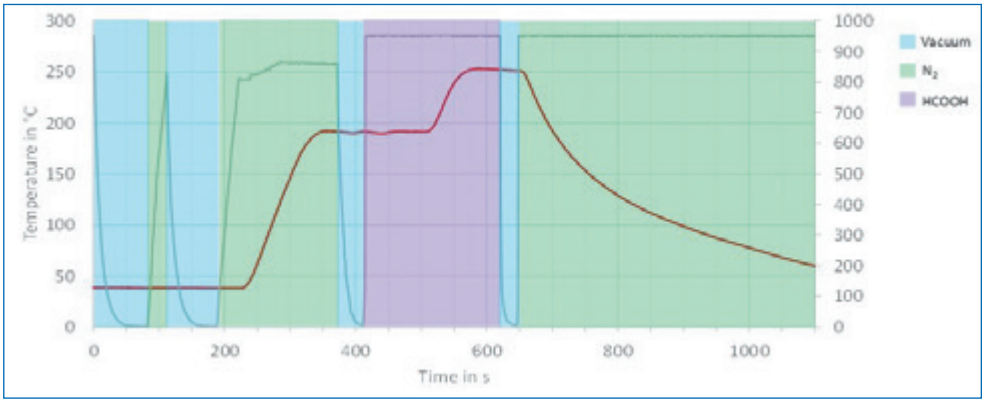

FIGURE 8. Soldering reflow profile.

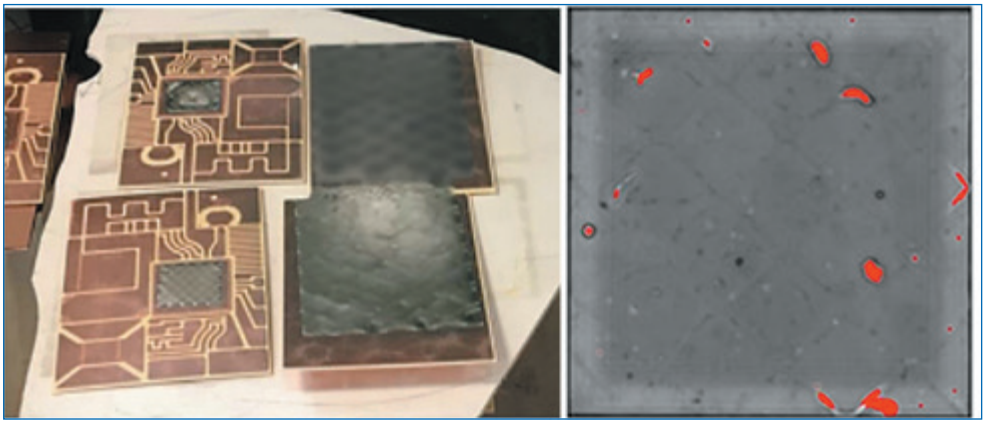

FIGURE 9. Soldering results showed good wetting (left) and voiding (right) of 1.0%.

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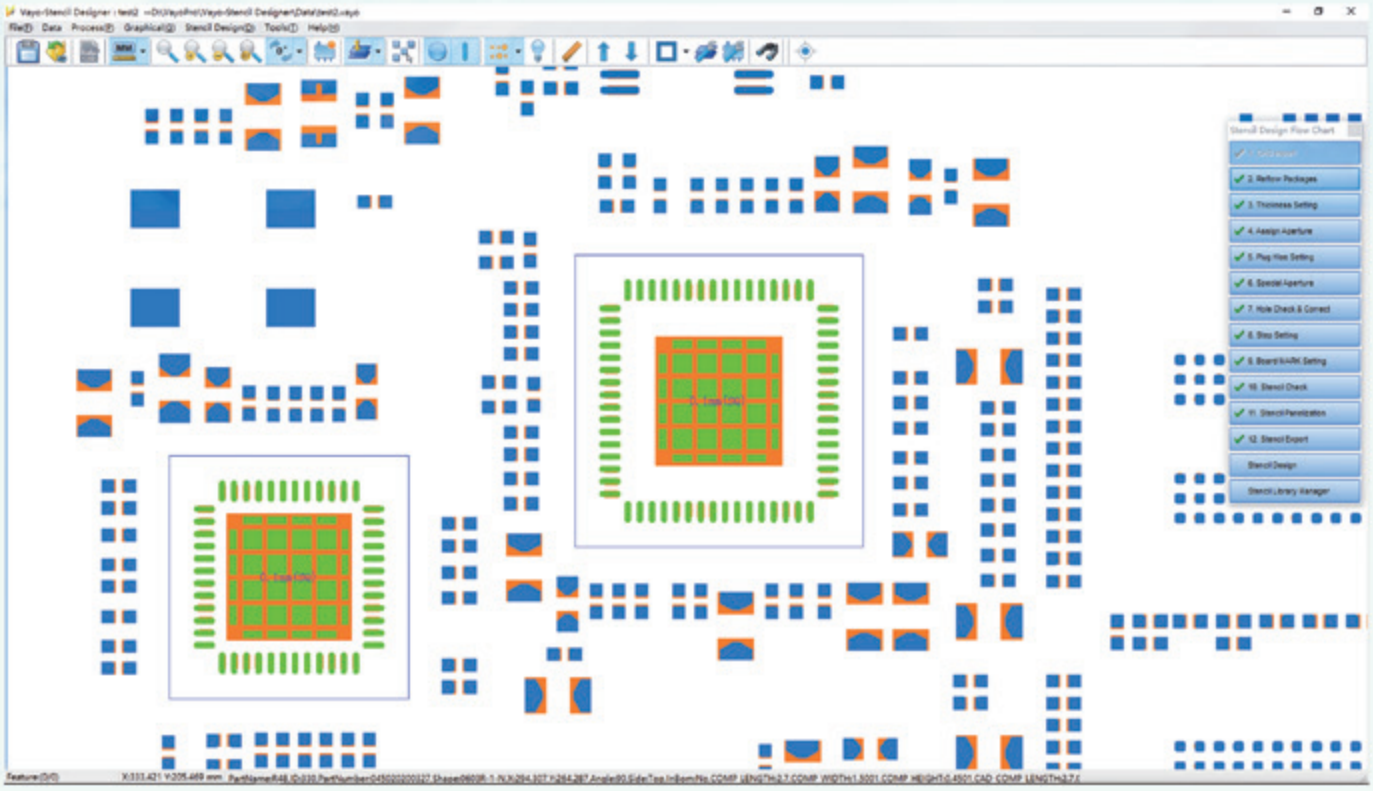

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Tools for Technology Innovation and CAREER ADVANCEMENT

The annual Women's Leadership Program offers hands-on mentoring for the next generation of engineers.

by PRIYANKA DOBRIYAL, PH.D.

What is the most recent skill you have added to your toolbox?

As I was sharing recent accomplishments with one of my mentors, she suggested I think of my new skills as new tools in my toolbox. That conversation gave me a different perspective to reflect on the skills I have collected so far and encouraged me to strategically plan the next steps in my career.

I started gravitating toward the idea of this imaginary toolbox and collected skills, which adhered to my core values of creating a sustainable and purpose-driven career. While planning the theme for the 2022 Women's Leadership Program (WLP), which takes place Nov. 1 at SMTA International, I discussed this idea with the organizing committee, and it was very well-received. We brainstormed on how to bring this idea to reality and enable women colleagues to advance their careers. Taking the time to reflect on the skills in your toolbox makes you self-aware and cognizant of your self-worth. Knowing what you bring to the table helps you build the confidence you need to navigate your career. Hence the concept of a toolbox seemed appropriate for the WLP, as the goal of this session is to empower women to explore technology innovations and career progression in the electronics industry. Now are you ready to think about the skills in your toolbox that could help your career advancement?

Priyanka Dobriyal, Ph.D.

This year's WLP will start with three presentations from women leaders in the electronics industry. These women have each charted a unique career journey that made them invaluable in the organizations they lead. Since our 2022 WLP session theme focuses on the career "toolbox" of technical, leadership and power skills, with the analogy of the "tools" for success to resources, personal / professional traits, as well as actual tools, we asked our speakers to share their experiences and learnings in the interview below.

The presentations will be followed by a speed mentoring session where attendees rotate through a selection of six tables hosted by the invited speakers and SMTA leaders on topics related to leadership skills, power skills, continuous learning, career development, encouraging innovation, etc.

We will wrap up the program with our annual Connection Reception. Earlier this year, the industry lost an inspirational leader with the passing of Irene Sterian of Celestica/REMAP. Irene made many contributions to the industry, SMTA and the WLP. She was a spark who encouraged numerous women to advance their careers in our industry. We will informally celebrate Irene's passion for engaging with her colleagues during the Connection Reception. We look forward to connecting with you all and discussing the skills in your toolbox.

SMTAI 2022 Women's Leadership Program Details

Free for everyone and all are welcome!

We extend an invitation to everyone to attend the Women's Leadership Program to promote women in engineering fields. Show your support for diversity in engineering fields by attending this session.

Invited Presentations on Technology Innovations and Career Advancement

Co-chairs: Tanya Martin, Jessica Molloy

1 – 1:45 p.m. ..... Carolyn R. Duran, Ph.D., Intel

1:45 – 2:30 p.m. ..... Loretta Renard, CEO, REMAP

2:30 – 3:15 p.m. ..... Jayshree Seth, Ph.D., 3M

3:15 – 3:30 p.m. ..... Refreshment Break

3:30 – 4:30 p.m. ..... Speed Mentoring Sessions

Co-chairs: Debbie Carboni and Julie Silk

4:30 – 6 p.m. ..... Social

Co-chairs: Michelle Ogihara, Sherry Stepp

We welcome you to stay and join us for the annual Connection Reception.

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Jessica Molloy


Debbie Carboni


Julie Silk


Michelle Ogihara


Sherry Stepp


Marie Cole

TABLE 1. Table 1. Speed Mentoring Topics

Skill	Tool	Topic	Host
Confidence, Communication	Multimeter, 2-Way Radio	Communicate with Confidence	Carolyn R. Duran, Intel
Professional presence	Sandpaper	Polish your presence	Chrys Shea, Shea Engineering Services
Conflict resolution	Hammer	Resolve Conflict with finesse	Rita Mohanty, Henkel Electronic Materials
Technical Skills (T-shaped)	T-Square	Cultivate T-shaped skills	Jayshree Seth, 3M
Paying it forward thru your power skill/strength	Wrench, Shared tools	Pay it forward with power skills	Marie S. Cole, Retired, IBM
Recharging your Tools	Power Strip	Recharge	Priyanka Dobriyal, Intel


Elizabeth Benedetto


Karlie Severinson

Leaning into Lifelong Learning – Carolyn R. Duran, Ph.D., Intel


Carolyn R. Duran, Ph.D.

Abstract: As a society, we are in a state of rapid change in how we innovate, develop and deliver new technologies and products to the world. Only those who embrace lifelong learning, adapting, growing and learning will truly thrive. Duran will share some key tools she has developed to explore and succeed in dramatically different roles within her company. With each new role there is opportunity: what you bring to the table to help the new organization's success, what you learn in your new role about the business, and what you learn about yourself. Through her own career journey Duran will demonstrate the value of this learning as she returned to where she started, technology development, after gaining valuable lessons in supply chain management and product development.

Carolyn R. Duran, Ph.D., is vice president and engineering manager, Components Research at Intel. In this role, Duran leads advanced process and materials research to invent, develop and demonstrate viable revolutionary technologies necessary for Intel's continued leadership in the industry. She also leads her organization's strategy for external engagements including academia, consortia, and supply chain.

Duran joined Intel in 1998 as a process engineer in research and development, moving to supply chain management in 2007. In this role she oversaw Intel's supply chain sustainability efforts spanning chemical regulations and policy, human rights and labor, and the company's responsible minerals sourcing program. She moved to the Data Platforms Group in 2017 to lead a corporate charter in Memory and IO technologies responsible for the pathfinding, development, implementation and broad industry enablement in these areas. In 2022, she returned to her technology development roots to lead the Process Engineering team within Components Research.

Duran is currently serving as president of the Materials Research Society and sits on the Materials Science and Engineering academic advisory board for Northwestern University, where she is also an adjunct professor. She has held chair positions for both the Responsible Business Alliance board of directors and the Conflict Free Sourcing Initiative (now the Responsible Minerals Initiative). A recognized industry leader, Duran was named on *Fast Company's* "Most Creative People in Business 1000" list in 2016 and ranked no. 2 on *Business Insider's* "Most Powerful Women Engineers in the World" list in 2014.

Duran received a bachelor's in materials science and engineering from Carnegie Mellon and a Ph.D. in the same field from Northwestern University. She holds five patents in semiconductor process engineering.

Changing the Perception of Manufacturing – Loretta Renard, CEO, REMAP


Loretta Renard, CEO

Abstract: As manufacturing becomes more advanced and digitized, perceptions about careers in manufacturing are changing – creating a more positive perception of the sector and incenting more women to pursue careers in manufacturing. This is further supported by workforce multiplier jobs, currently estimated to be 16 jobs created for every single high-tech manufacturing job. These multiplier jobs support

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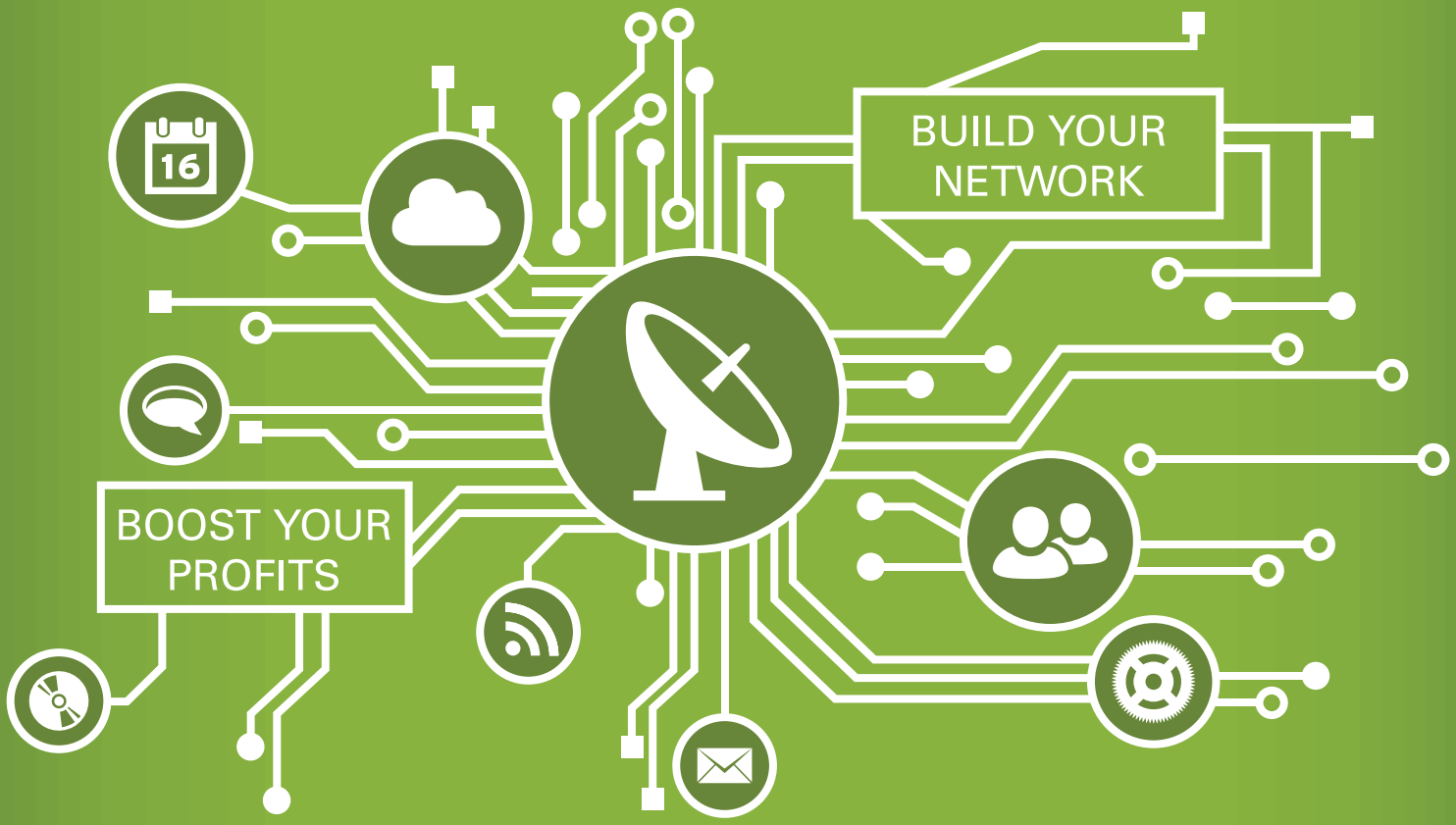

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and drive manufacturing but are not on the manufacturing floor, such as automation technologies, artificial intelligence, machine learning, and a host of supporting professions from supply-chain management through logistics, finance, marketing and beyond. Today, there is much sophistication and excitement around manufacturing, and this is quickly changing the demographics of the workforce.

The winners in this evolving industry will possess varying combinations of technical, leadership and power skills. Renard will discuss the growing role of women in the advanced manufacturing sector and how she has leveraged her communications, interpersonal and leadership toolkit to grow her unique and unexpected career in the manufacturing sector.

Loretta Renard is CEO of Canadian innovation accelerator REMAP. A member of the all-women leadership team since 2014, Renard has been instrumental in developing and deploying REMAP's mission to fund transformation, drive collaboration across industry and academia, and enable Canadian companies to navigate the digital economy. Renard is an experienced executive with 25-plus years of operations, strategy, corporate governance, communications and change management leadership for both for-profit and not-for-profit organizations. Prior to joining REMAP, Renard provided corporate communications for a global electronics manufacturer serving the healthcare and technology sectors. Renard is a lifelong volunteer and has supported a number of important causes including on-the-ground earthquake relief initiatives in Haiti.

Of Leaders and Ladders … – Jayshree Seth, Ph.D., 3M

Abstract: A perspective on lessons learned from a career in innovation. Seth believes that regardless of the educational path we follow and the career we end up in, real growth, true leadership and self-actualization come from tough transitions, deep reflections and meaningful actions. At the end of the day, it is what is inside all of us – it just takes effort to notice, read and realize that fine print. Jayshree will provide points to ponder based on her own experiences, against the backdrop of her personal and professional background and journey.

Jayshree Seth, Ph.D.

Jayshree Seth is a corporate scientist at 3M and leads applied technology development for the Industrial Adhesives and Tapes Division. She joined 3M in 1993 after receiving master's and doctoral degrees in chemical engineering from Clarkson University, and currently holds 75 patents for a variety of innovations, with several additional pending. Seth is a Distinguished Alumni Award recipient from her alma mater REC Trichy India (now NIIT Trichy), where she earned a bachelor's in chemical engineering.

Seth was appointed 3M's first ever Chief Science Advocate in 2018 and is using her scientific knowledge, technical expertise and professional experience to advance science and communicate the benefits of science and the importance of diversity in STEM fields. She is also a member of Carlton Society, the 3M Science and Engineering Hall of Fame, as the fourth woman and first female engineer to be inducted. In 2020, she was awarded Society of Women Engineers (SWE) highest Achievement Award. She is also the first-ever winner of a Gold Stevie Award in the new Female Thought Leaders of the Year – category in the 18th annual Stevie Awards for Women in Business in 2021. Seth was featured in a docuseries titled *Not the Science Type* that premiered during the 2021 Tribeca Film Festival and was accepted for Brand Storytelling Showcase, a sanctioned event at Sundance Film Festival. She is the author of *The Heart of Science – Engineering Footprints, Fingerprints, & Imprints,* and *The Heart of Science – Engineering Fine Print,* published by the Society of Women Engineers, for which all sales proceeds go to a scholarship for underrepresented minority women in STEM. She is a sought-after speaker, globally, on a multitude of topics such as innovation, leadership and STEM advocacy and has featured in local, national and international media.

Seth has served on the CEOs Inclusion Council, chaired the 3M Asian Employee Resource Group A3CTION and serves on its Advisory Board, as well as the Steering Committee for 3M Technical Women's Leadership Forum (WLF). She also serves on the Board of the Science Museum of Minnesota, Engineering Advisory Council for Clarkson, AAAS Committee on Science, Engineering and Public Policy (COSEPP) and the Advisory Group of Aspen Institute *Our Future is Science* program.

'Develop Your Sight and Gain Insight'

An interview with the three invited speakers of the 2022 WLP.

What is your favorite/valuable tool?

Carolyn Duran: Fundamentally, I believe that my thinking style has been the most valuable to me. Many years ago, a mentor helped me recognize this. He stated there are "convergent" thinkers – those that could really focus and drive execution, and "divergent" thinkers – those that would come up with radical out-of-the box ideas. Corporations need both, but they also need a few who can do both, and, most important, know which type of thinking is needed when. This is the tool in my toolbox that has served me well, and the one I continue to focus on and develop more.

Loretta Renard: Communications, interpersonal and leadership skills.

Jayshree Seth: That is a great question, and having spent almost three decades in my professional career I believe the tools that allow you to develop your sight and gain insight are the most valuable. I pick my favorite depending upon what task is in *scope*.

- The telescope: Look far ahead…. Ask yourself where you are going and see what the big picture, the vision, is for the team.
- The microscope: Look deep down…. Think about what you are doing, delving deeply to see the detailed view, the critical functioning, and the execution in the short term.

- The periscope: Look out! Look over, back and around.... See what is not in direct line of sight. Anticipate change and proactively identify opportunities.
- The stethoscope: Look within…. See what cannot be seen but only felt. Listen to the heart, your own and others, to be able to inform and inspire.
- The horoscope: Look above…. See and acknowledge what you can't control. Be grateful for the role of luck and chance. Humility makes for authentic leaders.

What tool do you wish you had when you started your career?

CD: I wish had better knowledge of "influencing" when I started. I naively thought that if you have a good idea, it will be heard. Sometimes even when you have that great idea, you need to *work* to be heard, and I didn't know how to do that very well.

LR: If I could have imagined that I would find myself passionate about the advanced manufacturing sector, I would definitely benefit from education in STEM to expand to engineering abilities and technical experience.

JS: When I started out, I hadn't quite realized what a powerful tool metaphorical thinking is, especially to visualize leadership concepts. For instance, microscopes and telescopes can be good metaphors for short-term and long-term views, respectively. Both of these scopes can provide a view that is not visible to the naked eye. Great leaders possess the ability to view both, and they have a keen understanding of when to use which one. Leaders also realize that the detailed microscopic view of the short term has to be consistent to realize the telescope's vision. Now I use metaphors as a powerful tool all the time! I find them brilliant in their ability to take an abstract thought and transform it into a very physical, easily understandable, and often universal concept. They can make a simple fact compelling as they add depth, character, and visual imagery.

What tool is usually difficult to master for women?

CD: I would say boldness. I think gender stereotypes give a large leeway for men to be "strong," "bold," "courageous." For women, we walk a tightrope between "you are too soft" and "you are pushy/arrogant." But we have to be bold.

LR: Women hold far fewer leadership positions, and many are stuck in the middle in their careers. Women need to learn to step forward to advocate for themselves and ask to lead big jobs and projects.

JS: With the rate of disruption in virtually every industry, the periscope view becomes an important metaphor and requires significant effort to master. A periscope is designed to look over and around obstacles that may be obstructing one's view. It's important to continually look outside our immediate surroundings to identify major trends and threats in the market, specifically how they will impact the products, platforms, and business models. A keen view through a periscope is critical for leaders because it can call for an adjustment of the telescopic and microscopic views to which we're accustomed. But using the periscope also means what you see or perceive needs to be communicated. I think sometimes it's a struggle for women to assert their point of view in largely male-dominated fields.

If you were a tool, which tool would you be? Why?

CD: Intellectual curiosity. That is what I am.

LR: My most significant leadership skill is communication – specifically, translating complex technology concepts into user-friendly and accessible knowledge transfer.

JS: Good leaders strive to use all the above views to enjoy the kaleidoscope of true leadership. With a stethoscope, good leaders need to listen to their heart and intuition to engage their teams in ways that might not be tangible. This is very important, especially since research indicates disengaged employees lead to lost productivity. Much has been written about leading with heart, and inspiring constituencies by capturing their hearts. Additionally, I have really learned to value the horoscope, as it feels more authentic to appreciate the role of luck along the journey. My mantra: Remember, it's not just you, it's your kismet and karma that come along on the journey too. Pay it forward.

I write a lot about these topics in my books, *The Heart of Science: Engineering Footprints, Fingerprints, and Imprints,* published in 2020, and *Engineering Fine Print,* published in 2021. All proceeds go to a scholarship for underrepresented minority women in STEM, administered by the Society of Women Engineers (SWE). ▫

PRIYANKA DOBRIYAL, PH.D., is technical assistant/chief of staff, Memory IO Division at Intel (intel.com) and Program Track Director of the Women's Leadership Program for SMTAI.

Evaluating and Communicating Shortage Risks

The horizontal report provides a supply vs. demand "map" showing where shortages will hit.

AT ITS FOUNDATION, Lean manufacturing philosophy is designed to eliminate waste and the associated chaos that inefficiency creates. Many of the core elements that improve factory efficiency, such as visible flow of work-in-process, small lot sizes, a strong focus on minimizing variation and *poka-yokes* to eliminate defect opportunities, have parallels that can increase efficiency in support organization tasks.

One of the most challenging tasks in the electronics manufacturing services (EMS) world is program management. This normally complex job has been made even more difficult by electronic component shortages that have been endemic since January 2021. As experts are predicting that component supply/demand imbalances are likely to continue through 2023, finding ways to eliminate inefficiency and waste is as important in program management as it is in production.

Just as design for excellence (DfX) contributes to elimination of defect opportunities in production, a program manager's ability to evaluate shortage risk and work with each customer to put a 24-month forecast in place can help to minimize shortage opportunities. This isn't always easy. Just as customers often need to be carefully educated on the rationale behind DfX recommendations in order to agree to the recommended change, they also have to be educated to realties of today's material situation. The current environment is different from prior material shortages because it is widespread across commodities and severe enough that suppliers are behaving in unexpected ways. Late decommits on day of shipment is one example of this type of behavior, and it drives a need for the program manager to create a process that enables consistency and follow-up on material status for all parts on the customers' bills of materials (BoMs) rather than just identified program parts.

One tool used at SigmaTron International to address this issue is the horizontal report. This provides each customer with a supply vs. demand "map" that shows where shortages will hit. More visual than an MRP record, it is organized in time buckets over a 12-month timeframe and shows the customer where the parts are used, how many parts are allocated to each assembly and the open order report. On most projects, MRP is run once a week and a refreshed horizontal report is provided to each customer. This frequency may increase if there are issues associated with the assembly that need to be watched more closely.

As with Lean manufacturing tools in production, the horizontal report is only effective if the team uses the visibility it provides to proactively manage the shortages it predicts. That is normally done in one of two ways. First, it is a great tool for customers to use in discussions with suppliers increasing their allocation to avoid the shortage the report is predicting. Second, the report's 12-month timeframe provides enough warning for customers to consider alternates or redesign activity on parts that will likely be constrained for the long term.

The report also educates customers on the realities of the market, helping them understand the tradeoffs they may face when increasing forecasted demand, making design changes or introducing new products. It helps drive visibility into on-hand inventory and its associated liabilities. Just as a well-trained production operator helps build quality in, a customer who understands the realities of the market and the shortage risks in their program can help address potential shortages before they become issues.

A report alone isn't a complete solution. Program managers see daily status changes. The quality of the way they communicate those changes and the options they provide determine how quickly and efficiently those changes are resolved. Tackling issues in small lots also makes the problem resolution process less overwhelming in the current chaotic environment. Some good processes to put in place include:

- Daily status reporting to give customers better visibility into why requests they may not otherwise understand well are being made by the program manager.
- Providing customers with a list of all options, including ones that are more expensive, as soon as it becomes evident tradeoffs must be made.
- Continually sharing all inputs, such as trends purchasing may be seeing that indicate a shortage may be likely, even if a supplier hasn't notified them yet.
- Establishing collaborative, empathic relationships with customers that share the full extent of bad news immediately so that recovery options can be explored.

Just as a visible factory tells production team members which processes are working efficiently and which need corrective action, a robust communication process keeps the team focused on the most efficient options for problem resolution.

Well-defined processes help production run smoothly. Well-defined escalation processes help both the EMS program team and the customer's team address challenges efficiently, typically before they cause issues in production. Predetermining when escalation at the component manufacturer moves from the

continued on pg. 62

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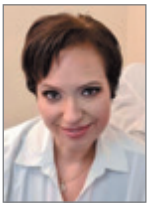

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Engineering the Sale

Knowing your limits is no casual thing.

BECAUSE THEY INTERPRET, manipulate and are acclimated to numbers, many engineers fancy themselves superior to the rest. The "rest" are lumped into the catchall contemptuous categories of "salesmen" or worse, "accountants." No room for improvisation; a certain analytical mindset likes it that way. Stay out of sales as a career option.

Pity those same engineers don't look up more from their algorithms, develop a firm handshake, maintain eye contact, read the room, and discern clients' actual intent. Supply doesn't ensure demand; sometimes you must stir it up in English rather than second derivatives. A skill largely born, not bred. That's also why there will always be a need for good sales folks; the best, most adventurous of whom are at ease technically, thus better equipped to know whereof they speak, and why, and make commitments on the spot, without appealing to the Mothership.

For context, consider this striking lesson from 2012.

Without prior warning, the summons came on a languid Friday morning. The kind going too well, where experience – maybe born of paranoia – says something is out there, waiting to happen. Those were the early days of casual Fridays, and that particular Friday we wore baseball jerseys at the office (It was Opening Day). The kind of Friday where you're trying to wind down, but someone victimized by their own bad choices conspires to wind you up and trash your weekend.

"Mr. W would like to meet with you at our office at 11 a.m. We have an urgent requirement for flying probe testing we wish to discuss with you."

It's 10 a.m. They are five miles up the road. And a world away. No doubt not wearing baseball jerseys.

We go. Without hesitation. Never mind the jerseys. Ten years ago, we needed the business. You swallow your pride and make accommodations, hoping the gems outnumber the lemons.

Their VP of operations didn't make accommodations. He was old school. Really old school. Cigarettes and coffee, and lots of both. He reeked of the former, and his twitchiness when we met belied veritable gallons of the latter. A face for radio. A bias for regimentation. Fifty going on 75. A metaphorical bugsplat, smashed head-on by the windshield of life. He was also a screamer, and not for our baseball team. Teamwork meant doing it his way, every day. The poster child for life as a conveyor belt of disappointments, and many low-bidder based decisions. A life of finding scapegoats. Yet he persisted in the same way, with the same business practices, because it was all he knew. Pity the cat on his front porch downrange from his foot after a bad workday. He had numerous bad workdays, and weeks, and years. I wonder to this day if he is still among the living.

Given this reputation, we knew we were in for theatrics when we met, one hour later, on that Opening Day Friday.

His conference room resembled more interrogation room than meeting place. A place to extract confessions rather than concessions. Blinky, dim, neglected fluorescent lighting. Partially broken stiff-backed plastic chairs scattered about the room. A chalkboard, not a white board, in front. A place of intentional neglect, and threats; forbidding in appearance. A theater for those to whom life is a hard slog, and for whom misery must be shared disproportionately with underlings. However one defines underlings. Did I say he was Old School?

He took it out on us, whatever "it" was. A bitter guy. Like we were guilty of some unspoken original sin. Made us wait in the interrogation room for 30 minutes, while anticipation and tension ratcheted up. All eyes would focus on him when he entered the room. A common technique authoritarians use to emphasize who's Boss.

He enters looking preoccupied, with not so much as a greeting or glint of recognition, and situates himself at the head of a long Putinesque conference table. We lock eyes. A nervous assistant shoves papers in front of him. He glances at them. Then he looks angry. We get down to business. You can feel the love.

"I understand from my assistant that your company performs flying probe programming and testing. We have a problem. Our own flying probe machine is down. It will remain down until a replacement part is installed. That part will take a month to arrive from Asia."

He continues:

"We have another problem. Our regular flying probe programmer left last night on vacation. He will also be gone for a month. We have a backlog of test projects to get through, starting with the high-priority project we wish to discuss with you today. Beyond this immediate requirement, we will need ongoing flying probe support for the next 30 days, and possibly longer."

I make a few mental calculations. It would be naïve to think he learned of his two problems the night before. Clearly, we weren't his first option. Perhaps not his second or third either. So what brought him, and

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us, to this point? Perhaps a midnight epiphany? Perhaps his wife's cousin's brother-in-law's nephew twice removed wasn't available to moonlight for minimum wage and psychic income this time. Had all his other usual tricks deceived him? Was that why he was red-faced with anger, as if we were the cause? He's not confessing his bad choices, and certainly not admitting weakness. He's manipulating as he goes, playing defense with offense, barking demands, terrorizing his lieutenants (for obviously leading him to this unpleasant set of circumstances) for show. Like we should be taking notes and giving in. But giving in to what?

We soon learn. We become the agenda. So he uses the skills he knows and tries to grind us down, shifting blame for adverse consequences. That means ordering, not asking. It's all he knows.

"Because of our own problems, we are late making a key shipment to a critical customer. You are going to help us make up some of that lost time and make that shipment by Monday."

It is 11:50 a.m. on a Friday. He effectively just cancelled our weekend, without asking permission. With no purchase order. No data. No documentation. No board details. Nothing but demands. And possibly no notification to their customer about being late, leaving status requests unanswered in the hope they'll just go away.

A command like a regimental marching order snaps me out of my daydream.

"What is it you need in order to provide us with a quotation?"

We respond with the usual. ODB++ file. Gerber files. Schematic in searchable PDF. Bill of materials. The relevant fab and assembly drawings. Why doesn't he already know this? He has his own machine.

"My assistant will email this information to you immediately after our meeting. When can we expect your quotation?"

This afternoon, including our best estimate of a delivery commitment.

"You don't understand. We must have 50 tested boards completed and delivered to us by 8 a.m. Monday morning."

On the contrary, we understand the difference between a request and a commitment. You have made a request. We have yet to see the details and are therefore reluctant to make a commitment.

What comes next is predictable. He pounds the table in front of him. I'm sure he reasons that if it works for underlings, it will work equally well for us.

"You will finish 50 boards by Monday at 8 a.m."

We keep our cool. We ask if we return him a quote by 3 p.m. today, when will we receive a purchase order?

"If the price is right, you will have a purchase order by the end of the day. When can we have your delivery commitment?"

Tactical error by Mr. Intimidation. He revealed two chinks in his armor: He needs a good price – whatever that means – and he leaves open the possibility of negotiating the delivery. It was all for show.

As if realizing his error, he reverts to form, and to his party line:

"We must have the project completed by Monday morning. Our customer expects this."

We continue holding straight and level.

Assuming you give us the full set of data and documentation by 1 p.m., and boards by 5 p.m. today, you will have our delivery commitment by 3 p.m. today. If not, all bets are off, and you'll most likely be looking at delivery from us by the middle to the end of next week.

This response makes him even angrier, as if he's not used to responses other than "yes," or "yes, sir." He flushes through several shades of red, settling on magenta. But we don't work for him, and he's only talking to us because his four prior alternatives have failed, and we represent the fifth-best alternative, leaving him no choice, and apparently angrier at having no choice. Life's hard sometimes. We want his business, but we won't prostitute ourselves to get it. Life's not that hard.

Except to him it is. He wants to make it harder and share the misery. He presses his waning advantage.

"Based on the description of the board we have provided you in this meeting, when do you think you can complete this project? It is vital that it be completed on Monday, no later."

The word "vital" is almost bellowed. Like his bonus depended on high decibels.

Based on a minimal amount of information provided to us by you at this meeting, it is probable we can complete your project, with weekend work, by Tuesday or Wednesday of next week. I don't see that it is possible to finish by Monday.

More table pounding. The aides jump. What a joy it must be to work for this guy. Like working for a troll living under a bridge, experimenting with dynamite during commute hours. Always and everywhere on edge. Everyone needs a hobby.

*"You **must** finish by 8 a.m. Monday. Anything later is unacceptable."*

Enough. He's inserting capital letters into his speech. Time for both barrels.

What part of "we will not finish your job by 8 a.m. Monday" are you failing to understand?

When I say this, I'm three feet away from his face (it's pre-Covid). I don't embellish the words, but let them linger like needles, piercing his thoughts. He doesn't flinch. But I don't back down. In this situation, some would. I keep silent.

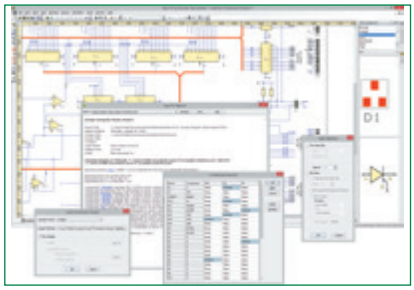
(This is the part in the movies where the dog barks, or the train whistle blows, or the saxophone plays, or the soundtrack from *The Good, The Bad, and The Ugly* reverberates, heightening the mood).

We get the order. Guess we passed the screening test.

We delivered on Tuesday. We never learned if he was happy or not. He had already moved on to his next crisis. His company paid our bill.

Anybody can write code.

Try selling under pressure some time. ▫



NUMBER ONE SYSTEMS EASY-PC V. 26 ECAD

Easy-PC v. 26 PCB design software incorporates IPC-2581 export capability, plus over 25 other new technology features. Fully implements IPC-2581 standard and includes a number of options to create the output required for manufacturing, assembly, and test. Incorporates new and enhanced design rules checks (DRC) and design for manufacturing (DfM) options in schematic capture and PCB design. Minimum Solder Mask Width, Solder Mask to Track, and Minimum Text Size aid manufacturability and prevent costly mistakes. Modified Pour Areas, a design verification check, alerts the designer to incomplete design changes that would not be incorporated in manufacturing. Unconnected Gates option removes unnecessary DRC warnings related to unconnected power pins in a multi-gate package.

New 3-D viewing option prevents components and other items that are not entirely within a board outline to be excluded from the view. Additional enhancements include Interactive Mitre/Fillet of Any Angle segments, Changes to the Rulers to further support 4K monitors, Cancel Move After Paste, Goto Text and Values and an enhanced Library Manager Report.

Number One Systems
numberone.com

T-TECH OFFERS ISOPRO 6.0 PCB PROTOTYPE SOFTWARE

IsoPro 6.0 software comes on Quick Circuit Systems and enables automatic data conversion from almost any CAD package. Is intuitive, eliminating lengthy learning curves. Imports DXF and exports Gerber data.

T-Tech
t-tech.com

UYEMURA C100 SILVER DISPERSION PLATING

C100 Silver dispersive plating for high-power connectors retains silver's conductive properties while providing anti-tarnish protection and greater wear resistance. Exceeds 10,000+ cycles without lubrication. Provides excellent conductivity and resistance to tarnish and high temperatures. Thermal aging tests (150°/180°C) show highly stable tribological behavior. Contact resistance is equal to that of pure silver. Friction trace tests on self-lubricating silver dispersion coatings show no wear-through, and high abrasion resistance, even under vibration loading. Demonstrates longer service life, even with heavily stressed connector applications; end-of-life tests up to 50,000 cycles document the system's low and stable coefficient of friction. Is cross-compatible with silver and silver alloys.

Uyemura International Corp.
uyemura.com

VENTEC TEC-SPEED 4.0 FLEX-RIGID MATERIAL

tec-speed 4.0 (VT-462(L) PP NF/LF) no- and low-flow FR-4.0 prepreg material offers high-Tg, low Dk, low loss, and excellent thermal reliability. The IPC-4101E-compliant material is designed for high-reliability military, aerospace/space, and other ultra-high reliability applications. Is suited for harsh environments and all flex-rigid applications with high BPS data rates, high-speed flex-rigid connectors, high-frequency and high-speed applications, satellite communications, navigation systems, and GPS.

Tg is 175°C, Td is 360°C, and Dk is 3.8, for thermal performance and ease of manufacturing. Glass fabric options include 1067, 1078, and 1080 with pressed thicknesses from 2.2 to 3.3 mil/ply (0.056 to 0.084 mm/ply). Is lead-free assembly compatible, fulfills RoHS and WEEE requirements, and complies with UL94 V-0. Whether formed once to permit installation during product assembly or flexing dynamically with moving parts such as printer heads or optical drives, the material formula withstands reflow temperatures and maintains its structural integrity to prevent fatigue or corrosion.

Ventec
venteclaminates.com

FUJIPOLY SARCON EGR30A SILICONE GAP FILLER

Sarcon EGR30A thermal interface material absorbs a range of unwanted electromagnetic energy. Tacky, gel-like consistency makes it easy to handle and apply without requiring additional adhesive. When placed on top of a heat source such as an IC chip, the compliant material fills any unwanted air gaps, permitting more efficient transfer of heat to nearby components or heat sinks. Provides absorption effectiveness across a broad frequency spectrum while exhibiting a thermal conductivity of 3.0 W/m°K (ASTM D 2326) and a thermal resistance of 1.65 K-cm^2/W at 14.5 PSI. Comes in five sheet thicknesses (0.5, 1.0, 1.5, 2.0 and 2.5mm) up to a maximum dimension of 300mm x 200mm. Also comes in die-cut form to fit almost any application shape. Is suited for environments with operating temperatures that range from -40° to +120°C and exhibits a UL94 flame retardant rating of V-0.

Fujipoly America
fujipoly.com/usa

INSPECTIS DIGITAL MICROSCOPE SOFTWARE V. 6.3

Inspectis software version 6.3 has several new features, improvements and bug fixes for its family of 4K and FHD digital microscopes. Is approved for use with Windows 11. Other notable improvements include live viewing distortion correction and auto-calibration that make

it possible to make precise calibrations quickly over a range of magnifications. Now saves up to 16 preset parameters via a user-configurable preset button. Each button can be named and the label read by hovering the mouse over the active button in the display. Preset calibration values for all cameras have been improved, and F35, F35s, DIM-F, DIM-FX, DIM-U, and DIM-UX camera microscopes have been added to the software.

Inspectis
inspect-is.com

KIC 24-CHANNEL PROFILING OPTION

Profiling Software 2G and SPS Smart Profilers now come with optional Dual Profiling, permitting up to 24 thermocouple locations in a single profile run for temperature profiling measurements. Consists of two 12-channel SPS units, paired together and run as a single 24-channel profiler inside of a new thermal barrier. Offers more sample locations on products but can be used on smaller boards requiring less. Two standard 12-channel profilers may be paired to function as a single profiler. Includes new shield design to protect two SPS profilers simultaneously. Comes with new SPS Smart Profilers or as an add-on option for existing 12-channel versions.

KIC
kicthermal.com

METCAL HCT-910 HOT AIR REWORK

HCT-910 hot air rework system is accurate and intuitive-to-use, with high thermal performance capable of meeting the full spectrum of application requirements needed for electronics production and rework. Generates 900W of heat with a maximum temperature of 600°C, to meet higher thermal demanding applications in military, defense, and aerospace, using highly metalized circuit boards. Intuitive, easy to use digital interface incorporates a novel control method for quick adjustments to temperature and airflow rates without looking away from the application. Multi-color status light on the hand-piece is a visual cue to the operator regarding the "current status" of the unit. Configurable for any worldwide standard voltage and power outlets. Intuitive user interface, multiple language settings, and a USB port to update software and power peripherals such as fans, lights, cameras, or cellphone. Includes hot air tool, power cord, and hand-piece cradle to support a variety of soldering and rework applications.

Metcal
metcal.com

MICROCARE STANDARD PRESATURATED IPA WIPES

Standard Presaturated IPA Wipes are for economical surface, tool and equipment cleaning. Come in two formulations: prestaurated with 99.8% high-purity IPA (isopropyl alcohol) and presaturated with a combination of 70% IPA and 30% DI (deionized) water. Both leave no residue and are safe to use on a variety of metals and plastics. Are for cleaning dust, dirt and fingerprints from workbenches, hand tools, machine control panels, material handling equipment and more. Are 8" x 5", for medium to larger cleaning tasks. Are ESD-safe, lint-free, tear resistant and stronger than other cellulose or polyester blend wipes. Feature a "slam-shut" lid to keep wipes wet, fresh and ready to use. In addition, 175-count presaturated wipe refills are available to drop into the reusable tub, helping to limit reorder frequency, reduce inventory and decrease waste.

MicroCare
microcare.com

OMRON FACTORY DRIVE RECORDER SOFTWARE

Factory Drive Recorder combines Industrial Camera line with Event Capture software to achieve a simple to use and feature-rich for monitoring automation for error detection and provide an easier way to record and evaluate potential problems. Records up to 5 min. before or after a designated incident. Has the capability of up to 8 cameras on a singular system, to record up to 8 different locations within the system when an incident occurs. Utilizes four different triggering methods to trigger the software to record; time-based trigger (trigger every X period of time); motion detection (e.g., when a door is opened); master image comparison; or from a hardware trigger signal (whether from a sensor, PLC, or other external source).

Is compatible with the M Series GigE Vision, B Series GigE Vision, M Series USB3 Vision, & UVC Omron industrial cameras. These cameras feature resolutions from 0.4 to 20Mp, and frame rates as high as 527 FPS, including a multitude of high-end Sony Pregius sensors with Global Shutter.

Omron
automation.omron.com/en/us/news/factory-drive-recorder-software-news

QUALITEK DELTA 769LF SOLDER PASTE

Delta 769LF is a zero-halogen, water-soluble solder paste for both nitrogen and air reflow applications. Is designed for high-melting temperature lead-free alloys, such as SAC 305 and Sn96.5/Ag3.5. Provides fluxing activity levels that promote thermal stability and prevents thermal degradation when reflowing under air atmosphere. Provides consistent print performance at wide humidity levels, solderability, and promotes cleaning performance to yield bright, shiny solder joints. Is a stable water-soluble formulation that provides consistent tack time, stencil life and print definition. Is classified as ORH0 flux under IPC-J-STD-004C.

Qualitek
qualitek.com

SHENMAO PF918-S PB-FREE BGA SPHERES

PF918-S lead-free BGA spheres are formulated with SnAg4.0Bi3.0 alloy designed with high thermal impact reli-

ability for long-service-life electronics with high-reliability requirements. Alloy has tensile strength performance 1.4 times higher than typical SAC 305 alloy. Thermal cycling life is two times longer than SAC 305. Melting point is 211°-221°C and has a similar range to SAC 305, with same workability and reflow profile. Reportedly increases thermal reliability performance by a minimum of 30%, and provides superior mechanical shock, tensile strength and thermal cycling performances than SAC 305 and SAC 405.

Shenmao
shenmao.com

SCS PRECISIONCURE TC IR THERMAL CURING SYSTEM

PrecisionCure TC IR thermal curing system can operate as standalone system or fully integrate with SCS PrecisionCoat selective conformal coater and dispenser. Features Windows-based software with touchscreen monitor and is designed for continuous operation. Comes with two or four heating zones, and each zone is heated with 12 ceramic heaters for even zone heating. Optional humidity control that incorporates an ultrasonic spray nozzle and humidity sensor to elevate the tunnel's relative humidity, decreasing the cure time for certain types of materials with a secondary moisture curing mechanism.

Specialty Coating Systems
scsequip.com

SCS PRECISIONHEAT IR THERMAL PREHEATER

PrecisionHeat infrared radiation (IR) thermal preheating system can operate as standalone system or fully integrate with SCS PrecisionCoat selective conformal coater and dispenser. Features Windows-based software with touchscreen monitor and is designed for continuous operation. Heats substrates prior to dispensing underfill materials. Two-zone system has 12 ceramic heaters per zone for even heating. Final zone is equipped with an IR temperature probe, providing users with real-time temperature feedback and control over the heating cycle.

Specialty Coating Systems
scsequip.com

VITROX V-ONE MANUFACTURING SOFTWARE

V-One 4.0 now comes with more extensive and innovative capabilities for data collection, data management/traceability, data analysis/visualization, asset management, process optimization, maintenance intelligence, imaging intelligence, and prescriptive insight. Enables supervision of the manufacturing line, collecting reliable data from IoT sensors and edge devices, databases in fog servers, MES connections and Cloud databases for analysis, with fully flexible visualization drill-down charts and flexible dashboard to furnish meaningful analytics to users in real-time basis and extend the platform toward complete data feeding for Artificial Intelligence processing.

Intelligent Control Tower provides real-time data analysis to monitor machine performance of multiple production lines and take immediate actions to ensure efficient production and reduce false alarms. In-house-built production impact calculation is generated based on the combination of false call trend, production board run quantity, shift time, and model changes, to provide the best sorting for users to fine-tune the most critical issue among all machines. Helps track and monitor results after fine-tuning.

Vitrox
v-one.com.my

Getting Lean, continued from pg. 56

EMS team to the customer's team can help address issues faster.

Finally, it is important to find ways to destress the stressful situations materials shortages create. We've gone from a situation that predicted a bumpy road, to entreaties to hang on, and now daily announcements that a critical part is on allocation. Everyone is overworked and tired and the situation will likely remain stressful for the foreseeable future. While it is important to share the full extent of bad news quickly and empathize with the challenges that creates, it is also important to build resilient relationships with customers that involve more than just bad news delivery. Look for positive news to share and successes to celebrate. From a stress management perspective, make sure team members are finding ways to unplug outside of work. Whether it is good times with friends, sports, a pet or a hobby, maintaining work/life balance is important in times of stress. We may not be able to control the current material environment, but we can control the way we respond to the challenges it creates. ▫

In Case You Missed It

E-Waste Reuse

"Value-added Fabrication of NiO-doped CuO Nanoflakes from Waste Flexible Printed Circuit Board for Advanced Photocatalytic Application"

Authors: R. Hossain, R.K. Nekouei and A. Al Mahmood, *et al.*

Abstract: Electronic waste (e-waste) presents metals could be recovered and transformed for use in beneficial applications, such as the manufacture of nanomaterials for the generation of hydrogen through thermodynamic water-splitting. This study used microrecycling techniques to synthesize nitrogen oxide (NiO) doped copper oxide (CuO) nanoflakes from waste flexible printed circuit boards (FPCBs) using microrecycling techniques. Several precise characterization and experimental analysis were used to validate the synthesized nanoflakes' phase purity, surface chemistry, morphology and optical properties. XRD analysis confirmed the nanoflakes produced in the system were predominantly tenorite, CuO (98.5% ± 4.5) with a dopant of NiO (1.5% ± 0.1). The nanoflakes had a specific surface area of 115.703m^2/g and mesoporous structure with an average pore diameter of 11nm. HRTEM analysis confirmed that the nanoflakes were not a single structure but assembled from 2-D nanorods. The width of the nanorods varied from ~10 to 50nm, and the length from ~30 to 80nm. After rapid thermal processing, the photocurrent response of the synthesized material was assessed, revealing a higher photocurrent density (– 1.9 mA/cm^2 at 0.6V vs. reversible hydrogen electrode (RHE) under 1.5G AM). Mott Schottky analysis and electrochemical impedance spectroscopy showed that the synthesized nanomaterial had the potential thermodynamic water-splitting capability. These results were an encouraging indication of the promise of techniques that use e-waste to produce nanomaterials with valuable properties. (*Scientific Reports,* Jul. 16, 2022, https://doi.org/10.1038/s41598-022-16614-4)

Reliability

"Time to Failure Prediction on a Printed Circuit Board Surface Under Humidity Using Probabilistic Analysis"

Authors: Sajjad Bahrebar and Rajan Ambat

Abstract: This paper presents the probabilistic study of time to failure (TTF), which is caused by combinations of various important controllable factors on a PCB surface under humidity. The study investigated the impact of four changeable factors, including pitch distance, temperature, contamination, and voltage, each at three levels upon the surface insulation resistance test boards. Constant 98% relative humidity with adipic acid as contamination related to flux residue was used for a 20-h parametric experiment. Two main states were considered on the whole output current measurements: the stable part before the short transition phase and the unstable part after due to electrochemical migration (ECM) on the PCB surface. Leakage current (LC) in the first state and TTF at the beginning of the second stage was measured with five replications for each condition as the predictive indicator in all models. The trend of LC and TTF was also investigated on three levels of each factor. In addition, probabilistic distribution analysis using fitted Weibull distribution, multivariate regression analysis, and the classification and regression tree (CART) analysis were used to predict the probability of TTF and failure risk prediction on the PCB surface. All the prediction models had an acceptable prediction of TTF at diverse accuracy levels, according to changing factors/levels. Nevertheless, the multivariate regression analysis had the best prediction, highest R2, and lowest error compared to the other models. (*Journal of Electronic Materials,* May 18, 2022, https://doi.org/10.1007/s11664-022-09668-7)

"Electrothermal Analysis of System in Package for Aerospace Application"

Authors: Hao-hang Su, Shuai Fu, Su-yuan Li and Jiang Bian

Abstract: Aiming at failure problems of aerospace electronics product in the complex space environment, the electrothermal coupling method was used to analyze the reliability of a 10-channel independently adjustable voltage conversion system-in-package (SiP) module based on an integrated forming package, which supplied voltage to the remote sensing camera detector. First, the electromagnetic model and thermal model were made based on the SiP module; second, the electrothermal coupling simulation of three working conditions at normal environment was made, and the maximum temperature of the SiP calculated. Then, the maximum temperature of the SiP was calculated at vacuum and 45°C to analyze the performance of this SiP in the space environment. Last, tests were conducted on the SiP product. Compared with the measured results, the electrothermal coupling method has much more accuracy than the traditional thermal method. At normal environment, the simulated temperature relative error is 2.8%. At vacuum and 45°C environment, the simulated temperature relative error is 9%. This method ensured the performance and accuracy of the SiP design, which verified the reliability of the aerospace SiP module at an early stage. (*Journal of Electronic Packaging,* Jul. 7, 2022, https://asmedigitalcollection.asme.org/electronicpackaging/article-abstract/145/1/011202/1140564/Electrothermal-Analysis-of-System-in-Package-for)

This column provides abstracts from recent industry conferences, technical journals and company white papers. Our goal is to provide an added opportunity for readers to keep abreast of technology and business trends.

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